Open Journal of Marine Science, 2015, 5, 422-442
Published Online October 2015 in SciRes. http://www.scirp.org/journal/ojms
http://dx.doi.org/10.4236/ojms.2015.54034

Finite Element Numerical Method for Nonlinear Interaction Response Analysis of Offshore Jacket Affected by Environment Marine Forces

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Received 2 September 2015; accepted 18 October 2015; published 21 October 2015

Abstract

In this paper a nonlinear response of a fixed offshore platform under the combined forces of waves, wind and sea currents is presented. Wave force acting on the elements is calculated using Morison equation. Hydrodynamic loads on horizontal and vertical tubular members and the dynamic response of offshore fixed platform coupled with distribution of displacement, axial force, and bending moment along the base of the platform for regular and severe cases have been investigated. The structure must be able maintain production in a one-year wave return period condition and also to be able to continue with one hundred-year storm return period. The results of this study show that bending moment values with a one-year wave return period condition for the base platform and junction of platform to deck are 70 percent and 59 percent, respectively more than bending moment with a one-year wave return period. The direction of wave and wind hit has significant effects on the shift platform response, also nonlinear response is important for the safe design and operation of offshore structures.

Keywords

Fixed Jacket Platform, Finite Element Method, Stokes Wave Theory, Nonlinear Response of Structure

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How to cite this paper: Ghassemi Zadeh, S.M., Shojayee B., R. and Vaziri K.O., S.M.S. (2015) Finite Element Numerical Method for Nonlinear Interaction Response Analysis of Offshore Jacket Affected by Environment Marine Forces. *Open Journal of Marine Science*, **5**, 422-442. http://dx.doi.org/10.4236/ojms.2015.54034

1. Introduction

The total number of offshore platforms in the Gulfs and oceans throughout the worlds is increasing each year. Most of these platforms are of jacket platforms types installed in water depths of 32 meters to 200 meters for exploration of oil and gas. Analysis, design and installation of offshore structures compatible with the environmental conditions are of the most challenging and innovative work in this area. Offshore jacket platforms are typically designed using offshore structures standards such as (API RP2A WSD, 2000), (API RP2A LRFD, 1993) and (ISO 19902, 2007). Nonlinear static analysis, *i.e.* the Pushover analysis is widely used in offshore standards such as API, ISO and DNV to study the nonlinear behavior and the final capacity of offshore platforms against the sea loads. In this method, the corresponding load pattern evenly increases until the collapse of the jacket platform under marine environment affected by special loads, for example, the (wave return period of 100-years). Reference [1] presented studies on offshore structures under the action of the wave's effects. Reference [2] carried out studies in the field of nonlinear hydrodynamic forces and their effects on the nonlinear response by platforms. Reference [3] presented studies on designing reliable offshore structures under the action of the waves. Reference [4] made studies on the dynamic response of a steel jacket platform with an effective specific activity and control under the wave's load and the impact of these forces on the response of a structure with and without vibration control mechanisms can be simplified. Reference [5] presented the effect of an active control system for a jacket platform under wave loading. Their studies showed that the proposed algorithm has better effect than conventional control strategies. Reference [6] analyzed the time domain of dynamic response of simplified offshore structures under the concurrent effects of accidental loads and seismic wave and showed the results of the displacement response of the time history and value of RMS. Reference [7] studied dynamic response reliability analysis of offshore structures under the effects of marine waves, ocean currents and earthquakes and showed that reliable indicators in long-term behavior and final responses on offshore structures have large effects. Reference [8] [9] conducted studies on the response of jacket platforms with active mass dampers under the force of the waves and showed that the active mass dampers TMD can reduce the respond of platform jacket considerably. Reference [10] [11] showed the effects of seismic estimates on coastal and offshore structures according to the most recent earthquakes and showed the effectiveness of viscoelastic dampers. In this paper, nonlinear analysis is formulated for reliable assessment of the response of jacket platform under constant structural loads, wave, sea currents and wind loads. A three-dimensional finite element model is used to estimate the displacement and stress in steel platforms under combined constructional and waveloads. This analysis includes a variety of nonlinear properties produced due to changes in the nonlinear drag force. Wave and current flow kinematic are generated by the 5^{th} order stokes nonlinear theory. The effect of wave forces on members is calculated by Morison formula. Natural periods and modes of the system are calculated. Nonlinear wave kinematic is a very important factor due to the interaction between structures and waves. Wave induced loads on fixed offshore platform under the sea storms is calculated using a nonlinear drag term in Morrison equation and changes in wave height. Moreover, the fixed jacket platform response under the ultimate structural loads is a function of the behavior of components in the range of nonlinear deformations.

2. The Environmental Loads

The water force can be classified into waves force and the current flow force. The wind blows over the ocean moves the water causing the current flow and the waves. Ocean waves force on the platforms is dynamic and natural, although the static design of platforms in shallow waters is also acceptable. With increasing waters depth, the platforms are flexible with more dynamic effects.

2.1. Current Flow Forces

Wave leads to the orbital motion of the water. The orbital motion in a closed cycle, but slightly drive forward due to surface wind effect. Current flow is generated by the wave. The current flow in a wave tends to drag wavelength. The induced current flow force on the cylindrical structure is defined as follows [12]:

$$F_D = C_d \frac{\rho}{2} A U^2 \tag{1}$$

In this equation, F_D, C_d, ρ, A, and U, are the drag force in Kilo Newton, drag coefficient, sea water density per ton per cubic meter, cross section depicted in terms of square meter and current flow rate in meters per second, respectively. The flow rate is usually between 0.1 and 2.3 meters per second. Profiles of sea currents in the Gulf of Mexico are shown according to the API [13] in **Figure 1**.

2.2. Wave Forces

The regular wave theories are used to calculate the forces on fixed offshore structures, illustrated in **Figure 2**, and based on the three parameters of water depth (*d*), wave height (*H*) and wave period (*T*), respectively. Hydrodynamic force vector is calculated in all degrees of freedom. The intensity of the wave force on each meter of the structure is calculated based on Morison formula shown in Equation (2), [13].

$$F = \rho C_m V \frac{\mathrm{d}u}{\mathrm{d}t} + \frac{1}{2} \rho C_d A u \left| u \right| \quad (2)$$

where, F, C_m, u, $\mathrm{d}u/\mathrm{d}t$, and V are total force exerted on an object, the coefficient of inertia, current flow rate, current flow acceleration and object size, respectively.

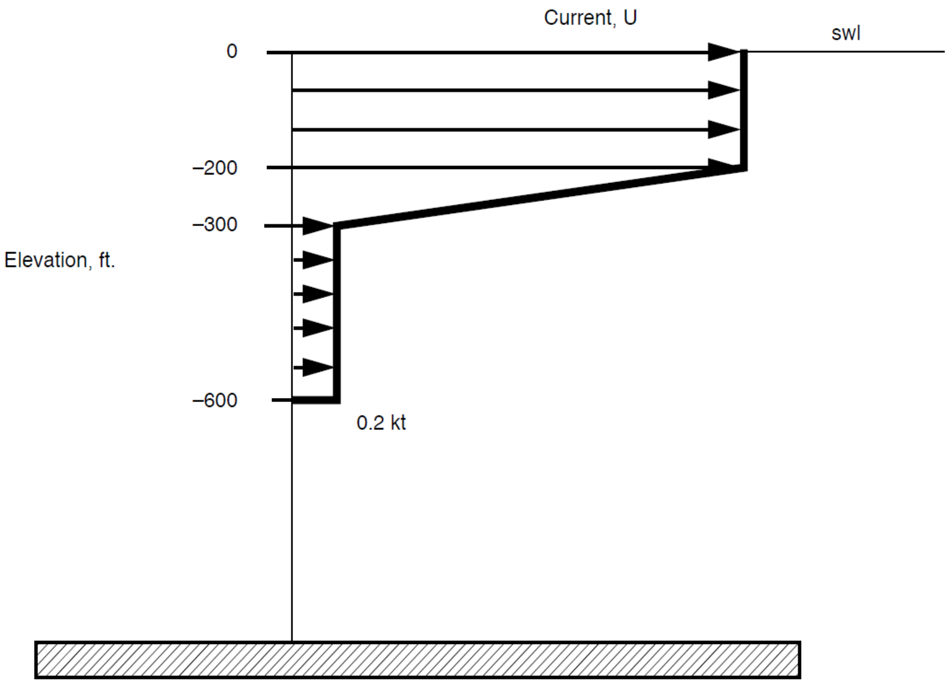

Figure 1. Sea currents profile in the Mexican gulf.

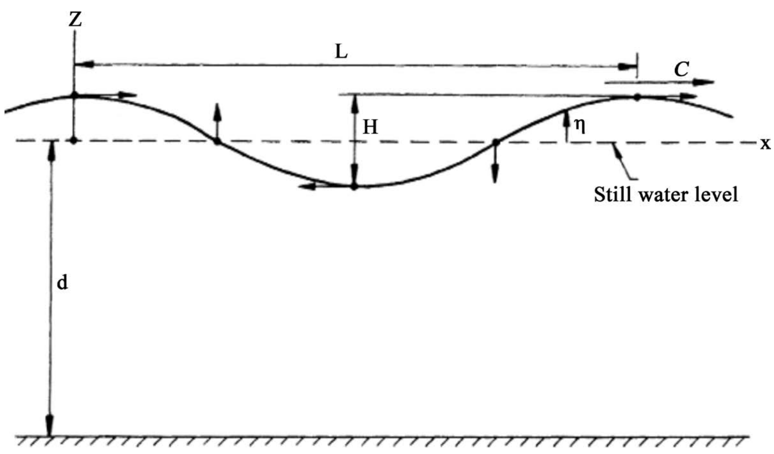

Figure 2. Wave parameters profiles.

2.3. Wind Forces

When a structure is placed in the path of the moving air so that wind is stopped or is deflected from its path all or part of the kinetic energy is transformed into the potential energy pressure. Therefore wind forces on any structure result from the differential pressure caused by the obstruction to the free flow of the wind. These forces are functions of the wind velocity, orientation, area, and shape of the structural elements. Wind forces on a structure are a dynamic problem, but for design purposes, it is sufficient to consider these forces as an equivalent static pressure. The force of the wind according to the API is shown in Equation (3).

$$F = 0.0437 C_s A_p U_{10}^2 \tag{3}$$

In this equation, F, C_s, A_p and U_{10} are the wind force in Kilo Newton, shape structure factor, cross section depicted in terms of square meter and wind speed in kilometers per hours, respectively.

3. Parametric Topics

3.1. The Finite Element Method

The finite element method is for the approximate solution of differential equations governing on the continuous areas. This method was initially proposed as a method of stress analysis and is widely used for this purpose. For a non-persistent problem, finite element approximation is defined as follows [14]:

$$\frac{\partial f}{\partial t} + U\frac{\partial f}{\partial x} = 0 \tag{4}$$

By transforming this equation into the integral one, and by using the weighted residual function ($W_{(x)}$), we have:

$$\int_{\Omega} \frac{\partial f}{\partial t} W \mathrm{d}x + \int_{\Omega} U \frac{\partial f}{\partial x} W \mathrm{d}x = 0 \tag{5}$$

Finite element is defined as follows:

$$f(x) = \sum\nolimits_I f_I N_I(x) \tag{6}$$

Using the relations (5) and (6), this equation will change as follows:

$$\sum_I \frac{\partial f_I}{\partial t} \underbrace{\int_{\Omega} N_I N_J \mathrm{d}x}_{M_{IJ}} + U \underbrace{\int_{\Omega} N_I \frac{\mathrm{d}N_J}{\mathrm{d}x} \mathrm{d}x}_{K_{IJ}} = 0 \tag{7}$$

In the above equation, M_{IJ} and K_{IJ}, represent the mass matrix and stiffness matrix respectively.

