UNIVERSITI PUTRA MALAYSIA

STUDY OF VISCOUS DAMPER AND BASE ISOLATOR UNDER EARTHQUAKE LOAD

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UNDER EARTHQUAKE LOAD

BY

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ABSTRACT

Earthquake as one of most dangerous disaster could cause many damage to the city. To overcome this problem, many scientist and engineering try to development some new technology, as the result, damper and base isolator has come out for building construction. This project is reporting the investigation about effect of implementing damper device in seismic response of high rise building. for this purpose, a highrise 27 story structure is considered and three finite element models are developed include of structure without having any damper, structure with viscous damper and structure with base isolation. All the model will use same materials for the frame and under the same seismic load which is EI-centro earthquake load. The evaluate for model will base on: displacement, joint reaction for force and moment, the joint acceleration, the frame axial force, shell area for the structure and link axial force. After the evaluation, the compression between three models will be discuss in terms of displacement, frame axial force, and base reaction to study the advantage for damper and base isolator. As the result, all the properties for three models has been shown, and according to the compression, the damper shows good ability in control the displacement while base isolator could help to reduce the axial force for the frame and base reaction forces and moments. Therefore, it is recommended to have economic consider to analysis and get the suitable choice for seismic design.

ACKNOWLEDGEMENTS

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Thanks for his help, the problem during the software analysis could be easy to solve, so that the analysis could be continues. Also, the result checking, and how to analysis it is guide by Dr. FARZAD. It could be say that without his help, this report cannot be finish such easily.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Earthquake, as one of the most serious disaster for people, will caused many damage to the city such as in 1940, Imperial Valley occur a 6.9 Mw earthquake, caused 6 million USD damage and 9 people dead with 20 injured. To overcome this problem, many scientist and engineering try to development some new technology. As the result. viscous damper and base isolator coming out.

1.2 Introduction

Earthquake, caused by suddenly release energy in earth's crust, create the shaking of the surface of the Earth. Due to the shake on the ground by the seismic waves, the building structure basic on the ground foundation will suddenly shaking, hence the structure will be broken and lead the building breakdown.

Due to the effect of the earthquake, the seismic design of building structure become a popular topic in order to reduce the damage of the building structure from the earthquake and provide the safety to the resident. As the result, many new technologies have come to the world

Therefore, viscous damper and base isolator, which is one of the new technology for the seismic design, will be discuss in the following report.

1.3 Problem Statement

As the development of the world, many new technologies to against the earthquake has come to our life. As the result, viscous damper and base isolator, become the top popular technology that has been use in many countries for seismic design. Therefore, one of the problem come out, how does such kinds of technology work, what is their effect to the structure under the earthquake and their behavior, and what is their advantage for the seismic design.

1.4 Aim and Objectives of Study

The aim of this project is to design a seismic against model, therefore, according to the design model, apply with damper and base isolator, to study the effect of damper and base isolator to the structure.

The objectives have been listed below:

1. To design a building structure in order to against the earthquake.

2. To implement damper and base isolator to the structure and evaluate the effect of damper and base isolator, and their response to the structure.

3. To study the advantage of implement damper and base isolator by compare their analysis result.

1.5 Scope of Study

The scope of this study is to develop a seismic design model, provide a study of the effect of damper and base isolator to the structure.

The limit of the project is that the design is based on the ground which have no slope. The damper has been choosing for this project will be viscous damper and the base isolator will consider use rubber isolator.

The suggestion and recommendation of this report is to provide a study and analysis of the seismic design structure and the effect of damper and base isolator to the structure. Besides, the structure has been design might be an idea for the building construction.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter, the Journal article, report and references book that could help to analysis for this project will be discuss and recommend below in order to make the analysis got a good result.

2.2 Earthquake in World

According to the Statistics by USGS, each year there will be more than millions of earthquakes happened all over the world. Most of them was lower than Mw 6.0, more than hundreds of earthquakes will higher than Mw 6.0. and for each ten year, there will be about 7.8 numbers of earthquake that could higher than Mw 8.0, and recently, from 2000 to 2010, there were 14 numbers of earthquake has been found to higher than Mw 8.0, which was the highest risk in 110 years. Therefore, it seemed that a good earthquake against system of building will be very important. (Mooney and White,2010)

2.1 Damage from Earthquake

Stronger earthquake always means the loss of economic, the death and injured of the people. The reason why earthquake could cause so much damage is mostly due to its effect to the building.

The shake from the earthquake cause the broken of binding structure, hence the breakdown of the building, especially for the higher building. The broken building is the main role cause people's death and injured. Earthquake won't hurt people, however, the broken-down building will cause injured to the people inside or near the building. Therefore, a good structure that could against the earthquake will be important to protect the people's safety (IRIS and the University of Portland, 2010).

2.3 How Earthquake Effect Building Structure

An earthquake will hence a series of periodic displacements of the earth, for each point of the surface in the earthquake could acquires to a new position, or return back, therefore, it changes the ground layer of the earth.

During this process, the binding structure base on foundation could be a good conductor to transfer the force and waves cause by the earthquake. The moment of the structure will affect each part of the structure, the change of tension and compression force will hence the broken of beam, therefore, due to part of the structure has been broken, the whole structure will be effect, and the worst situation is the breakdown of the building.

It could be seen that how to deal with the moment change caused by shake waves in the structure is the important key to against the earthquake (Mohorovičić, 1909).

2.4 Earthquake Effectives on Buildings

For the higher building, the shake hence multiple force acting on the structure will be a challenge part for seismic design. The figure shown below will show how earthquake effect the structure, therefore, it will help to provide idea on how to control the displacement for this project.

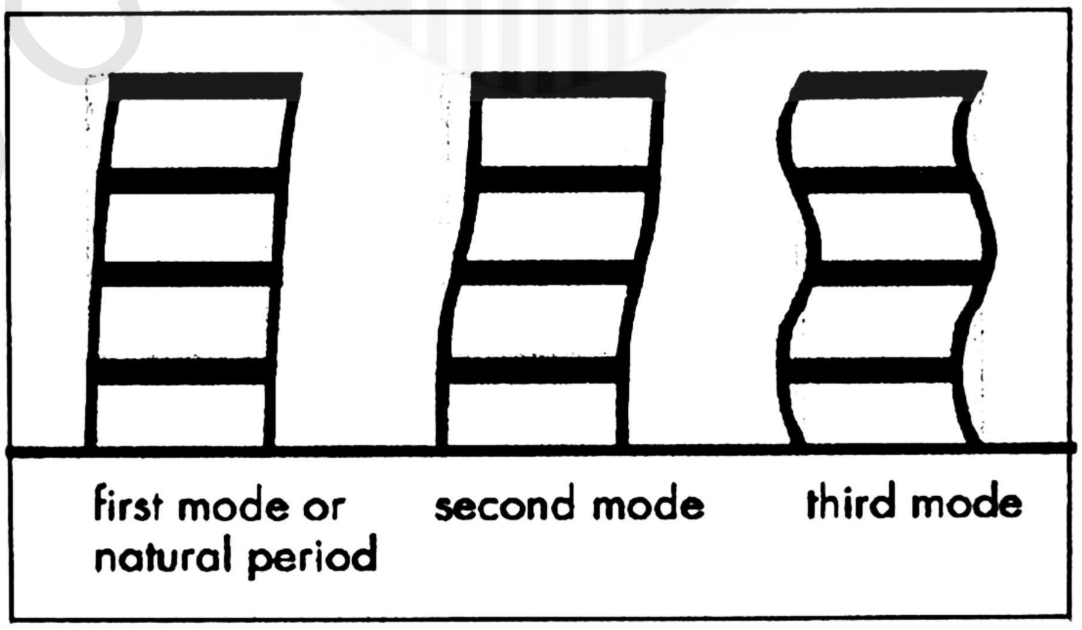


Figure 2.1 Structure deflection under earthquake (Christopher Arnold, 2013).

2.5 Top Technology Could Help for Seismic Design

In order to against earthquake, many scientist and engineering trying to come out some idea and until now, there are many new technologies that could help for seismic design, which include: The Levitating Foundation、Shock Absorbers、Pendulum Power、

Replaceable Fuses、Rocking Core-wall、Seismic Invisibility Cloak、Shape Memory Alloys 、 Carbon-fiber Wrap 、 Biomaterials and Cardboard Tubes. Such kind of technology could be a good idea and reference for the seismic design for this report (William Harrism, 2013).

2.6 High Output Fluid Viscous Dampers

The report shows how does the damper work to against the earthquake, therefore, it provides some engineering data for the damper produce by the Taylor Inc.

Such kind of data include:

Maximum damping force = 330,000 lb. at 60 in/sec.

Damping function, nominal:

$F = 58{,}400\ V^{4}$

where F = Damping Force (lbs.) and V = Damper Velocity (in/sec.)

Therefore, those kinds of data will be a reference to design the damper properties in this project in order to get good result (Taylor. 1995).

2.7 Behavior of Base-Isolated Structures

The report provides the behavior of the base isolator. It shows how does the bearing acting, how it works and its technology information. It provides series formulas for design the base isolator, the accelerate effect to the base isolator.

Therefore, the information provide by this report will be a reference to design the base isolator properties in order to get the reasonable analysis (Fenz and Constantinou, 2008).

2.8 Seismic Protective System: Seismic Isolation

The report come out idea about seismic isolation systems. It specially menation about how does seismic isolation systems work, types of seismic isolation systems can be use and its behavior and some analysis.

The formula come from this report could be useful for the project. However, the report does not have too much analysis about the structure effect, how does the damper response to the structure and the test result, which is just how this project trying to come out (Symans, 2010).

2.9 The Use of Base Isolation Systems to Achieve Complex Seismic Performance Objectives

Seismic Performance Classification (SPC), which is used to describe satisfaction of a complex seismic performance objective, defined as aggregate damage state limitation over multiple levels of seismic hazard.

The shake table test and it analysis from this report could be used as a reference for the project shake table test. On the other hand, the calculation and the concept from this report shows a good way to analysis the wood structure for the project (Morga, and Mahin, 2008).

2.10 Seismic Isolation and Protection Systems

The Seismic Isolation Systems about Rubber isolator has been discuss in this report, which include the technology information, test result on Lead Rubber Bearing's strength. The result from this report is mostly for technology test, therefore, it could be as a reference for this project test on the structure analysis (Kelly, Skinner and Robinson, 2011).

2.11 Engineering Data for Base Isolator

Some engineering data for base isolator by MAGEBA company has been shown in the table, therefore, it will provide reference for propertied design.

Table 2.1 Engineering data for base isolator LASTO@LRB

LASTO®LRB – d_{bd} = 15.75 inches / 400 mm																				
D (in)	D (mm)	t_e (in)	t_e (mm)	H_g (in)	H_g (mm)	N_{sd} (kips)	N_{sd} (kN)	N_{Ed} (kips)	N_{Ed} (kN)	F_1 (kips)	F_1 (kN)	F_2 (kips)	F_2 (kN)	K_r (kips/in)	K_r (kN/mm)	K_{eff} (kips/in)	K_{eff} (kN/mm)	K_v (kips/in)	K_v (kN/mm)	ξ (%)
19.7	500	6.3	160	12.8	326	809	3,600	281	1,250	71	315	170	755	6.28	1.1	10.79	1.89	4,648	814	29
23.6	600	6.9	176	13.8	350	1,338	5,950	483	2,150	94	420	223	990	8.28	1.45	14.22	2.49	7,686	1,346	28
27.6	700	7.6	192	14.7	374	1,967	8,750	776	3,450	116	515	277	1,230	10.28	1.8	17.64	3.09	11,368	1,991	28
31.5	800	8.2	208	15.7	398	2,462	10,950	1,147	5,100	139	620	337	1,500	12.39	2.17	21.30	3.73	15,560	2,725	26
35.4	900	8.5	216	16.1	410	3,653	16,250	1,517	6,750	155	690	393	1,750	15.13	2.65	25.01	4.38	20,887	3,658	26
39.4	1,000	8.8	224	16.6	422	4,215	18,750	2,271	10,100	171	760	456	2,030	18.04	3.16	28.95	5.07	26,797	4,693	25

Important Note This table is intended only as a preliminary reference for the design of the isolator. Final design and technical details will be fully defined once all the parameters of the project are considered in the final design.

