

In-Place, Seismic and Fatigue Analysis of Offshore Platform for Life Extension

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ABSTRACT

This paper presents reassessment of existing offshore platform in the Ardjuna Field, Northwest of Java, Indonesia. The existing platform of B1C was installed in 1975 and owned by PHE ONWJ. The B1C platform is numerically evaluated for service life extension purposes until the next twenty years. The reassessment analyses focus on in-place analysis, seismic analysis and fatigue analysis. These analyses refer to recommended practice issued by American Petroleum Institute standard. The results indicated that the entire value of unity check for all members fulfill the requirements of API RP 2A - WSD. Analysis of fatigue computation showed that three joints have the fatigue life less than 59 years.

KEY WORDS: *Offshore platform, assessment, fatigue, in-place, seismic*

1.0 INTRODUCTION

The offshore platform or known as the oil and gas drilling offshore structure is one example of offshore structures. The platform is a structure that is equipped with a variety of tools to support the process of oil and gas exploration, ranging from

drilling, processing, transportation, extraction of drilling results, and even accommodation for workers.

Start around 1970/1980's, many offshore platforms were built in Indonesian seas. An increasing number of platforms are now reaching their design life. Then the question about how the structural integrity of the platforms can be maintained becomes increasingly important for the platform owners. Basically, an offshore platform structure should be evaluated (assessment) periodically. An assessment to determine structural integrity may be required during the life of a platform.

According to API RP2A [1], an existing platform will require an assessment evaluation if the platform is already beyond the age of design life, the presence of significant damage or deterioration of primary structural component found during inspections and significantly changes from the original design or previous assessment basis.

Many oil companies in Indonesia are planning to extend platforms lifetime that exceed the service design life as part of their program to enhance oil or gas production with minimum investment. One of the platform known as B1C platform, belonging to *Pertamina Hulu Energi* Offshore North West Java (PHE ONWJ) have exceeded its initial service life design (40 years). This platform located offshore in Northwest of Java, Indonesia and it was installed in 1975. Because of its productivity remains high, PHE ONWJ intends to extend the service life until the next twenty years. Thus, a reassessment (reappraisal) is essential in order to evaluate the feasibility of the platform structure, for an extended period of service life until the next twenty years.

The procedure for design and reappraisal of B1C offshore platform for this study is refers to recommended practice issued by American Petroleum Institute (API RP2A). Three analyses are performed to platform structure, which is in-place analysis, seismic analysis and fatigue analysis by combining the operational, self-weight and environmental loads induced on the structure.

2.0 PLATFORM DATA

Based on available data and documents provided by PT. Tripatra Engineers and Constructors, the B1C Platform is located in the Ardjuna Field, Northwest of Java, Indonesian Seas (05° 54' 53.0" S, 107° 43' 51.0" E). This platform is located in 131.0 ft water depth and was installed since 1975.

The B1C Platform consist of two level deck structures with Main Deck with top of steel elevation at (+) 43 ft, and Cellar Deck with top of steel elevation at (+) 25 ft. The B1C platform considered in the study is a four legged production platform as shown in Figure 1. Water depth at the location is 131 ft below MSL as shown in Table 1. The platform is designed based on the API recommended criteria for 100-years return period for a wave height of 27.3 ft [6]. The environmental data required to determine the loads to this study is presented in Table 1-5, respectively.

The Jacket Leg structure is 40" diameter (with batter 1:8). All Piles are 36" diameter and penetrated to 165 ft below mud line. For axial pile capacity is recommended to use 2870.0 kips for B1C Platform based on report study by Soilmaklelan (1993). For eartquake source information, Dames dan Moore (2000) reported that the estimation of peak ground acceleration (PGA) for Ductility Level Eartquake (DLE) condition is 2.39 m/s².