The finite element method uses the integral shapes of equations; it means that integration have to be carried out on governing equations of the scope of problem; Therefore, finite element is only used for discretization the local terms of the equations and for discretization of the time terms the finite difference method is used consequently [14].

3.2. Nonlinear Wave Theory

In the theory of nonlinear waves, the sinusoidal shapes of wave profile and rotation of the particles in a circular path in the profile does not exist simultaneously. One of the nonlinear wave's theory in 1880 was presented by Stokes; it was based on adding unlimited number of successive approximation and adding it to a series of equations. In this research, the 5$^{\text{th}}$ order Stokes nonlinear wave theory is used to estimate the water particle kinematics. In this theory, by using the two characteristics amplitude and period of the wave, water particle kinematics is determined using the following equations. One of the ways by which the higher order Stokes theory can be estimated is Fenton method [15]. The wave profile can be written as:

$$\eta(x,z,t) = \frac{1}{k}\sum_{i=1}^{5} \beta_i \cos i(kx - \omega t) \tag{8}$$

Horizontal and vertical velocities are calculated as follows:

$$u(x,z,t)=\frac{\partial\phi}{\partial x}=c_E+\frac{\sqrt{gk\tanh kh}}{k}x\times\sum_{i=1}^{5}i\alpha_i\cosh ik(z+d)\cos i(kx-\omega t) \tag{9}$$

$$w(x,z,t)=\frac{\partial\phi}{\partial z}=\frac{\sqrt{gk\tanh kh}}{k}x\times\sum_{i=1}^{5}i\alpha_i\sinh ik(z+d)\sin i(kx-\omega t) \tag{10}$$

In these equations k is wave number, ω is angular velocity, ϕ is velocity potential function, C_E is average of steady flow, α_i, A_{ij} and β_{ij} are affiliate factor related to k_d that d is the depth of the water. The coefficients are available in reference number [15].

4. Platform Structural Model

The platform studied in this paper is a fixed jacket platform that had been proposed for installation in Venezuela Gulf in 1977 [16]. The platform is composed of 8 bases made of hollow cylindrical steel. Outside diameter of vertical, horizontal and diagonal elements are 1.8, 1 and 0.5 meter, respectively; and the thickness of vertical, horizontal and diagonal elements are 2.5, 1.55 and 1.1 centimeter, respectively. In order to meet the hardness requirements on platform, cross bracing was used on both sides of the bases. Also, platform height is 57.5 meter with sea water density of 1.0252 tons per cubic meter. To simplify the model, platform, all deck loads were model in one story. Steel profile used in this platform has the Specific weight: 7850 (Kg/m^3), Elastic Modulus: 2.1 × 10^9 (Kg/m^2), Shear modulus: 8.077 × 10^8 (Kg/m^2), Yield stress: 360 (MPa) and Ultimate tensile stress: 420 (MPa).

5. The Platform Finite Element Analysis

Finite element analysis of platform is performed under various wave, sea currents and wind loads. Structural model is focused on a detailed description of the deformation properties of the column loads. These platform columns are modeled by equivalent beams. For the present analysis, the dead weight of all fixed equipment located on the deck is 7.25 ton per square meter and a live load objects on deck of 0.3 ton per square meter is taken. This platform has been installed in water depth of 54.5 meters. C_d and C_m parameters were considered equal to 0.65 and 1.6, respectively according to API regulation. A one-year and 100-year wave parameters are shown in **Table 1** Wind speed of one-year and 100-year of 85 and 100 (Knot) were considered according to API regulation. **Figure 3** depicts two-dimensional and three-dimensional view of the platform model. Columns 1 and 2 are considered to analyze the platform. Also, the Nodes a_0, a_1, a_2, a_3 and a_4 are considered to show displacement and stress on the columns.

Marine wave and wind parameters and current flow directions of ±0˚, ±45˚, ±90˚, ±135˚ and ±180˚ intended for the analysis of these platforms. 19 different load cases have been shown for analysis at this platform **Table 2** [17]. In the **Table 2** DL, LL, W_a, W_i and C_u, represent dead load, live load, wave load, wind load and sea current load, respectively.

6. Numerical Results

For more effective and accurate design, a finite element model to estimate the internal forces and columns displacements of offshore platform under structural loads and the waves were evaluated. Structural vertical loads are actually static loads, whereas the lateral wave is in oscillation in the time domain directly linked with the angle of the incident wave. The model used in this research is a steel platform proposed in 1977 to the Gulf of Venezuela. Three-dimensional finite element model of the platform is designed in SAP2000 software. Second hand parts such as ladders, stairs and so forth are not directly modeled and only the weight effects are applied. Z axis in a Cartesian system is in the direction of water depth. Fixed end boundary condition is located at 3.5-meter mud line/seabed along with the bases (depth 57 meter). Natural periods and related vibration modes shapes are analyzed by Eigen values. **Table 3** shows 12 vibrating modes of the platform.

Table 1. Wave parameters.

Definitions	Water depth (m)	Wave height (m)	Wave period (s)
Wave with a return period of 1-year of operation	54.5	10	7.2
Wave with a return period of 100-year for safety		16	10.6

Table 2. Loading combinations.

Loading combination	Description	Loading combination	Description
Load Comb 1	DL + LL	Load Comb 11	DL + LL + $(W_a + W_i)_{100yr}$ + $W_a/W_i/C_u$ 0°
Load Comb 2	DL + LL + $(W_a + W_i)_{1yr}$ + $W_a/W_i/C_u$ 0°	Load Comb 12	DL + LL + $(W_a + W_i)_{100yr}$ + C_u 45°
Load Comb 3	DL + LL + $(W_a + W_i)_{1yr}$ + C_u 45°	Load Comb 13	DL + LL + $(W_a + W_i)_{100yr}$ + C_u 90°
Load Comb 4	DL + LL + $(W_a + W_i)_{1yr}$ + C_u 90°	Load Comb 14	DL + LL + $(W_a + W_i)_{100yr}$ + C_u 135°
Load Comb 5	DL + LL + $(W_a + W_i)_{1yr}$ + C_u 135°	Load Comb 15	DL + LL + $(W_a + W_i)_{100yr}$ + C_u 180°
Load Comb 6	DL + LL + $(W_a + W_i)_{1yr}$ + C_u 180°	Load Comb 16	DL + LL + $(W_a + W_i)_{100yr}$ + $W_a/W_i/C_u$ 45°
Load Comb 7	DL + LL + $(W_a + W_i)_{1yr}$ + $W_a/W_i/C_u$ 45°	Load Comb 17	DL + LL + $(W_a + W_i)_{100yr}$ + $W_a/W_i/C_u$ 90°
Load Comb 8	DL + LL + $(W_a + W_i)_{1yr}$ + $W_a/W_i/C_u$ 90°	Load Comb 18	DL + LL + $(W_a + W_i)_{100yr}$ + $W_a/W_i/C_u$ 135°
Load Comb 9	DL + LL + $(W_a + W_i)_{1yr}$ + $W_a/W_i/C_u$ 135°	Load Comb 19	DL + LL + $(W_a + W_i)_{100yr}$ + $W_a/W_i/C_u$ 180°
Load Comb 10	DL + LL + $(W_a + W_i)_{1yr}$ + $W_a/W_i/C_u$ 180°		

Table 3. Natural periods of offshore platform.

Mode No.	Period (s)	Mode No.	Period (s)	Mode No.	Period (s)
1	0.332	5	0.208	9	0.129
2	0.269	6	0.191	10	0.122
3	0.243	7	0.150	11	0.104
4	0.211	8	0.142	12	0.104

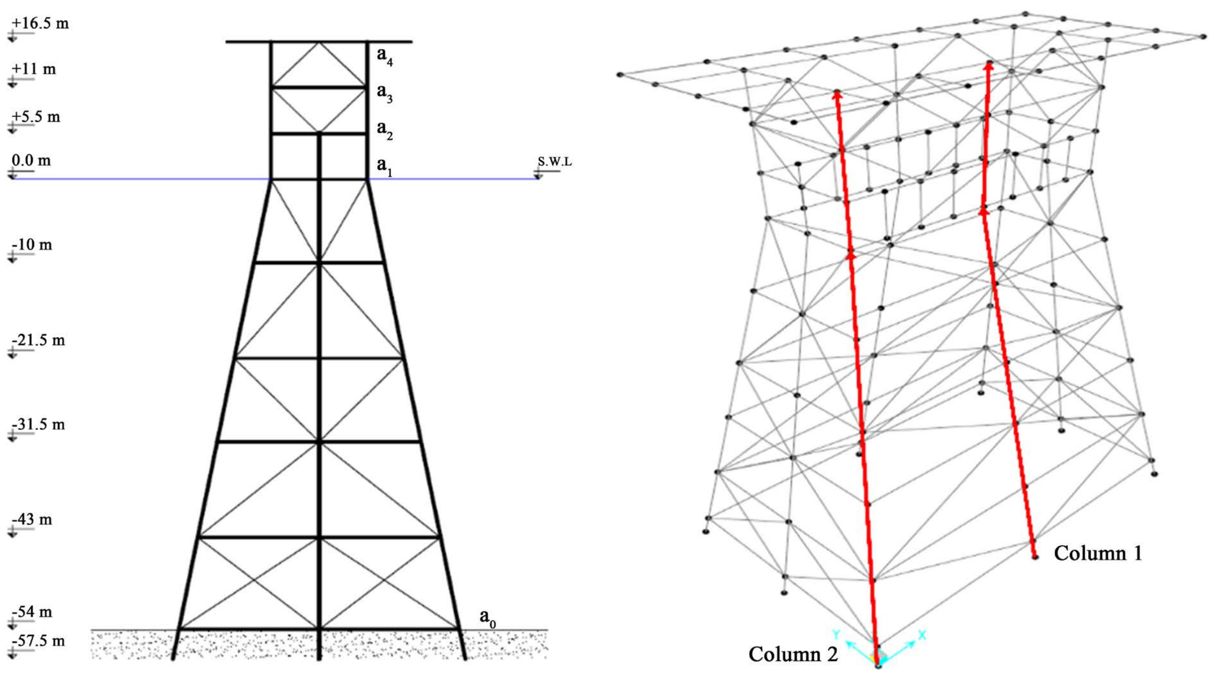

Figure 3. Three-dimensional and two-dimensional view of modeled platform from different views.

6.1. Structure Displacement Response

In order to understand the behavior of fixed offshore platform, the analysis of these platforms in water to a depth of 54.5 meters under the sea waves, winds and sea currents were studied. Maximum deformations under mentioned loads have been precisely calculated. Deformations responses of U_1, U_2 and U_{abs} (which represents the absolute horizontal displacement is equal to the square root of the sum of squares U_1 and U_2) and are depicted in the following figures in line with platform height under the action of waves loads and sea currents with return period of 1-year (operating conditions) and 100-year (extreme conditions/ storm). U_1, U_2 deformation are in X and Y directions, respectively.

