SEISMIC RESPONSE OF TYPICAL FIXED JACKET TYPE OFFSHORE PLATFORM UNDER SEA WAVES: A REVIEW

Abhijeet A. Maske[1], Nikhil A. Maske[2] , Preeti P. Shiras[3]

[1]Civil Engineering Department, III Semester M-Tech Structural Engineering,
Government College of Engineering, Amravati, Maharashtra, (India)

[2,3] Civil Engineering Department, Assistant Professor, Nagpur Institute of Technology,
Rashtrasant Tukdoji Maharaj, NagpurUniversity, Nagpur, Maharashtra, (India)

ABSTRACT

Offshore platforms in seismically active areas should be designed to service severe earthquake excitations with no global structural failure. In seismic design of offshore platforms, it is often necessary to perform a dynamic analysis .This study summarizes the nonlinear dynamic analysis of a 3-D model of a typical Jacket-Type platform which is installed in Persian Gulf (SPD1), under simultaneously wave and earthquake loading has been conducted. It is assumed that they act in the same and different directions. The structure is modeled by finite element software (ANSYS Inc.). It is concluded that when the longitudinal components of the earthquake and wave are in different directions, an increase on the response of platform can be seen.

Index Terms: Offshore Platforms, Dynamic Analysis, Earthquake Loadings, Jacket-Type Platform, Finite Element Software (ANSYS Inc).

I INTRODUCTION

Offshore construction is the installation of structures and facilities in a marine environment, usually for the production and transmission of electricity, oil, gas and other resources. An oil platform, (offshore platform) is a large structure with facilities to drill wells, to extract and process oil and natural gas, and to temporarily store product until it can be brought to shore for refining and marketing.

The purpose of the study is to identify the adequate capacity of existing offshore structures in under earthquake effect as well as wave loads. Another purpose of this study is to analyze the behavior of the offshore structures under the earthquake and sea waves using nonlinear dynamic analysis i.e. Time history analysis. The main objective of this study is to determine the effect of earthquake loading and sea waves acting simultaneously to the existing structure.

II TYPES OF OFFSHORE PLATFORM

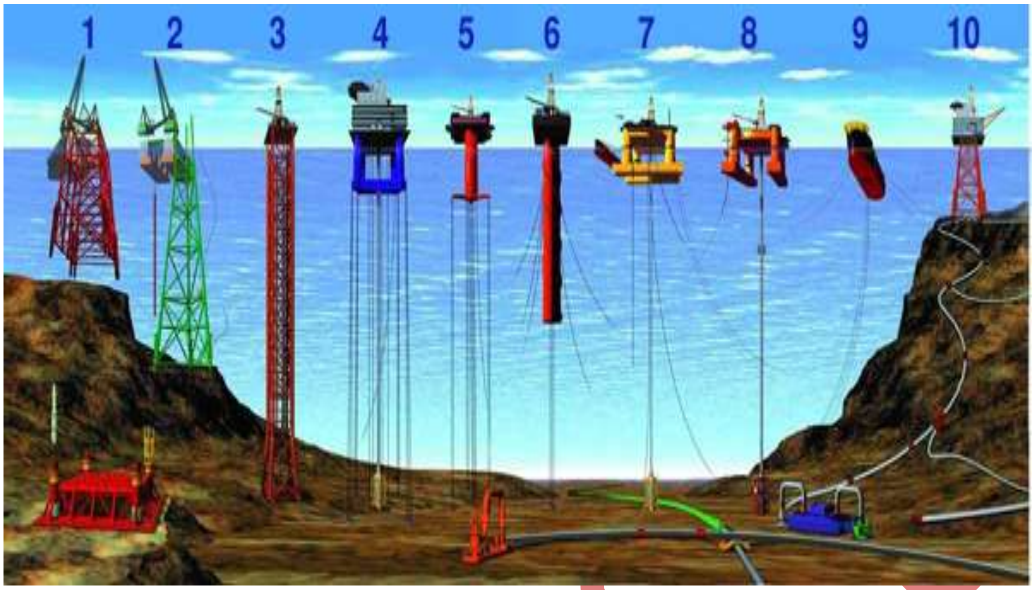

Fig : 1), 2) conventional fixed platforms; 3) compliant tower; 4, 5) tension leg platform; 6) spar platform; 7,8) semi-submersibles; 9) floating production, storage, and offloading facility; 10) sub-sea completion and tie-back to host facility.