Legend

d_{bd}	*Design seismic displacement*	F_1	*Yield force*
D	*Rubber block diameter*	F_2	*Maximum horizontal force (at dbd)*
t_e	*Total rubber height*	K_r	*Horizontal stiffness*
H_g	*Total isolator's height*	K_{eff}	*Effective stiffness*
N_{sd}	*Maximum vertical service load*	K_v	*Vertical stiffness*
N_{Ed}	*Maximum vertical seismic load*	ξ	*Damping ratio*

(MAGEBA Inc, 2013).

2.12 Lead Rubber Bearing on bridge

Lead Rubber Bearing could be use not only in building but also bridge. Exactly, it could be use as long as the structure could match with it. This report provides series test result on Lead Rubber Bearing for the bridge design. However, the report does not mention about seismic design and it's use on building, which is the proposal of this project (Robinson and Tucker, 1981).

2.13 Seismic Design of Buildings Worked Examples

The report includes series types of work for seismic design, which include structure design, analysis of structure, special problem to care, and the way for check out. It could be useful for reference for structure design. But the report does not mention about the use of damper, therefore, only design concept and calculation and analysis will be useful for this project (Eurocode 8, 2011).

2.14 Buildings: Design for Damping

The report explains the concept about how to design damping for the structure. The concept about how damper work, the analysis of damper response on the structure has been discuss. But most of the report is talk about the shock absorber, therefore, for the sliding and load bearing damper for this project could not totally refer this report (Taylor, 1999).

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The model design will be conduct on computer by software AutoCAD 2017. Most of the test for the structure with damper and base isolator analysis will be using computer software (SAP2000).

The project will be conduct on the plan according to the Work procedure. The structure properties include damper and base isolator will be describe in this chapter, therefore, it is expected to get the correct result, and it will be displaced and discuss in the following chapter.

3.2 Work Procedure

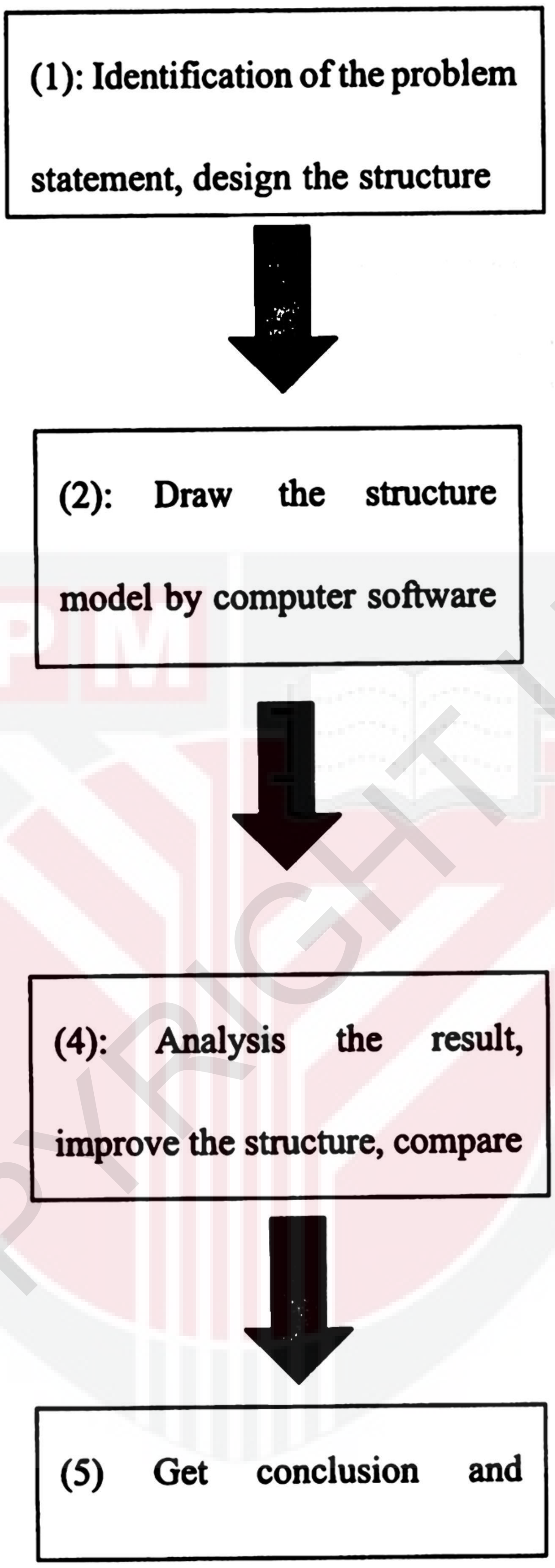


Figure 3.1: Flow chart of work procedure of this project

3.3 Project Description

3.3.1 Design Drawing of Conventional

Type: office building

Floor:27

Level High: 2m, with Ground floor high of 4m

Total height: 58m

Base area:18m*18m=324m^2

Second section area: 12.7m*12.7m=161.29m^2

Top section area: 9m*9m=81m^2

Base: Fixed base

Material: all in steel, S235 (Yield strength:235N/mm^2)

Figure 3.2 3D view of structure by sap2000

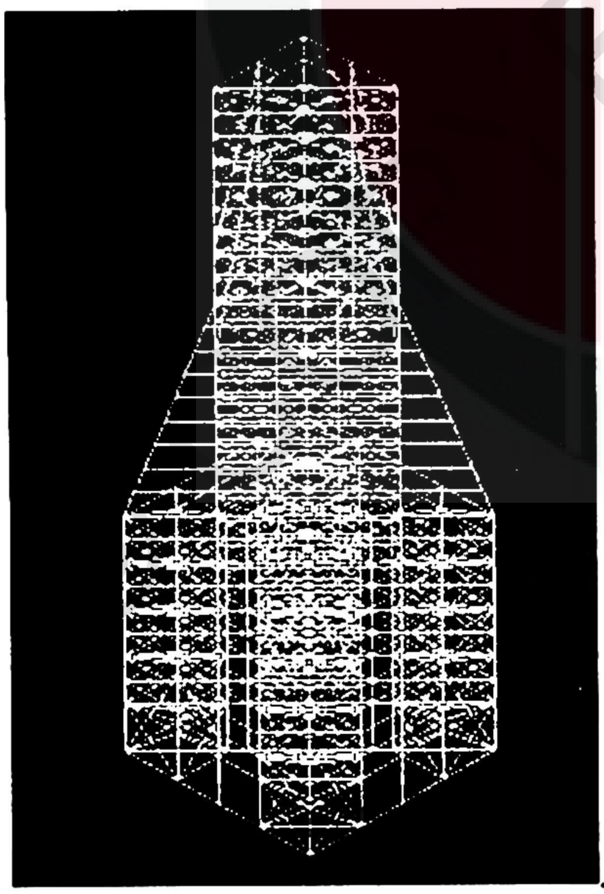


Figure 3.3a 3D view AutoCAD

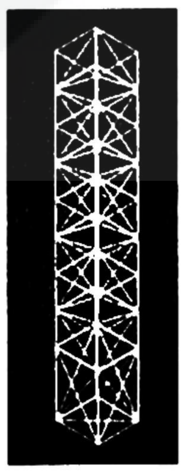


Figure 3.3b Section of side part

Figure 3.4 Top view

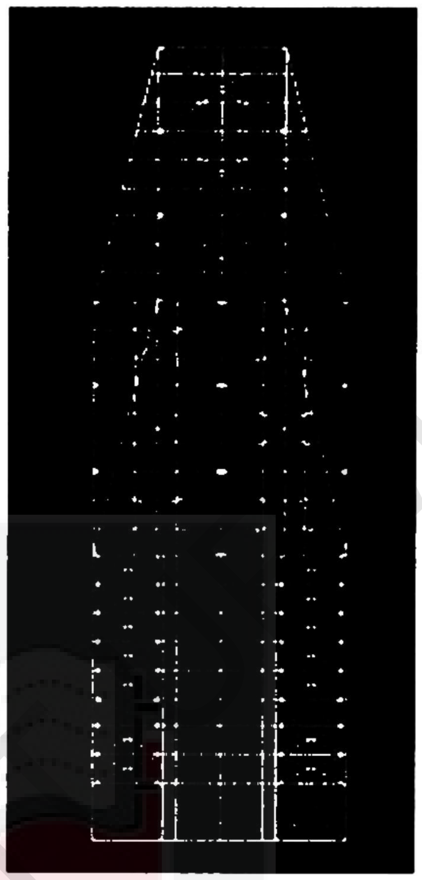


Figure 3.5 Side view

3.3.2 Analysis the Problem

In this part, the problem which is what kind of structure will be used and how to apply the damper and base isolator will be discuss.

3.3.3 Draw the Structure on the Computer

In this section, the structure model will be draw by computer software SAP2000. The model drawing will be 3D view. The drawing shall include column, beam, and frame part.

3.3.4 Analysis the Structure

The result test will be analysis by computer software SAP2000.

