NON-LINEAR DYNAMIC AND PUSH-OVER ANALYSIS OF AN AIR TRAFFIC CONTROL TOWER

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I dedicate this dissertation to three beloved people, to my adored wife "ELNAZ". She helped me to find my way and inspired me to try for bright future. To my precious parents who are the foundation for my life. I am really honored to have them. Everything that I am now is because of them.

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ABSTRACT

Airport is one of the vital metropolitan organizations that should be endured totally practicable during and after urban calamity such as seismic threat. Principally different types of assistance from other cities could be needed for the sufferers, so the high significance of airports cannot be neglected. Likewise, all airports require one or more Air Traffic Control (ATC) towers which are compulsory to be serviceable. Designers often apply linear structural analysis methods for most ATC towers. However, this application may give not reliable results. The reason is that during an earthquake, nonlinear response of ATC tower is very feasible. Since usual techniques may face to a stark misguide from factual behavior of the structure for analyzing such particular structure an accurate nonlinear analysis is strongly essential. This study investigates the seismic behavior of Oroumieh ATC tower which is located in Iran rises 30 meter above ground level using Non-linear static analysis (Push-Over Method) and non-linear dynamic analysis (Time History Method). This also assesses the effect of Near-Field (distance from fault to structure below 15 km) and Far-Field earthquakes (distance from fault to structure above 15 km) on the seismic behavior of the case study structure and compares the obtained results with the code-based seismic design and concludes on the safety level of ATC towers designed based on building codes. In this study, fifteen Far-field and fifteen Near-Field ground motion records will be selected based on characteristics of the construction site. Nonlinear analysis will be carried out with SAP2000 software. Concentration will be given to the evaluation of code-based design of ATC towers and their capability in satisfying the ATC tower's safety during earthquakes. It is found that the effect of far-field records are more critical than near-field. Besides that, time history results are higher than linear analysis based on codes and push-over results are found in between linear analysis and time-history analysis.

ABSTRAK

Lapangan Terbang adalah salah satu organisasi metropolitan penting yang perlu benar-benar dipertahan dengan praktik semasa dan selepas bencana bandar seperti ancaman seismik atau gempa bumi. Serta-merta selepas berlakunya gerakan tanah, tekanan seismik bertambah dengan pesat. Secara asasnya, pelbagai jenis bantuan daripada bandar-bandar lain boleh diperlukan untuk mangsa, jadi kepentingan yang tinggi lapangan terbang tidak boleh diabaikan. Begitu juga, semua lapangan terbang memerlukan satu atau lebih menara Kawalan Trafik Udara (ATC) yang wajib untuk diselenggara. Pereka bentuk sering menggunakan kaedah analisis struktur linear untuk kebanyakan menara ATC, walaubagaimanapun andaian ini masih meragukan. Justeru, respon tak linear menara ATC ketika berlaku gempa bumi adalah amat penting dan praktikal. Berdasarkan kenyataan di atas, analisis tak linear yang tepat adalah sangat penting memandangkan teknik biasa bagi analisis struktur tertentu boleh membawa kepada penyimpangan yang jelas daripada tingkah laku sebenar struktur tersebut. Kajian ini mengkaji tingkah laku seismik menara Oroumieh ATC yang terletak di Iran dengan ketinggian 30 meter di atas permukaan tanah menggunakan analisis statik tak linear (kaedah tolak-atas) dan analisis dinamik tak linear (kaedah Sejarah Masa). Kajian ini juga menilai kesan-kesan gempa lapangan dekat dan lapangan jauh ke atas tingkah laku seismik struktur kajian kes dan membandingkan keputusan yang diperolehi dengan reka bentuk berdasarkan kod seismik dan membuat kesimpulan pada tahap keselamatan menara ATC direka berdasarkan kod bangunan. Dalam kajian ini, rekod pergerakan tanah bagi lima belas lapangan dekat dan lima belas lapangan jauh akan dipilih berdasarkan ciri-ciri tapak pembinaan. Analisis tak linear dilakukan menggunakan perisian SAP2000. Tumpuan akan diberikan kepada penilaian reka bentuk berdasarkan kod-menara ATC dan keupayaan mereka memenuhi keselamatan menara ATC semasa gempa bumi. Adalah ditemui bahawa kesan rekod lapangan jauh adalah lebih kritikal berbanding kesan lapangan dekat. Di samping itu juga, keputusan sejarah masa adalah lebih tinggi berbanding analisis linear yang berdasarkan kod dan keputusan tolak-atas adalah ditemui di antara analisis linear dan analisis sejarah masa.

