PUSHOVER ANALYSIS OF JACKET STRUCTURE IN OFFSHORE PLATFORM SUBJECTED TO EARTHQUAKE WITH 800 YEARS RETURN PERIOD

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ABSTRACT

In offshore structure the regulation of lateral load condition against earthquake is quite different with common building structure developed in Indonesia. Based on the code API- WSD2000 the return period of earthquake is 800 years, this condition is different with Indonesian National Standards (SNI 1726-2002) for earthquake loading in which the return period used is 500 years.

In this research the offshore jacket structures is modeled as a truss structures with fix-end condition since the foundation is using pile foundation. The performance of structure and will be checked using pushover analysis to get the performance level of structure during several response spectrum of earthquake. Where in this research one response spectrum based on the earthquake data acquired from BMKG and was calculated using the attenuation calculation to find the initial PGA on site. Three other response spectrums was directly taken from SNI 1726-2002 which is consist of Zone 2, Zone 4 and Zone 6 of earthquake.

The modeling and non-linear pushover analysis was done using SACS. The performance of structure against non-linear pushover analysis is normalized as a capacity spectrum and three response spectrums were normalized as demand spectrum. Based on these curves the performance level of structures can be known and the differences between each response spectrums also shown in this research.

Keywords: Pushover Analysis, Offshore Structures, SACS

1. INTRODUCTION

In offshore structure analysis and design there is a significant difference against common building structure analysis and design. This difference is caused by the use of code is not the same and as a result many adjustments should be to perform the analysis and design in offshore structure for civil engineer. Mainly in offshore structure the dominant load is come from wave load

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periodically but in the special section the load occurred from earthquake also need to be analyzed. In offshore structure the earthquake return period for analysis is divided into two region, the first region is for periodically earthquake with return period of 200 years which must be provided by the structure in Strength Level (SL) and 800 ~ 1000 years return period which is also provided by the structure in Ductility Level (DL).

It is common in analysis and designing the structure against earthquake load using static analysis where the force can be derived from static equation of earthquake load. But this type of analysis doesn’t show the performance of structure and commonly the performance of structure is set in to some level according to the detailing of connection and its material also. More advanced analysis using non-linear analysis whether it is dynamic or static can show the performance of structure and what level are the structure against some earthquake level. With this nonlinear analysis we can also control the behavior of structure and the collapse mechanism of structure.

In this research we had conduct a response spectrum calculation to get the earthquake coefficient from the earthquake data because in the new map of earthquake hazard there is no guidance about offshore structure. Moreover the return period is also different, so in this research the response spectrum calculation is based on 800 years of earthquake return period. To get the performance level of structure according to the code used in offshore structure (API RP 2A) we conduct a non-linear pushover analysis based on the earthquake coefficient from response spectrum that have been created before.

The location of this offshore structure is in Bekapai-BL in Makassar strait. This location according to SNI 1726-2002 earthquake zone is equal to zone 2 with 0.1 g. But with the earthquake data and were calculated the location PGA is about 0.452 g. There is a large difference. In analyzing against earthquake loading the program used is special for offshore structure which called SACS (Structural Analysis Computer System) which is developed by Engineering Dynamics Incorporated (EDI).

2. MODELING AND ANALYSIS

The type of offshore structure is fixed jacket platform with foundation. The structure is divided into two parts consist of deck and template or jacket. The deck is a place of facility where the personnel works and the jacket structure function is to ensure the load from the deck to the foundation. In the modeling phase the upper structure such as deck and other facilities is not modeled since the main structure that hold the upper structure will play an important role. If the jacket structure is fail then the deck will also fail. Other components that included in the modeling and analysis are skid beam, deck beam, longitudinal trusses and wind girders.

2.1. Performance Level Criteria

Performance level of offshore structure is based on API RP 2A, more detailed about this performance level can be seen in Table 1. This performance level is quite different with building
structure level which is consist of Immediate Occupancy (IO), Life Safety (LS), Collapse Prevention (CP) and Collapse (C). Commonly based on API RP 2A three level introduced, L1 which is called High Consequences of Failures, L-2 Medium Consequences of Failures, L-3 Low Consequences of Failures.

Other parameter can be acquired using SACS program is Reserved Strength Ratio (RSR) in which is defined for reserved strength available against nominal load at earthquake equal to 800 return period. The formula for calculated RSR in each direction of earthquake can defined as follows:

\[
RSR = \frac{F_{\text{end}}}{F_o} = \frac{F_o + \sum I_{cr}}{F_o}
\]  

(1)

Where Fo, Fend and \( \sum I_{cr} \) are Initial Load, Final Load at Collapse and Total Incremental Load, respectively.

2.2 Non-Linear Performance Level of Structure Based on API – RP2A

Non-linear performance level of structure based on API-RP2A is based on two categories. The first category is based on Safety and Security and the second category is based on Failures. Both of these category has three performance level which is denoted by L-1, L-2 and L-3. These two category then combined to get the reference that will be used in determining the load factor and RSR. More detailed explanation about these performance level criteria based on API-RP2A is shown below :

- L-1 (High Consequences of Failures).

This consequence of failure category includes drilling and/or production, storage or other platforms as well as platforms which support major facilities or pipelines with high flow rates usually fall into this category. Also included in the L-1 classification are platforms located where it is not possible or practical to shut-in wells prior to the occurrence of the design event such as areas with high seismic activity. (RSR > 1.6)

- L-2 (Medium Consequences of Failures).

