Housing Design for Resisting Earthquakes Using the Base Isolation Method and Building Load Reduction

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Abstract

This research aims to compare the structure of a typical building which may or may not be earthquake resistant with buildings designed using a separate foundation, which is known to be earthquake resistant. Using a separate foundation (Based Isolation) is done by simulating the underlying structure of the foundation, a foundation isolation system (Based Isolation) and original foundations.

Using a computer program a strong earthquake vibration can be simulated and the strength and stabilization of the structure and can be monitored and compared while observing various forces. And build a photo type building by using this method to observe the real effect of earthquake.

Based on the assumption that if the building is movable and the superstructure and its foundations are fragmented it is able to withstand strong shaking from earthquakes due to the resistance or absorption of the energy produced during the earthquake. Based on the simulation results of an earthquake with the SAP2000 structural analysis and design program it was found that an earthquake force applied to the joint 3 of building, Case 4 (foam wall + isolated-base) was 1613.33 kgf and Case 1 (brick wall + fixed-base) was 3723.33 kgf shows that a building constructed using the light-weight wall (EPS Foam wall system) and the Isolated-Base system will be affected by the earthquake force less than one constructed with a heavy-weight wall system (brick wall) and a Fixed-Base system by around 50 percent.

Keywords: *earthquake, EPS foam, architectural design, separate foundation (base isolation), isolated-base, SAP 2000*

1. Introduction

The climate of the world is gradually changing and as a possible result, natural disasters are becoming increasingly severe. In 5 May 2557 at 18.08 PM Thailand suffered earthquakes up to 6.3 in magnitude. The epicenter of the earthquake was in the north of Thailand in Dong ma da, Mae Lao district, Chiang Rai province. The city, approximately 25 kilometers from Chiang Rai, had aftershocks not less than 3,000 times for the following 5 months. This earthquake had the highest intensity ever recorded in Thailand. One person died and the vibrations caused a lot of damage to buildings, houses, schools and temples as well as caused cracks in the roads, known as "ground cracks".

Therefore, when considering the design of buildings it is necessary to concentrate resistance to earthquakes. The main building structure should be designed to reduce the force exerted by the shaking of the ground. Applying structural modifications to buildings can greatly increase its resistance to earthquakes.

Structural movement or joint shifting caused by force directly from the soil can be reduced through the following design methods:

1. The Base Isolation system, which implements the use of a spherical mortar layer under the base foundation, enabling the foundation to move freely from the main building or superstructure.

2. The weight of the building can be reduced using EPS foam with a density of 1.5 pounds, 3 inches thick, and should be used to construct the wall instead of heavy brick. Weight can also be reduced by using EPS foam with a density of 2 pounds, 6 inches thick on the ground floor. This will reduce the earthquake's force acting on the structure and absorb part of the seismic energy.

2. Objectives

The objectives of this research were to study the effect of earthquakes on buildings that use the Base Isolation method, investigate the effectiveness of lightweight building walls such as EPS foam walls and whether or not they can reduce damage caused from earthquakes and thirdly, to use demonstrate how to design a building using these two methods of construction.

3. Materials and Methods

When designing buildings that can withstand an earthquake disaster one must make the structure of the building flexible. This can be done by making sure that the building does not come into direct contact with vibrations from the earth. The correct foundation will separate the foundation from the ground, allowing it to move while absorbing the force of the earthquake. This will minimize the severity of the earthquake and help the building survive such a catastrophic event.

3.1 The base-isolation system

Using a Base Isolation Device is a popular method in various countries that experience earthquakes.

This method is widely used in the United States because it reduces the impact of earthquakes on houses and buildings. The underlying principle is to make the house free from the shaking of the ground thus reducing the forces one the house from the vibrations of the earth from underground (Rasheed & Vasudevan, 2015).

At the 10th World Seismic Engineering Conference in Rotterdam on the concept of using separation techniques Anand (1994) said... "In order to deal with seismic earthquakes as an appropriate alternative to earthquake control and separation of the foundation and the super structure, the base-isolation system has to perform 3 functions: 1. horizontal flexibility; 2. energy dissipation; and 3. rigidity against normal lateral loads."

3.2 Building load reduction

When designing buildings to deal with earthquake disasters one must be able to make the building lighter. This includes the roof of the building. The roof or top of the house should not be too heavy either with the materials used nor carry a heavy load. During an earthquake, houses with heavier rooftops will collapse more easily than would a building with a lightweight roof. The use of flexible materials such as wood or steel will also increase the strength (Graham, 1998).