II LITERATURE REVIEW

2.1 Morrison's Equation

The resulting force on a body in an unsteady flow is given by,

$$F_x(t)=\rho*C_m*A*\mathring{U}+0.5\rho*C_d*D*U|U|$$

Where,

ρ = Density of water
Cm = Mass coefficient
Cd = Drag coefficient
U = Velocity
$\mathring{U}$ = Acceleration

Khosro Bargi et.al (2011)

Assessed seismic response of fixed jacket type offshore platform under sea waves according to the API Recommended Practice 2A-WSD.

The results obtained from study show that the maximum displacement response of platform under combination of two loads (earthquake and wave loads) are more than maximum displacement response of earthquake load alone.

Shehata E. Abdel Raheem (2013)

Presents the study of nonlinear response of fixed jacket type offshore platform currently installed in Suez gulf, Red sea and it is analyzed using nonlinear dynamic analysis program SAP 2000.

Concluded that the reduction of dynamic stress amplitude of an offshore structure by 15% can extend the service life over two times, and can result in decreasing the expenditure on the maintenance and inspection of the structure.

Elsayed M.A.Abdel Aal et.al (2012)

Presents the study about fixed jacket type offshore platform. From results of non-linear analysis, they concluded that nonlinear analysis is required for a realistic determination of the behavior of structure and to obtain an economical and rational structural design.

American Petroleum Institute ,API-RP2A 1997 (2.2)

The majority of world's platforms have been designed according to the different editions of recommended practice by the American Petroleum Institute (API)

Environmental loads with the exception of earthquake, should be combined in a manner consistent with the probability of their simultaneously occurrence during the loading condition being consider.

2.2 Concluding Remarks

The research has shown that nonlinear analysis is very essential to the offshore structure which is one of the important structures, subjected to earthquake and sea waves. Therefore, an attempt has been made to investigate the behavior of offshore structure to sustain under earthquake as well as wave effect using Time History analysis.

III METHODOLOGY

This study is based on nonlinear analysis of fixed jacket type platform of offshore structure. In this chapter summary of various parameters defining the computational model and the frame geometry considered for this study are explained. Accurate modeling of the nonlinear properties of various structural elements is very important in nonlinear analysis.

3.1 Structure Geometry

The general purpose finite element analysis software ANSYS 9 was used to perform analyses. Fig. 3.1 shows a 3D Computer models of the fixed jacket based offshore platform.

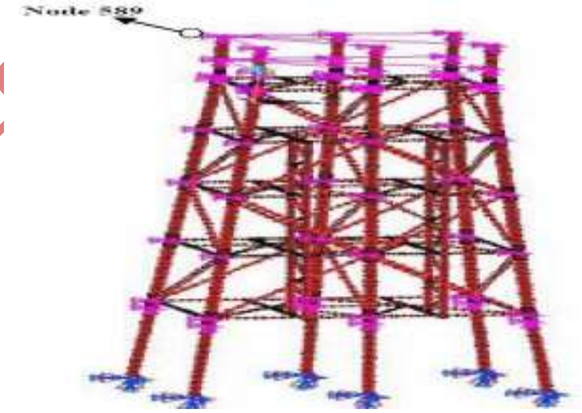

Fig 3.1 Schematic Model of Jacket-Type Platform

The Seismic response of a fixed jacket type offshore platform will be carried out Non-linearly i.e. by Time history analysis. The different time histories to be used are as follows:

1. El-Centro
2. Kobe
3. Tabas (Source: http://PEER.Berkeley.edu.html)

Figures below, showing the longitudinal and horizontal components of time-history of earthquake displacement which are used in this study.

