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GEOMETRICALLY NON-LINEAR TIME HISTORY ELASTIC ANALYSIS FOR THE PERFORMANCE BASED DESIGN OF A PRILLING TOWER

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Bachelor Of Engineering With Honours
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GEOMETRICALLY NON-LINEAR TIME HISTORY ELASTIC ANALYSIS FOR THE PERFORMANCE BASED DESIGN OF A PRILLING TOWER

HANDY PRIYO NURJULIYANTO

A final year project submitted in partial fulfillment

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TO MY BELOVED FAMILY

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ABSTRACT

For 5000 years of return period seismic events, the structural response of Prilling Tower, 108.850 meters (353ft) high and 24.3 meters (80ft) width, was studied through the dynamic time history elastic analysis. The ground motions in Palembang, South Sumatera, were selected as a representative of local seismic excitement potential. Global structure behavior was monitored to meet the requirement for serviceability and damage control. For acceptance criteria for performance at the global structural level, compared to SNI 1726-2012, ACI 318-14, ASCE7-2010, EC8, FEMA 356, IBC 2009, PuSGen 2017, and UBC97. The codes were also used as a primary reference for the limit response of structural element for performance acceptance criteria of the structure.

The structural model created by STAAD Pro is a widely used engineering analysis software program. The structure's behavior has been checked to meet the demand for serviceability and damage control. Dynamic analysis can be carried out by two methods, one is the method of the response spectrum, and the other is the method of time history. In the response spectrum method, the values are taken by code, but the previous Earthquake data is utilized in the time history method. In this Final Year Project (FYP), the time history analysis used for analysis response of the structure. By using time history method for high rise structure, the storey displacement and storey drift calculated. The dynamic time history elastic of Prilling Tower analyses confirmed the acceptable global and local performance.

CHAPTER 1

INTRODUCTION

1.0 General

1.1 Indonesian Tectonics

Indonesia's tectonic conditions which located at the convergence of the world's large plates and some small plates or micro blocks cause the area to experience many earthquake events potentially. Indonesia is surrounded by four main plots, namely the Indo-Australian Plate, the Philippine Sea Plate, the Eurasian plate and the Pacific Plate ***(Figure 1.1a)***. Further research using geodetic, geological, and seismological information showed that tectonics in Indonesia could divide into several small plates, namely Burma, Sundae, Banda Sea, Maluku Sea, Timor, Bird's Head, Maoke and Woodlark. (PuSGEN, 2017)

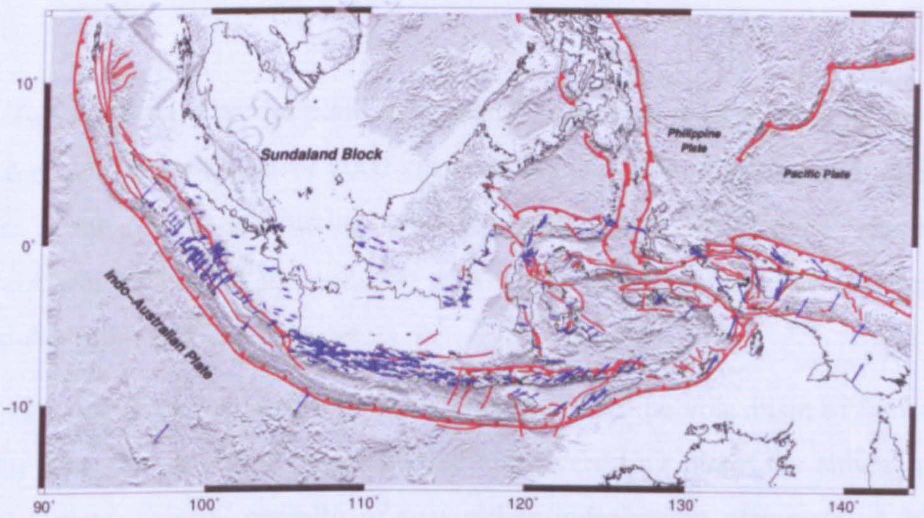

Figure 1.1a Tectonic maps of the Indonesian region from geodetic data up to 2016, speed vectors in the 2008 ITRF reference system (PuSGEN, 2017)

As a result of tectonic processes that occur, earthquake events often happen in most parts of Indonesia as shown in ***Figure 1.1b***. One source of an earthquake that identifier is the active subduction zone in the west to the eastern part of Indonesia. Also, the remaining energy from the collision process between these plates will result in a fault on land or sea on several islands and Indonesian Seas.