This consequence of failure category includes conventional mid-sized drilling and/or production, quarters, or other platforms. Storage is limited to process inventory and “surge” tanks for pipeline transfer. Platforms in this category have a very low potential for well flow in the event of a failure since sub-surface safety valves are required and the wells are to be shut-in prior to the design event.
L-3 (Low Consequences of Failures).

This consequence of failure category generally includes only caissons and small well protectors. Similar to Category L-2, platforms in this category have very low potential for well flow in the event of failure. Also, due to the small size and limited facilities, the damage resulting from platform failure and the resulting economic losses would be very low. (RSR > 0.8)

Based on these three levels of failures we can determine where our level structure is located and what will happens to the production if seismic activity occurred. With this parameter and using SACS we can analyze the RSR of structure and we will get the level of structure based on the RSR and also to check whether with its level of failures does the structure function still working after the earthquake happens.

2.3. Response Spectrum Calculation

The data used in calculating the response spectrum analysis before moving to non-linear analysis in SACS is collected from the area around the location within radius 500 km. These data is collected within 105 years of earthquake occurrence. The step by step of analyzing the data or data calculation to create the response spectrum is shown below:

- Distance Calculation, calculate the distance of each data to location of jacket structure.
- Hypocenter Calculation, calculate the hypocenter of each data to location of jacket structure.
- Seismic Ground Acceleration Calculation, calculate the seismic ground acceleration based on attenuation formula developed by Donovan.
- Annual Exceed Rate Calculation.
- Annual Risk and Earthquake Risk with 20 years of structure lifetime.
- Exceedance Rate with structure lifetime.
- Maximum PGA Acceleration Calculation.
- Plotting the result in Tri-Patra graphics of response spectrum with Amplification Factor.

2.4. Analysis and Modeling Phase in SACS

The program used in this research is SACS which is based on finite element modeling, the phase of modeling, analysis and pushover analysis using non-linear static analysis is divided into several steps as follows:

- Modeling, this phase is about structure modeling, geometry and material properties, equipment of appurtenance and load modeling. The 3D model of jacket structure in SACS is shown in Figure 1.
• Analysis and Design, these phase is consist of Linear Static Analysis, Static condensation (Super Elements), Structure Interaction between Soil and Pile, Tubular Member and Joint Check.

• Dynamic Analysis, this phase is consist of analyzing frequency and mode shape, response spectrum analysis, time domain linear dynamic analysis, ground acceleration and general time dependent-loads.

• Non-Linear Analysis, this phase is consists of static incremental of non-linear analysis with material and geometry non-linearity.

3. RESULT AND DISCUSSION

3.1 Response Spectrum Graphics

Based on calculation step in 2.6 we can created the response spectrum on the project location with specific input of earthquake return period (T) 800 years, structure lifetime 20 years and damping coefficient 5 %. The maximum PGA acquired is 0.452 g which is quite difference based on SNI 2847-2002. The response spectrum graphics is shown in Figure 2.

3.2 Non-Linear Pushover Analysis

In this nonlinear pushover analysis based on API RP 2A in which the design is based on Allowable Stress Design (ASD). The pushover analysis is also attached with RSR as a performance function which is quite different with building structure. The Figure 3 shown the
results of non-linear pushover analysis at the end stage or near collapse where the structure began to fail until the ultimate strength which is started at load step 22 through 26.

Figure 2. Response Spectrum Graphs

Figure 3.a Structure Behavior and Members Failure in Pushover Analysis (LC 22,23,24)
The graph between force and deformation also with addition of Acceleration Displacement Response Spectra (ADRS) based on ATC-40 with various earthquake zone in SNI 1726-2002 and with specific response spectrum (800 years earthquake return period). The graph is shown in Figure 4.

Figure 4 Non-Linear Pushover Curve With ADRS based on ATC-40
3.3 Reserved Strength Ratio (RSR)

The result RSR will be compared with performance level based on API RP 2A. The RSR value is based on Eq.1. The RSR value is increment with 0.1 from the original value and the results at the end of load step where the structure failure or collapse is shown in Table 1. Based on the performance level in section 2.2, it can be seen that the performance of structure is adequate for High Consequence Failure with RSR > 1.6.

Table 1. Load Step Vs Reserved Strength Ratio (RSR)

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4. CONCLUSION

It can be concluded that from this research about non-linear behavior of jacket structure in offshore platform can be conducted with adequate data of earthquake that occurred around the location of offshore platform. From this research several conclusion as follows:

- The evaluation of non-linear pushover analysis in offshore platform need to be performed to ensure the Reserved Strength Ratio (RSR) is still adequate. This is also functioning for the life time remaining study if the offshore platform is old and still need to be used.

- By using non-linear pushover analysis we can set the performance level so we can ensure that our offshore platform condition is still at good shape without any sufficient damage when the earthquake occur.

- More further research in non-linear pushover analysis by using dynamic pushover analysis should be research to measure the ductility of cyclic loading and behavior of offshore jacket structure if cyclic loading such as earthquake occur. The energy from the plastic hinge of the structure also can be used to see how the structure performance against fatigue especially for current load.
REFERENCES