The weight reduction of the building is one way to reduce the risk of damage caused by the earthquake. Prof. Dr. Amorn Pimanmas, structural and earthquake engineering specialist said "The heavy weight structure will increase the earthquake vibration. Again, the earthquake vibration will be less if the building structure is lightweight. Because the building push is less. Selection of quality wall and lightweight material. This makes it safer." (Pimanmas, 2014). This is in agreement with Sattcha Boonyachathad who stated in a structural design book that "The strength of the earthquake is proportional to the mass of the structure," Therefore, the use of lightweight materials can greatly reduce the force of earthquakes (Boonyachathad, 2544).

4. Results and Discussion

4.1 Design the prototype of The foundation

Results of the foundation study showed that the Base Isolation system or the foundation structure separation with the main structure of the building will allow forvertically flexibility thus distributing force and resisting lateral loads and the separation of the foundations. This is accomplished by using a slider or roller system that works by limiting shear force through contact splitting (James, 1991).

Base Isolation: Friction Pendulum bearing (FPS) type is called the Roller pendulum system, which uses a spherical ball bearing that can move in all directions. Suitable for small buildings and can be made by local contractors. A prototype foundation of a 1.00 meter x1.00 meter x1.00 meter, supported by 20 cm EPS foam with a density of 2 lbs. can handle weigh 20 tons per cubic meter. Cement is poured over the foam to protect the foam surface and lay round concrete balls of 0.15 m. diameter in size. No less 30 balls per foundations should be used.The exact amount depends on the size of the foundation. Each ball should have a compressive strength of more than 1.5 tons. This method can resist the compression and complies with engineering standards. Precast concrete is placed on top of the concrete balls creating the base of the building post. (Figure 1, 2 and 3).

