Faculty of Engineering

SEISMIC PERFORMANCE OF MAJOR COMPONENTS IN CRITICAL SYSTEM OF SINAGAMA IRRADIATION PLANT, PENINSULAR MALAYSIA

Malachi Ting Jia Jing

Bachelor of Engineering with Honours

(Civil Engineering)

2020

UNIVERSITI MALAYSIA SARAWAK

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SEISMIC PERFORMANCE OF MAJOR COMPONENTS IN CRITICAL SYSTEM OF SINAGAMA IRRADIATION PLANT, PENINSULAR MALAYSIA

MALACHI TING JIA JING

A dissertation submitted in partial fulfillment

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To my beloved family and friends.

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ABSTRACT

Earthquake has been known to cause much damage to industrial facilities. This research aims to assess the seismic response for the source storage pool cooling system of the Cobalt-60 Irradiator in the Sinagama industrial building, Peninsular Malaysia. Said industrial facility houses radioactive materials, and its operation is crucial to various sectors, such as the medical sector, where it is used to sterilize medical equipment. All the parts in the source storage pool cooling system are modelled and analysed by means of finite element analysis. The parts include the concrete storage pool, heat exchanger, pool water tank, steel piping system, water chiller compressor, and water pump. All the parts and the system is subjected to seismic loading, where the earthquake time history is taken from the Eregli station for the Kocaeli earthquake in Turkey. Ground motion with peak ground acceleration of 0.10g, 0.20g, 0.50g, and 1.00g is used, and the finite element analysis is conducted using Abaqus/CAE 6.14 software. The parameters that are obtained are maximum principal stress, acceleration, and displacement. The results obtained indicate that the materials that make up the parts in the system will not fail, even when subjected to ground motion with peak ground acceleration of 1.00g. Nonetheless, attention needs to be given to the connections of the parts and components in the source storage pool cooling system, as it is found that the area that joins the steel pipes and the pool water tank is subjected to high levels of stress. This indicates that the steel piping system is the critical part in the source storage pool cooling system.

ABSTRAK

Gempa bumi diketahui mampu menyebabkan kerosakan kemudahan perindustrian. Penylidikan ini bertujuan untuk menilai tindak balas seismik sistem penyejukan kolam simpananan sumber penyinaran Kobalt-60 dalam bangunan perindustrian Sinagama, Semenanjung Malaysia. Kemudahan perindustrian tersebut menempatkan bahan radioaktif, dan operasinya adalah amat penting bagi pelbagai sektor, seperti sektor perubatan, di mana peralatan perubatan perlu disterilkan. Semua komponen dalam sistem penyejukan kolam simpanan sumber dimodelkan dan dianalisis dengan menggunakan analisis unsur terhingga. Komponen tersebut merangkumi kolam simpanan konkrit, penukar haba, tangki air kolam, sistem paip keluli, pemampat penyejuk air, dan pam air. Semua komponen dan sistem tersebut tertakluk kepada daya seismic, dan sejarah masa gempa bumi diambil daripada stesen Eregli untuk gempa bumi Kocaeli di Turki. Gempa bumi yang mempunyai nilai pecutan tanah puncak 0.10g, 0.20g, 0.50g, dan 1.00g digunakan, dan analisis unsur terhingga dijalankan dengan menggunakan perisian Abaqus/CAE 6.14. Parameter yang diperoleh ialah tekanan utama maksimum, pecutan, dan anjakan. Hasil analisis menunjukkan bahawa bahan yang digunakan oleh semua komponen tidak akan menghadapi kegagalan, walaupun dengan gempa bumi yang mempunyai nilai pecutan tanah puncak 1.00g. Walaupun begitu, perhatian perlu diberikan kepada sambungan komponen dalam sistem penyejukan kolam simpanan sumber, kerana didapati bahawa kawasan yang menyambung paip besi dan tangka air kolam tertakluk kepada tahap tekanan yang tinggi. Ini menunjukkan bahawa sistem paip keluli merupakan bahagian yang kritikal dalam sistem penyejukan kolam simpanan sumber.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Ixx	-	Moment of inertia along the x-x axis
Iyy	-	Moment of inertia along the y-y axis
Izz	-	Moment of inertia along the z-z axis

LIST OF ABBREVIATIONS

HDPE	-	High-density polyethylene
OBE	-	Operating basis earthquake
PGA	-	Peak ground acceleration
SSE	-	Safe shutdown earthquake

CHAPTER 1

INTRODUCTION

1.1 Background

Numerous events in the past has demonstrated the impact of earthquakes on industrial facilities. During the Great East Japan Earthquake and Tsunami in 2011, 3324 oil storage and facilities that housed hazardous materials were damaged (Yu et al., 2017). Being at the coastal area, a tsunami followed after the earthquake, causing a direct and indirect economic loss of 19.66 and 7.73 million USD respectively (Yu et al., 2017). The loss of production and business interruption left a dent in Japan's economy, and time is needed to recuperate from the damage done. In 2016, a study was conducted on the seismic failure probability of a transformer, as the author recognized the consequences of damages to a transformer in the event of an earthquake. The direct consequence would be power shortage, and being a basic lifeline, such an event would cease most social and economic activities (Zareei, Hosseini, & Ghafory-Ashtiany, 2016). In light of the two events mentioned above, it is clear that the collapse of industrial facilities due to an earthquake will affect the economy and activities of a country, and in turn the welfare of the society. Other significant events of earthquake include the Kocaeli, Turkey earthquake in 1999 (with moment magnitude of 7.6), where a refinery was damaged and caught fire, leading to a loss of around US$ 350 million (Erdik & Uckan, 2014). The

Niigata, Japan earthquake (with moment magnitude of 7.5), on the other hand, took 28 lives in its wake in 1964 (Akatsuka & Kobayashi, 1964), while the Alaska earthquake (with moment magnitude of 9.2) caused a loss of around US$ 27 million in the same year (Pecorn, 1964).