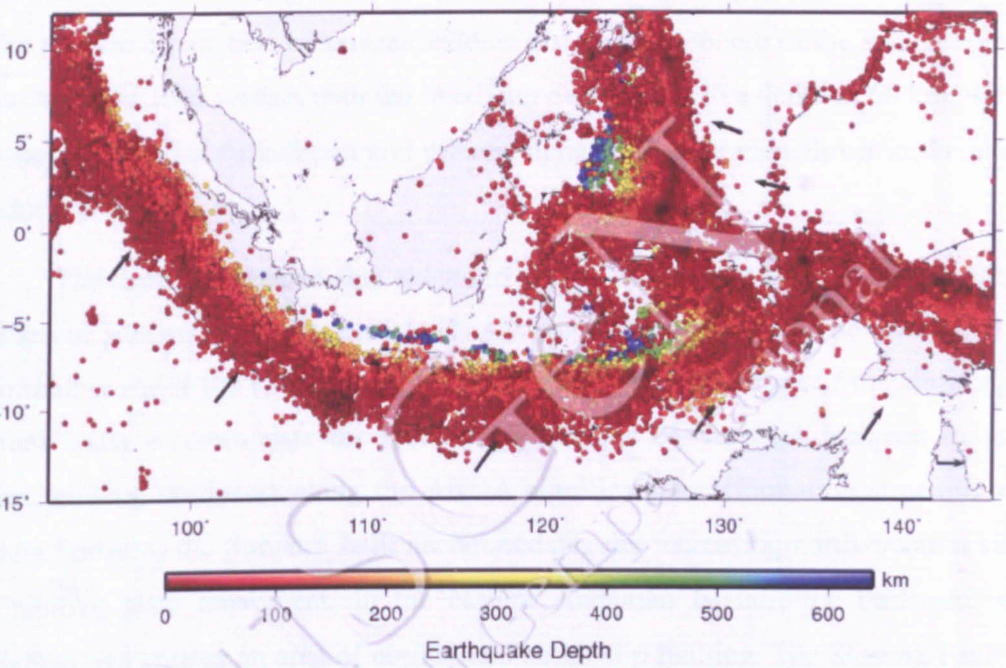

Figure 1.1b Earthquake in Indonesia as a result of relocation until 2016
(Catalogue PuSGeN, 2016)

The south-west border plate of Sumatra, Indonesia is located along the tectonic collision region, extending over 8000 km from Papua, NG in the east to the Himalayan Frontier. A megathrust subducting zone, the Sunda Arc (Sunda-Java trench), is the Sumatra-Andaman part of the collision area which accommodates the convergence of the Indo-Australia and Sunda plates.

This convergence causes the intense seismic and the volcanism of Sumatra. The plates are also not restricted to subductive and overriding plate; the subducing Indo-Australian plate consists actually of two rather independent plates (India Plate and Australian Plate), with small amounts of motion, related to one another, connected throughout a broad region that is active deformations of region producing seismicity, up to a few hundred kilometers west of the trench.

Relative movement between the plates of Indo-Australia and Sunda is rapid, from approximately 63 mm / yr. close to the south end of Sumatra (Australia plate relative to the plate of Sunda) to 44 mm / yr. north of the Andaman Islands (India relative to the Sunda). The movement turns northwest in the opposite direction and makes relative movement near Jakarta almost trench normal but almost trench parallel near Burma. The Sumatra-Andaman part of a plate boundary is made up of several inter-related tectonic elements by the rotation of the relative plate motion along the arc strike and the interaction of several tectonic plates. Lithosphere of the subduction plate Indo-Australia is in contact with the overlying Sunda plate to a depth of 60 km, which is the most strained accumulation and release along the Sunda megathrust in the primary subduction zone.