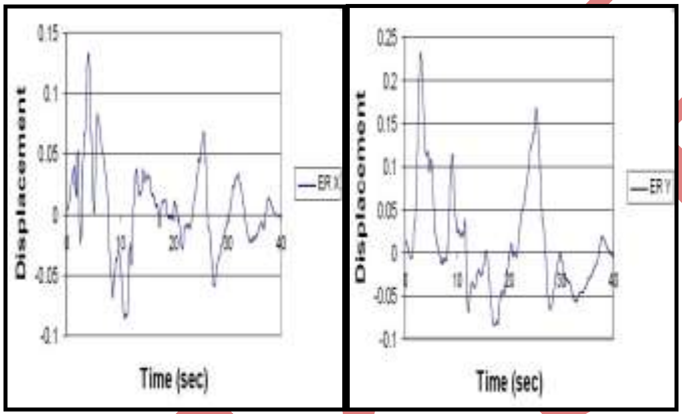

Fig 3.2 Time history Longitudinal and horizontal component of El Centro

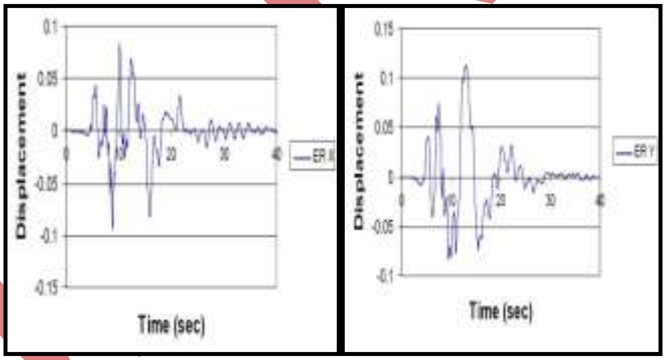

Fig 3.3 Time history Longitudinal and horizontal component of Cobe

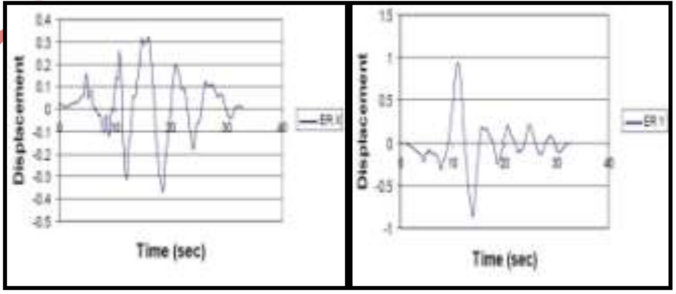

Fig 3.4 Time history Longitudinal and horizontal component of Tabas

3.2 Analysis Procedure

Wave and earthquake phenomena occur at different direction. Studied structure is symmetric around Y direction, therefore according to Figure 3.5, for analysis, four directions for earthquake and wave loads imposed on structure are selected.

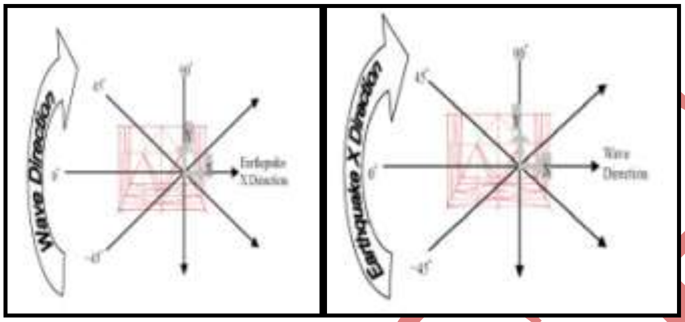

Fig 3.5 Wave and Earthquake imposed direction

In order to evaluate the response of studied platform under earthquake and wave loads, simultaneously four studies regarding to wave and earthquake directions have been performed. In the first study, only earthquake load analysis was performed at four directions Figure 3.5.

Regarding to the random features of sea waves, since it is possible that the direction of wave and earthquake loads to be different, in the second analysis, earthquake longitudinal component fixed at zero direction simultaneously acts with wave load at four directions.

For tertiary analysis, wave load component fixed at zero direction simultaneously acts with earthquake longitudinal component at four directions. For all conditions, both earthquake longitudinal and horizontal components were used. Finally, analysis for 100 years wave was performed at four directions.