Many seismic codes were written with the protection of the urban environment in mind, resulting in the extensive development of seismic codes that applies to buildings (Arze, 1993). Over time, buildings have been designed to resist seismic loading, in order to minimize its damage, and prevent collapse and loss of human lives (Arze, 1993). With rapid development taking place globally, more and more industrial facilities are built in the urban environment, making the seismic resistance of industrial facilities just as critical as structures, as they are the main powerhouse of a country's economic activities, on top of being in direct contact with the populace.

1.2 Seismicity in Peninsular Malaysia

Malaysia is categorized as having low to moderate seismicity (Lam & Chan, 2006), and this presents a question: what level of seismic protection should be provided? Being a developing country, resources should be wisely allocated, and it is important to provide a level of seismic resilience that is sufficient (Lam & Chan, 2006). Hence, it is crucial to assess the seismic vulnerability of different structures or facilities, in order to locate the structure or facility at a safe position whenever possible, and also design for seismic resistance wherever applicable. On that note, the action to assess the industrial facility should not be delayed due to the clouded judgment that Malaysia is still considered as safe from major seismic events. An example to illustrate this would be the belief that the Korean Peninsula is safe from major seismic events as it is not located on the boundary of tectonic plates (Choi & Kim, 2018). This is soon proven wrong when Gyeongju is hit with an earthquake measuring 5.8 on the moment magnitude scale, followed by more than 600 aftershocks in the year 2016. The event changed the public's perception towards the seismic condition in the Korean Peninsula (Choi & Kim, 2018). While the Malaysian peninsula sits on the stable Sunda tectonic plate, one cannot dismiss the fact that its neighboring country, Indonesia is exposed to high rates of earthquake, making it important for Malaysia to take safety measures should the need arise (Petersen et al., 2004).

Peninsular Malaysia's seismic hazard has been assessed, and seven major faults were identified, namely 1) Bok Bak fault, 2) Lebir fault, 3) Terengganu fault, 4) Bukit Tinggi fault, 5) Kuala Lumpur fault, 6) Lepar fault, and 7) Mersing fault (Weijie Loi, Eshwaraiah Raghunandan, & Swamy, 2018). A series of low-magnitude, i.e. moment magnitude, $M_W < 4.0$ earthquakes were registered at Bukit Tinggi from November 2007 to May 2008 (Weijie Loi et al., 2018). These events were not expected, as historical records have labelled Peninsular Malaysia with a low intensity seismicity of around level VI on the Modified Mercalli scale. Figures 1.1 and 1.2 show the peak ground acceleration (PGA) maps of Peninsular Malaysia for the sources originating from the Sumatran subduction zone and Sumatran fault zone respectively (Weijie Loi et al., 2018).

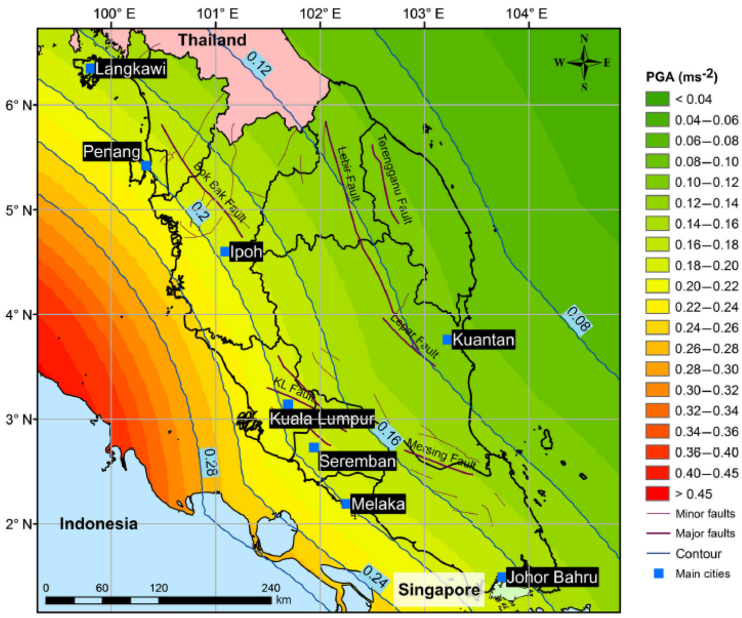

Figure 1.1: PGA map for Peninsular Malaysia for the sources originating from the Sumatran subduction zone (Weijie Loi et al., 2018)