The test will include:

The seismic against ability, maximum strength can be afforded by structure

The effect of damper and base isolator to the structure

The top displacement of the structure

3.3.5 Conclusion and Recommendation

The result on how the damper and base isolator effect the structure will be discuss. The difference of two link behavior will be discuss. The design structure's ability for seismic against and recommendation will be discussed

3.4 Analysis the Structure

3.4.1 Design Drawing with Damper

Figure 3.6 Structure with damper, shows with green link

The damper properties, refer by *Taylor Devices Inc.* is given below:

Non-linear viscous damper for seismic design,

Material: from type 17-4 PH stainless steel billet

Stiffness (unit: KN/m): 200,000

Damping coefficient (unit: KN/(m/s)): 1000

Damping exponent: 0.4

3.3.2 Design Drawing with Base Isolator on Down Side

Total number of base isolator: 24

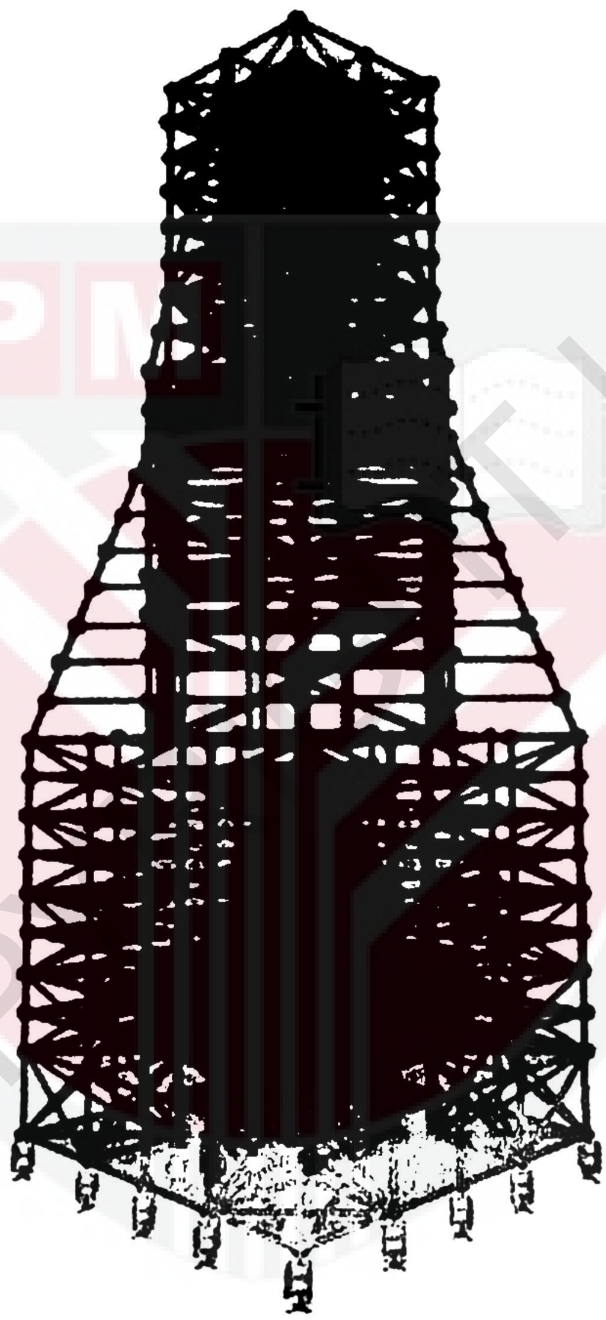
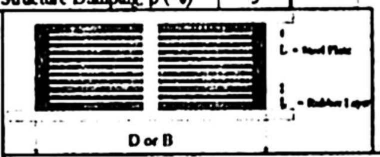


Figure 3.7 Structure with base isolator on down side

The properties refer from a calculate sheet from *civilea.com*, is shown in Table 3.1:

Table 3. 1 Calculate sheet from Civilea.com

Isolator Properties						
Elastomer Properties (Material)			Isolator Dimensions		Design Assumption	
Units:	MPa	KN, mm	Units	mm	Units:	KN, mm
Shear Strain (%)	50	50	Plan Shape	Circular	Maximum Applied Dis., D_m	351.8
Shear Modulus, G	0.707	0.00071	Plan Dimension (d-B)	800	Structure Damping, β (%)	5
Ultimate Elongation	5	5	Rubber Cover Th.	10		
Material Constant, k	0.7	0.7	No. of Rubber Layers	18		
Elastic Modulus, E	2.63	0.00263	Rubber Layer Thickness, t_r	9		
Bulk Modulus, E_∞	1500	1.5	No. of Mid. Steel Pl.	17		
Damping	0.05	0.05	Mid. Steel Pl. Thickness, t_s	2		
Lead Yield Strength, σ_{pl}	8	0.008	Lead Core Diameter, d_{pl}	140		
Gravity	9810	9810	Total Height	196		

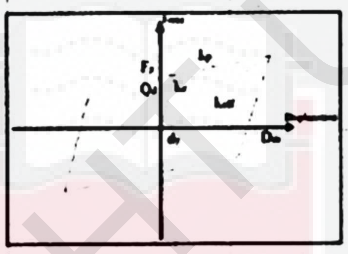


Hardness IRHD±2	Young's Modulus E (MPa)	Shear Modulus G (MPa)	Material Constant k	Elongation at Break Min, %
37	1.35	0.40	0.87	650
40	1.50	0.45	0.85	600
45	1.80	0.54	0.80	600
50	2.20	0.64	0.73	500
55	3.25	0.81	0.64	500
60	4.45	1.06	0.57	400

Cell Contains	INPUT
	AUTO

Bearing Properties (KN, mm)	
Gross Area, A_g	502655
Plug Area, A_{pl}	15394
Rubber Area, A_r	487261
Total Rubber Thickness, T_r	162

Hysteresis Loop Properties (KN, mm)		
Characteristic Strength, Q_d	123.2	$Q_d = A_{pl} \times \sigma_{pl}$
Post-Yield Stiffness, K_p	2.13	$K_p = G_r A_r / T_r$
Coefficient on A_{pl}/A_r	12	
Coefficient on K_r	6.5	
Elastic Stiffness, K_e	19.06	$K_e = 25K_p$, $6.5K_p[1+12A_{pl}/A_r]$
Yield Displacement, D_y	7.27	$D_y = Q/(K_e - K_p)$
Yield Force, F_y	138.6	$F_y = Q + K_p D_y$
Maximum Force, F_m	871.3	$F_m = Q + K_p D_m$
Effective Stiffness, K_{eff}	2.48	$K_{eff} = F_m / D_m$
Area Hysteresis Loop, A_h	169715	$A_h = 4Q_d(D_m - D_y)$
Equivalent Viscous Damping, β_{eff}	0.088	$\beta_{eff} = A_h / 2\pi K_{eff} D_m^2 = A_h / 2\pi F_m D_m$



Civilea.com
Civil Engineering Association

Calculate result: (all unit in Kn,mm,s)

For U1:

Effective stiffness: 2477

Effective damping: 0

For U2 & U3:

Linear case:

Effective stiffness: 2.48

Effective damping: 0.038

Distance from J: 7.3

Non-linear case:

Stiffness:19.06

Yield strength: 138.6

Post yield stiffness ratio: 0.11

3.3.3 Design Analysis

The analysis will be done by three models, which is the conventional, with damper and with base isolator.

The basic step about how to do the analysis is shown below:

- Step one: the conventional structure will be built in the SAP2000
- Step two: define the structure materials and the model load.

  In this project, the structure will use steel structure, S235, as the frame.

  The load for the structure assigned will take self-weight of structure, the area load of each floor, and the wall load acting on the structure.

The building is defined as the office building, according to <*Code of Practice for Dead and Imposed Loads 2011*> the general office building the area load QK=4.5kn/m^2

The wall considers use 100 block wall, which provide the load of 10.2 Kn/m for the first floor (4m height) and 5.1Kn/m (2m height) for the rest of floor.

- Step three: assigned with quake load.

  In this project, Elcentro-Acceleration has been considered to use in order to analysis the structure.

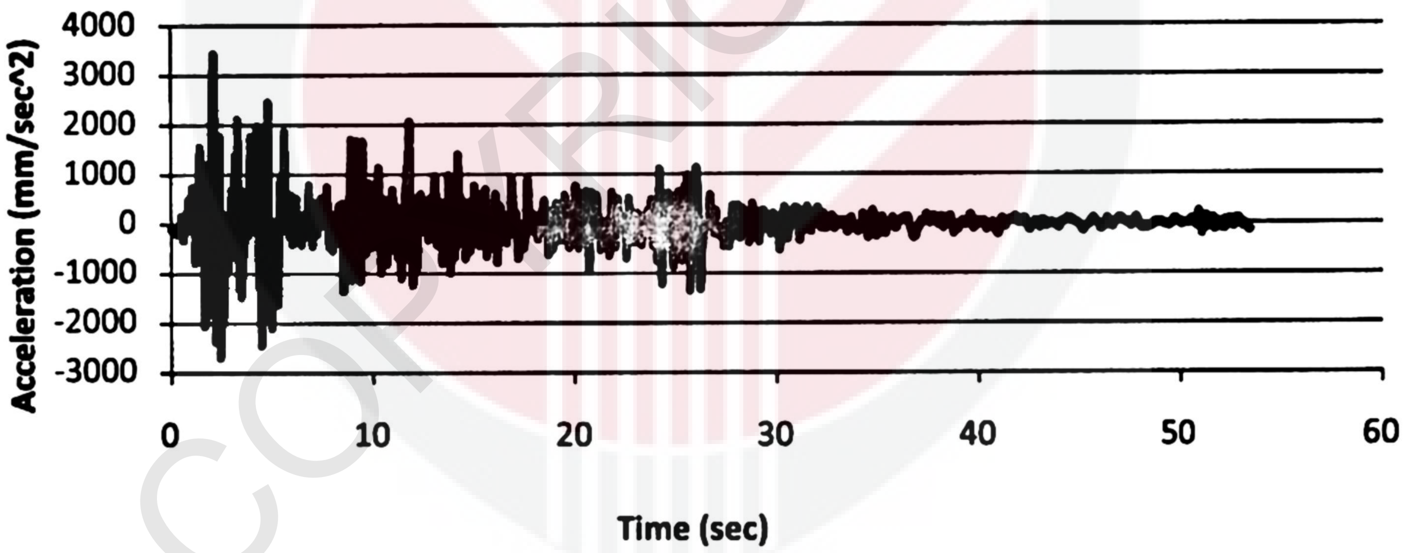


Figure3.8 Elcentro-Acceleration

- **Step four: run the analysis, show the result with time and history function.**

- **Step five: copy the structure, apply with damper and base isolator, do the analysis again to get the result.**

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the analysis of the software result for the conventional model, damper model and base isolator model will be discuss in this chapter. The result will be shown by figure or table which come from software SAP2000 or Excel data collect from the software.

Each of the model will be evaluated in terms of displacement, joint reaction force and moment, joint acceleration, frame axial load, element force for shell area and link axial force (only for damper and base isolator model).

After analysis, the compression study between three models will be discuss in terms of displacement, base reaction and frame axial force.

4.2 Parameters for Seismic Evaluation

The evaluation for the model will be continues by following item: displacement, joint reaction for force and moment, joint acceleration, frame axial force, element force-shell area, and link axial force for model damper and base isolator.

The following part will describe the definitions of those parameters.

4.2.1 Displacement

The displacement is the total length between the initial and final position shortest travelled distance.

4.2.2 Joint Reaction Force and Moment

Joint reaction force and moment is defined as the force and moment generated within a joint in response to forces/moment acting on the joint.

4.2.3 Joint Acceleration

The joint acceleration is described the rate of change of velocity per unit of time. Therefore, the relative acceleration is within the reference frame local to the structure

4.2.4 Frame Axial Force

The elements force for the frame axial force is the compression or tension force of the frame member.

4.2.5 Element Force for Area Shell

Area shell describe the area element internal the membrane direct force per length reported in the area element local coordinate system (CSC Inc. 2017)

Therefore, it can be calculated as: Force/Length (unit kn/mm)

4.2.6 Link Axial Force

The elements force for the line axial force is the compression or tension force of the link member. In this project, the line indicates damper or base isolator.

4.2 Performance Evaluation of Model

After analysis all the structure, each model will be evaluated according to the Parameter for Seismic Evaluated which has been talked above.

First, the displacement of the top joint of the model will be discuss, therefore, force elements for the joint in terms of reaction force, reaction moment and relative acceleration will be discussed. last part will be elements force for the frame, area shell and link axial force (for damper model and base isolator model).

After discussing each performance for the model, the compression figure or table between three models will be analysis. The analysis will include displacement, axial force for frame, and base reaction. Therefore, a discussion will be made according to those figure or table.

4.2.1 Conventional Model Analysis

The conventional model will be the first model to be analysis and discuss to provide the benchmark for the compression.

The model is under the EI-centro earthquake load. The maximum displacement for the top joint is 452mm at 18.6s. And the minimum displacement is -466mm at 15s. The time history figure for displacement is shown in Figure 4.1 below.