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LIST OF ABBREVIATIONS

ATC	-	Air Traffic Control
SDOF	-	Single Degree Of Freedom
MDOF	-	Multi Degree Of Freedom
PBSD	-	Performance Based Seismic Design
MMS	-	Moment Magnitude Scale
IO	-	Immediate Occupancy
LS	-	Life Safety
CP	-	Collapse Prevention
DC	-	Damage Control
RC	-	Reinforced Concrete
NSP	-	Nonlinear Static Processes
PBEE		Performance-Based Earthquake Engineering
PEER		Pacific Earthquake Engineering Research
PBRA		Peak Bed Rock Acceleration
ATC		Applied Technology Council
FEMA		Federal Emergency Management Agency

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Amongst the natural phenomena that have concerned human kind, earthquakes are doubtless the most irritating ones. The happening of earthquakes has been unpredictable and this makes them especially dreaded by the common residents because they feel there is no way to guarantee an effective preparedness. The most dreaded effects of earthquake are failures of structures because they are not only usually indicate human victims but also signify vast damages for individuals as well as for the public. The essential goals of any structural design are safety, serviceability and economy. Attaining these goals for design in seismic zone is especially important and difficult. Ambiguity and unpredictability of time, situation and features of an earthquake event will attack a community increase the overall difficulty. In addition, lack of knowledge and ability to approximation the performance of constructed facilities make it difficult to achieve the above declared objectives.

Airport is one of the vital metropolitan organizations that should be endured totally practicable during and after urban disaster such as seismic hazard. Immediately after ground motion carriage requests develop tremendously.

Particularly different kinds of supports from other cities could be required for the victims, so the high significance of airports cannot be neglected (Roark, Turner and Gould, 2000). Moreover, each airport needs one or more Air Traffic Control towers which are needed to be functional, it is shown in Figure 1.1 requires. Each enter to or exit from airport monitoring staff in controller tower to be available if not catastrophe is more likely, such as ATC tower of Seattle-Tacoma airport in Alaska, Jakarta Airport in Indonesia and Bam Airport in Iran. Designers often use linear structural analysis software for most ATC towers, but this assumption may be not realistic. Besides that, since during an earthquake nonlinear behavior of ATC tower is very probable, the finite element software applied in analysis of the structure must be capable to do nonlinear analysis. According to what stated above, since usual techniques may face to a severe mislead from actual behavior of the structure for analyzing such specific structure an accurate nonlinear analysis is strongly required (Eshgi and Farrokhi, 2003).

Figure 1.1 ATC tower's samples (Aviation, 2014)

1.2 Background of Study

An earthquake is defined as “a sudden motion or trembling in the Earth caused by the abrupt release of strain energy on a fault.” A fault is a break in the Earth’s crust on which rupture occurs or has occurred in the past. Faults are classified according to the type of rupture that occurs on them, it is shown in Figure 1.2. Motion on a normal fault is predominantly vertical and is caused by tension or extension. The block overlying the fault (the “hanging-wall block” in fault lingo) moves down relative to the block beneath the fault (the “footwall block”). Motion on a reverse fault also is predominantly vertical, but it is caused by compression, and the hanging wall block is pushed up relative to the footwall block.

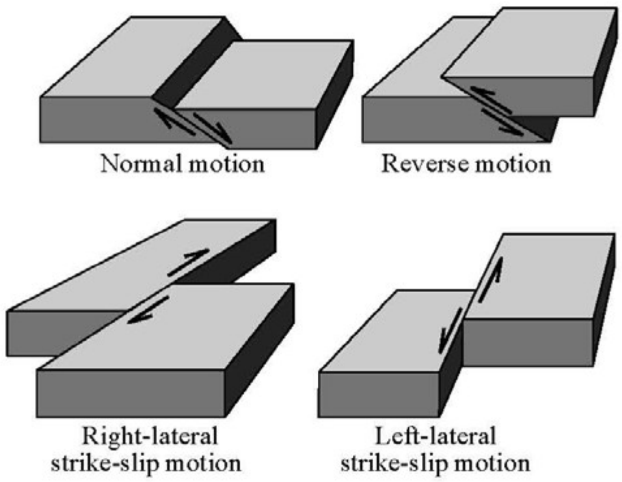

Figure 1.2 Types of faults based on sense of movement.(Roberts, 2002)

