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A study on effects of base isolators and dampers on steel structures design

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Abstract

Base isolation is a design method for reducing response of a structural system under ground motion. With progress of science and technology in recent years, enhancing safety and performance of buildings during the earthquake, is exceedingly considered important. Today there are two methods for resisting earthquake forces: first, improvement of structural seismic capacity by for example using of lateral resistant systems such as moment frames and shear walls and bracings. Second, reducing the structural seismic demand by base isolation system.In this paper we investigated the effect of base isolation system on behavior of a 10 stories steel frame, in comparison of using ordinary systems. We studied some cases such as base shear, period, drift and structural member sections.

Keywords: steel frame; base isolator; plumbic damper;frictional damper;time history analysis;

1. introduction

Earthquake ground motions, cause tensions in structures that bring structural members to the yielding and collapsing limits. For preventing of more damages, many methods has been used, that divided in three categories: passive, semi active, active.Base isolation is one of the most effective on economic passive methods that causes reducing earthquake energy in structure under ground motion without structural damages. Reducing strong earthquakes effects on structures, by base isolation, needs appropriate setting of isolator's time period, so the dynamic properties and earthquake frequencies must be considered. In other words, isolators reduce the earthquake's effects on structure, by isolating

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vibration's main frequency of dominant frequencies caused by earthquake and un-isolated structure [1-4].

2. Pendulum Frictional Isolator

This kind of frictional isolator has a sliding hinge part that slides on a spherical steel surface. The surface of upper sliding part -which is in contact with

depreciation of isolator during the time. When the horizontal earthquake force is more than friction force, sliding will happen and isolator will work.

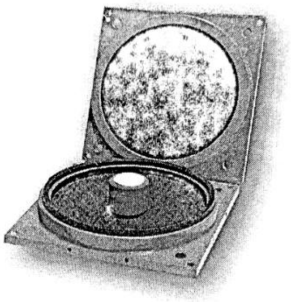

Fig1. Pendulum Frictional Isolator

3. Plumbic Rubber Isolator

Rubber support isolator is consisting of rubber and steel layers which by laying rubber layers between steel sheets, will achieves horizontal flexibility and vertical stiffness. In this type of isolators, one or several plumbic core uses in center of isolator. Under the shear forces –resulting of earthquake- this plumbic core in ordinary temperature will be yielded and deformed [5].

In this situation, Plumb will behave as a elasto-plastic material and then under the continuous cycles with creating hysteresis circles, shows two linear behavior and reaches damping of 3% (in rubber with low damping) to 10% . In this type of isolator, plastic or secondary stiffness varies from 1/10 to 1/6 primitive stiffness or plastic.

a spherical surface is covered by low frictional materials.

This type of isolator has a moving phase. In this system when the horizontal earthquake force is less than friction force, any movement will not happen and isolator has high lateral stiffness. Usually isolator will not slide under service loads. It should be mentioned that sliding under service loads will cause

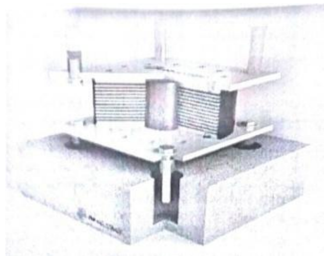

Fig2. Plumbic Rubber Isolator

4. Frictional And Yielding Dampers

Frictional dampers show stable and safe behavior and at the same time they have stable costs.

These dampers have considerable capacity of energy dissipation and with increasing the structure's damping, they add more stiffness to structures. This additive stiffness will be lost after sliding of dampers.This stiffness can be used for more resistance against wind and earthquake. This type of dampers have large rectangular hysteresis cycles which will cause increasing temperatures-due to dissipating energy- and sometimes will make changes in section properties. But this changes are not considerable and have no remarkable effect on response.

Yielding damper are often designed in a way to be installed on a bracing system. In this damping system –regarding stories' shear forces- shear displacements are plasticized and earthquake energy will be dissipate. Due to shear displacement, this system is called as the shear panel. This type of dampers cause increasing structure stiffness and strength.