IV RESULT AND DISCUSSION

The selected model is analyzed using non linear dynamic analysis. At first results from dynamic analysis for modal verification and then results from time history analysis are discussed in this chapter.

4.1 Results from Dynamic Analysis

A dynamic analysis is normally mandatory for every offshore structure, but can be restricted to the main modes in the case of stiff structures. The first step in a dynamic analysis consists of determining the principal natural vibration mode shapes and frequencies of the undamped, multi-degree-of-freedom structure. First rigid structures have a fundamental vibration period well below the range of wave periods (typically less than 3sec.), first and second modes are effective on structure behavior and higher order mode shapes having less effects on structure behavior.

In order to model verification, 10 first modes of structure compared with initial design modes. It shows that first and second modes correspond with fact and high order modes have approximately 35% - 50% difference, because jacket modeled with equivalent pile length. This comparison is show in Table 4.1.

Table 4.1: Comparison of results

Mode	Model Periods (sec)	SPD1 Periods (sec)	% Error
1	2.02	2.05	-1.4
2	1.89	1.9	-0.5
3	0.77	1.52	-49.0
4	0.47	0.82	-42.1
5	0.44	0.75	-41.1
6	0.32	0.53	-39.1
7	0.32	0.5	-36.4
8	0.30	0.49	-38.3
9	0.30	0.47	-36.0
10	0.29	0.46	-36.5

4.2 Results from Time History Analysis

Results obtained from different time history analysis at node 589 (one of the dek's node) as shown in figures given below.