For operating conditions of platform, based on **Figure 4**, **Figure 5** and **Figure 6**, with increasing angle of the sea current attack, angle from zero to 180, platform displacements are reduced, so that the angle of zero degrees shows the maximum displacement and 180 degrees exhibits the minimum displacement in the X direction. This condition is contrary for the Y direction, attacks with angle of 90 degree showing the maximum displacement and the minimum displacement are with zero and 180 degrees angle. Furthermore, the average value of absolute displacement difference for the 1-year sea current for combined number 4 (maximum absolute displacement) and combined number 6 (minimum absolute displacement) is about 11 percent. For operating conditions of platform, based on **Figure 7**, **Figure 8** and **Figure 9**, with increasing angle of the wave, wind and sea current attack, angle from zero to 180, platform displacements is reduced, so that the angle of zero degrees shows the maximum displacement and 135 degrees exhibits the minimum displacement in the X direction. This condition is contrary for the Y direction, attacks with angle of 90 degree showing the maximum displacement and the minimum displacement is with 180 degree angle. Also the average value of absolute displacement difference for the 1-year wave, wind and sea current for combined number 8 (maximum absolute displacement) and combined number 10 (minimum absolute displacement) is about 16 percent. For storm conditions, as **Figure 10**, **Figure 11** and **Figure 12** illustrates, hits with 90 degree angle create the maximum displacement, while hits with 180 degree angle create the minimum displacement. The average value displacement difference for a 1-year wave of combination number 4 (maximum absolute displacement) and combination number 6 (minimum absolute displacement) is at about 8 percent. With increasing angle of the sea current attack, angle from zero to 180, platform displacements is reduced, so that the angle of zero degrees shows the maximum displacement and 180 degrees exhibits the minimum displacement in the X direction. This condition is contrary for the Y direction, attacks with angle of 90 degree showing the maximum displacement and the minimum displacement is with 180 degree angle. Also the average value of absolute displacement difference for the 100-year sea current for combined number 14 (maximum absolute displacement) and combined number 15 (minimum absolute displacement) is about 15 percent. In **Figure 13**, **Figure 14** and **Figure 15**, with increasing angle of the sea current attack, angle from zero to 180, platform displacements is reduced, so that the angle of zero degrees shows the maximum

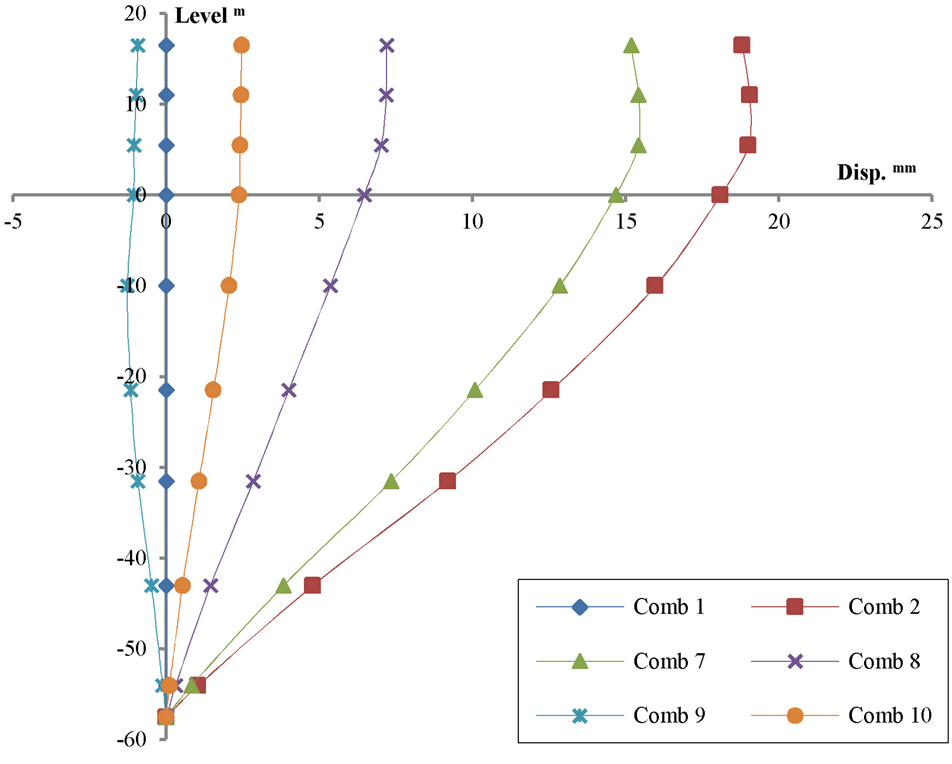

Figure 4. Displacements in the X-direction with 1-year currents Column 1.

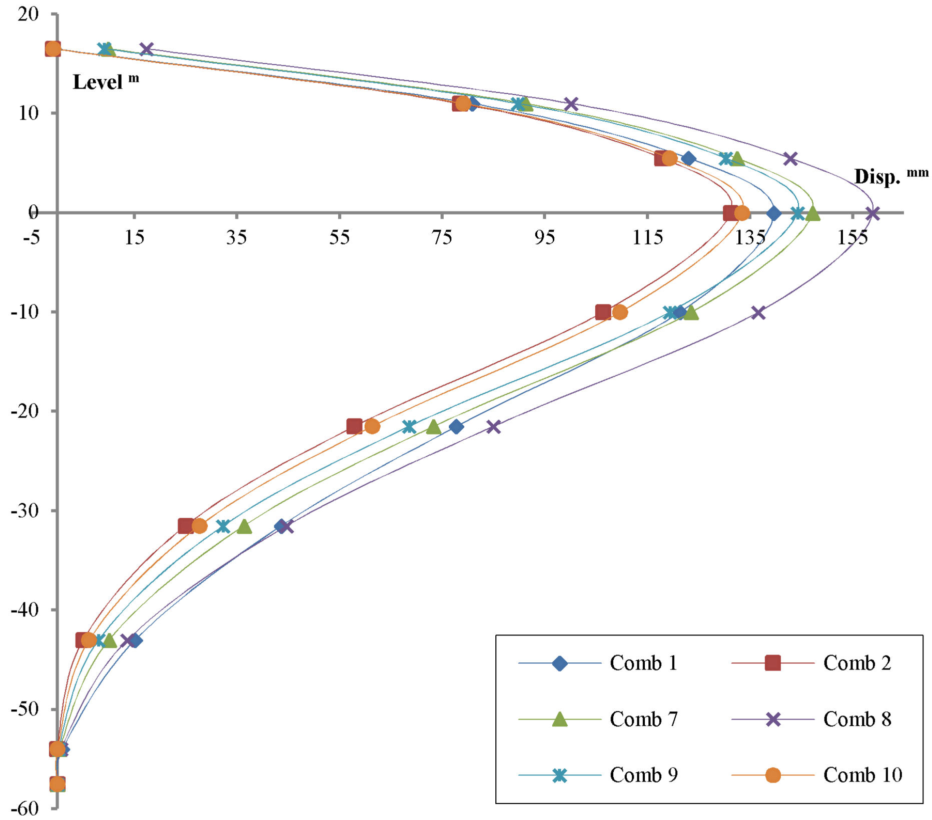

Figure 5. Displacements in the Y-direction with 1-year C_u Column 1.

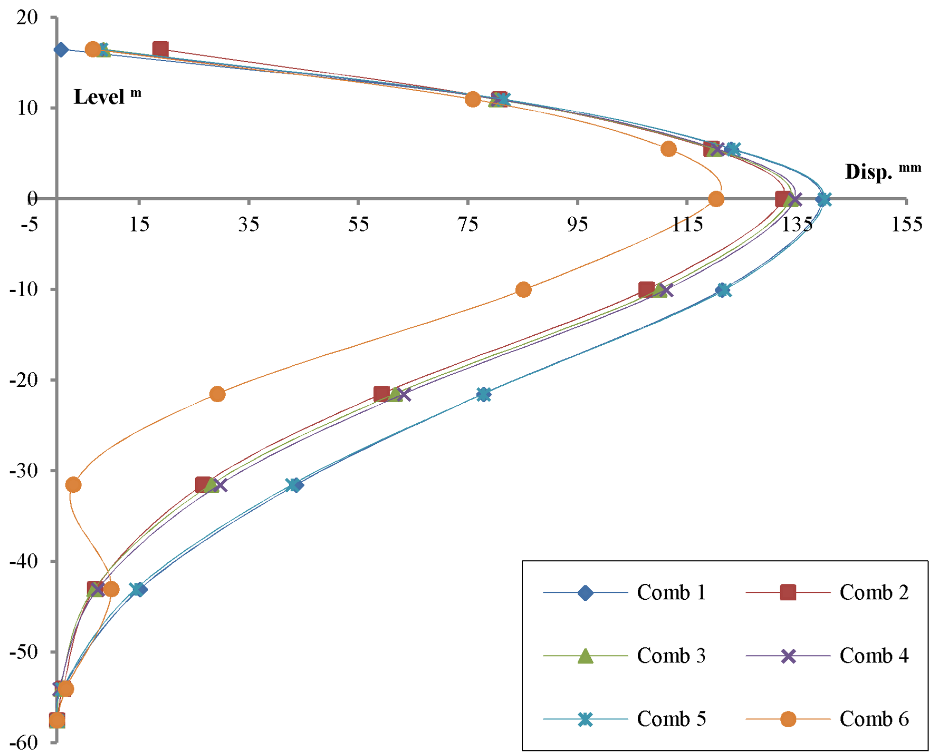

Figure 6. Absolute displacements with a 1-year C_u Column 1.

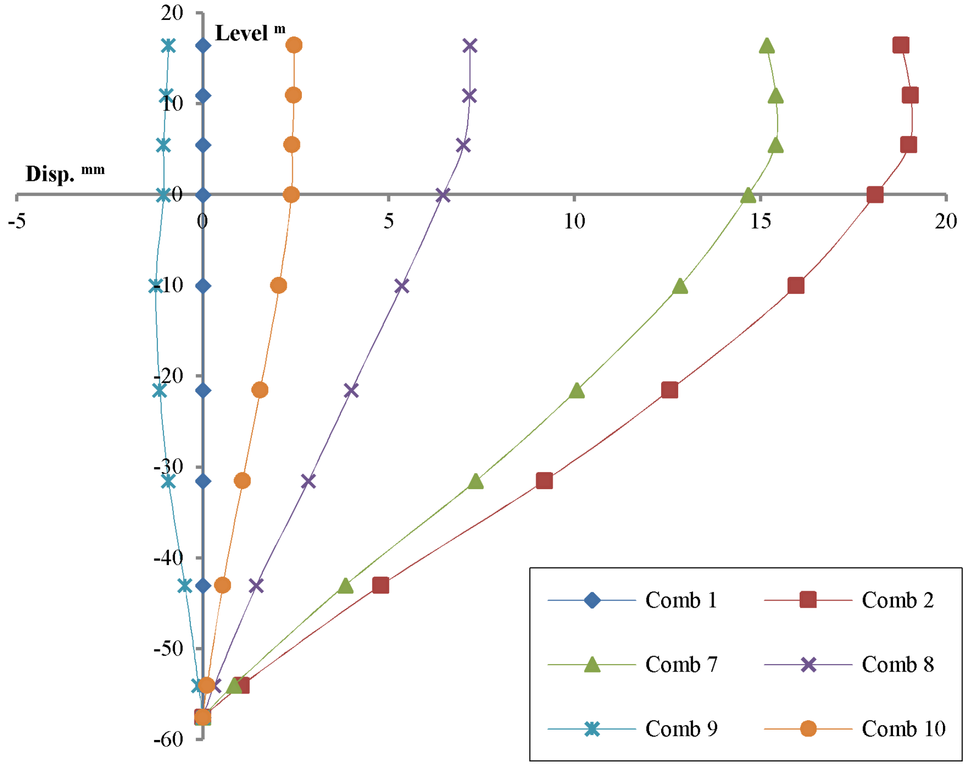

Figure 7. Displacement in the X-direction with 1-year W_a, W_i & C_u Column 1.