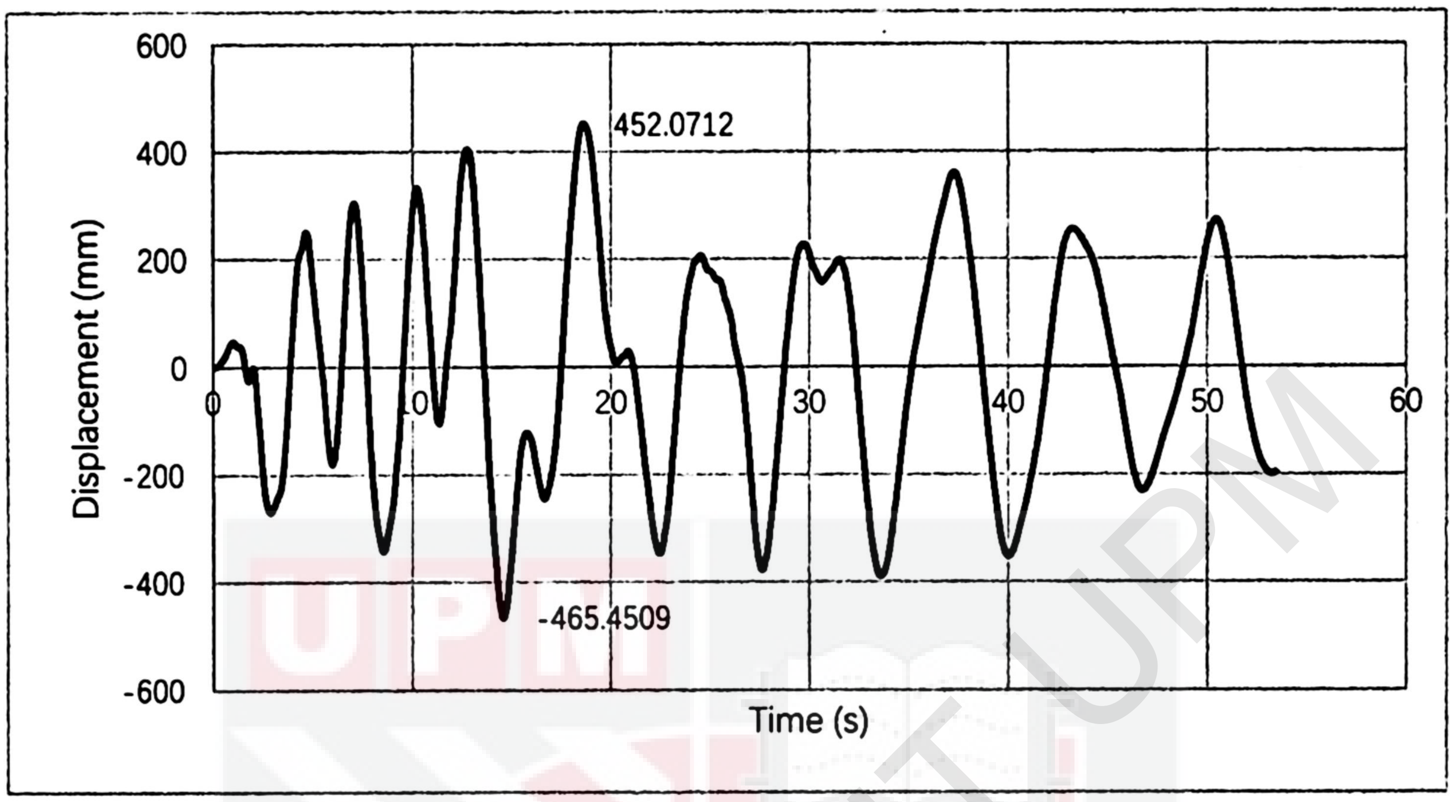


Figure 4.1 Time history figure for conventional model

The maximum allowable displacement is calculated as 280mm, which means the conventional model is totally out of the range in terms of displacement.

For the joint, the minimum joint reaction force is -1560.621kn and maximum 2528.201kn. For the moment, the minimum joint reaction moment is -13256.83kn-mm while the maximum moment is 13288.55kn-mm. As for the joint relative acceleration, the minimum acceleration is -4636mm/s^2 and the maximum acceleration is 4152mm/s^2.

The minimum frame axial force is -3311.344kn, and maximum frame axial force is 3318.752kn.

Figure 4.2 Frame axial force diagram for conventional

For the area shell elements force, the minimum area shell force is -661.85051kn/mm while maximum is 661.84654kn/mm.

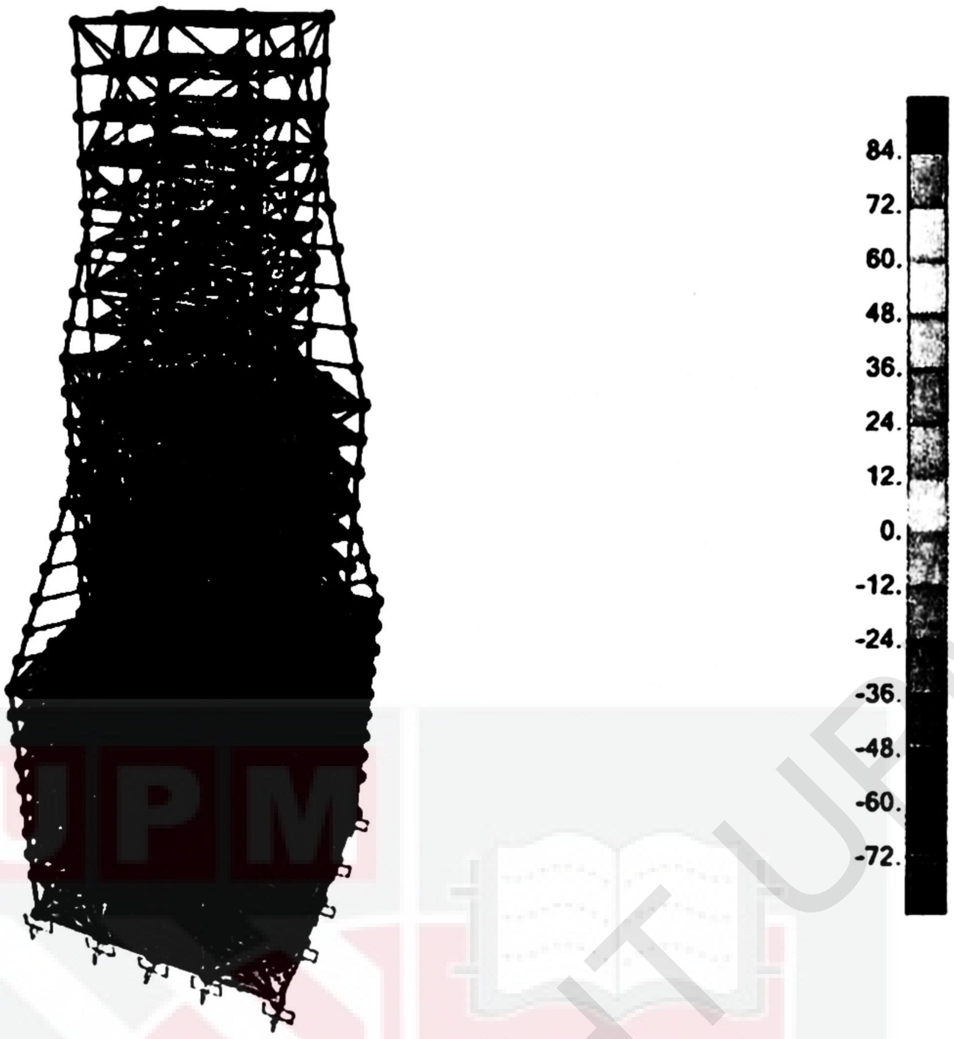


Figure 4.3 elements force-area shell for conventional model

4.2.2 Model with Damper Analysis

The second model for analysis is the model add with damper. The damper properties are shown in methodology chapter as talked above. The earthquake load assign is same as conventional model which is EI-centro earthquake load.

The displacement for the joint on the top part is minimum -266mm at 27s while maximum displacement is 234mm at 29.8s.

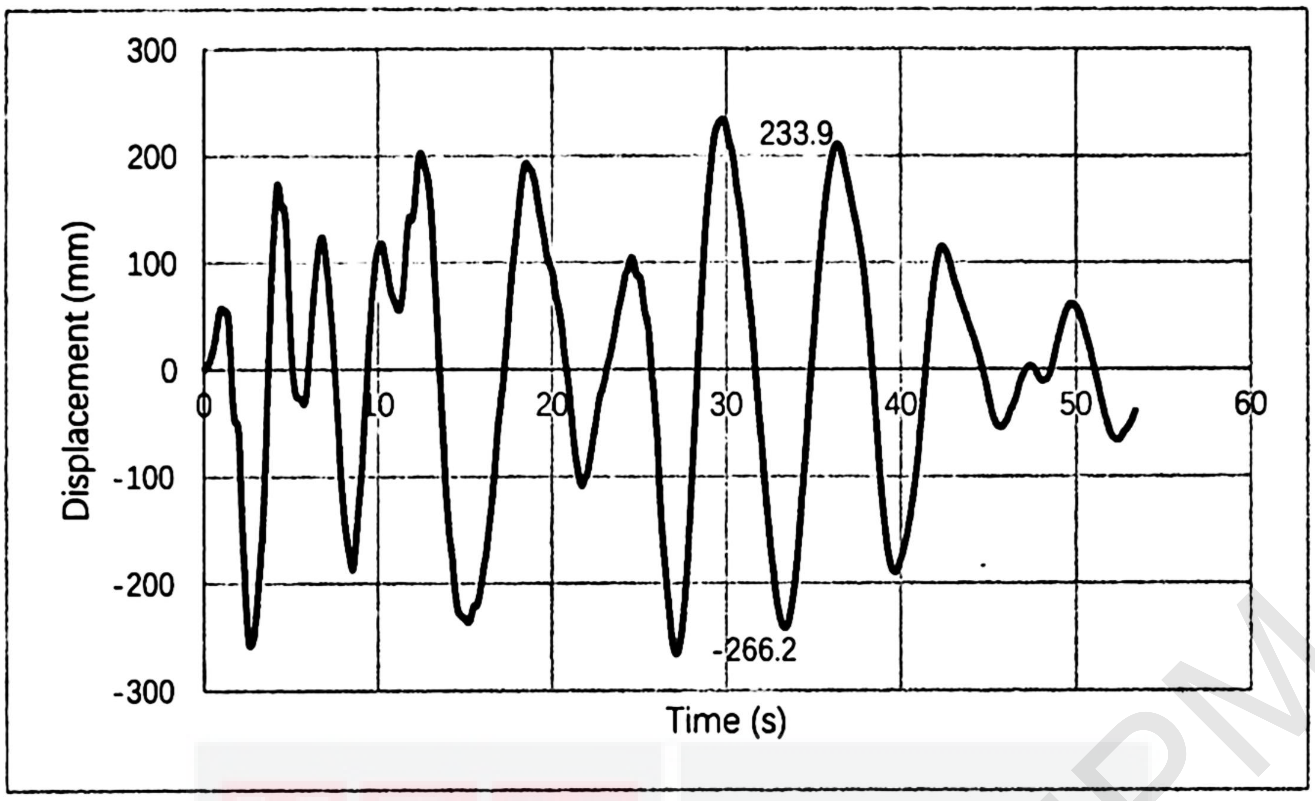


Figure 4.4 Displacement time history result for damper model

According to the analysis, the maximum and minimum displacement is smaller than 280mm, which is safety enough.