Strike-slip faults are characterized by horizontal motion, and material is displaced either to the right or to the left relative to material on the opposite side of the fault. An earthquake is caused by the sudden release of elastic (recoverable) strain that gradually builds up on a fault over time. Strain accumulation may occur over just a few decades, such as on a major fault system like the San Andreas Fault, or over thousands of years on slower-moving faults. In general terms, a fault ruptures when the amount of strain exceeds the strength of the rocks, but the actual triggering mechanism or process is not well known. The energy of the resulting earthquake depends on the amount of strain built up, the strength of the rocks along the fault, and the dimensions of the rupture area. Rupture begins at a single point on the fault surface, known as the earthquake's focus, but it spreads rapidly. The largest earthquakes may break a fault or faults over several hundred kilometers. When newspapers report the occurrence of an earthquake, the location they cite usually is the earthquake's epicenter. The epicenter is the point on the surface directly above the earthquake's focus; it is shown in Figure 1.3.

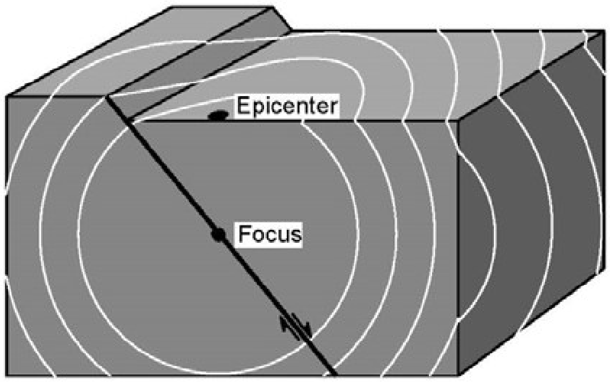

Figure 1.3 The focus and epicenter of an earthquake.(Roberts, 2002)

Perhaps the most important aspect of earthquakes, at least to people near the epicenter, is shaking. Shaking is the result of seismic waves that are transmitted to or along the Earth's surface. Rupture on a fault causes seismic waves, similar to the way a thrown stone causes ripples on the surface of a pond. There are three main types of seismic waves, and they are categorized by their type of motion it is shown in Figure 1.4. P-waves are compressional, so that particles displaced by the waves move forward and back parallel to the direction the wave propagates. S-waves are shear waves, in which particles move perpendicular to the propagations direction.

There are two types of surface waves (Love waves and Rayleigh waves), involving either shearing or elliptical motion.