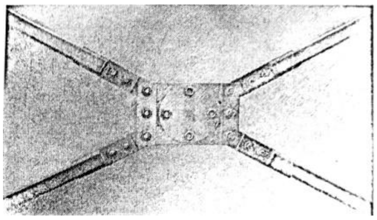

Fig 3. Frictional Dampers

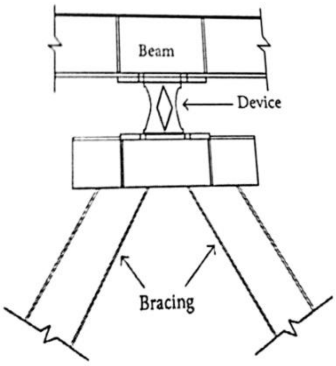

Fig 4. Yielding Dampers

5. Studied structural models

In this research, first it is discussed a ten story steel frame with five span(everyone 6m) and 3.2m structural height for every story ,that is designed by SAP ver 17.20 software, according to sixth volume of Iranian buildings national code. Then for the investigation of effect of seismic isolators, frictional and yielding dampers, this steel frame has been retrofitted by these members.

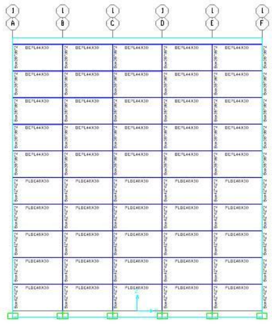

Fig 5.Steel frame without isolater and damper

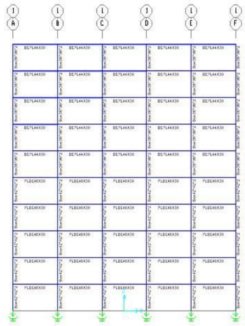

Fig 6.Steel frame with isolater

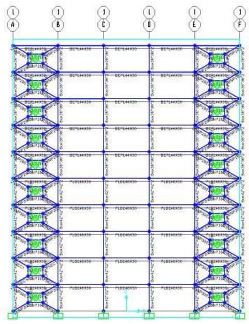

Fig 7.Steel frame with frictional damper

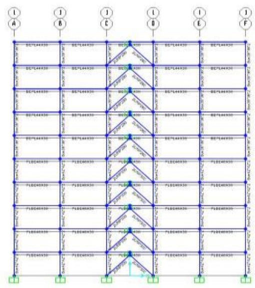

Fig 8.Steel frame with yielding damper

6. Information and properties of materials, sections and loads

The characteristics of steel used in members' profiles and beams and columns and concrete are shown in following table:

Table1 Material properties for steel profiles

Subject	Value
Yield stress f_y	2400kg/cm^2
Ultimate stress f_u	3700kg/cm^2
Effective yield stress f_{ye}	2880kg/cm^2
Effective ultimate stress f_{ue}	4440kg/cm^2

Table2 Properties of used materials for steel reinforcement in slabs and beam plate

Subject	Value
Yield stress f_y	2400kg/cm^2
Ultimate stress f_u	3700kg/cm^2
Effective yield stress f_{ye}	2760kg/cm^2
Effective ultimate stress f_{ue}	4255kg/cm^2

Table3 Properties of used concrete in roofs of steel frames

subject	value	subject	value
γ_{ST}	7850kg/m^3	γ_c	2500 kg/m^3
μ_{ST}	0.3	μ_c	0.2
E_{ST}	kg/m^2 2× 10^6	E_c	kg/m^2 2× 10^5
F_y	2400 kg/m^2	f_c	250 kg/m^2

Besides structural sections used in this steel frame are shown in following table:

Table4 Properties of structural sections

Stories	Braces	Beams	Columns
5-1	2unp300	48×30 Grid plate	box42× 42 × 2
10-6	2unp280	44×30 Grid plate	box36× 36 × 2

In addition, considering building site in a high risk region and type of soil (type 4), properties of seismic and weight loads are shown in following table:

Table5 Properties of seismic and weight loads of steel frame

Load	Perimeter walls	Staires	roof	stroies
Dead	450kg/m^2	600kg/m^2	500kg/m^2	450kg/m^2
Live	100kg/m^2	500kg/m^2	150kg/m^2	200kg/m^2
Design acceleration	Earthquake factor	Behavior factor	Importance factor	Reflection factor
A=0.3	C=0.165	R=5	I=1	B=2.75

7. Properties of seismic isolators and dampers used in models

The amount of stiffness and other properties used in seismic isolators and frictional and yielding dampers modeled in software are shown in following 1-7 table.These results are concluded by time history analysis.