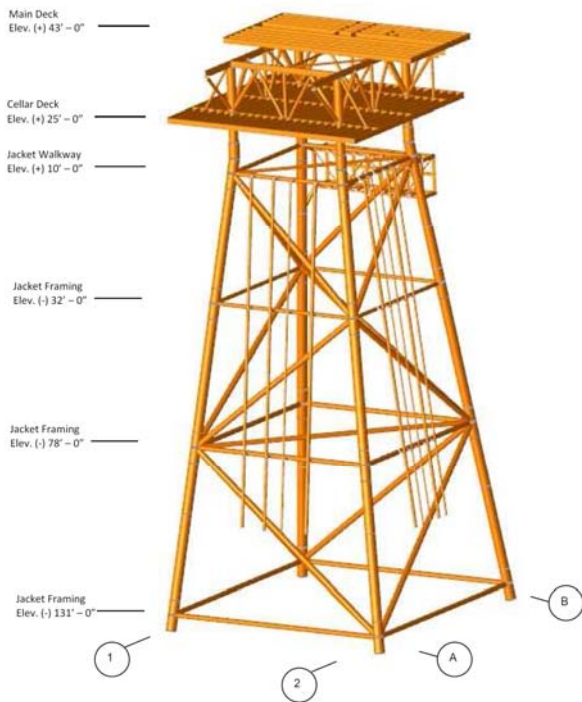


Figure 1: B1C Platform model

Table 1: Water depth

Description	1-year Operating	100-years Storm
Mean Sea Level (MSL)	131,0 ft.	131,0 ft.
Highest Astronomical Tide (HAT)	3,8 ft.	3,8 ft.
Storm Tide (surge)	0,3 ft.	0,5 ft.
Minimum Water Depth (MSL + 1/2 HAT + Storm Tide)	128,8 ft	128,6 ft
Maximum Water Depth (MSL + 1/2 HAT + Storm Tide)	133,2 ft.	133,4 ft.

Table 2: Wind speed

Description	1-year Return Periods	100-years Return Periods
1 Hour Wind	38.0 Mph	63.0 Mph

Table 3: Wave design

Description	1-year Return Periods	100-years Return Periods
Heigh of Maximum Wave	16.4 ft.	27.3 ft.
Period of Maximum Wave	7.0 sec.	9.3 sec.

Table 4: Current profile

Percent of depth (%)	Current speed (ft/sec)	
	1-year Operating	100-years Storm
0	2.6	3.6
10	2.4	3.3
20	2.3	3.1
30	2.1	2.8
40	2.0	2.6
50	1.8	2.4
60	1.7	2.2
70	1.5	2.0
80	1.4	1.8
90	1.2	1.5
100	0.8	0.9

Table 5: 10-year directional wave height distribution for fatigue analysis

Wave Height (ft.)	N 315	NE 270	E 225	SE 180	S 135	SW 90	W 45	NW 0
2	6.714.600	8.996.200	19.296.200	8.083.600	1.825.300	1.564.600	9.713.300	8.996.200
6	229.880	308.050	660.750	276.760	63.640	54.490	332.600	308.050
10	7.752	10.390	22.270	9.336	1.060	910	11.212	10.390
14	260	348	754	314	0	0	375	348
18	8	11	25	10	0	0	13	11
22	0	1	1	0	0	0	0	1
TOTAL	6.952.500	9.315.000	19.980.000	8.370.020	1.890.000	1.620.000	10.057.500	9.315.000

3.0 METHODOLOGY

The procedure for reassessment of B1C offshore platform for this study is refers to the standard API RP2A-WSD2 1st edition and the 13th edition of AISC-ASD. In-place, seismic and fatigue analysis are performed using structure analysis computer program by considering all loads conditions. All the loads are calculated using the information provided by PT. Tripatra Engineers and Constructors.

3.1 Static Analysis

Static analysis performed by considering loading conditions for Still Water Case, 1-Year Condition and 100-Year Condition. Still Water condition cases combines maximum load operation without taking into account the environmental load, while operational conditions using extreme environmental loads with return period 1 year, and for extreme conditions using extreme environmental loads with return period of 100 years. Design and strength of structures are expressed in Unity Checks (UC) as the ratio between the actual stress that occurs on the member of structure with allowable stress. The UC criteria for each member in the structure should be less than 1.0. The flowchart for in-place analysis can be seen in Figure 2.

3.2 Seismic Analysis

Seismic analysis is the type of analysis conducted to study the response of structures to earthquake loads. The main source in the seismic analysis is information related to the movement of soil that affects the structure. In general, seismic analysis is performed to determine the pile strength of jacket leg, the strength of each joint of jacket leg (punching shear), and strength members on deck. Detail of flowchart for seismic analysis in this study can be seen in Figure 3.

3.3 Fatigue Analysis

Fatigue analysis is performed to determine the structural response to continual wave loading. Wave induced dynamic force is one of the most significant force leading to fatigue of offshore member structures. Numerical fatigue assessment method is based on S-N curve approach for API standard utilizing spectral method. The calculation of cumulative fatigue damage is based on Palmgren-Miner's rule, which can be written as:

$$D = \sum_{i=1}^J \frac{n_i}{N_i}$$

Where, D is the cumulative fatigue damage, n_i is number of stress cycles of a particular stress range, N_i is average number of loading cycles to failure under constant amplitude loading at that stress range according to the relevant S-N curve, and J is number of considered stress range intervals. Failure is predicted to occurs when the cumulative damage (D) over J exceeds a critical value equal to unity.