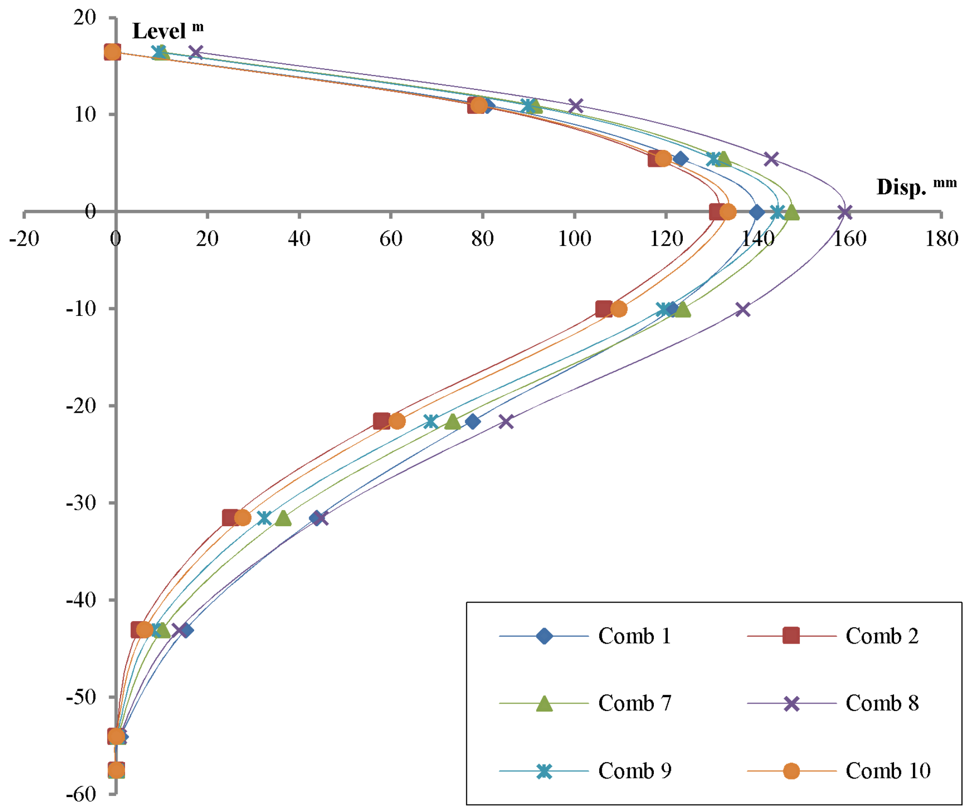

Figure 8. Displacement in the Y-direction with 1-year W_a, W_i & C_u Column 1.

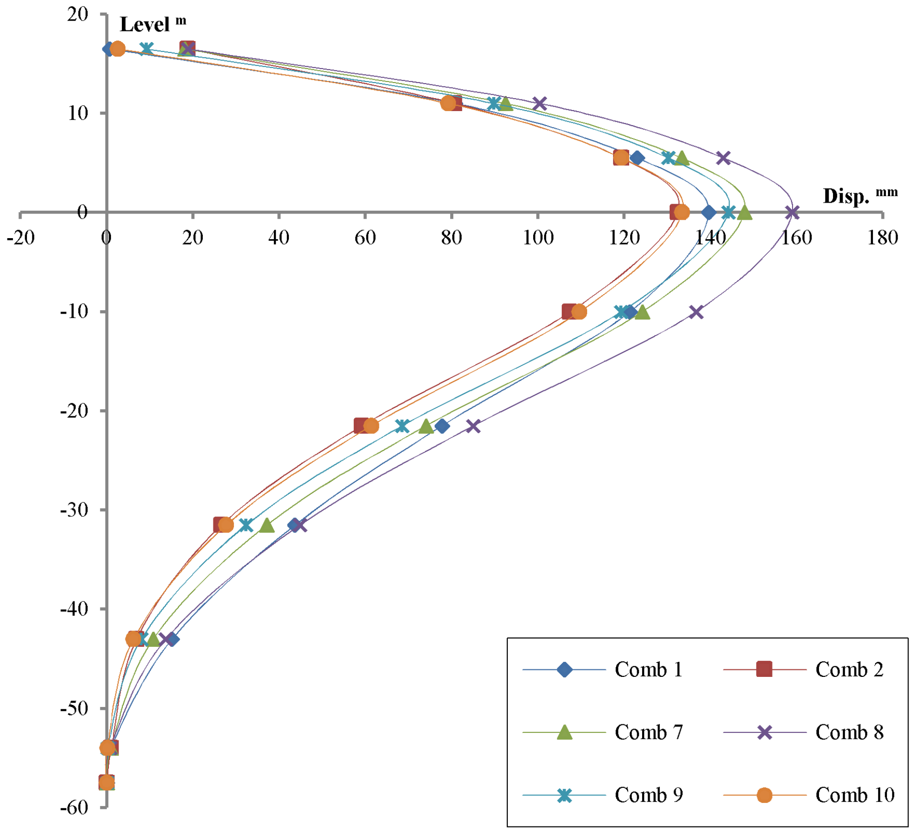

Figure 9. Absolute displacement with 1-year W_a, W_i & C_u Column 1.

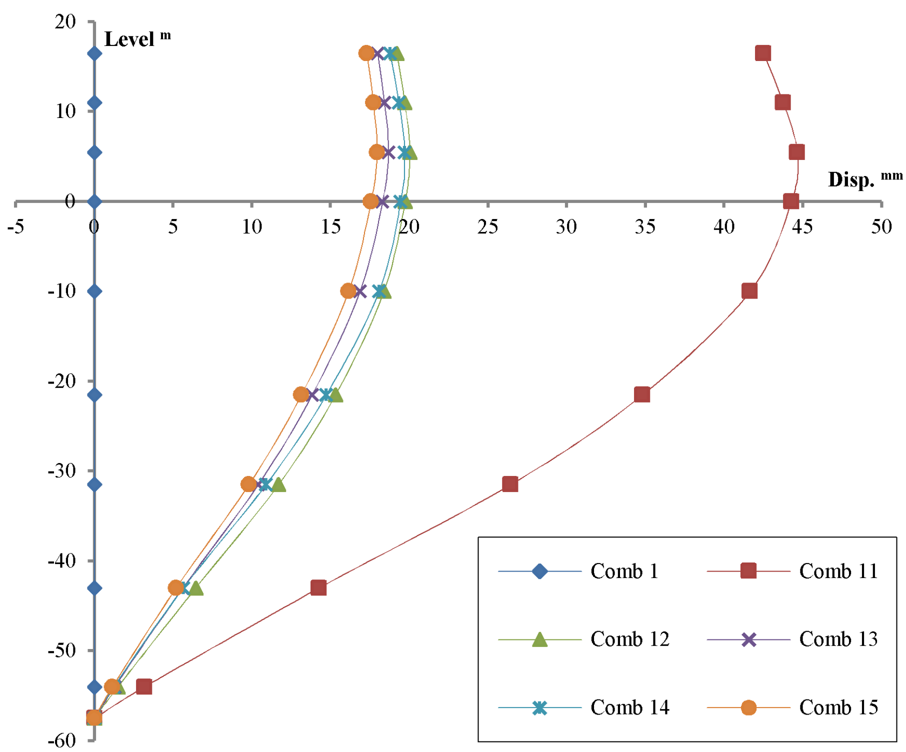

Figure 10. Displacement in the X-direction with 100-year C_u Column 1.

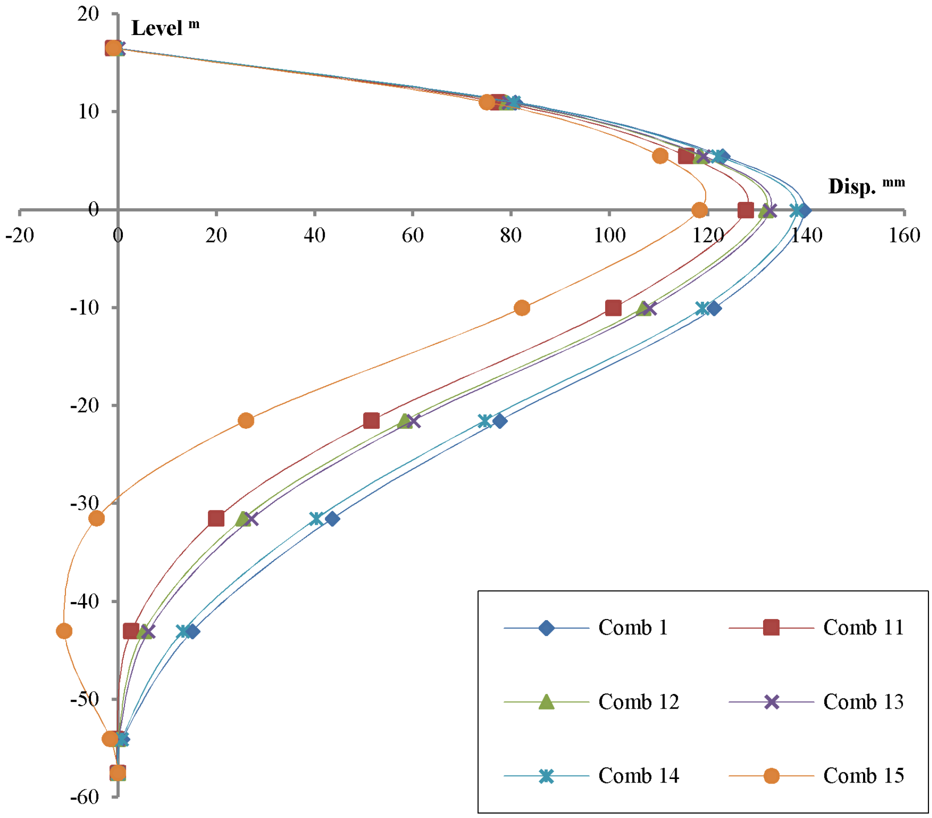

Figure 11. Displacement in the Y-direction with 100-year C_u Column 1.

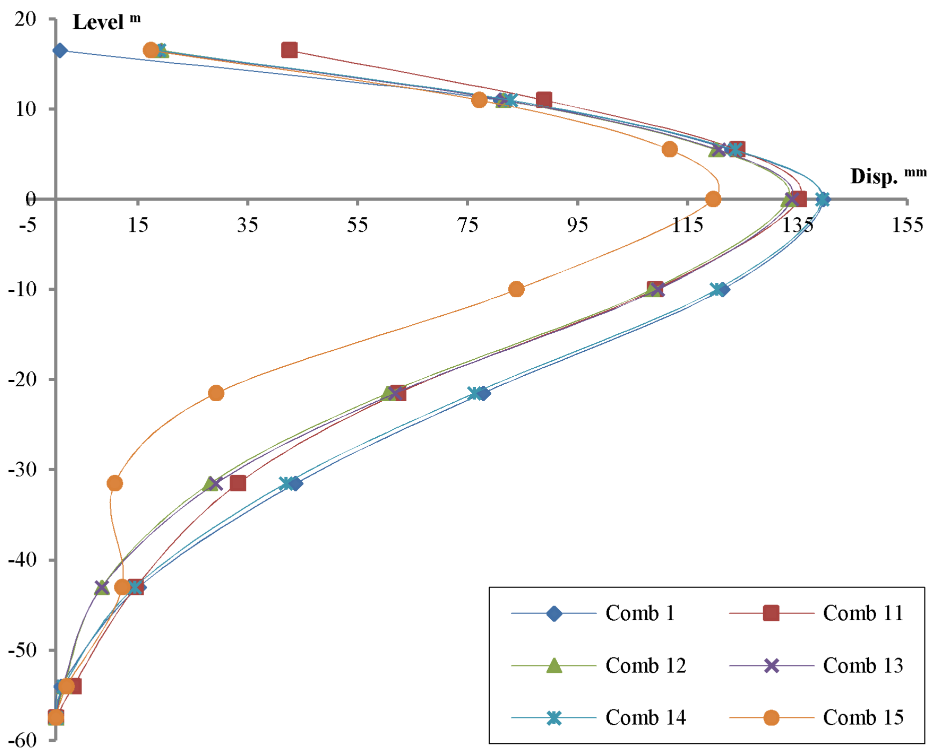

Figure 12. Absolute displacement with a 100-year C_u Column 1.