Table6 Structural properties of seismic isolator and damper

Other characteristics	Ultimate Stiffness	Effective Stiffness	Device
μ_{slow} = 0.0 μ_{fast} =0.05	2249.6	112.48	Frictional isolator
effective damping=106.76	961	114	Plumbic isolator
yield strength=5.46 yield strength=15	100×10^{3}	100×10^{3}	Frictional damper
yield strength=56.07	8451.26	8451.26	Yielding damper

8. Results of base shear, period time, story drift, and structural sections concluded by software

After modeling the steel frames with seismic isolators and dampers used separately in different models, and combination of them in a model, following results has been concluded:

Table7 Results of SAP software for steel frame structural models with or without isolator and damper

NO.	Structural system	Structural section	Story drift	Period timeT	Base shear force V
1	Moment frame with medium ductility without isolator and damper	$\frac{D}{C}$(colst1)=0.936 $\frac{D}{C}$(colst6)=0.73	Δ_{10}=15.898 Drift10,9=0.0021 Δ_5=8.766 Drift5,4=0.0057	T_1=1.45 T_2=0.51 T_3=0.29	V_b=156.95t
2	Steel frame with frictional isolator	$\frac{D}{C}$(colst1)=0.92, 0.21(t.h.a) $\frac{D}{C}$(colst6)=0.73 , 0.02(t.h.a)	Δ_{10}=2.21 Drift10,9= 4×10^{-6} Δ_5=2.20 Drift5,4=7×10^{-6}	T_1=2.73 T_2=0.72 T_3=0.36	V_b=6221kg
3	Steel frame with frictional plumbic isolator	$\frac{D}{C}$(colst1)=0.91 ,0.22 $\frac{D}{C}$(colst6)=0.73 , 0.3	Δ_{10}=0.84 Drift10,9= 1×10^{-4} Δ_5=1.01 Drift5,4=2×10^{-4}	T_1=2.72 T_2=0.72 T_3=0.36	V_b=80.34t
4	Steel frame with frictional damper	$\frac{D}{C}$(colst1)=0.59 , 0.66 $\frac{D}{C}$(colst6)=0.4 , 0.59	Δ_{10}=1.95 Drift10,9= 3×10^{-4} Δ_5=1.12 Drift5,4=6×10^{-4}	T_1=0.84 T_2=0.28 T_3=0.5	V_b=151.43t
5	Steel frame with yielding damper	$\frac{D}{C}$(colst1)=0.86, 0.56 $\frac{D}{C}$(colst6)=0.64 , 0.57	Δ_{10}=1.93 Drift10,9= 4×10^{-3} Δ_5=1.48 Drift5,4=6×10^{-4}	T_1=1.33 T_2=0.46 T_3=0.26	V_b=135.86t
6	Steel frame with yielding and plumbic damper and isolator	$\frac{D}{C}$(colst1)=0.86 , 0.14 $\frac{D}{C}$(colst6)=0.44 , 0.01	Δ_{10}=2.17 Drift10,9= 9×10^{-7} Δ_5=2.18 Drift5,4=3×10^{-6}	T_1=2.47 T_2=0.45 T_3=0.19	V_b=76.83t

Through calibration of results (shown in rows 2 to 6) in retrofitted steel frames by isolators and dampers, compared result row1 which is related to steel moment frame without isolator and damper , these results are concluded:

1. 1-By investigation of used isolator and damper systems. It can be concluded that steel frame with pendulum frictional isolator, has most effect on reducing base shear force in comparison of seismic isolator system and yielding damping system (chevron bracing).
2. 2-Damping system causes reducing period time in comparison of isolator system, this indicates that for rather high building like this ten story steel frame, damper system causes improvement in structural dynamic behavior.
3. 3-Between damper and isolator systems, Damper frictional system has most effect on reducing story drifts. Of course damper yielding system has more effect on reducing story drifts in comparison of Damper frictional system.
4. 4-By investigation of results of structural members' capacity in isolator and damper systems, it has been shown that frictional isolator system has most reduction in design capacity of structural sections in comparison of steel frame without damper. These results are concluded by time history analysis according to Elcentro earthquake.
5. 5-By investigation of seismic isolator and damper systems, it can be concluded that frictional damper system with reducing period time and optimizing designed sections, and frictional isolator system with reducing base shear force and story drifts have the best energy dissipation systems, among dampers and isolators, respectively. By combination of these two systems we can achieve proper results such as base shear forces, period times and story drifts.

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