The deep earthquakes that extend to depths of less than 300 km on Sumatra and 150 km or less on the Andaman Islands are proof of the strain release associated with deformation inside the subducting slab. Crustal seismicity and a set of transforming and normal faults accommodate the increasingly oblique convergence between these two plates, moving northwest along the Arc. A significant transformation structure which bisects Sumatra, the Sumatra fault accommodates the increasing north-western side of the relative plate movement. In the eastern Andaman Islands, the back arc in the Andaman Sea creates an area of normal and strike-slip faulting. The Sagaing Fault near Burma also accommodates the strike-slip component of the oblique of plate motion similarly to Sumatra fault.

1.2 Problem Statement

Consisting of 16,056 islands, Indonesia is the world's largest archipelago country, with a total area of approximately 192,68 million hectares. With that much potential, one of the critical sectors of the Indonesian economy is agriculture. In the early 2018s, almost 20 percent of the 262 million population of Indonesia or 44.9 percent of the labor force was in the rural sector. Agriculture and forestry provide 11 percent of the gross domestic product (GDP). Of the total land area, 145.8 million ha potentially uses in agriculture and forestry, 8.1 million hectares (4.2 percent) planted with food crops, 75,611 hectares (0.04 percent) with Vegetables, 26.5 million hectares (13 percent) with estate crops and 68.8 million hectares (35 percent) are under forest (BPS, 2018). Rice and maize are the primary food crops, and oil-palm and palm kernel are the major plantation crops.

Population growth and geographical distribution are followed closely by agricultural development in Indonesia. Eight percent of Indonesia's land area such as Java, Madura, Bali, and Lombok (inner islands) is occupied about 61.4 percent (161 million) of the 262 million resides in Indonesia. While Sumatra, Kalimantan, Sulawesi and Papua (outer islands) which the larger occupied by 101 million people only.

The long-term effect of disparity soil fertility conditions in various parts of the country causes the uneven distribution of populations. Thus, fertile soil with high base saturation, such as Inceptisols, Mollisols, and Vertisols have densely populated communities; this case occurs in the inner islands. Whereas Ultisols, Oxisols, and Histosols dominate the soil condition of the outer islands. The three latter soils are acidic in their natural state and have a low plant nutritional status. That is what causes the outer islands rarely inhabited even though they have a large area. They require higher fertilizer inputs to achieve higher crop yields that obtained in Java and the other inner islands. However, agricultural conditions are worsening because the use of fertilizers is generally lower in the outer islands, and as a result, the yields are in general lower than inner islands.

The high use of mineral fertilizers in recent decades, reflecting the requirements of high yielding rice varieties, contributes to success in increasing rice production, a staple food for Indonesia's growing population. However, over the past five years (2013 to 2017) the use of imported fertilizers tended to increase to reach 8 million tons in 2017 (BPS 2018).

The significant increase in fertilizer imports annually has not reduced the number of imported rice commodities in Indonesia, which has now become substantially around 0.8 to 1.3 million tons over the last three years from 2016. Increasing in imported rice commodities is not only influenced by population growth but also creating wetland area outside the inner islands are still not optimal because the type of soil over there requires fertilizer doses which tend to be higher than in inner islands. Also, the lack of regeneration of farmers and farming system has also been a factor in the slow down national productivity.

One of the sustainable solutions to this critical issue is the construction of cutting-edge technology and energy-efficient of Ammonia and Urea Fertilizer Plant. It hopes that this plant can contribute more increasing food production to support national food security and help the country, reducing dependence on imports of strategic commodities, which could threaten Indonesia's national security. Therefore, this study aims to investigate the seismic response of an existing prilling tower located in Sumatera using dynamic time history elastic analysis method.

1.3 Prilling Tower

In early 2017, one of the factories producing urea and ammonia fertilizer in southern Sumatra has been completed and is ready to operate. 2000 Metric Tons Per Day (MTPD) Ammonia and 2750 Metric Ton Per Day Urea Plant, with the total budget of US$561 million, is part of a revitalization development project, which is replacing an old factory with more cutting-edge technology and energy-efficient factory. One of the essential structures in this factory is the prilling tower.