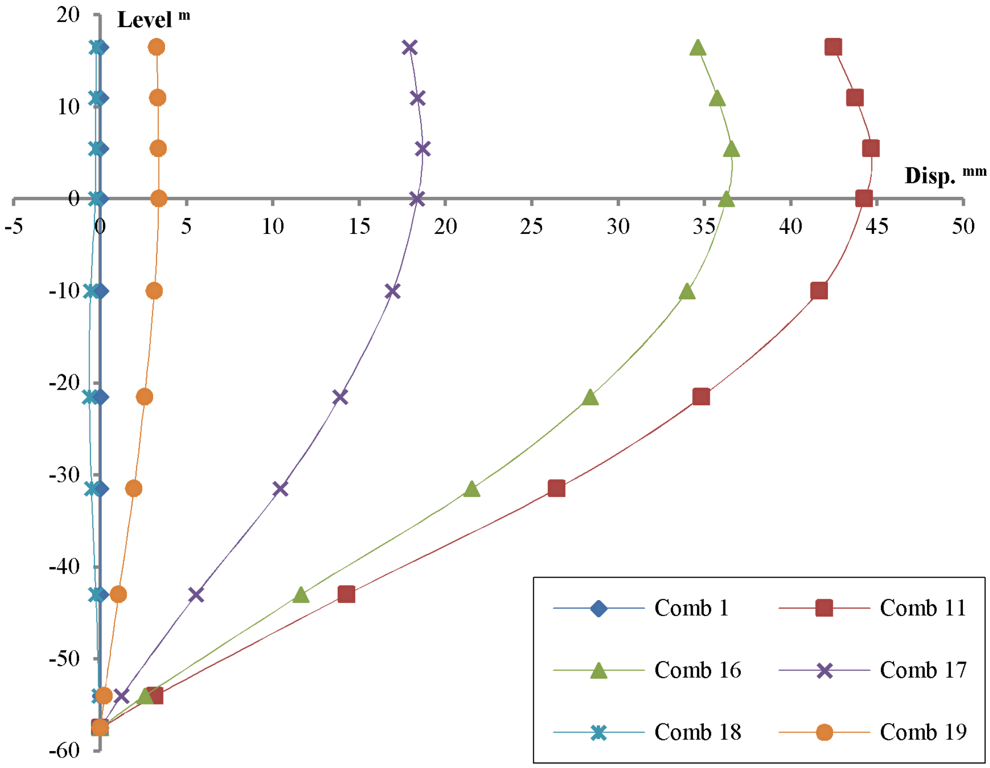

Figure 13. Displacement in the X-direction with 100-year W_a, W_i & C_u Column 1.

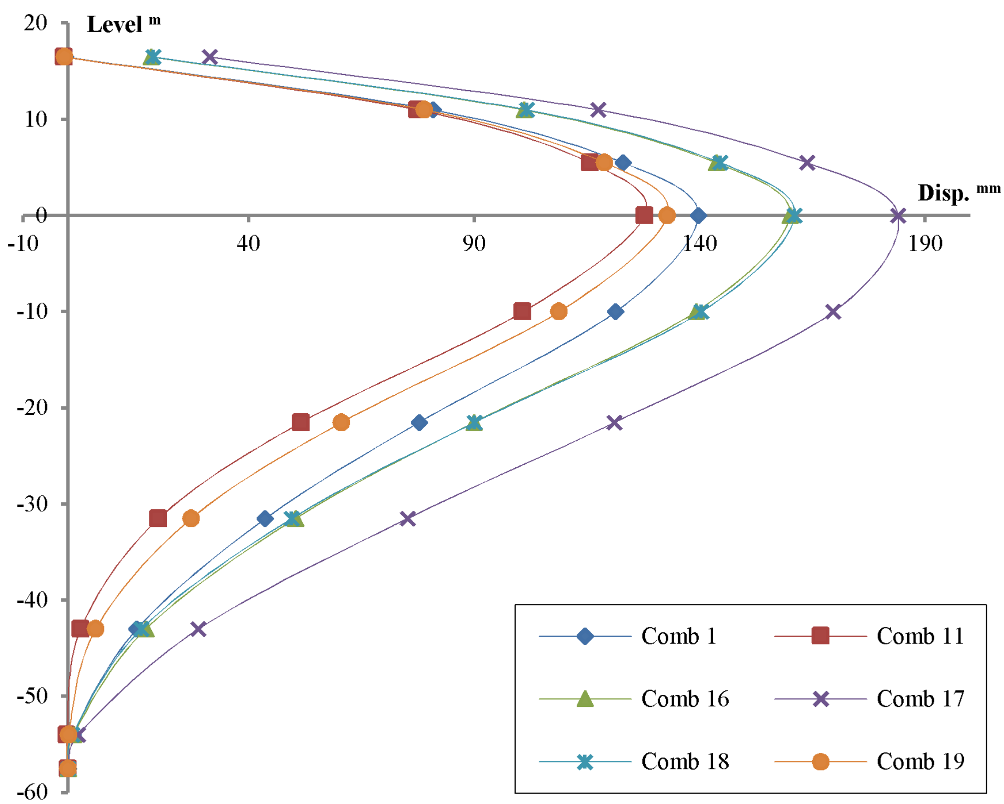

Figure 14. Displacement in the Y-direction with 100-year W_a, W_i & C_u Column 1.

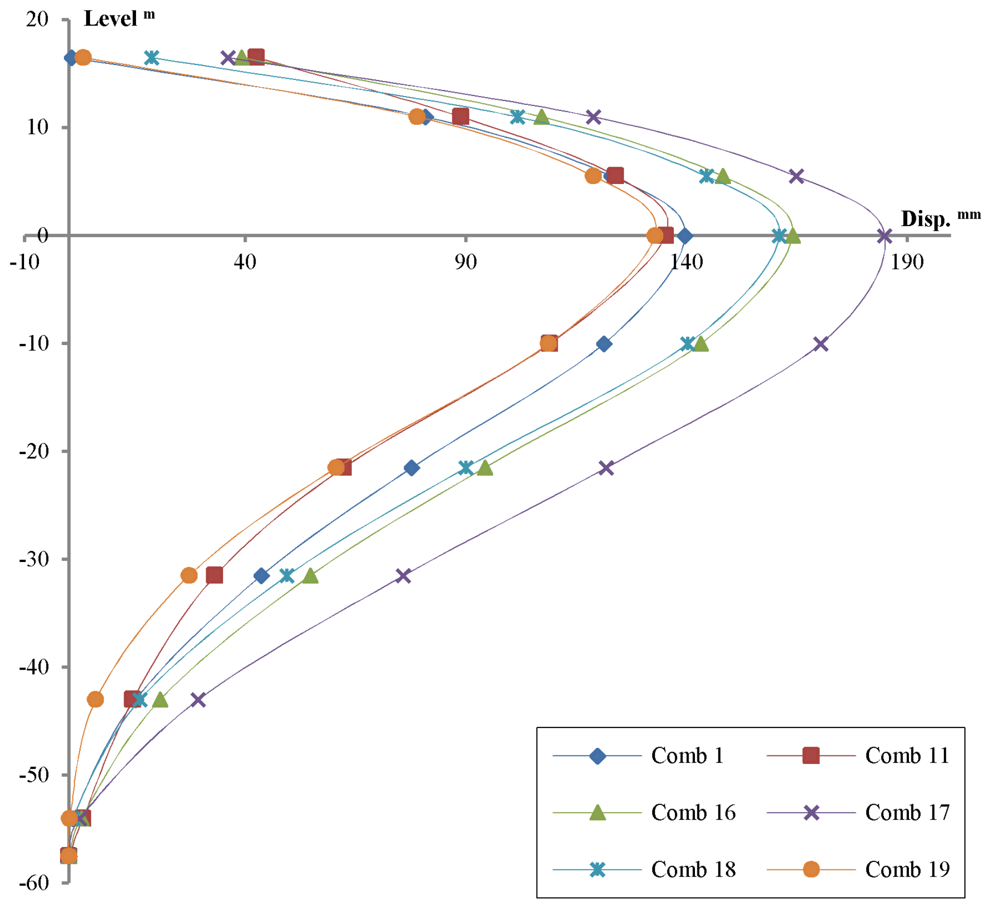

Figure 15. Absolute displacement with a 100-year W_a, W_i & C_u Column 1.

displacement and 135 degrees exhibits the minimum displacement in the X direction. This condition is contrary for the Y direction, attacks with angle of 90 degree showing the maximum displacement and the minimum displacement is with zero degree angle. Also the average value of absolute displacement difference for the 100-year sea current for combined number 17 (maximum absolute displacement) and combined number 19 (minimum absolute displacement) is about 37 percent.

Figure 16 and **Figure 17**, indicates that the maximum displacement at a_1 (still water level) and a_4 (junction between deck and jacket) are under the combined effect of all the loads. As the figure suggests, by changing the operating mode to a storm condition, column 1 displacement becomes more. The average displacement value for the node a_1 in two modes of one and 100-years with the same wave, wind and sea current hit, angles is about 7 percent and for the node a_4 this difference is about 13 percent.

6.2. Axial Forces and Bending Moments Responses

Figure 18, **Figure 19** and **Figure 20** show the bending moment $M_{2\text{-}2}$, $M_{3\text{-}3}$ and absolute for levels of a_0 to a_3. The values for the bending moments of a_1 to a_3 levels are almost uniformly and changes in hit angles of the wave, wind and sea currents have little effect on the bending. The average bending moment value of one and 100-years with the same wave, wind and sea current hit, angles is about 54 percent. In **Figure 21**, the maximum amount of bending moment at the base of columns of jacket is shown. According to this figure, in both operating and storm condition, with increase angle of attack of the wave, wind and sea current, the bending moment decrease.

Figure 22 shows the maximum axial force at critical levels in line with the height of the jacket platform structure. It is important in the design of a platform bases that the maximum axial force be considered, because the thickness of the base platform can be reduced with respect to the maximum stresses.

