

SEISMIC PERFORMANCE OF WATER TANK TOWER

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requirements for the award of the degree of
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“I declare that this project report is the result of my own work except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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DEDICATION

“.... teristimewa buat mama dan ayah,
Puan Adzura Abdullah dan Encik Ismail Ishak,
ini adalah hasil titik peluh anakmu...
kepada kakak dan adik-adik tersayang,
Zira, Keyi, Radi, Zana, Ashraf, dan Wani
ini adalah hasil usaha Apis di menara gading...
dan kepada rakan-rakan seperjuangan,
ini adalah usaha kita bersama
....”

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Harapan saya agar laporan ini dapat menyumbangkan sedikit sebanyak ilmu untuk kita semua. Segala yang berlaku adalah kehendak ilahi dan sesungguhnya ilmu yang ada pada manusia adalah diibaratkan setitik air dihujung jarum berbanding air di lautan, itulah ilmu Allah S.W.T.

“Sekalung budi setinggi-tinggi penghargaan”

TERIMA KASIH SEMUA.

- Fadrul Hafiz Bin Ismail -

ABSTRACT

A water tower consists of an elevated water tank and a shaft. Purpose of water tank tower is storage of a certain quantity of water at sufficient pressure for transporting water over certain distance. Water tower's design should be able to resist lateral load if earthquake occurs. Earthquake is a sudden movement of the earth caused by the abrupt release of strain that has accumulated over a long time. This dynamic vibration of lateral movement affects structures strength and behaviors. Thus, this study is based on seismic performance of water tank tower structure during earthquake and the objective is to determine the behavior of structure using computer software. Scope of this study is seismic performance effect on water tank tower around Malaysian region due to the nearest earthquake loading. The tower will be designed and analyzed using SAP 2000 and will produce structure behaviors according to the maximum earthquake loading. The findings and result analysis gained from this study can be used as reference, and be researched further focusing on improved design of water tank tower and less structure damage can be expected when earthquake loading occurs.

ABSTRAK

Menara air terdiri daripada tangki air dan struktur di bawah tangki. Tujuan menara air dibina adalah untuk menyimpan air dalam suatu kuantiti yang diperlukan pada suatu ketinggian yang sesuai bagi tujuan agihan di suatu kawasan. Rekabentuk menara air perlu dibina dengan kekuatan yang mampu ditanggung daripada beban gempa bumi. Gempa bumi didefinisikan sebagai pergerakan secara tiba-tiba diantara kerak bumi yang disebabkan oleh tekanan yang ditanggung dalam suatu jangka masa dan membentuk getaran dinamik. Getaran dinamik membentuk pergerakan sisi yang menyebabkan kesan terhadap kelakunan dan kekuatan suatu struktur terganggu. Dalam hal ini, kajian ini bertujuan mengkaji kesan seismik terhadap menara air apabila gempa bumi terbentuk dan objektif kajian ialah untuk melihat kesan kelakunan struktur menara air dengan menggunakan perisian komputer. Skop kajian ini ialah kesan seismik terhadap menara air di Malaysia hasil gempa bumi daripada negara jiran. Menara air akan direkabentuk dan dianalisis menggunakan perisian komputer SAP2000 dan fokus kepada kelakunan struktur menara terhadap beban gempa bumi paling optimum. Hasil keputusan daripada kajian boleh digunakan sebagai rujukan bagi tujuan lanjutan kajian dan membaik pulih kajian terhadap menara air di Malaysia bagi mengurangkan kemusnahan pada struktur menara daripada beban gempa bumi.

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LIST OF SYMBOLS

\ddot{u}	Acceleration with respect to time
u	Displacement, initial displacement $u(0)$
m	Mass of the structure
k	Stiffness of the structure
$p(t)$	External force varies with time
f_D	External force of the damper equal and opposite with the internal force in the damper
c	Viscous damping coefficient
\dot{u}	Velocity varies with time
f_S	External force equal and opposite to the internal force resisting the displacement, u
k	Lateral stiffness of the system
u	Displacement varies with time
u_g	Displacement of the ground
$u^t(t)$	The total (or absolute) displacement of the mass
$u(t)$	The relative displacement between the mass and ground
ω_n	Natural circular frequency
T_n	Natural period of vibration
f_n	Natural cyclic frequency of vibration
f_{rf}	Flexural Strength of concrete
f_{rs}	Shear Strength of concrete
E	Modulus of Elasticity
f_{cu}	Concrete Compression Strength

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Water is human basic needs for daily life. Sufficient water distribution depends on design of a water tank in certain area. An elevated water tank or water tank tower is a large water storage container constructed for the purpose of holding water supply at certain height to pressurise the water distribution system. Pressurisation occurs through the elevation of water on the tower height as per requirement of the distribution system. Water tank should be placed at the highest point and at the centre of the pipeline system. Size of water tank depends on the quantity of water needed at the maximum daily peak usage.