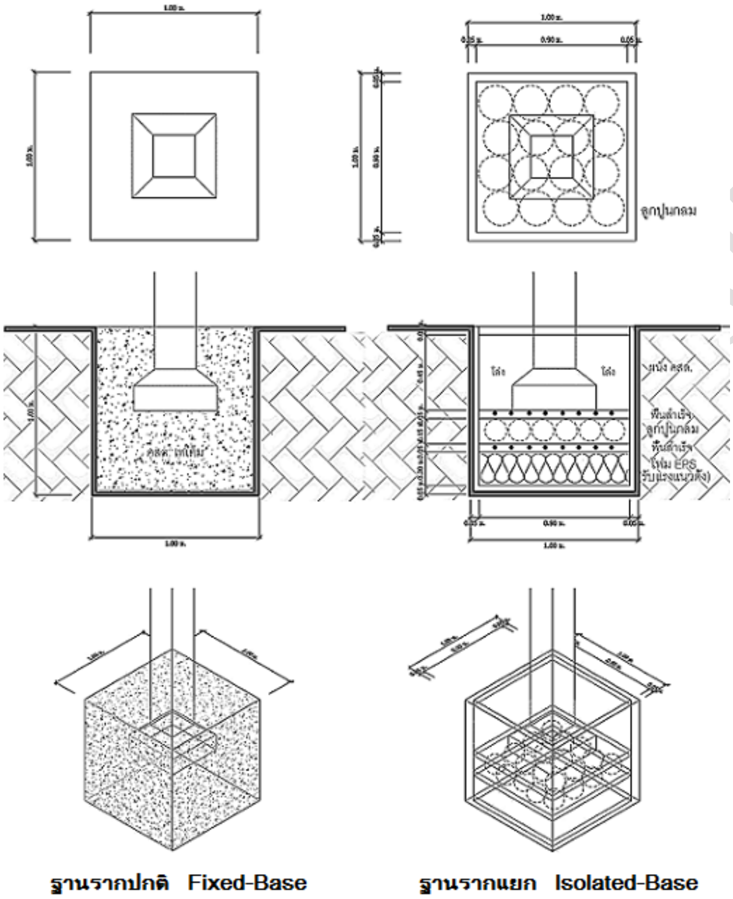


Figure 1 Fixed-base profile and isolated-base

Figure 2 To do base isolation by using local materials

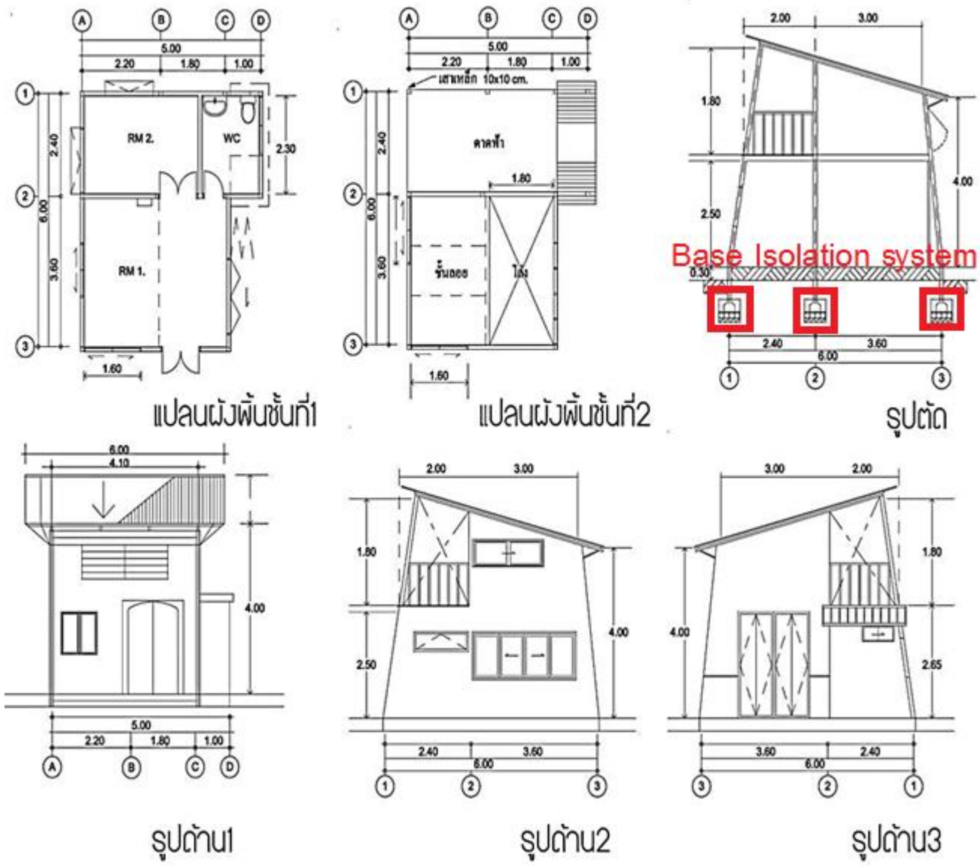


Figure 3 Building plan and base isolation area

4.2 Build a prototype building by Using (EPS Foam) to be the wall in Figure 4, 5 and 6 and Base Isolation system in Figure 2

Figure 4 Steel frame preparing to install EPS foam wall

Figure 5 Welded wire mesh topping up the foam wall for better plastering

Figure 6 Plaster over the foam walls to protect the foam surface

4.3 Examining the impact of the earthquake on an actual building

Compare the building before and after the earthquake by observing. There is a crack at the surface of the plaster on the building where the wall structure connects to the building pole in Figure 7. The size and length of the cracks, while compared over time, has changed very little.

Figure 7 The crack between the window frame at the front wall of the building

4.4 Building simulation results

Figure 8 shows an analysis of the earthquake's force by simulating with the SAP2000 program. The analysis shows the impact of the earthquakes on the foundation at the joint between the post and foundation.

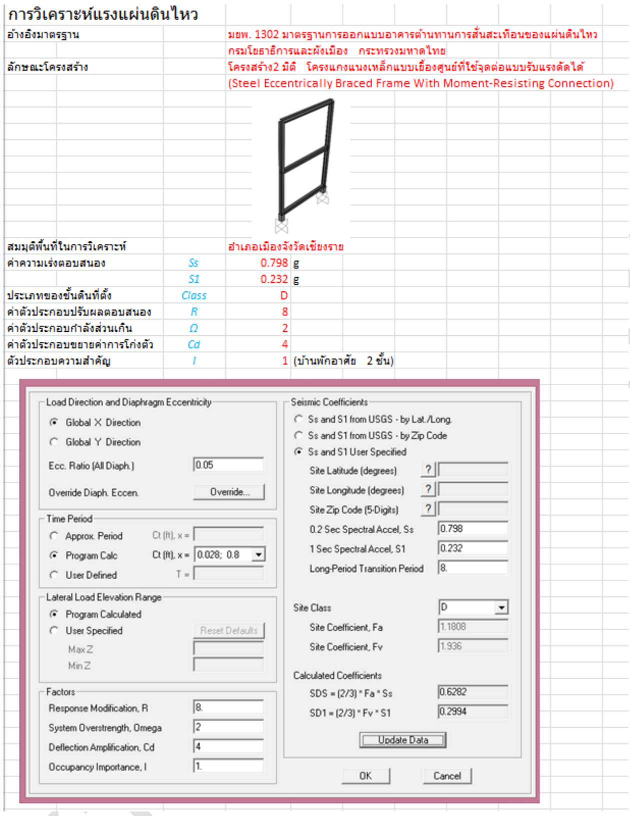
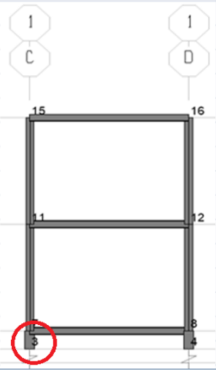