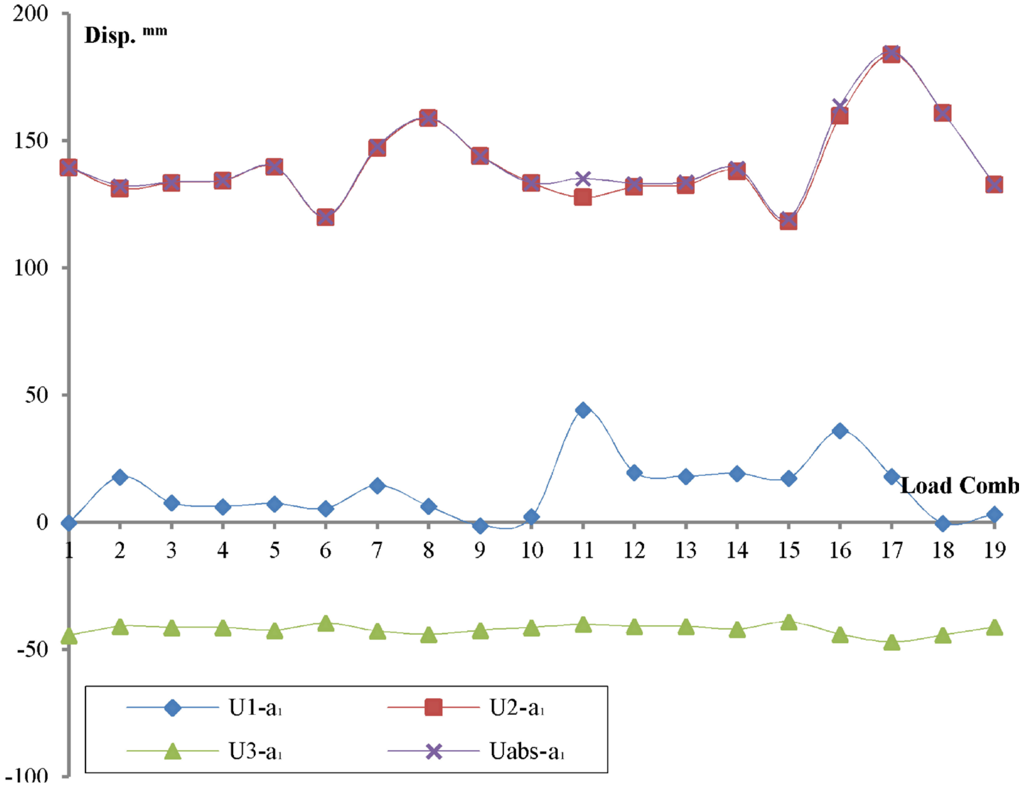

Figure 16. Column 1 displacement varies for a_1 level.

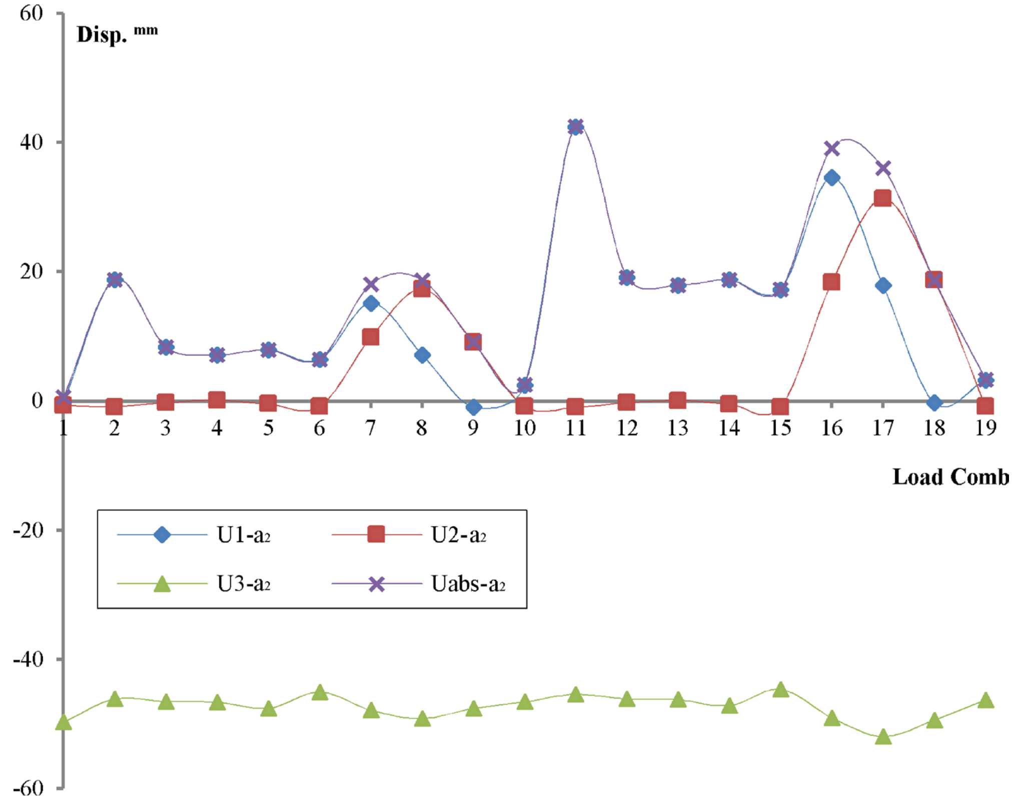

Figure 17. Column 1 displacement varies for a_2 level.

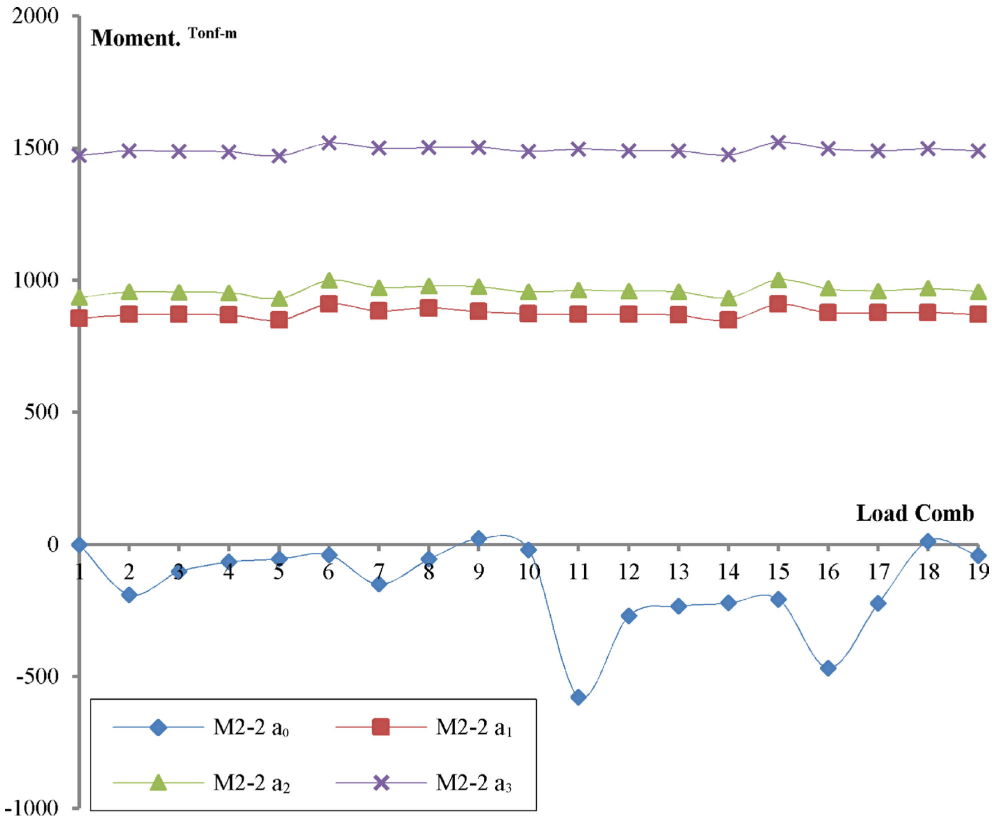

Figure 18. Column 1 bending moment $M_{2\text{-}2}$ for different levels.

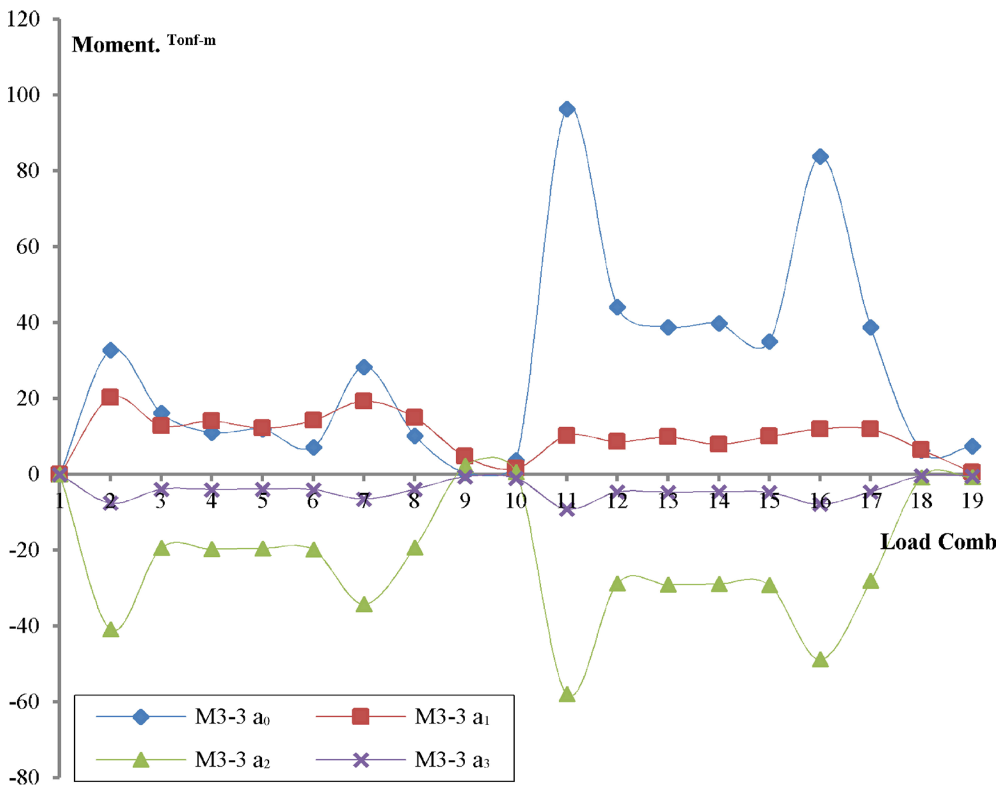

Figure 19. Column 1 bending moment $M_{3\text{-}3}$ for different levels.