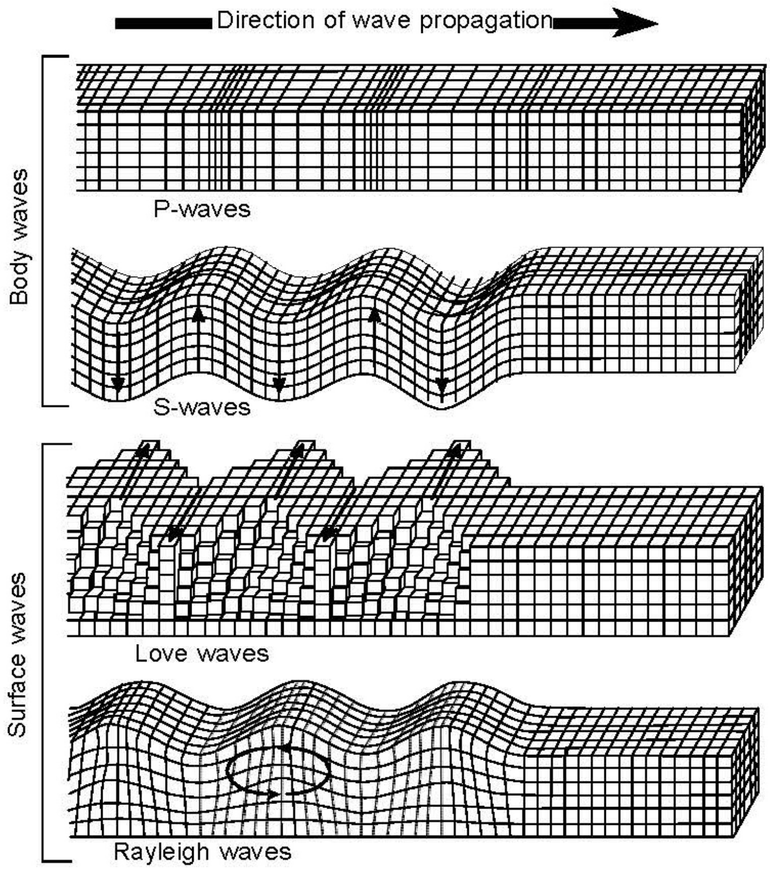

Figure 1.4 The nature of P-waves, S-waves, and surface waves(After Bolt, 1988. Earthquakes. W.H. Freeman: New York)

An important detail about the different types of seismic waves is that each type travels at a different speed. P-waves travel the fastest, S-waves not as fast and surface waves more slowly. In fact, the “P” in “P-wave” stands for “primary” because they are the first waves to arrive after an earthquake. The “S” in “S-wave” stands for “secondary” because they arrive after the P-waves. The different travel times of seismic waves are the key to locating the epicenters of earthquakes, the lag time is the interval between P- and S- wave arrivals, it is shown in Figure 1.5.

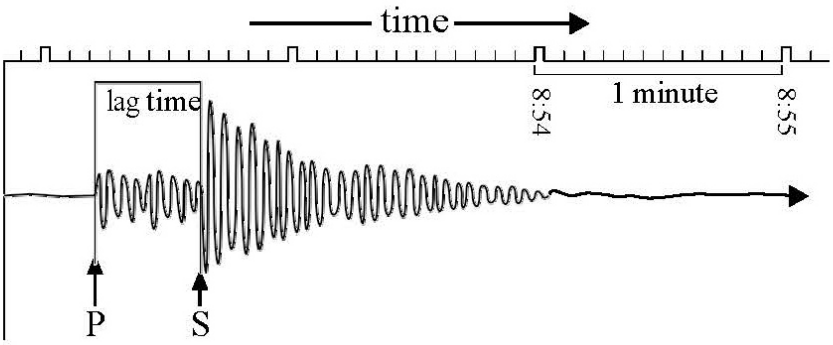

Figure 1.5 A seismogram.(The first arrivals of the P-waves and S-waves) (Roberts, 2002)

1.2.1 Situation of the ATC tower

This ATC tower is placed in Oroumieh Airport, Azarbaijan Gharbi, Iran. It is shown in Figure 1.6. The height of the tower is about 30 m from ground level, the soil class is type 3 and PGA=0.3g.

Figure 1.6 Situation of the ATC tower in Iran (West Azerbaijan Province. 2014)

1.3 Problem Statement

The seismic design and performance of ATC towers have been challenging matters for structural engineers. On one side, their seismic performance level is remarkably higher than normal buildings due to the major role that they play in catastrophe rescue after a seismic incident. On the other side, the lack of exact guidelines and procedures for the seismic assessment and design of ATC towers results in the improper usage of current building codes. For example, some building codes, such as the (ASCE, 2010), consider the seismic design of non-building structures; however, since ATC towers have dynamic behavior that do not totally satisfy the classification of non-building structures existing in most building codes, application of code-based procedure may not be reliable for seismic design of such important structures. This problem is deliberated until present time, so more research is required to propose special procedures for seismic design and performance assessments of ATC towers.

1.4 Objectives of Study

There are total of three objectives to be achieved upon the completion of this project with SAP2000 software. The objectives of this study are:

(i) To study the effect of far-field earthquake records on the seismic behavior of a dual seismic resistance system ATC tower
(ii) To study the effect of the effect of Near-field earthquake records on the seismic behavior of a dual seismic resistance system ATC tower
(iii) To compare the code-base seismic design parameters with those obtained from nonlinear time-history and push-over analysis.

1.5 Scope and Limitations of Study

i. This study only includes seismic behavior of ATC tower located in Oromueh, Iran. The height of the tower is almost 30 m and has steel moment resistance frame supported by concrete shear walls.

ii. This study does not include any experimental investigation

iii. Two series of fifteen (15) Near-Field records and fifteen (15) Far-Field records will be gathered and used to perform nonlinear time history analyses.

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