The first water supply system complex was developed in Germany in the middle of the 19th century, leads to an important improvement in hygienic standard. A central element of this modern water supply system was the water tank tower. This is where water storage and elevation of water were united for the first time. In the beginning of 1900 , and thirty to forty years later the largest number of water tower were built when the villages and cities were equipped with public water distribution system. When comes to 20th century, many tall building was built and the water tank tower starts to lose their importance as the tanks were incorporated within the

building. However, water tank tower still presented aesthetically to the industrial and town development of certain places in some countries and remain with its design elements of structure. (Sara Hamm, 2004)

Apart from the design of water tank tower structure, the main purpose of its built is to distribute water effectively and sufficiently. Water is important to human being for their daily usage in residential and commercial service. It being important, we should think of what will happen to water tank tower if earthquake occurs?

Earthquake was proven to cause worst phenomenon that can happen in human life with a lot of damages. Earthquake happened when two tectonic plates moved or slipped from its placed and produced energy that transfered to the earth's surface. The energy is transform into a seismic wave or vibration of the ground motion. The ground acceleration from the wave are recorded and keep as time history analysis data.

Based on seismotechnic setting map, Malaysia is located outside of earthquake active zone. However, there is still a small percentage effect on earthquake vibration that would reached Malaysia because of its location surrounded by active earthquake zone. The nearest seismically active faults around Malaysia are Indonesia and Philippines archipelagos as well as in the east and northeast of Sabah (Azlan, 1999).

Therefore according to the above situation, Malaysia shall not be considered as one of the totally free vibration country or totally safe from earthquake. Structure design within Malaysian region must include the seismic effect which will increase the safety factor of the structure including the structure of the water tank tower. This paper is written to elustrate the analysis from a study an effect to a water tank tower design in Malaysia when earthquake vibration occurs.

1.2 PROBLEM STATEMENT

It is known that water tank tower in Malaysia have low intensity of seismic influence effect. The conventional structure design does not include the seismic loading. Therefore, this study is conducted to observe the effect and the performance of the water tower structure to resist the earthquake loading.

1.3 OBJECTIVE OF STUDY

The objectives of this study are:

- (a) To study the dynamic characteristic of the structure.
- (b) To determine the behavior of water tank tower structure when earthquake occurs.
- (c) To compare performance of structure under seismic loading with the design capacity of the water tank tower.
- (d) To compare the performance of structure using SAP2000 software with the theoretical calculation.

1.4 SCOPE OF STUDY

The scope of study is limited to only one type of water tank tower structure. The tower is analyzed using SAP2000 to see the behavior of the structure so that it can be designed with less structural damages caused by earthquake vibration. The result from SAP2000 will be compared with the theoretical calculation method using Microsoft Excel as a medium to solve the problem. The water tower's located at UITM Shah Alam, Selangor is taken as a model for this study and the earthquake data for analysis purposes is taken from RapidKL's data simulation for seismic hazard assessment for Malaysia Region.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Simple way to describe an earthquake is dynamic vibration which will cause disaster. Many definition was produced by researchers about theory of earthquake, what causes earthquake and what it's relationship with plate theory. This chapter will be look into detail about the fundamental of earthquake, types of fault and waves, how to measure earthquake and mesurement that has been used to determine the earthquake. This chapter also will explain about the introduction of water tank tower, types of elevated water tank that exists, examples of seismic performance of water tank tower, and simple briefing about relation between water tank tower and single degree of freedom theory.

2.2 FUNDAMENTAL OF EARTHQUAKE

Earthquake is closely related to plate tectonic theory. The plate tectonics theory in 1960s helped us to understand the theory behind the earthquake's definition. According to plate tectonic theory, the earth's surface contains tectonic plates also known as lithosphere plates. Each plate consists of the crust and the more rigid part of the upper mantle. Earthquake is related to the movement between plate's boundaries from its original places (Robert, 2002).