For the joint, the minimum joint reaction force is -1487.222kn and maximum is 2528.261kn. while for the joint reaction moment, the minimum moment is -24680.4kn-mm and maximum is 25161.61kn-mm. The relative joint acceleration, as analysis, is -4591.9 mm/s^2 for minimum and 4056.38mm/s^2 for maximum.

The minimum frame axial force is -1905.807kn while the maximum force is 1901.642kn.

Figure 4.5 Frame axial force diagram for damper model

For the area shell, the minimum area shell is -320.19477kn/mm and maximum is 320.19342kn/mm.

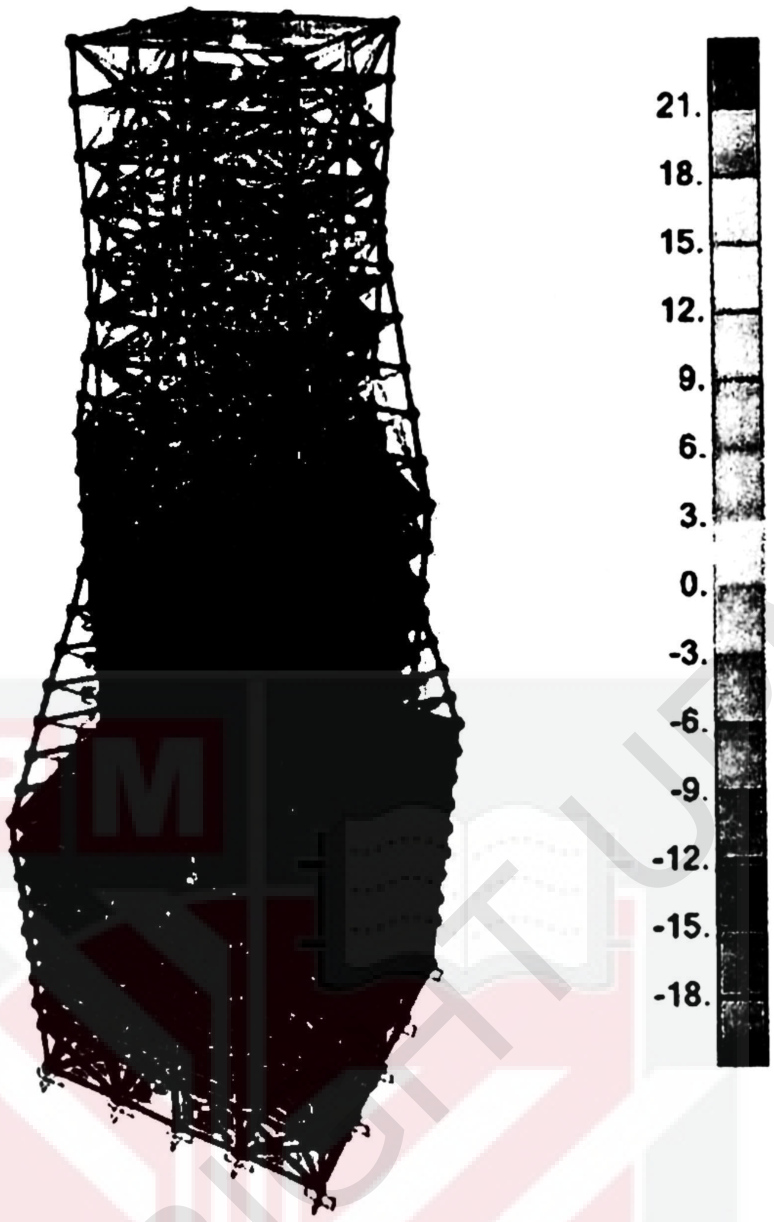


Figure 4.6 Element force-area shell for the damper model

For the link which is damper in this model, the minimum link axial force is 320.19342kn while the maximum is 349.815kn.

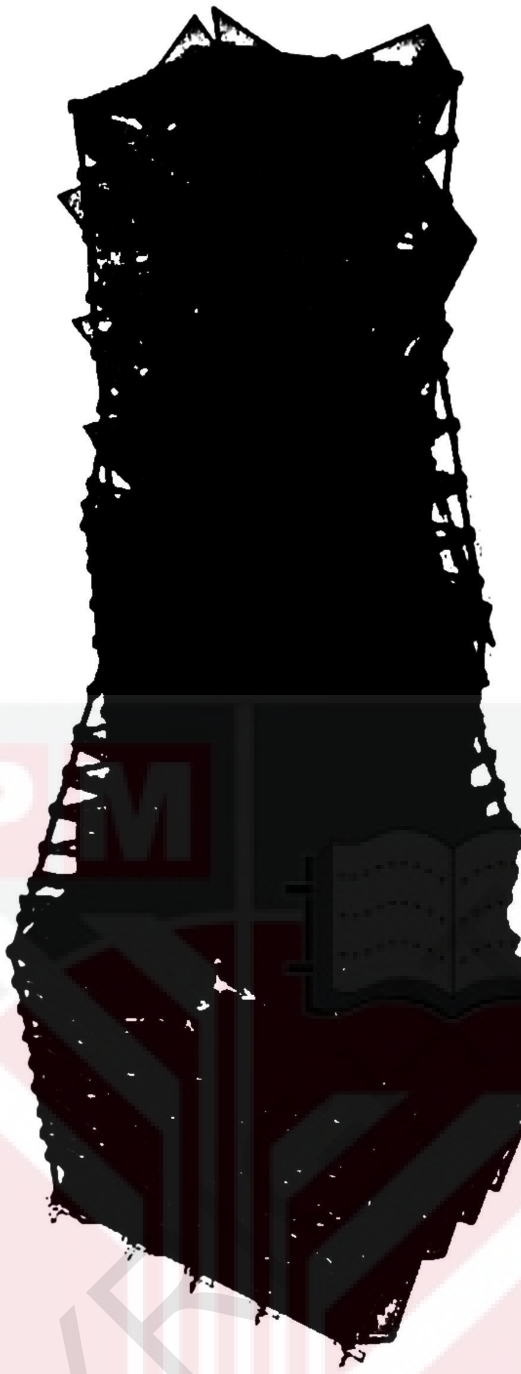


Figure 4.7 Axial force for the link damper

4.2.3 Base Isolator Model Analysis

The last model for analysis is base isolator mode. The properties for the base isolator is already be discuss in Methodology Chapter above.

The displacement for this model is minimum -294mm at 15.8s and maximum displacement is 242mm at 19.5s.

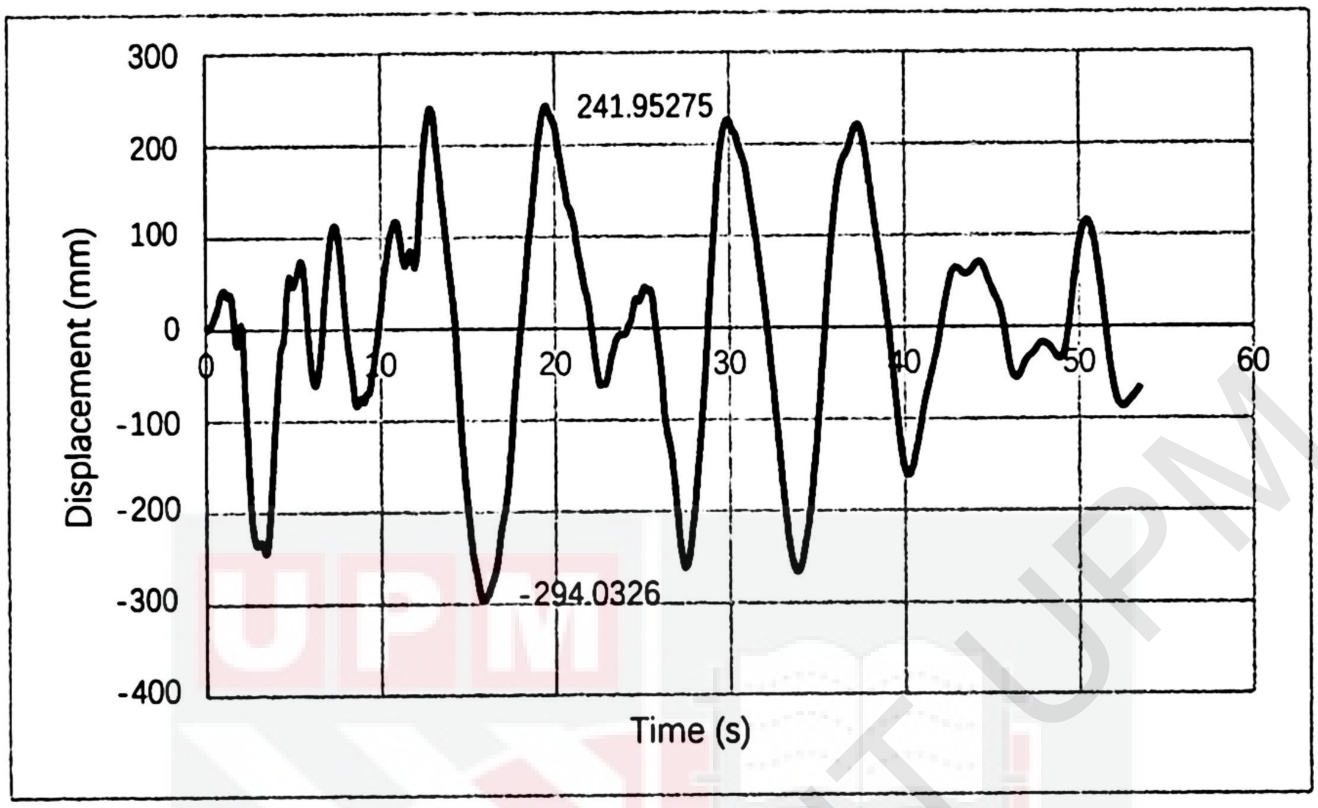


Figure 4.8 Displacement time history result for base isolator model

The allowable displacement is 280mm, therefore, this model has minimum 294mm displacement, which is little beyond the range, means little dangerous for the displacement.

The minimum joint reaction force for this model is -1592.392kn and the maximum reaction force is 1541.979kn. For the reaction moment, the result is -34644.49kn-mm for minimum and 42267.91kn-mm for maximum. The joint acceleration for the minimum is mm/s^2 while maximum is mm/s^2.

The minimum axial force for the frame is -1592.392kn and 1541.979kn for maximum.