Figure 8 Using the SAP2000 program simulates the earthquake values

A	B	C	D	E	F	G	H	I	J
CASE	Joint	)utputCas	CaseType	F1	F2	F3	M1	M2	M3
Text	Text	Text	Text	Kgf	Kgf	Kgf	Kgf-m	Kgf-m	Kgf-m
CASE1 BRICKWALL+FIXSUPPORT	3	SLSEQ	Combinati	1404.73	0	3723.33	0	-38.91	0
CASE2 BRICKWALL+ISOLATESUPPORT	3	SLSEQ	Combinati	571.06	0	3169.33	0	0	0
CASE3 FOAMWALL+FIXSUPPORT	3	SLSEQ	Combinati	597.88	0	1963.33	0	-53.3	0
CASE4 FOAMWALL+ISOLATESUPPORT	3	SLSEQ	Combinati	226.47	0	1613.33	0	0	0



	Reaction node 3	Sum [kg]
CASE 1	3723.33	3723.33
CASE 2	3169.33	3169.33
CASE 3	1963.33	1963.33
CASE 4	1613.33	1613.33

Figure 9 Comparison of the seismic force applied to the building structure. Between light-weight or heavy-weight wall with fixed-base foundations and light-weight or heavy-weight wall with isolated-base foundations

In Figure 9 we can see the results of an earthquake simulation using the SAP2000 program (the structural analysis and design program) shows that the force on joint 3 of the building Case 4 (foam wall + isolated-base) was 1613.33 kgf and Case 1 (brick wall + fixed-base) was 3723.33 kgf in. This shows that building constructed using a light weight wall or expanded polystyrene soam (EPS Foam wall system) and use the isolated-base system will be affected by the earthquake less than one constructed with a heavy-weight wall system (brick wall) and fixed-base system by around 50 percent. The earthquake force is proportional to the mass of the structure. The base-isolation system, while making the house free from the shaking ground, performs 3 functions: 1. horizontal flexibility, 2. energy dissipation and 3. rigidity against normal lateral loads. Also, the earthquake vibration will be less if the structure is lightweight because the building push is less.

5. Conclusion

5.1 Prototype foundations for earthquake resistance using a base isolation system instead of a fixed-base system will consolidate wide spread lateral loads allowing the house to be free from the shaking ground. It reduces the impact force on the building from underground seismic waves better than the original foundation.

5.2 Lightweight Wall Building System (EPS Foam wall) is to use the EPS foam with a density of 1.5 pounds, 3 inches thick, replacing the typical masonry walls, which are very heavy. The floor of the building will use EPS foam with the density of 2 pounds 6 inches thick, instead of a typical floor reducing the weight of the building. Whenever the structure is lighter in mass, we will get the benefit of reducing vibrations from the earthquake. The thrust of the building will be less too.

Suggestions

1. Friction Pendulum bearing (FPS) type called the Roller pendulum system, which utilizes spherical ball bearings that can move in all directions is suitable for small buildings but we have to control the movable spacing around the ball in the foundation pit.

2. We can use another technique for base isolation through the use of rubber to be a dumper instead of spherical balls.

3. Using foam for the wall in the steel structure is difficult to connect the joints of steel and foam because they are two different materials. The foam surface should be protected from scratches and rubbing by plastering the surface of the foam. One technique to accomplish this is to use wire mesh to cover the foam providing for better plastering.

6. Acknowledgements

This research has been accomplished with financial support from the Research Institute, Rangsit University. Thanks should also be given to Dr. Pisit Kuntiwattanakul for his useful advice.

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