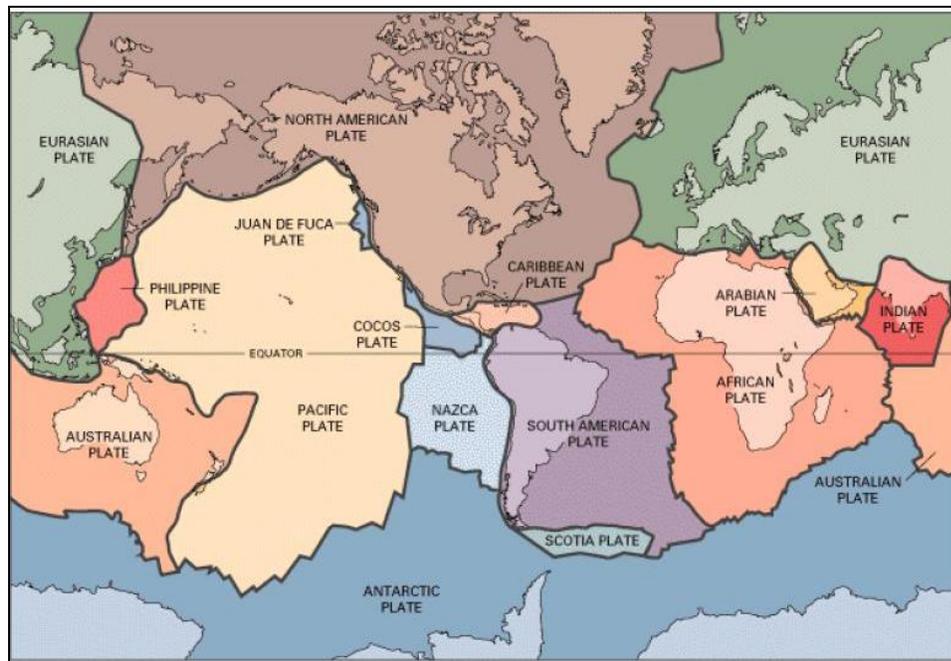


Figure 2.1: World Plate Tectonic Map (Source: Park & Plates: R.J. Lillie, 2005)

There are three types of plate boundaries depending on direction of movement of the plates. The three types of plates are; divergent boundary, convergent boundary and transform boundary. Divergent boundary occurs when the relative movement of two plates is away from each other. Second type is convergent boundary which occurs when the relative movement of two plates is towards each other.

There is relation between divergent and convergent boundary which means if divergent boundary happened at one area, convergent boundary must occur in another area because earth's surface remain relatively constant. The third type of plate boundaries is transform boundary which involves the plates sliding past each other without the construction or destruction of the earth's crust.

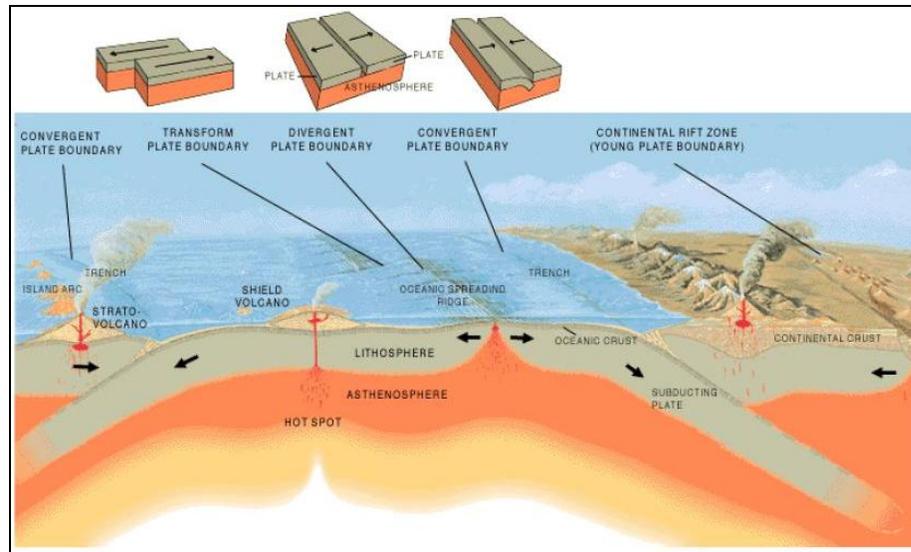


Figure 2.2: Three types of boundaries (Source: USGS, 2002)