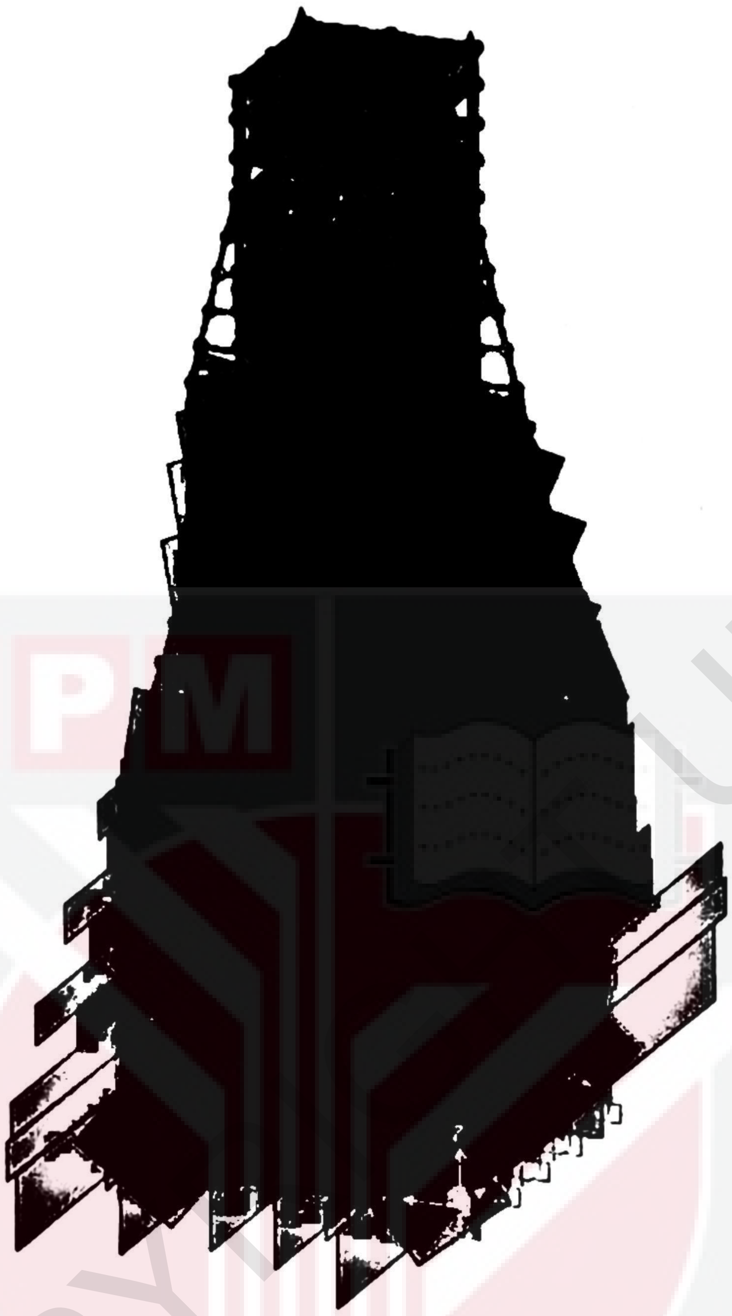


Figure 4.9 Frame axial force diagram for base isolator model

For the shell area elements force, the minimum as analysis is -201.46427kn/mm while maximum is 201.46417kn/mm.

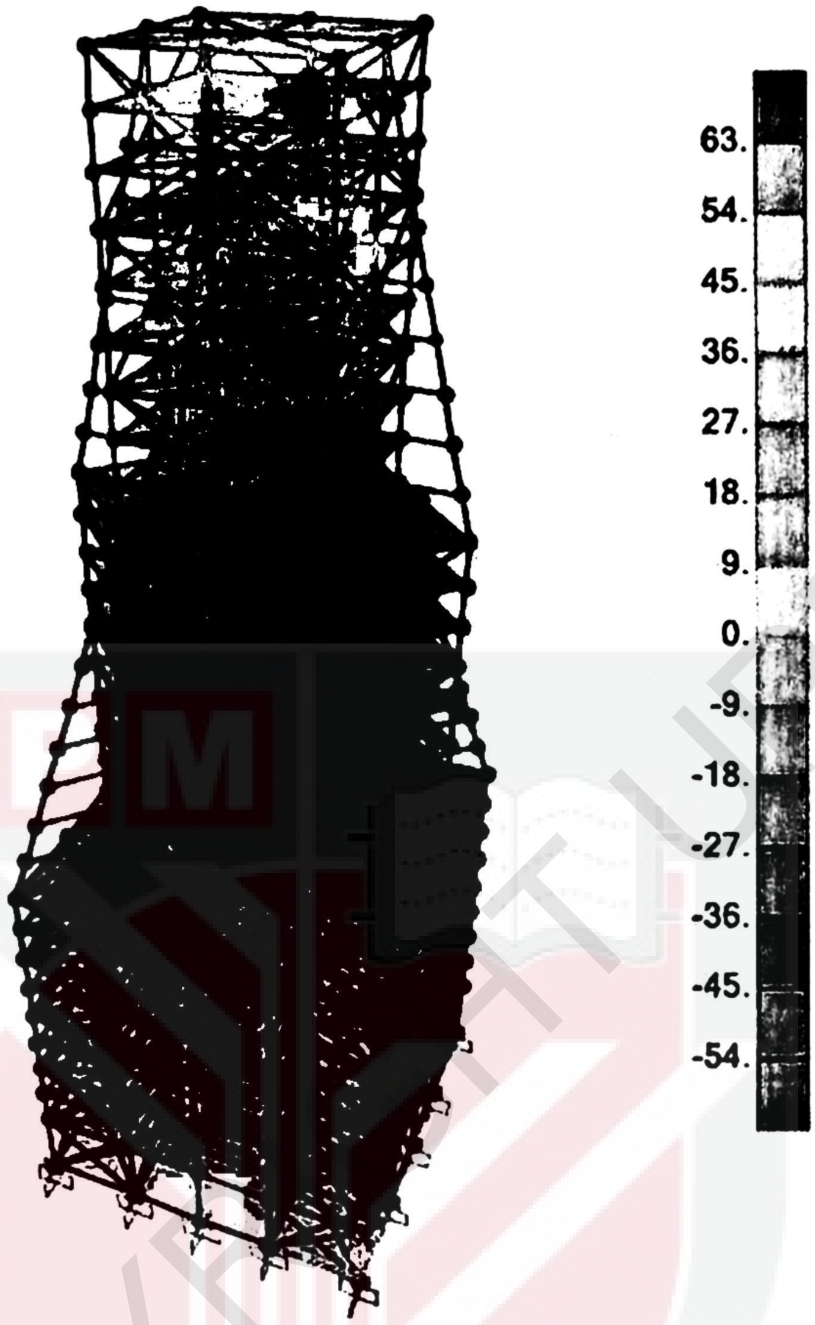


Figure 4.10 Element force-area shell for the damper model

For the link axial force, which is base isolator in this model, is -1871.96kn for minimum and 1842.005kn for maximum.

4.2.4 Compression of Displacement

Figure 4.11 show the displacement of the top part of the structure.

The function consists of three lines, which are normal (Conventional), damper (structure with damper) and base isolator (structure with base isolator)

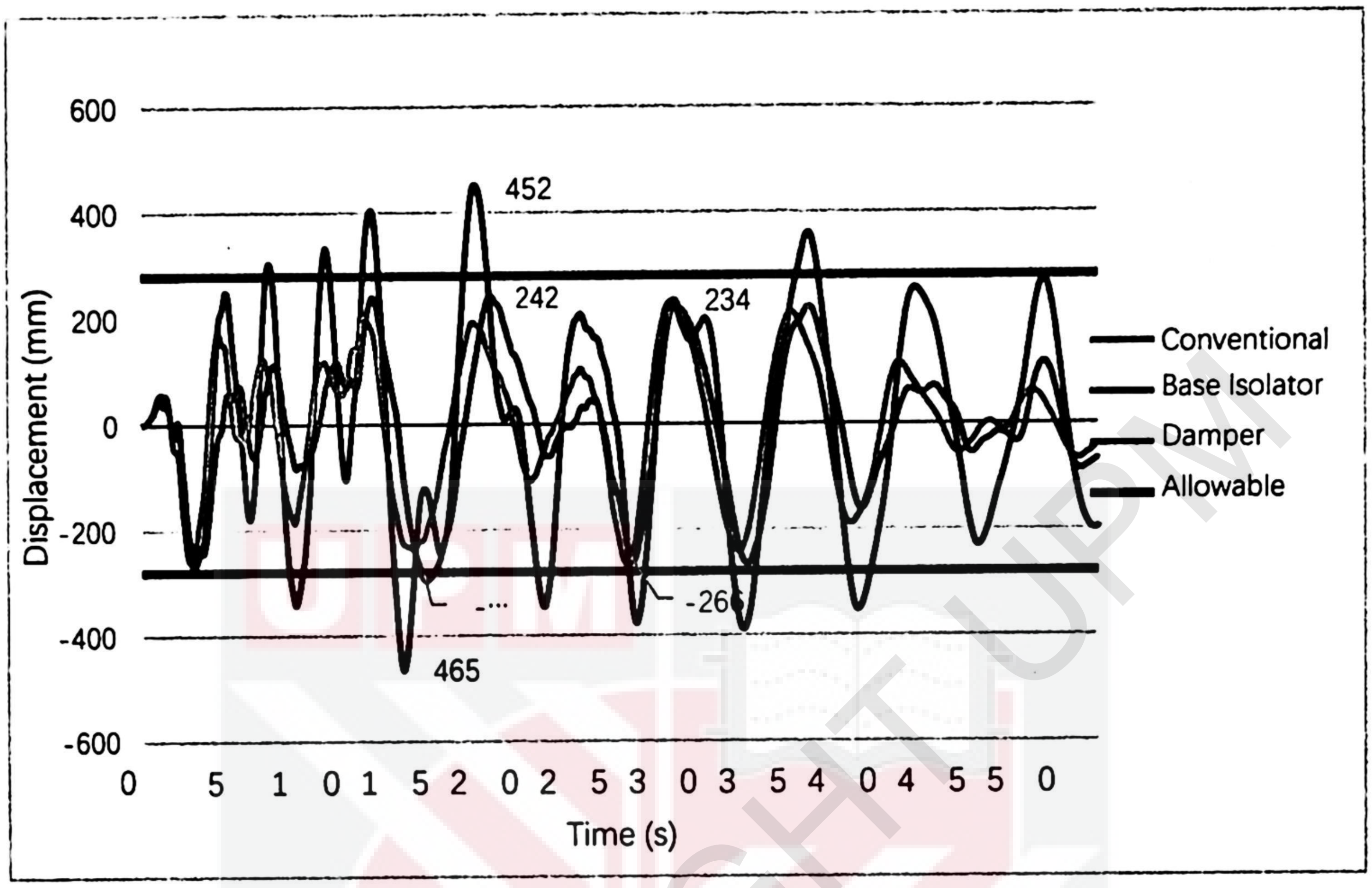


Figure 4.11 Displacement of the top joint

The total height of building is 58m, according to the seismic design formula allowable displacement=H/200 we get allowable displacement is:

56m/200=0.28m=280mm

According to the graph, the structure without damper and base isolator will have about maximum -465mm displacement, which means the structure might break due to the earthquake.

For the Damper, the displacement has success to be control to below 280mm, which means the damper apply on the structure has successful to reduce the displacement of the structure under earthquake.

For the base isolator, it limits the displacement to 290mm, which is little danger but due to steel structure could have more displacement than concrete structure, therefore, it still could be acceptable.

Compare with those two results, both has a good ability to reduce the displacement of the structure, while damper seemed to be work better than base isolator. This might due to damper directly acting on the frame structure, it provides a good ability to link the frame together, hence it shows advantage in reduce displacement case.

4.2.5 Compression of Base Reaction

The Table 4.2 shows the base reaction for each types of structure.