In this study, the B1C platform is analyzed for the design service life for next 20 years. Originally, the B1C platform was designed to have service life for 40 years or until 2015. Based on API RP2A, the value of the safety factor 2.0 is used for the next 20 year service life. So, the entire joint in the structure should have fatigue life more than 59 years. Detail of procedure for fatigue analysis in this study can be seen in Figure 4.

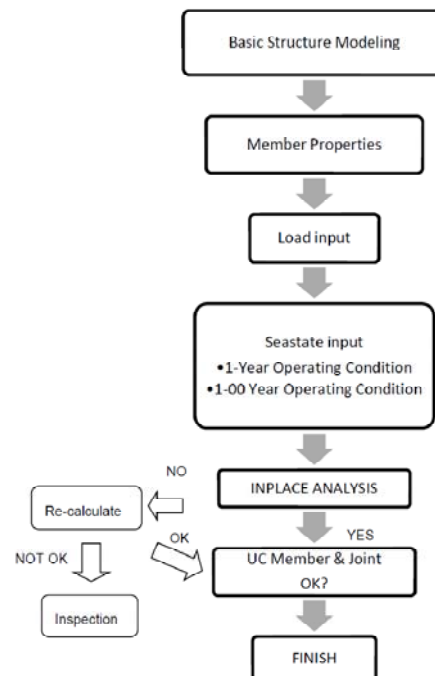


Figure 2: In-place analysis methodology

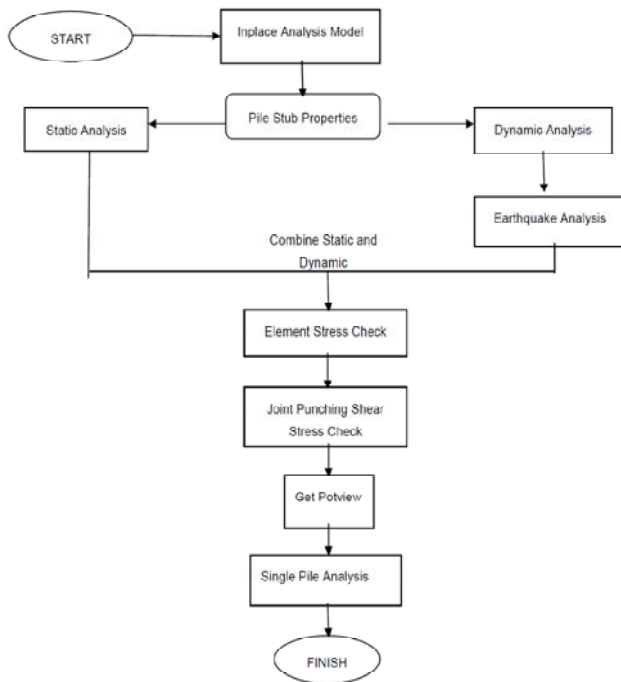


Figure 3: Seismic analysis methodology

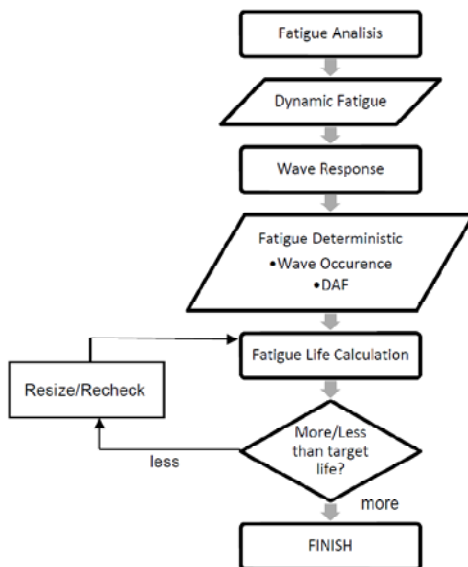


Figure 4: Fatigue analysis methodology

4.0 RESULTS

Structure and results of the above analysis is modeled with programs structure analysis computer system. The output generated from the three analysis of in-place, seismic and fatigue is shown in Table 6-9 below, respectively.

Based on the computer modeling analysis, the outline of the result can be concluded as follows:

1. For in-place analysis as shown in Table 6, the entire values of UC members on operational conditions and storm condition are under 1 ($UC < 1$).
2. Pile Safety Factor and Joint Punching Shear results from in-place analysis shown that all members have a safe UC value ($UC < 1$) as indicated in Table 7 and 8. Table 7 and 8 presented the maximum value of stress unity members check on each part of the structure based on in-place analysis.
3. For seismic analysis, as shown in Table 7 and 8 below, there are no members who failed and needs to be redesigned due to the lateral load on seismic analysis of DLE conditions.
4. From the results of fatigue analysis, it is known that three joints have the fatigue life less than 59 years or the intended total service life as shown in Table 9. These joints are joint 301L, 303L and 304L with age serviceability 42.2, 50.54, 48.45 years, respectively. Therefore, the inspection and monitoring of B1C offshore platform must be scheduled in 2015 for these three joints.