The prilling tower is generally the core structure of nitro-composite fertilizer technology processes whose safety is directly linked to the regular operation of fertilizer production. Prilling is a dynamic process in which jets of concentrated / molten liquid are formed and divided into droplets on the showerhead. The droplets fall during solidification and cooling in a countercurrent airstream via heat transfer. The droplets begin to fall at a limited speed and accelerate and decelerate to end speeds.

The type of piling is cylindrical, with temperature conditions 70°C upper and 39°C lower. The pressure condition is in the range 0-50 mmH_2OG (millimeters, water gauge). In that case, the temperature design condition is increased by 100°C and pressure becomes 100 mmH_2OG. The diameter of the prilling is 23.5m with a height of approximately 108.65m as shown in ***Figure 1.3.1***. The prilling tower material consists of reinforced concrete and epoxy coating. Since the prilling tower is the backbone of fertilizer or any other chemical industry where the final products are in the form of solid prills urea fertilizer, this structure considered to be the most critical structure in urea plant.

Table 1.3.1 Structure Statistics

NUMBER OF JOINTS	27288
NUMBER OF MEMBERS	3291
NUMBER OF PLATES	26965
NUMBER OF SUPPORTS	168
NUMBER OF MODES REQUESTED	25

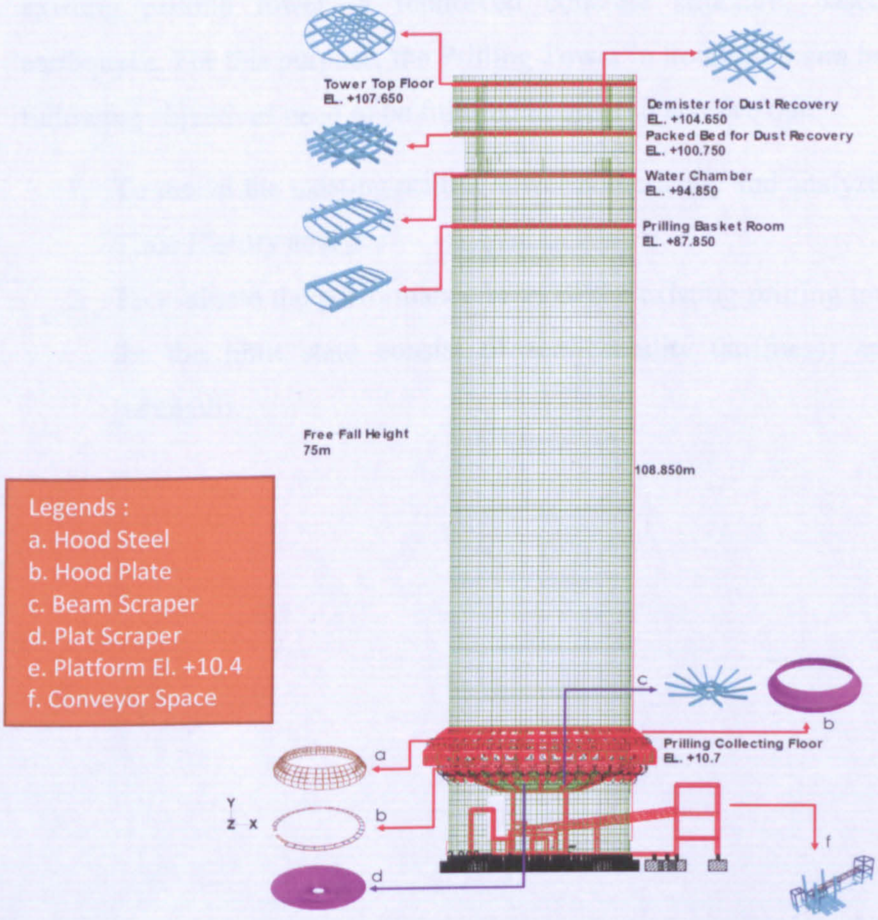

Figure 1.3.1 3D Model view from z+

1.4 Research Gap

Introducing new engineers to advanced structural dynamics and elastic behaviors with user-friendly software to bridge the gap between the researchers and applications, as the inelastic static analysis is widely used in design agencies, while dynamic analysis is still a challenge. This FYP is one of the right times to achieve this.