Table 4.1 Base reaction for the structures

ABLE: Base Reactions									
OutputCas	CaseType	StepType	GlobalFX	GlobalFY	GlobalFZ	GlobalMX	GlobalMY	GlobalMZ	
Text	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m	Conventional
quake	NonModHist	Max	16824.81	118.562	326.617	4303.695	183200.4	126178.2	
quake	NonModHist	Min	-14092.4	-126.865	-319.352	-4740.62	-177779	-150762	
ABLE: Base Reactions									
OutputCas	CaseType	StepType	GlobalFX	GlobalFY	GlobalFZ	GlobalMX	GlobalMY	GlobalMZ	
Text	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m	Base isolator
quake	NonModHist	Max	7181.13	130.68	225.326	2804.604	128350.9	59584.83	
quake	NonModHist	Min	-6640.71	-105.669	-234.929	-3585.67	-99313.7	-64652.6	
ABLE: Base Reactions									
OutputCas	CaseType	StepType	GlobalFX	GlobalFY	GlobalFZ	GlobalMX	GlobalMY	GlobalMZ	
Text	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m	Damper
quake	NonModHist	Max	12633.08	76.986	135.911	1679.301	147212	89920.81	
quake	NonModHist	Min	-10146.7	-100.065	-194.734	-1289.5	-120565	-112712	

For the force acting on the x-direction, it's clear that both damper and base isolator could reduce the force pressure acting on the base. However, the displacement for damper is reducing about 0.75 of the conventional and base isolator success to reduce half of the conventional.

For the moment on the base, the result shows for each structure is similar as the force. Which is both damper and base isolator could reduce the moment force acting on the base while base isolator could reduce more.

Therefore, compare with two results, both damper and base isolator have ability to reduce the base reaction in terms of force and moment. However, the base isolator could reduce much more than the damper. Personally, it may cause by the damper is acting on the frame while base isolator is work on the base, that make the base isolator has more advantage for base section part.

4.2.6 Compression of Frame Elements

For this part, the researcher chooses three frames for analysis the result. The chosen section is shown in Figure 4.12:

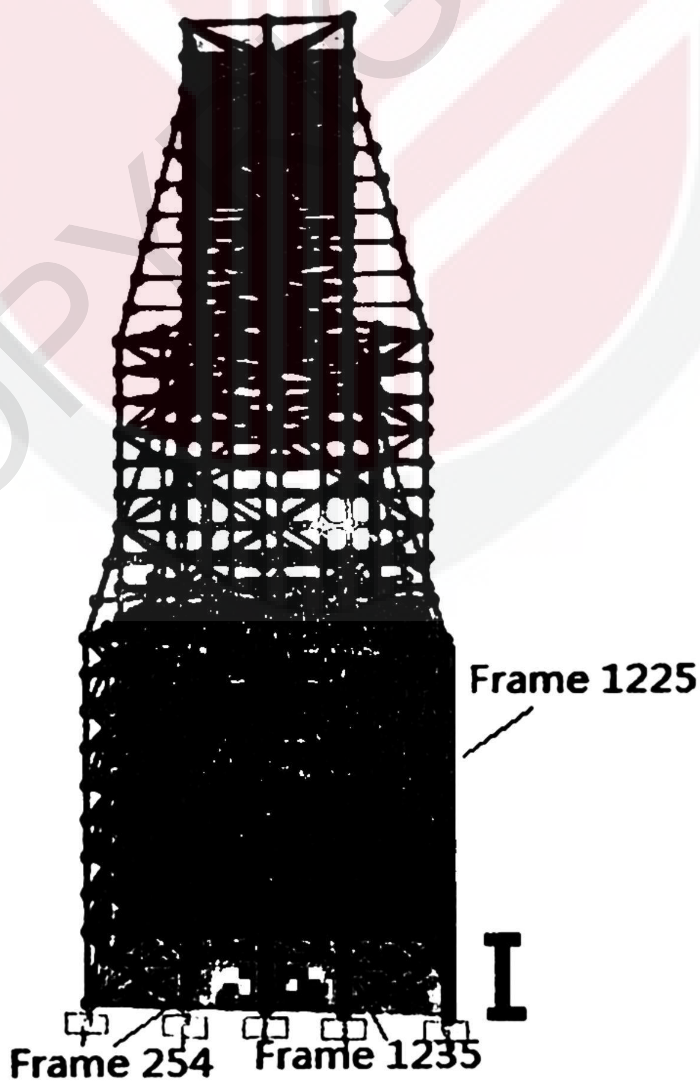


Figure 4.12 Frame choose for analysis

Frame 254, frame 1235 and frame 1225, which is the base column of the structure, therefore, it was expected to get the maximum axial force elements for the structure.

For Frame 254:

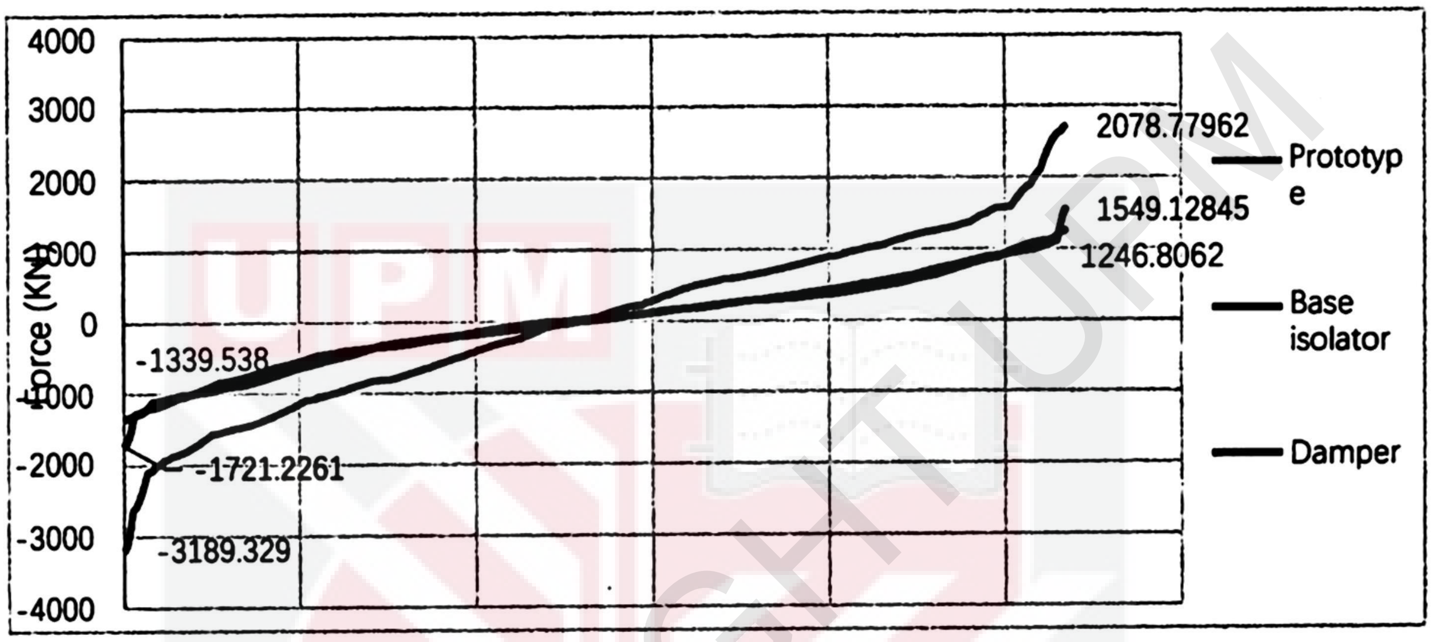


Figure 4.13 Force elements for the frame 254

From the figure, the conventional structure has the largest axial force, damper and base isolator structure shows a smaller value for the axial force, while base isolator is smaller than damper.

For Frame 1335:

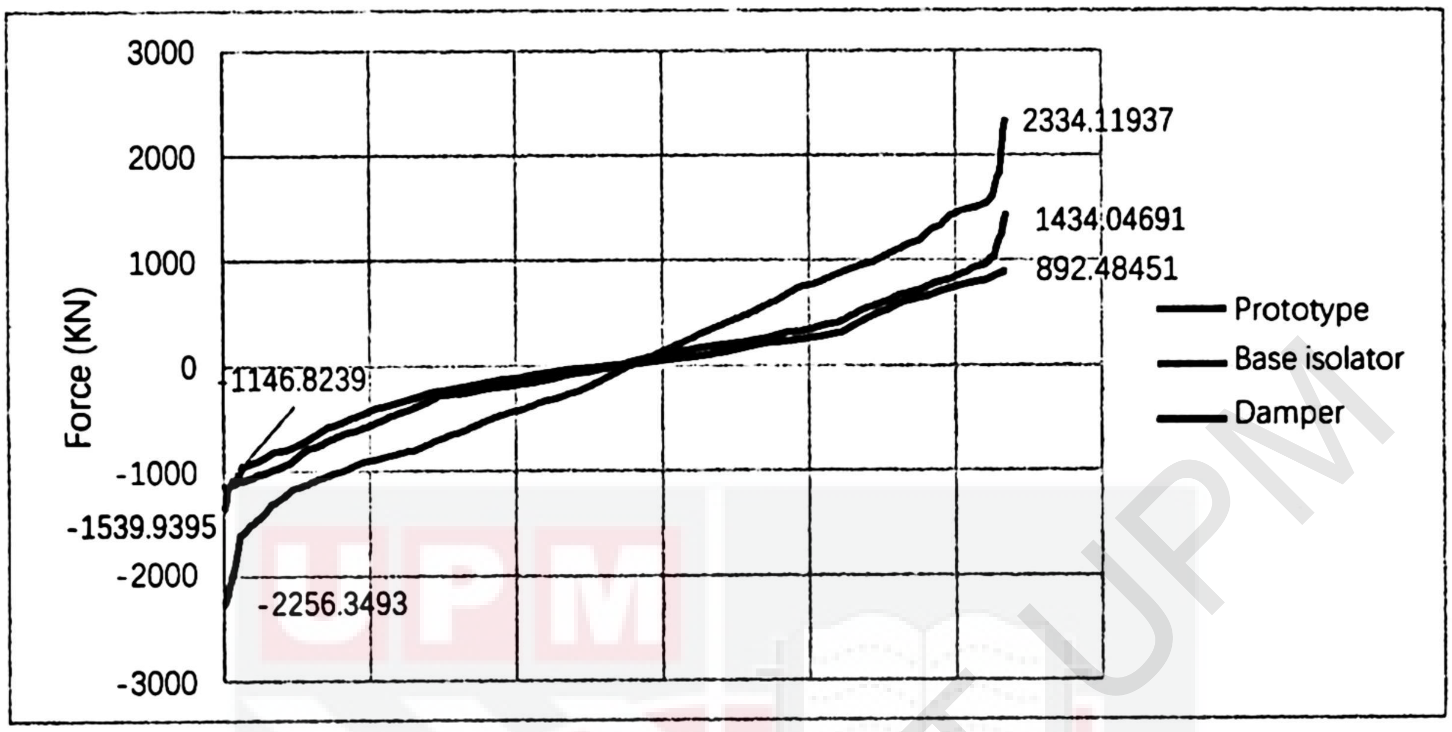


Figure 4.14 Force elements for the frame 1235

The figure shows damper and base isolator success to reduce the axial force for frame1235, while base isolator worked much more batter than the damper.