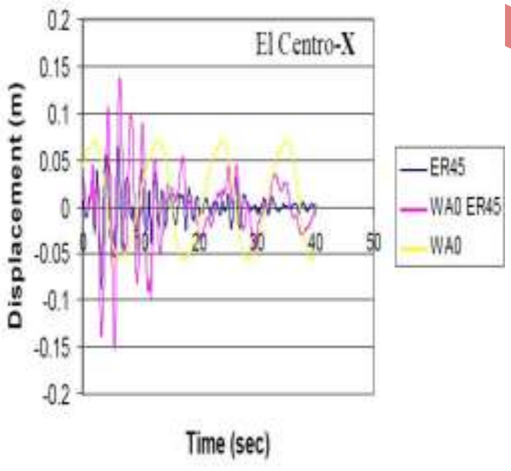

Fig 4.1 Response of platform in X direction at node 589

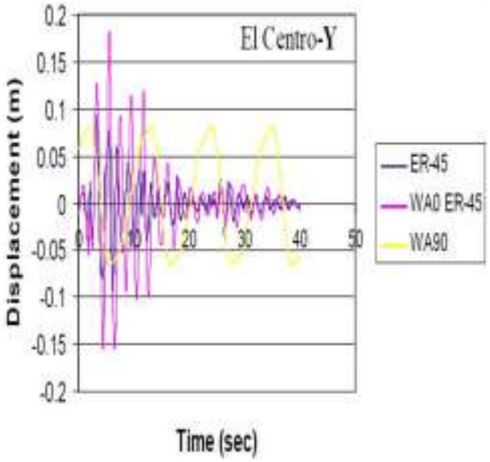

Fig 4.2 Response of platform in Y direction at node 589

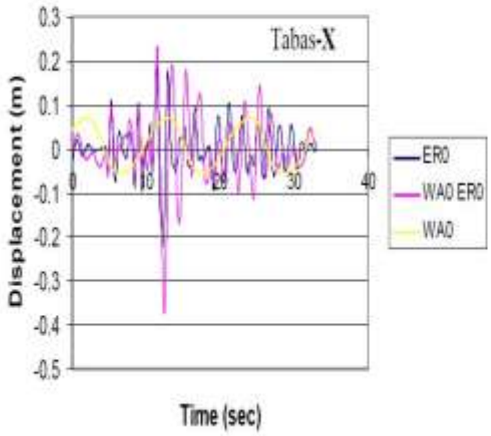

Fig 4.3 Response of platform in X direction at node 589

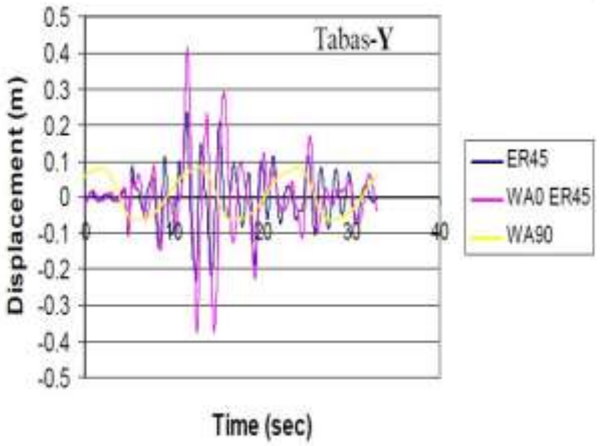

Fig 4.4 Response of platform in Y direction at node 589

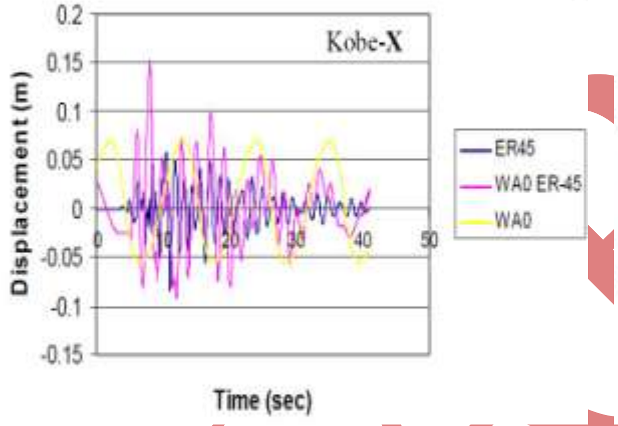

Fig 4.5 Response of platform in X direction at node 589

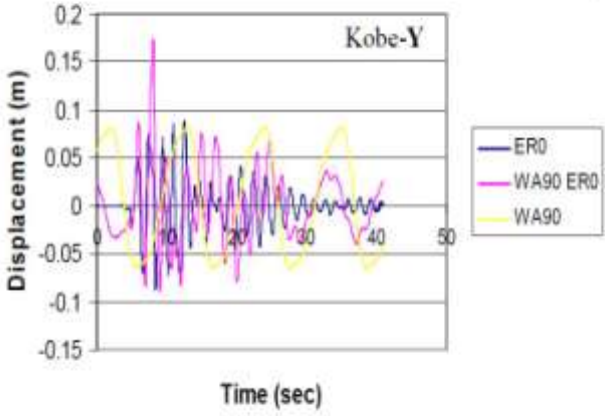

Fig 4.6 Response of platform in Y direction at node 589

(Loads: pink line: earthquake; Blue line: earthquake and wave; Yellow line: 100 years wave)

Drift of Structure

This study shows significant difference between drift under simultaneously wave and earthquake loads compared with regulations criteria (for earthquake load). This difference is shown in Table 4.2.

Table 4.2: Difference between Drifts.

Earthquake	El-Centro		Kobe		Tabas	
Direction	X	Y	X	Y	X	Y
Difference ratio between wave and earthquake compared with earthquake	1.97	1.94	2.65	1.94	1.71	1.75

alone						
Difference percent ratio between wave and earthquake compared with 100 years wave	2.74	2.41	2.15	2.13	6.81	5.74

The response of jacket under wave loading and El-Centro seismic loading was studied on severe direction separately. This comparison was done for other seismic records and other conditions. Those results are shown below.

This method of analysis considers the wave in one direction is constant and earthquake lateral component direction is applied 45 degrees by 45 degrees. The drift of node 589 is evaluated in X direction. Figure 4.7 shows the result of effect of non-directional act of wave and earthquake components on jacket.