1.5 Aims and Objectives

Hamburger (2009) concluded that the earthquakes not only potentially result in significant life loss, but also can cause costly damage and unnecessary interruption of business. Concerning about major earthquake that can come any time and caused damage to their facilities which resulted in the loss of long-term use and threatened economic viability, bring on industrial corporation demand engineers to design seismic retrofits for structures.

Therefore, the presented project aims to analyse the seismic performance of the existing prilling tower, a reinforced concrete structure, based on site specific earthquake. For this purpose, the Prilling Tower in South Sumatra has been chosen. The following objectives need to be fulfilled in order to achieve that:

1. To model the existing prilling tower numerically and analyze the structure using Time History analysis.
2. To evaluate the performance level of the existing prilling tower based on codes for the limit state consist of serviceability (stiffness) and damage control (strength).

1.6 Scopes of Work

This project pertains the analysis of existing civil and structural to Prilling Tower (from now on referred to as PROJECT) at Palembang–South Sumatera. This project will cover the scope of design as follows:

a) Seismicity in Palembang-South Sumatera, Indonesia
b) Determine the performance level of the structure with Geometrically Non-Linear Time History Elastic Analysis.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The definition of an earthquake is discussed first to provide a basic understanding of earthquakes, explaining measurements of earthquake and modeling of structures and finally discussing the method of analysis and previous studies. The next layer of the earth's surface (lithosphere), the wavelike motion produced by the constant forces that traveling through the earth's crust is defined as an earthquake. There is energy in the earth's crust to discharge because of sudden dislocations in the segments of the crust, volcanic eruptions, explosions or underground cavities like mines or cast made by humans.[1]

Seismic waves in the form of vibrations are generated through a dislocation process. The speed of the waves coming out of the source of the earthquake varies causing the earth to quiver. Two critical parameters affect the size and severity of the earthquake — the intensity and magnitude. The measure of the amount of energy released is called magnitude, while the real effect experienced by a particular location is called the intensity.

For this reason, earthquakes are classified as naturally occurring, and there are certain types of earthquakes, caused by fault rupture, volcanic, mined and caused by the large reservoir. All things related to the relative movement of plates (tectonic) change at deep-seated (plutonic) or volcanoes with a source of stresses produce the movement classified as natural earthquakes.

[1] Dislocations of crust segments, however, lead to the most destructive earthquakes

2.1 Measurements of Earthquakes

There are various ways to present the measurements of an earthquake which are quantitative or instrumental measurements and qualitative or non-instrumental measurements; the latter measurements are either based on regional or worldwide calibration. The latter either measurements based on regional calibration or applicable worldwide. For pre-instrumental events, non-instrumental measurements are vital to compile the earthquake history catalog with the intent of hazard analysis while a qualitative scale complements instrumental data for earthquakes that have been recorded instrumentally.

On the structure, the results of the earthquake ground motion are the concern of structural engineers, specific to the amount of damage caused to the structure. The size (severity) of an earthquake dramatically affects the damage (stress and deformation) potential.

The following methods are used to assess the severity of an earthquake:

(i) magnitude is quantified based on the energy released—measuring the amplitude, frequency and location of seismic waves,

(ii) consider the destructive effects of shocking ground on people, structures and natural features as a basis for evaluation in intensity.

It is easier to measure the magnitude because, unlike the intensity, which can vary with location and has no mathematical backing, the magnitude of a particular earthquake remains constant

2.1.a Intensity

Intensity is defined as non-instrumental perceptions of structural damage, land surface effects, such as fractures, cracks and landslides, and human response to earthquakes. The intensity of a pre-instrumental shock is a descriptive method traditionally used to measure the excitations. The subjectivity is the measurement of