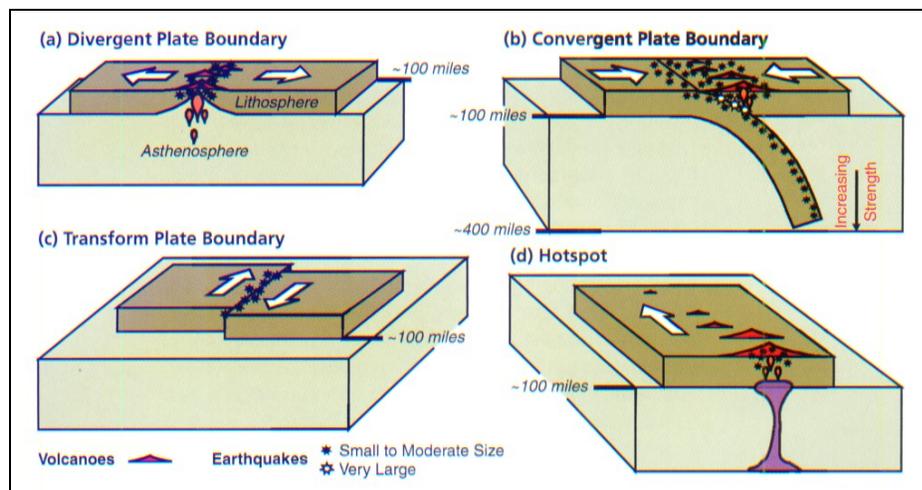


Figure 2.3: Relation between divergent and convergent boundaries and other types of plate tectonic activities (Source: Park & Plates: R.J. Lillie, 2005)

These three types of plate boundaries form from many types of faults. A fault is defined as a fracture or a zone fracture in rock along which displacement has occurred. This sudden displacement releases the energy and sometimes cause earthquake. Earthquake will generate the motion of the earth's surface and form the seismic wave. Seismic wave is divided in two basic types which is body wave (motion past through the interior of the earth) and surface waves (motion observed close to the surface of the earth). The motion due to seismic waves is recorded by the instrument called *seismograph*.

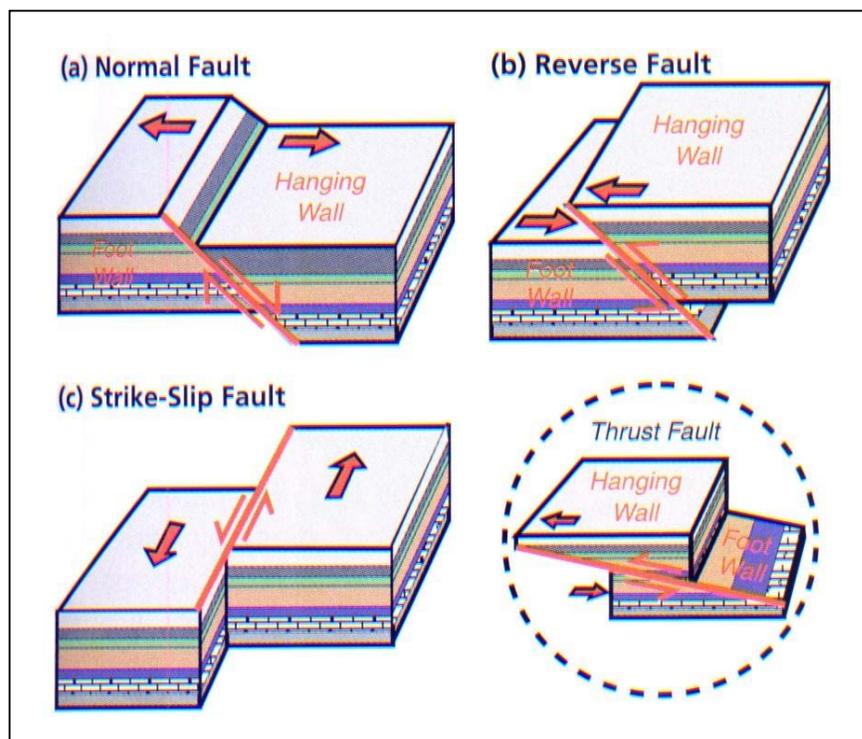


Figure 2.4: Several types of faults from plate tectonic movement
(Source: Park & Plates: R.J. Lillie, 2005)

2.2.1 DEFINITION OF EARTHQUAKE

Many different definition term and theory have been produced by researcher but the basic it still related to theory of plate. According to Y.X. Hu and S.C. Liu in 1996,

“Earthquake related to global tectonic processes that are continually altering the configuration of the earth’s surface. There are several geographical regions in which earthquakes occurs most frequently which are the Circum-Pacific belt around the Pacific Ocean, The Alplide belt through western and also at the central Asia the areas where damage to man-made systems.”