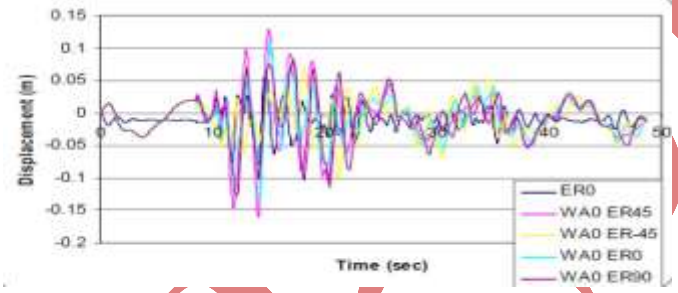

Fig 4.7 Comparison of X direction Drift when water wave lateral component is applied on zero degree and seismic lateral component is applied 450 by 450.

According to the Figure 4.8 the result is that the maximum drift on X direction occurs when the seismic lateral component is applied on 45 degrees and water wave is applied on zero degree.

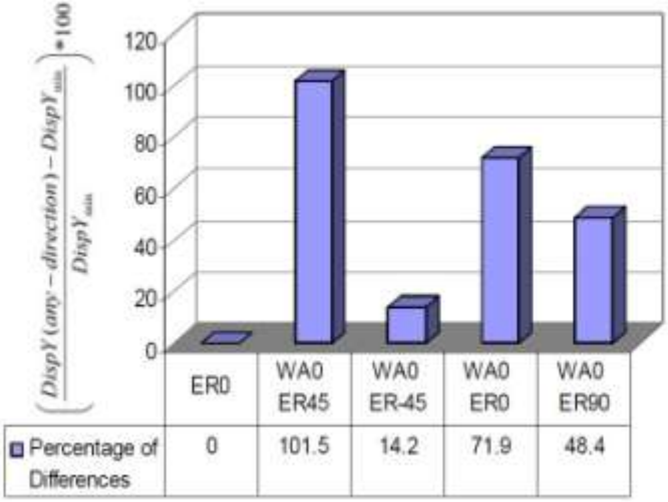

Fig 4.8 Comparison of Percentage changes in relative displacement in X direction on node 589 for Figure 4.7.

Figure 4.9 shows the comparison effect of non-directional of water wave and seismic lateral component such as conditions discussed above, but Y direction drift is studied.

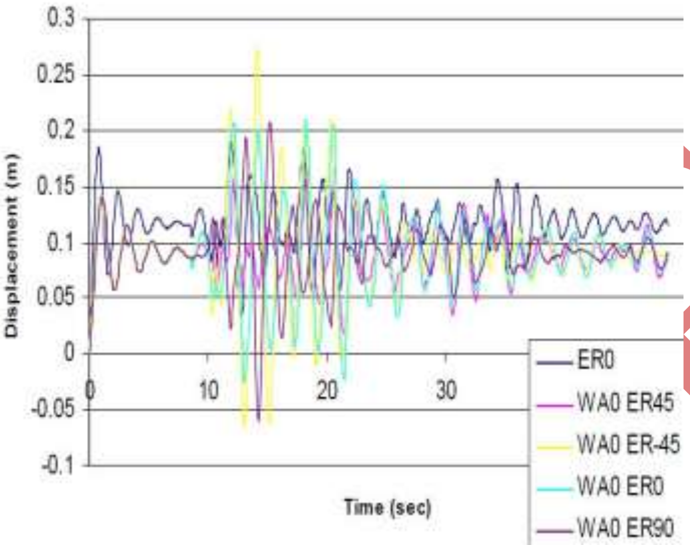

Fig 4.9 Comparison of Y direction Drift when the water wave lateral component is applied on zero degree and seismic lateral component is applied 450 by 450.

According to Figure 4.10 the result is that the maximum drift on Y direction occurs when the seismic lateral component is applied on –45 degrees and water wave is applied on zero degree.