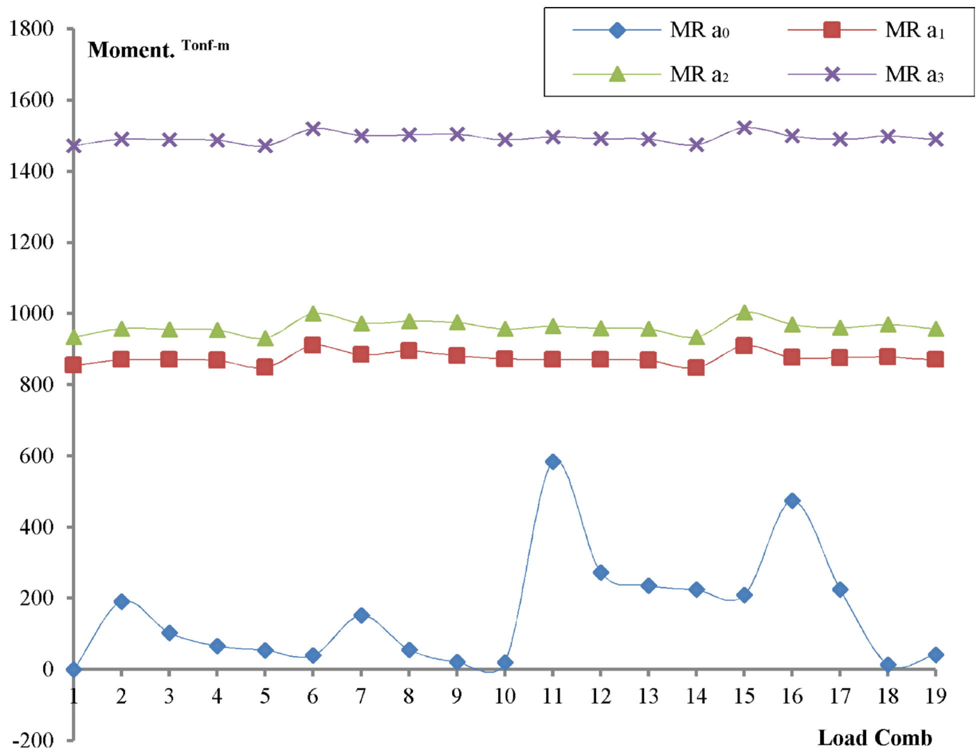

Figure 20. Column 1 absolute bending moment for different levels.

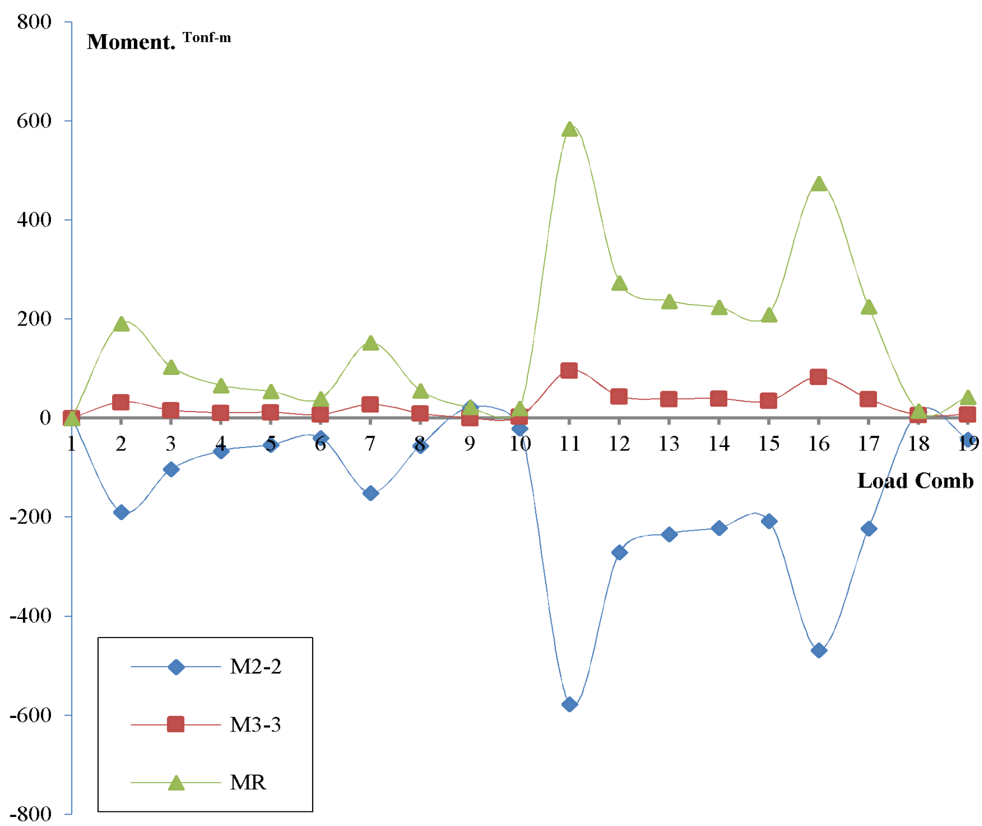

Figure 21. Base of Column 1 bending moment respond.

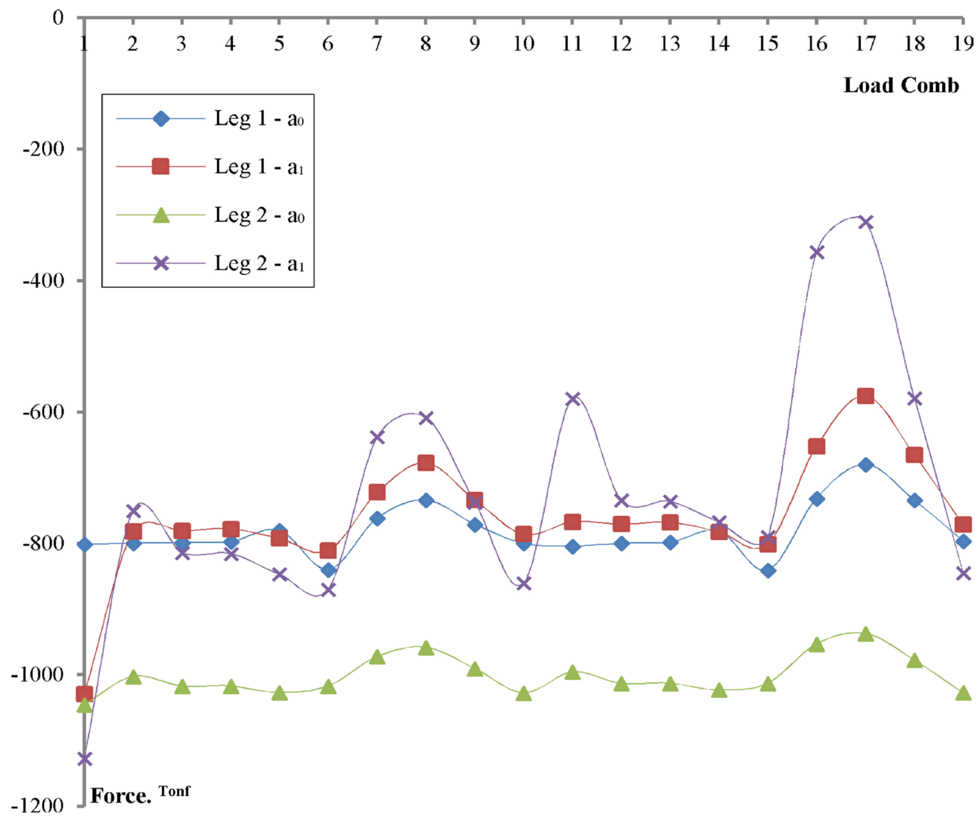

Figure 22. Column 1 & Column 2 axial force for a_0 and a_1 levels.

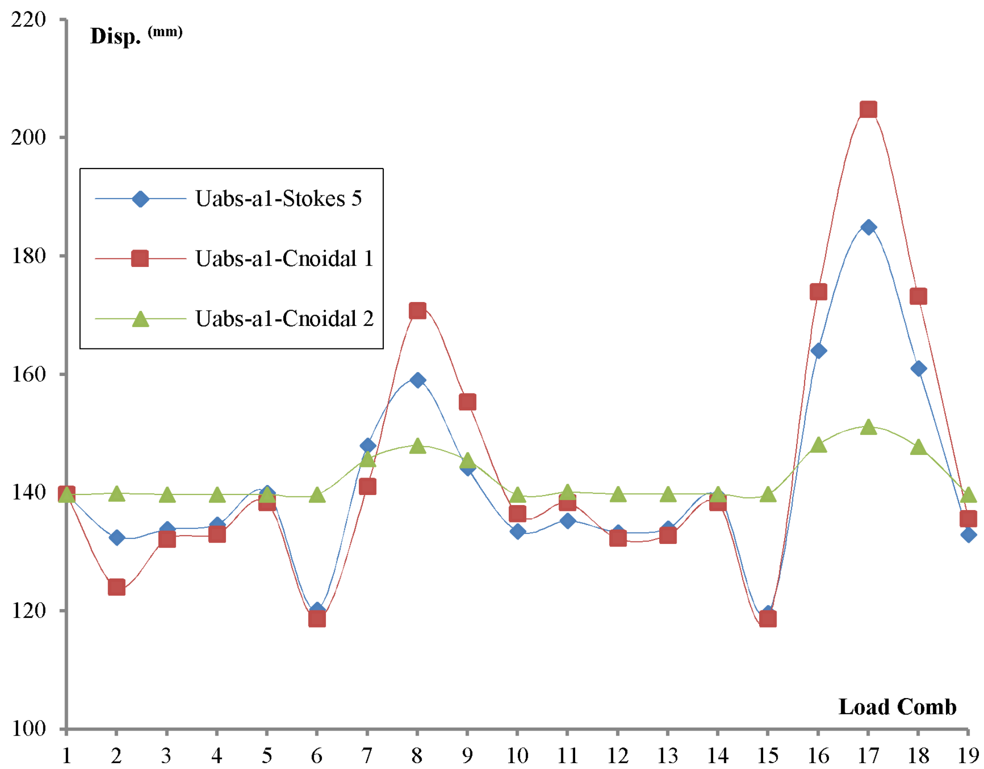

Figure 23. Comparison of displacement with all load combinations Column 1.

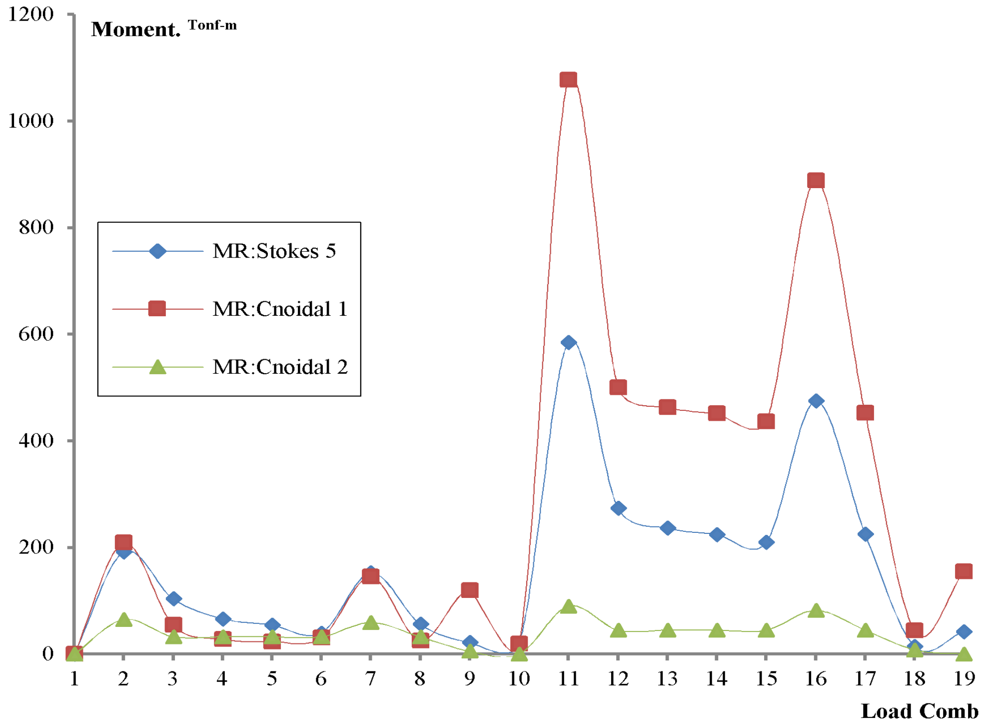

Figure 24. Comparison of moment with all load combinations in Column 1.