For Frame 1225

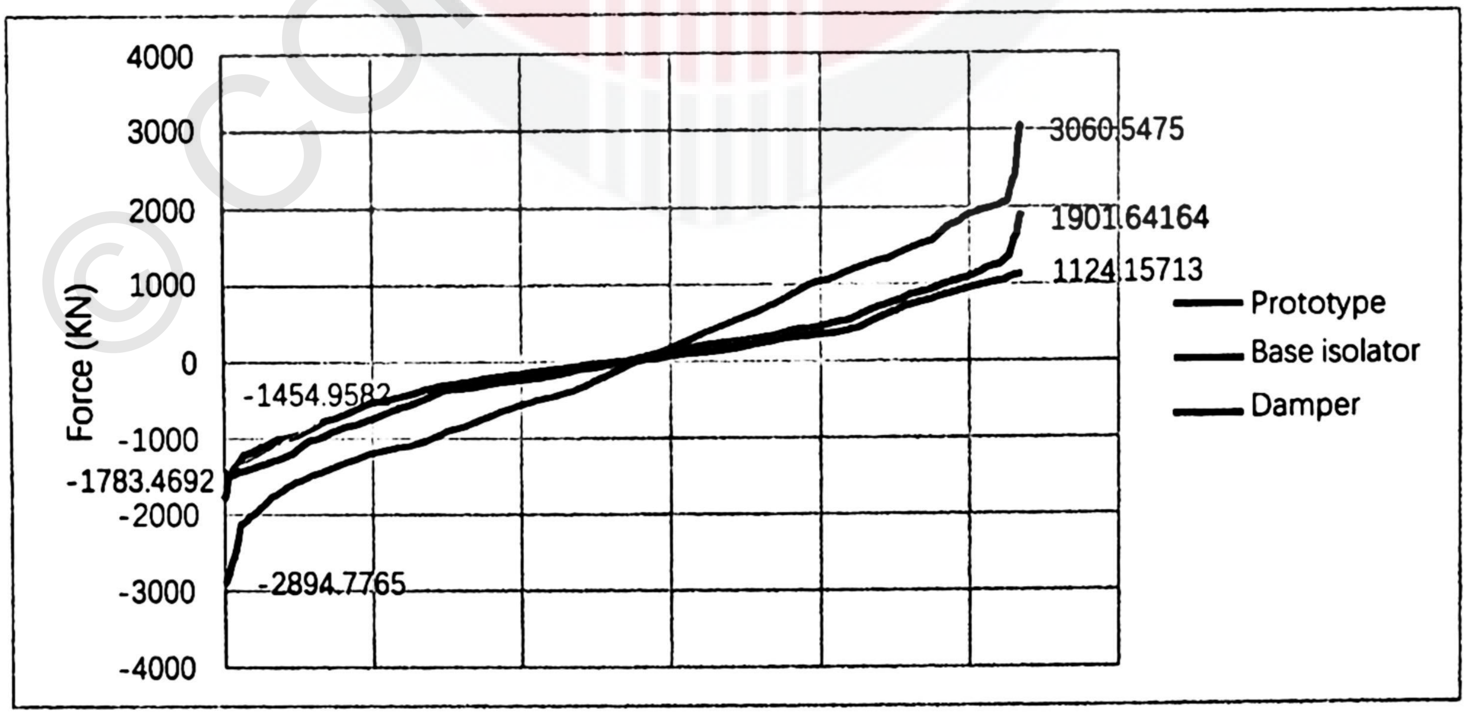


Figure 4.15 Force elements for the frame 1225

The analysis force elements for frame 1225 shows that base isolator has the smallest axial force, damper is the second smaller one while conventional structure has the largest axial force value.

The figure above shows the force elements change from minimum to maximum for the three frames for each structure.

According to the graph shown, it can be concluded that damper and base isolator has ability to reduce the axial force acting on the frame. Compare between damper and base isolator, the base isolator shows much more advantage than damper in terms of reducing axial force.

The reason for this is caused by the base isolator allowed the whole structure against the earthquake due to it could moving follow the force. So, when earthquake come, the whole part of structure will afford the seismic force, hence the force will spread to each frame of structure, therefore, it will reduce the pressure for the base and main-load frame, which is just like the picture shows below:

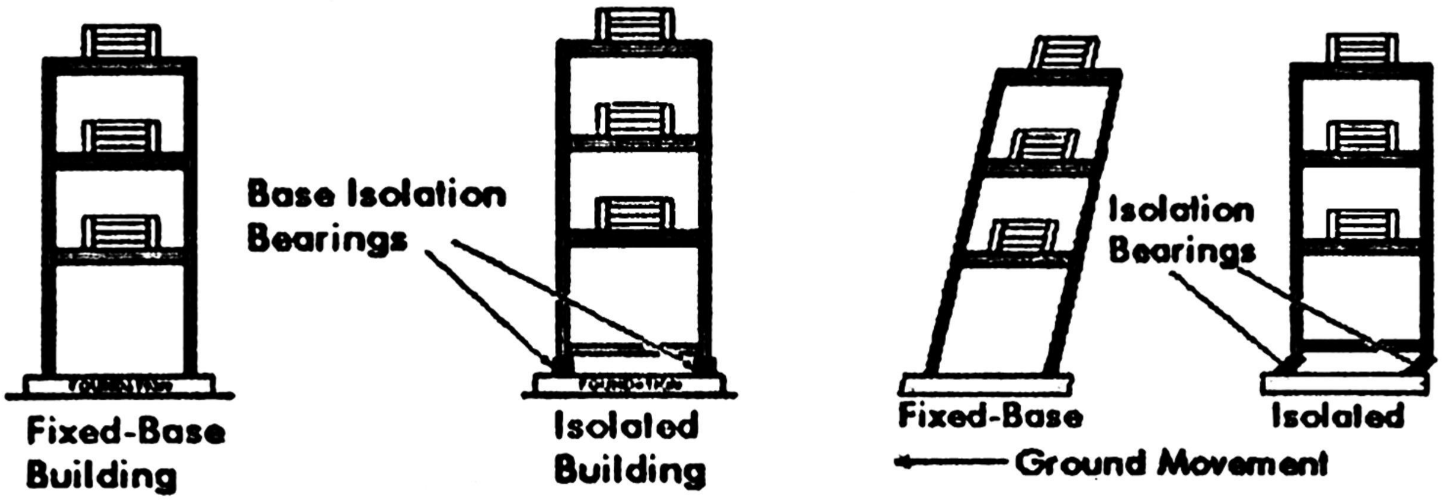


Figure 4.16 Base isolator structure and fix-base structure under earthquake (Viva, 2013)

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In this chapter, the summary of the analysis of the result will be discuss, then, the recommendation of the project will be considering and explain in order to improve the result.

5.2 Conclusion

Earthquake is one of the most dangerous disaster caused death and finance loss especially for the city area. Therefore, to reduce the damage of the building cause by earthquake will be very important.

The technology about viscous damper and base isolator could be a good choice to reduce the damage of earthquake. Both of them shows good properties to control the displacement and help to reducing the elements force for the frame. And each of them has their own advantage and disadvantage to the frame.

Damper shows advantage in control the displacement. Due to it good ability to link each frame, the seismic wave will be release a lot to the damper, hence the whole structure will have a good ability to control the displacement.

The base isolator will be good at reducing the force elements. Whatever for base reaction or axial force for the frame, the base isolator shows good ability to reduce the force, even less than half of the force or moment compare with structure without base isolator due to it behavior.

In conclusion, the project has success aim the objective. The structure with damper or base isolator could success to against the earthquake and the behavior study for the damper and base isolator and their effect to the structure has been studied, analysis and discuss in the report. Therefore, it is expected this report will be helpful for the seismic design.

5.3 Recommendation

5.3.1 Control the Error

The analysis is process by the computer software, which means there could possibly be some error due to the software.

Such kinds of problem may cause by:

- wrong define or set of the model
- Mistake drawing
- Wrong define of material include damper properties and etc.

Therefore, it's suggest having a double check by other software or by hand calculate.

5.3.2 Limit of Economic Consider

the project does not include the economic consider to the structure. Such kinds of problem include the price of damper and base isolator, the construction cost for apply each type of technology and it's difficult for construction.

Those kinds of things make the result cannot compare in the same cost level, therefore, leak of some proof of comparison.

5.3.3 Suggestion in Future Study

The suggestion to improve the study is shown below:

- **Do another analysis by software or hand calculate to check the result**
- **Design different model to give more proof of behavior study**
- **Make an economic study in order to compare in same cost level**

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APPENDICES

Elcentro-Acceleration:

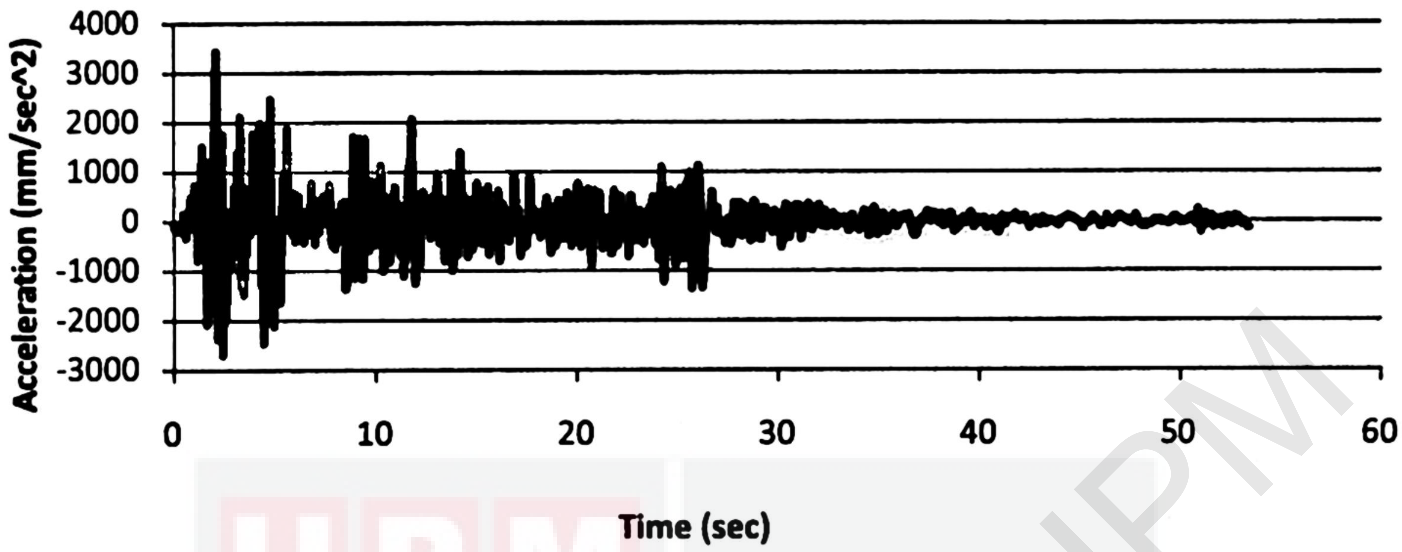

Figure3.8 Elcentro-Acceleration

Elcentro-Acceleration refer to 1940 El Centro earthquake, which occur at Imperial Valley on May 18, caused 6 million USD damage with 9 people dead.

The information of this earthquake from *The Southern California Earthquake Data Center (SCEDC)* is shown below:

- TYPE OF FAULTING: right-lateral strike-slip
- TIME: May 18, 1940 / 8:37 pm, PST
- LOCATION: 32° 44' N, 115° 30' W 8 km (5 miles) north of Calexico 145 km (90 miles) east of San Diego
- MAGNITUDE: MW6.9
- FAULT RUPTURED: Imperial Fault

- RUPTURE LENGTH: at least 40 km (25 miles)
- MAXIMUM OFFSET: at least 4.5 meters (15 feet)
- Max. intensity X (Extreme)