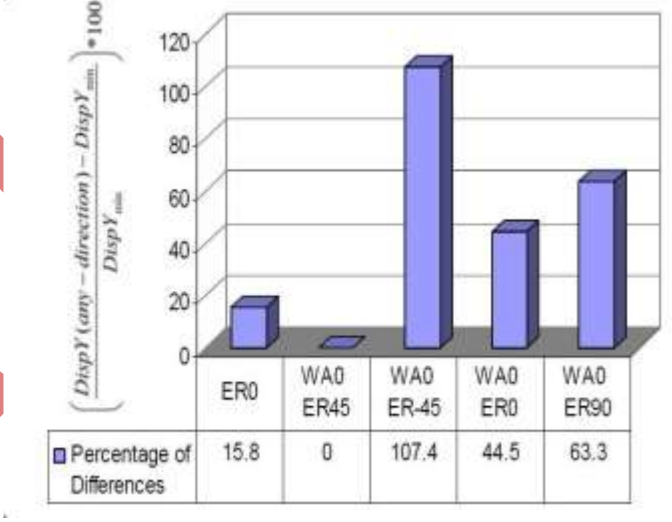

Fig 4.10 Comparison of Percentage changes in relative displacement in X direction on node 589 for Figure 4.9.

Figure 4.11 shows the comparison of non-directional effect of water wave and seismic lateral component applied simultaneously on jacket. In this case the direction of seismic lateral component is constant on zero degree and water wave direction changes 45 degrees by 45 degrees. Drifts are compared in X direction for node 589.

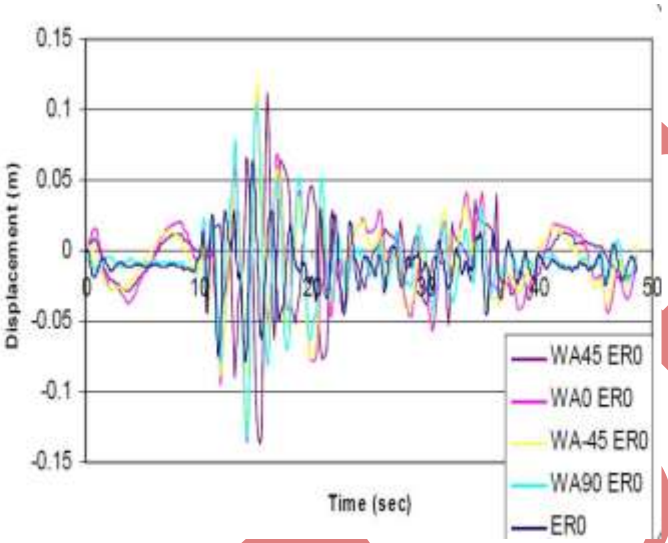

Figure 4.11 Comparison of drifts on X direction when seismic lateral is applied on zero degree and water wave direction changes 450 by 450.

Figure 4.12 shows that maximum drift on X direction when the seismic lateral component is applied in zero degree and water wave is applied in -45 degrees. The same comparison for drift in Y direction for node 589 is given below.

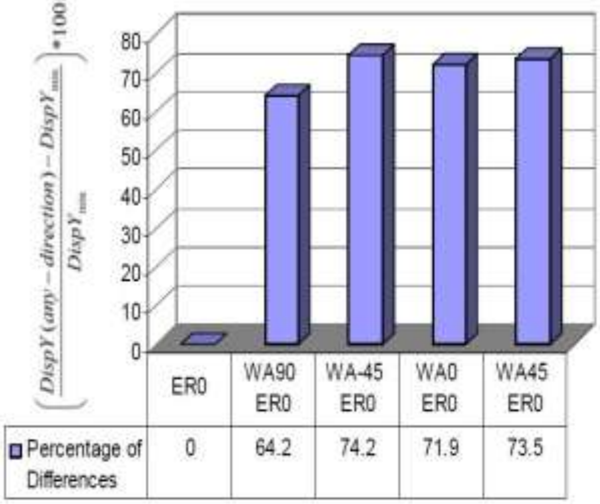

Figure 4.12 Comparison of Percentage changes in relative displacement in X direction on node 589 for Figure 4.11.

Figure 4.13 shows the comparison of non-directional effect of water wave and seismic lateral component applied simultaneously on jacket. In this case the direction of seismic lateral component is constant on zero degree and water wave direction changes 45 degrees by 45 degrees. Drifts are compared in Y direction for node 589.