6.3. Parametric Compares

In order to compare the behavior of fixed offshore platform, three different wave theories (Stokes IV, Cnoidal I & Cnoidal II) were developed. In **Figure 23** and **Figure 24** displacements of (Node a_1) and moment of (Node a_0) under these three different wave theories with all load combinations were shown respectively. As was shown in **Figure 23**, the average of absolute displacement in column 1 (Node a_1) by using Cnoidal I wave theory is 3.4 percent more than Stokes IV wave theory and 12.6 percent more than Cnoidal II wave theory. In **Figure 24**, the average amount of absolute moment in column 1 (Node a_0) by using Cnoidal I wave theory is 11.8 percent more than Stokes IV wave theory and 24.5 psercent more than Cnoidal II wave theory.

As respects, load combination 2 shows the maximum displacement and moment with return period of 1-year (operating conditions) and load combination 11 shows the maximum displacement and moment with 100-year (extreme conditions/storm), the parametric comparison on (Node a_1) shows that by increasing wave height, the moment and displacement of jacket increases exponentially. These results are shown in **Figure 25** and **Figure 26** respectively. In **Figure 27**, the normalized comparison of wave height on (Node a_1) shows that by increasing (H/d) in which (H) is wave height and (d) is constant water level, the amount of (D/d) in which (D) is displacement of jacket is increases exponentially and can performs by $Y = me^{nX}$ equation, that m is (0.0002) and b is between (3.38 - 4.2).

7. Conclusion

Designing effective and affordable offshore platforms largely depends on the proper evaluation of the responses of hit during the useful life of the structures. However, the performance of the platform in various operations in bad weather requires that the entire structure is designed to meet the final condition. The design depends on the site of the platform. It is important that the response of the offshore platform reduce according to environmental loads. In general, offshore structures dynamic stress range reduction to about 15 percent leads to double increase of the service life and thus reduced maintenance costs. Periodic and regular inspections of offshore platforms to issue the certificates assurances require studying the structural response according to wave forces. In this study a finite element formulation is developed to study the nonlinear response of offshore fixed platform. A three dimensional element including large-scale displacements and time dependent wave force as a drag component of

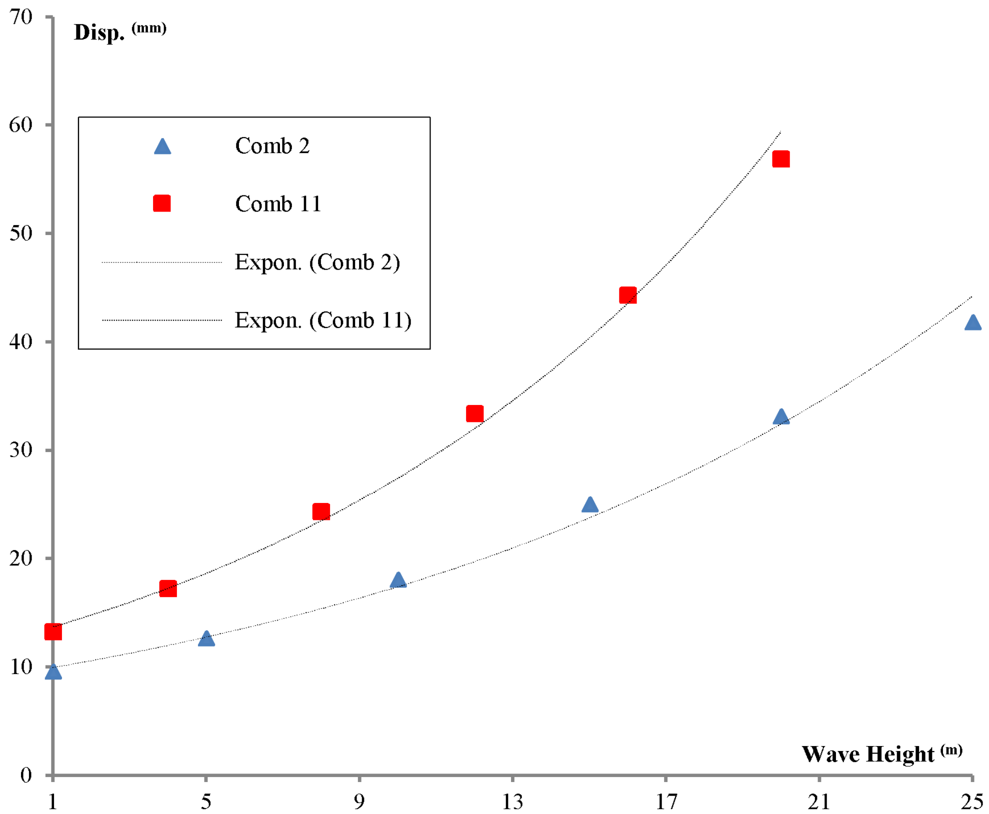

Figure 25. Comparison of displacement with different wave heights in Column 1.

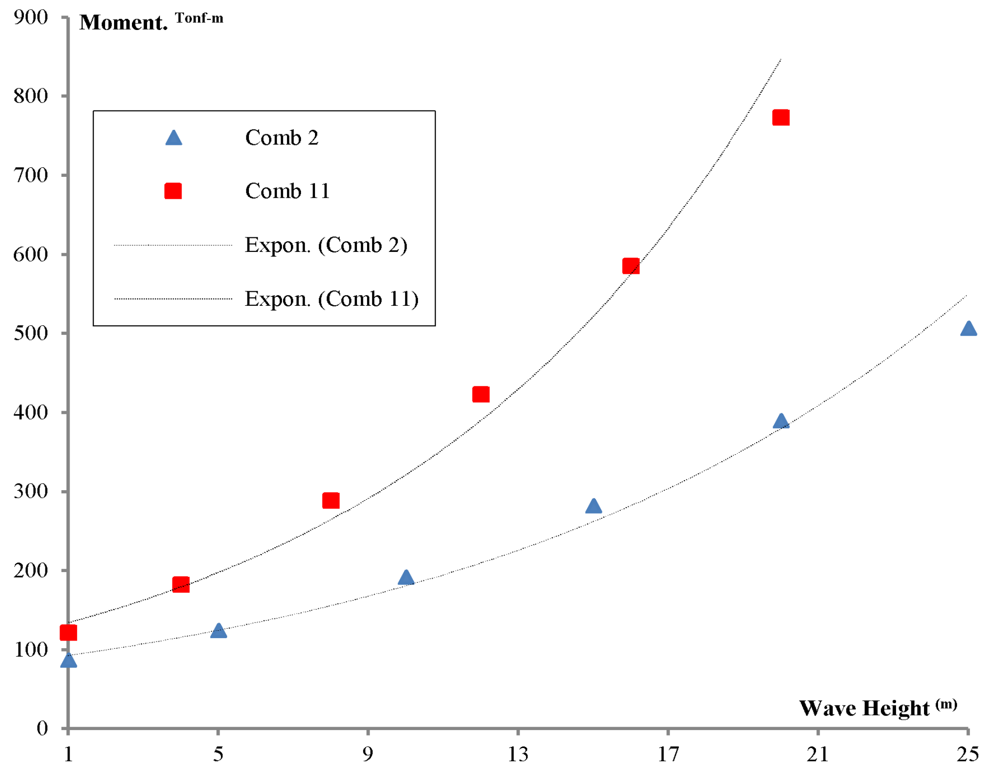

Figure 26. Comparison of Moment with different wave heights in Column 1.

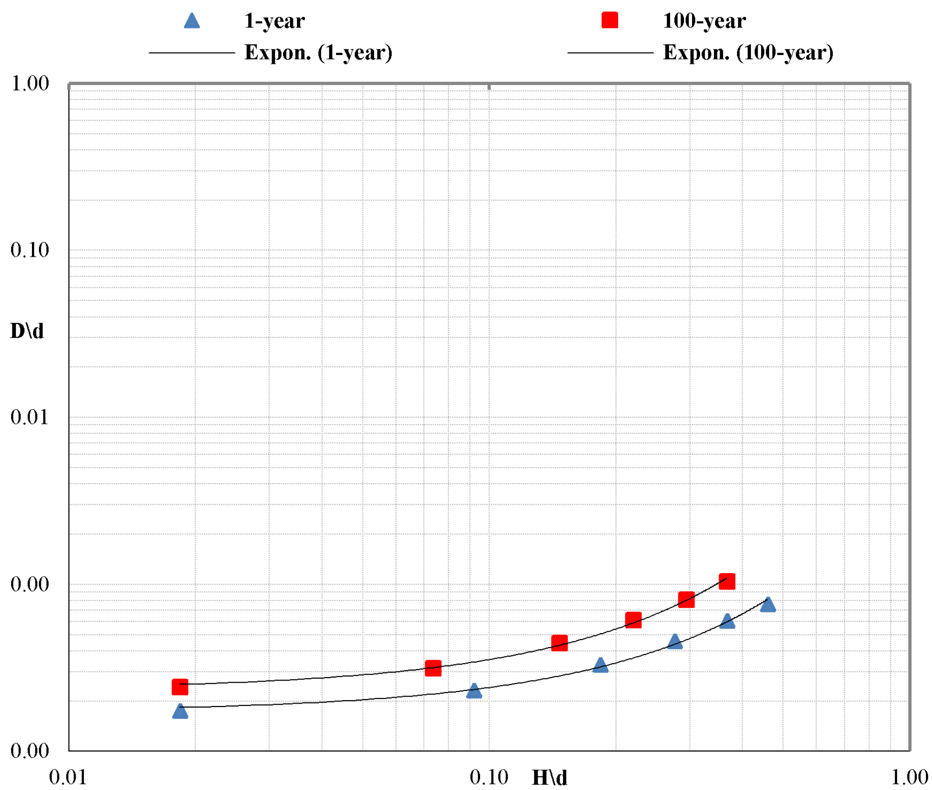

Figure 27. Normalized comparison of wave height on node a_1.

the wave force, which is a function of second-order water particle velocity was developed. Structural offshore analysis has been conducted in order to obtain a platforms shift response under different loads. Deformation of platform under combined waves, wind and ocean current flow loads was investigated. Offshore platform displacements, axial forces bending moments and free vibration frequencies were evaluated. The maximum displacement of all nodal points for wave and ocean currents with different angles of incidence was analyzed. The results shows that different angles of sea currents have little impact on the response of the horizontal displacements; while the wave hit directions shows significant effects on the value of displacements response. Displacements response U_1 increases nonlinearly with increasing platform height, but a significant curvature in displacements response U_2 is observed in the height of the platform. The results show that the wave-current flow direction shows little effect on the wave bending moment in a one-year return period, while sea current flow impact direction has a significant effect on the amount and direction of the bending moment. The wave bending moment $M_{3\text{-}3}$ with a return period of 100-years for the a_0 (the base of the platform) and a_1 (junction platform deck) are respectively 70 percent and 59 percent higher than the wave bending moment with a return period of 1-year. Compression between three different wave theories shows that Cnoidal I wave theory made the larger displacement and moment in the jacket than Stokes IV and Cnoidal II wave theories. Also by increasing wave height, the amount of displacement can perform by $Y = ae^{bX}$ equation, that a is between (9.3 - 12.7) and b is between (0.06 - 0.078) and moment can performs by $Y = ce^{dX}$ equation, that c is between (86 - 122) and d is between (0.074 - 0.096) increases exponentially.

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