By Robert, 2002, says;

“Most earthquakes are caused by the release of energy due to sudden displacements on faults. The major earthquake is characterized by the buildup of stress and then the sudden release of this stress as the fault rupture. And a fault is defined as a fracture in rock along which displacement occurred.”

Others view is from Salman Abu-Sitta, 1980 expressed that;

“The event of earthquake is centre at a focus that is the point at which the rupture initiates. The point on the surface of the ground about the focus is the epicenter and the vertical separation of these two points is the focal depth. This rupture occurs because of the excess straining and releases energy that spread in various directions.”

Therefore from these several definitions, it shows that the earthquake occur when two plates tectonic moved or slipped from its place and produce energy that transfer on the earth’s surface. It is possible for the energy to transform into a seismic wave or vibration of the ground motion.

2.3 TYPE OF WAVES

A fault rupture cause the acceleration of the ground motion on surface and generated various seismic waves. There are two basic types of seismic waves; body wave and surface wave.

P and S waves are both called body wave because they can pass through the interior of the earth. Surface waves are only observed on the surface of the earth. Surface wave is divided into two types which are Love wave and Rayleigh waves. Surface wave happened from the interaction between body wave and the surficial earth materials.

The P wave is one of the body waves; also known as the primary wave, compressional wave, or longitudinal wave. This type of wave causes a series of compressions and dilations of the material through the earth. The P wave is the fastest wave and can travel through both solids and liquids because of compression-dilation type of wave. And because of this compression-dilation effect, P wave usually have least impact on ground surface movement because of soil and rock.

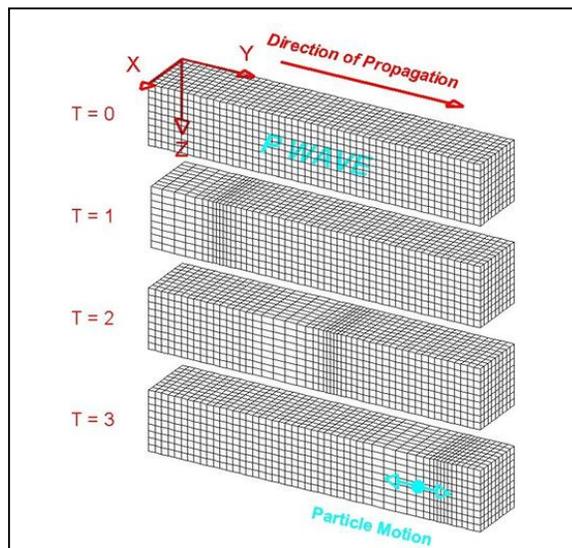


Figure 2.5: A P-wave travels through a medium by means of compression and dilation (Source: Lawrence Braile, UPSeis.com, 2000)

The S wave is also one of the body waves, and known as the secondary wave, shear wave or transverse wave. The S wave causes shearing deformation of the material through earth which it travels. S wave can only travel through solid material because liquid have no shear resistance. The shear resistance of soil and rock is usually less than the compression-dilation resistance, so S wave travel more slowly through the ground than the P wave. Soil is weak in terms of its shear resistance, and S waves typically have the greatest impact on ground surface movements.

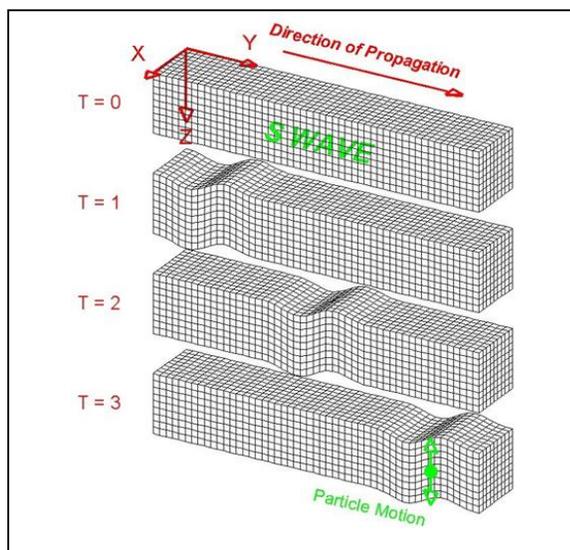


Figure 2.6: An S-wave travels through a medium causes shearing deformation
(Source: Lawrence Braile, UPSeis.com, 2000)

The Love and Rayleigh wave both are surface wave types. Love waves are analogous to S waves in that they are transverse shear waves that travel close to the ground surface and the fastest surface wave. Rayleigh wave is also described as surface ripples which produced both vertical and horizontal displacement of the ground as the surface waves propagate outward.