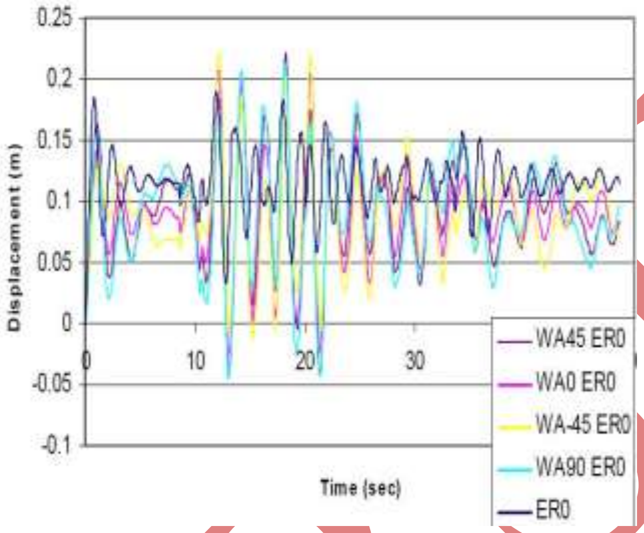

Figure 4.13 Comparison of drifts on Y direction when seismic lateral is applied on zero degree and water wave direction changes 45 degrees by 45 degrees.

Finally, Figure 4.14 shows that maximum drift on Y direction when the seismic lateral component is applied in zero degree and water wave is applied in 45 degrees.

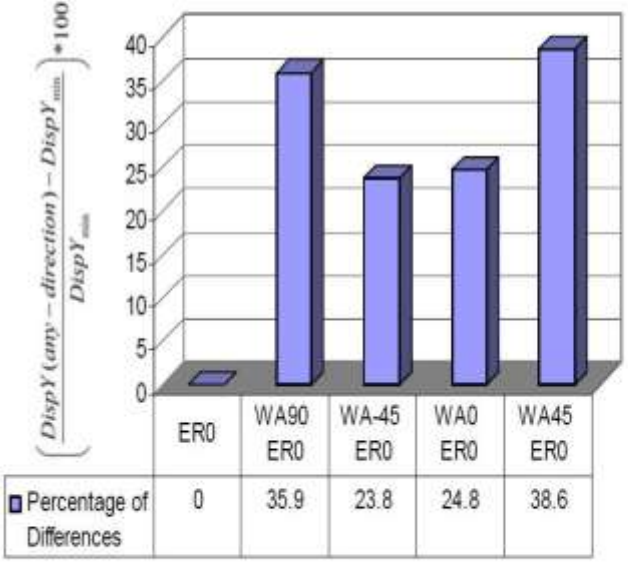

Fig.4.14 Comparison of Percentage changes in relative displacement in Y direction on node 589 for Figure 4.13.

CONCLUSION

The response of fixed jacket type offshore platform was investigated using the time history analysis. As a result of the work that was completed in this study, the following conclusions were made:

- When the longitudinal components of the earthquake and wave are in different directions, an increase on the response of platform can be seen.
- The displacement for earthquake load alone is less than the displacement for the combination of earthquake and wave loads.
- This study shows significant difference between drift under simultaneously wave and earthquake loads compared with regulations criteria (for earthquake load).
- It may also conclude that nonlinear response investigation is quite crucial for safe design and operation of offshore platform.
- The time history analysis is a relatively simple way to explore the non linear behavior of offshore structures.

REFERENCES

[1] Khosro Bargi, S.Reza Hosseini and Mohommad H. Tadayon "Seismic response of a Typical Fixed Jacket type offshore platform (SPD1) under sea waves", Open journal of marine science,1,36-42 (2011)

[2] Shehata E. Abdel Raheem , "Nonlinear response of fixed jacket offshore platform under structural and wave loads" Coupled system mechanics, VOL. 2, NO. 1 (2013).

[3] Elsayed M.A.Abdel Aal and Fayez K. Abdel Seed, "Nonlinear analysis of offshore structures under wave loading", 15th World conference on earthquake engineering, (2012).

[4] American Petroleum Institute (API) , API-RP2A-WSD "Recommended practice for planning, designing and constructing fixed offshore platforms.