5.0 CONCLUSION

In this study, reassessment of B1C offshore platform that owned by PHE ONWJ is numerically evaluated for service life extension in the next twenty years. This platform structure located in the Ardjuna Field, Northwest of Java and was installed on 1975. The reassessment analyses of B1C platform focus on in-place analysis, seismic analysis and fatigue analysis. These analyses refer to recommended practice Codes and Standards, Specifications, and Regulations issued by American Petroleum Institute (API RP2A). The results showed that the entire values of unity check for all members fulfill the requirements of API RP 2A - WSD. Meanwhile, fatigue analysis result showed that three joints have the fatigue life less than 59 years.

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Table 6. Members stress Unity Check (UC)

Location	Still Water Case			1-Year Operating			100-Year Storm		
	Member	Group	UC	Member	Group	UC	Member	Group	UC
Maximum Jacket and Pile Stress Unity Check									
Jacket Leg	403L-0055	P4B	0.17	303L-0055	P4B	0.46	303L-0055	P4B	0.54
Jacket Vertical Brace	201L-303L	B2	0.12	201L-303L	B2	0.48	201L-303L	B2	0.61
Jacket Horizontal Brace	0177-204L	B1	0.13	0177-204L	B1	0.26	303L-302L	B1	0.41
Pile above Mudline	003P-103P	PL6	0.45	103P-203P	PL2	0.72	103P-203P	PL2	0.60
Pile Below Mudline									
Maximum Topside Member Stress Unity Check									
Main Deck	0236-180	W20	0.71	W20	W20	0.99	W20	W20	0.96
Cellar Deck	151-125	W21	0.71	W21	W21	0.85	W21	W21	0.74
Deck Leg	503L-111	P36	0.41	P36	P36	0.80	P36	P36	0.73
Deck Leg Truss	171-111	P14	0.64	P14	P14	0.94	P14	P14	0.89

Table 7. Joint Punching Shear Check Summary

Location	Still Water Case			1-Year Operating			100-Year Storm			Seismic		
	Joint	Properties	UC	Joint	Properties	UC	Joint	Properties	UC	Joint	Properties	UC
Elev. (+) 10'-00"	403L	41''O.D 1.0''WT	0.12	403L	41''O.D 1.0''WT	0.31	404L	41''O.D 1.0''WT	0.34	404L	41''O.D 1.0''WT	0.33
Elev. (-) 32'-00"	302L	41''O.D 1.0''WT	0.14	302L	41''O.D 1.0''WT	0.55	302L	41''O.D 1.0''WT	0.82	303L	41''O.D 1.0''WT	0.67
Elev. (-) 78'-00"	202L	41''O.D 1.0''WT	0.07	201L	41''O.D 1.0''WT	0.28	201L	41''O.D 1.0''WT	0.41	201L	41''O.D 1.0''WT	0.60
Elev. (-) 131'-00"	104L	41''O.D 1.0''WT	0.16	104L	41''O.D 1.0''WT	0.32	103L	41''O.D 1.0''WT	0.42	103L	41''O.D 1.0''WT	0.45

Table 8. Pile safety factor

Conditions	Pile Group	Pile Penetration (ft)	Pile Weight (kips)	Pile Axial Load (kips)	Pile Axial Safety Factor
Still Water Case	PL1	165	69.8	787.4	2.74
	PL2	165	69.8	863.4	2.48
	PL3	165	69.8	781.1	2.72
	PL4	165	69.8	738.6	2.87
1-Year Operating	PL1	165	69.8	795.9	2.70
	PL2	165	69.8	687.0	3.09
	PL3	165	69.8	1213.0	1.82
	PL4	165	69.8	1088.0	2.02
100-Year Storm	PL1	165	69.8	1081.5	2.14
	PL2	165	69.8	976.8	2.37
	PL3	165	69.8	1430.5	1.62
	PL4	165	69.8	1262.5	1.83
Ductility Level Eartquake	PL1	165	69.8	864.8	2.50
	PL2	165	69.8	928.6	2.34
	PL3	165	69.8	865.7	2.50
	PL4	165	69.8	884.9	2.45

Table 9. Maximum Joint Fatigue Life

Joint	Location	Member	Group ID	Type	Result	
					Fatigue Life	Inspection Schedule
301L	Elev.(-) 32"	301L-401L	P4	TUB	42.24	2015
303L	Elev.(-) 32"	303L-0055	P4B	TUB	50.54	2015
304L	Elev.(-) 32"	304L-0052	P4B	TUB	48.45	2015

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