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ABSTRACT: The Concept of isolating structures from the effects of ground shaking has been discussed for many years. Its practical application was delayed until the successful development has been made. One of the most easiest and lowest cost of base isolation system is the sliding or pure friction type that can be used for unreiforced forced masonary bearing wall building.This type of building are very common in different parts of Iran. Preliminary studies have indicated that the represented system for small buildings situated in the seismic region works very well.

1- Introduction

Seismic isolation is a design strategy based on the premise that it is both possible and feasible to uncouple a structure from the ground and thereby protect it from the damaging effects of earthquake motions. To achieve this result, while at the same time satisfying all of the in-service functional requirements, additional flexibility is introduced usually at the base of the structure.Additional damping is also provided so as to control the deflections which occure across the isolation interface.

A very basic problem in the earthquake design of low-to medium-rise buildings is that their fundamental frequency of vibration is in the range of frequencies where earthquake energy is strongest. This means that the building acts as an amplifier for the ground vibrations and the accelerations experienced at each floor level increase to the top. This also causes stresses in the frame and interstory drifts which may result is damage to the column between floors.The amplified accelerations at each floor act on the contents and occupants of the floor and can cause sever damage to these contents even no damage occurs to the structure itself. The degree of amplification can be reduced by making the building more rigid since a completely rigid building can experience an acceleration no greater than ground acceleration, but this is an expensive approach that cannot be exactly realized in practice, and in any case the ground accelerations alone could be high enough to damage the contents of the building even if unamplified.

The goal should be to reduce the acceleration in buildings to below the level of the ground accelerations, and to do this the building must be flexible. Flexibility in a structural floors may vibrate under foor. In a low-or medium-rise building the necessary flexibility can only be achieved at the foundation level by the use of base isolation.

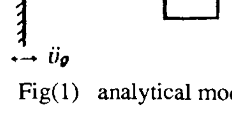
A simple form of seismic isolation is bearing isolation system which can be used for small building espicially in suberb area that couldnot need the advanced technology to construct the buildings. to construct this system the isolater layer is needed at the level of the foundation, slide bearing offer the simplest method of isolation and are relatively easy to manufacture. One type of the isolater layers which are made by cleaned sand whith the grains of diameter 1-1.2 mm. has been used in China for one to two story buildings: An isolation system of this kind has also been designed for a three- story masonary dormitory building in tangshan (China). No wind restraints or damping devices are used in this system since the displacements under wind load and earthquake action are small.

Experimental work on the response of this type of isolated systems carried out on the shaking table [3]. Dimentions of the model are 80 cm wide and 70 cm height. Two layers of small brick were laid with cement mortar on shaking table, uper surface was levelled made smooth , then a thin layer of selected sand grains was spread as sliding material, on which two layers of small brick were laid with cement mortar and the uper part were built with adobes. After drying, the table was shaked, when acceleration reached to 0.2 g, the upper part slides with out collapse. The tests were repeated five times, five models with slight differences all survived the shaking.

The purpose of this paper is to introduce the sliding system for unreinforced masonary bearing wall buildings, which have been widely recognized for their sustaining of life hazardous damage as a result of partial or complete collapse during past moderate to strong earthquake. this type of buildings are very common in different parts of Iran. Preliminary studies have indicated that the maximum earthquake acceleration transmitted to the building will beμ g, whereμ, is friction coefficient for sliding layer. Experimental studies have been applied on the various type of materials, particularly those which are accessible in the rural areas.The experimental and analytical results show that the represented system for small buildings works very well. Dynamic analysis of an one story unreinforced masonary building for two cases of sliding and rigid fondation for horizontal components of different earthquake records accelerations such as Tabas 1978, Manjil 1990 and EL Centro 1940 has been done.

2- Method of analysis of sliding base isolation system.

According to the investigator [2] the unreinforced masonary buildings may be modeled as a rigid body, Since descreasing the height of building will increase the rigidity, therefore for rural buildings which most of them are one or two story, this assumsion is reasonable. The analytical model can be represented as Fig (1)



Fig(1) analytical model

For pure friction system of base isolation the equation of motion while the structure has contact with the foundation can be written as

$$\ddot{x}+\mu.g.Sgn(\dot{x})=-\ddot{u}g \quad (1)$$

where, $\ddot{u}g$ is horizontal component of ground acceleration, μ friction coefficient and g gravity acceleration. This equation indicates the behavior of structures during sliding. Equation of motion for the case of non sliding may be obtioned from following relation.

$$\dot{x}=0 \quad (2)$$

Equation (2) will be governed if the friction force is grater than relative force, therefore

$$\mu g - |\ddot{u}g| >0 \quad (3)$$

Equation of motion for the case of inclined foundation with a small angle of α may be written as

$$-\ddot{u}g= \ddot{x}+ \frac{\mu sgn(\dot{x}) + \tan\alpha}{1+\mu sgn(\dot{x}) \tan\alpha} \times g \quad (4)$$

The following condition would not be satisfied, if the stracture slids on its foundation.

$$\mu g +\tan\alpha.g-|\ddot{u}g| >0 \quad (5)$$

for considering the vertical component of earthquake acceleration in equations (1) and (3), g may be substituted by $(g+\ddot{v}g)$, then the equation of motion and condition for no sliding can be written respectively as

$$-\ddot{u}g=\ddot{x}+\mu(g+\ddot{v}_g)sgn(\dot{x}) \quad (6)$$

$$\mu(g+\ddot{v}_g)-|\ddot{u}_g| > 0 \quad (7)$$

3- Solution Method

The soution of above equations can be done withe the aid of eletronic computer. For the case of time history solution, selection of time duration is very important for obtaining accurate result, which in this study has been selected as .0002 sec. In order to study the influence of different parameters on dynamic behavior of small building during earthquake loading, an one story building with dimension of 8.00 m lenght, 6.00 m width and 3.50 m hight with 35 cm thichnes of masonary bearing wall is considered. This system has been analysed by finite element method and the results are presented by a series of graphs. The acceleration-time records of different earthquakes such as Tabas, Naghan,Manjil and El Centro have been used and induced maximum and residual displacement of the structure are caculated and tabulated. The effect of different factors on maximum and residual displacement as well as relative velocity are investigated. The parameters which are studied in this research are as follow:

1- Fricition coefficient effect on the maximum acceleration, maximum and residual displacement.
2- Cohesive effect on the maximum acceleration, maximum and residual dsiplacement.
3- The effect of inclined angle on the maximum acceleration, maximum andresidual displacement.
4- The effect of peack ground acceleration on the maximum and residual displacement.
5- The effect of time-record acceleration period on the maximum acceleration, maximum and residual displacement.

4- Discussion of the results

According to the mathematical formulation, the applied maximum acceleration of the rigid body on the sliding foundation with fricitional coefficient of μ will be limited to $\pm\mu g$, Fig (2).
From table (1) can be seen that the increase in the frictional coefficient results increasing linearly in the maximum acceleration up to peack ground acceleration, while decreasing the maximum velocity and displaecement.This condition can be seen from results of different acceleration-time records. But the maximum residual displacements don't follow speciall rule because of different earthquake paramenters, Fig (3).
From Comparison of four earthquake time-records results, it can be seen that maximum and residual displacement have a main role for selecting the optimum friction coefficien μ and application of sliding layers with

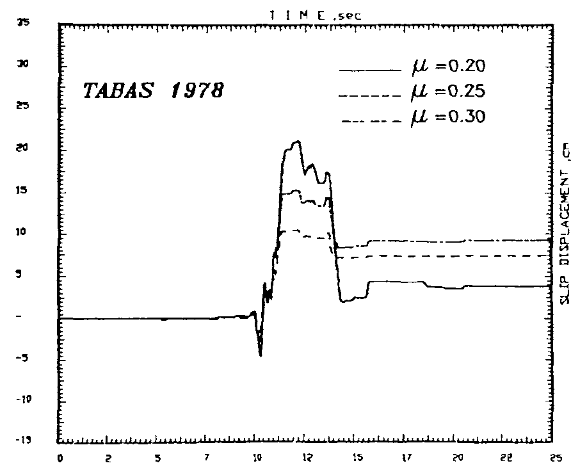


Fig (2): Effect of friction coefficient on relative displacement

small frictioanl coefficient are not useful, Since in practice, wider foundation is needed which increase the construction cost.

type of earthquake	friction coefficient	max. acceleration	max. relative velocity	max. relative displacement	residual displacement
		cm/sec^2	cm/sec	cm	cm
Tabas	0.10	0.10 g	84.64	60.48	9.04
	0.15	0.15 g	60.41	29.50	12.83
PGA: 0.93 g	0.20	0.20 g	48.84	21.10	3.79
	0.25	0.25 g	43.60	15.23	9.22
	0.30	0.30 g	35.37	10.39	7.38
Naghan	0.10	0.10 g	40.42	7.17	6.40
	0.15	0.15 g	33.34	5.31	5.03
PGA: 0.72 g	0.20	0.20 g	30.95	5.44	5.33
	0.25	0.25 g	25.09	4.88	4.70
	0.30	0.30 g	16.37	3.68	3.56
Manjil	0.10	0.10 g	22.61	5.05	1.46
	0.15	0.15 g	18.66	2.54	1.53
PGA: 0.53 g	0.20	0.20 g	14.45	1.64	0.99
	0.25	0.25 g	10.16	1.01	0.63
	0.30	0.30 g	7.71	0.55	0.33
El Centro	0.10	0.10 g	20.31	2.87	1.50
	0.15	0.15 g	17.82	1.71	0.88
PGA: 0.32 g	0.20	0.20 g	10.49	1.24	0.84
	0.25	0.25 g	4.32	0.37	0.26
	0.30	0.30 g	0.34	0.01	0.01

Table (1): Results of rigid body analyses on Sliding layer foundation

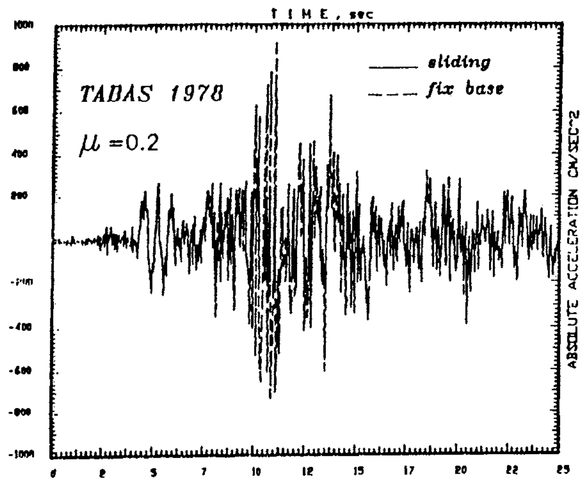


Fig (3): Acceleration of base and structure dueto Tabas earth quake

In table (2) the effect of coheision has been shown. It can be seen that if the sliding layers are cohesive material the structure slide when the applied forces are grater than the resultant of frictional and coheision forces. In this situation the variation of the maximum displacement and velocity are so small. Since up grading of maximum acceleration is not suitable for stractures, therefore the induced coheision factors sould be removed.

PGA of earthquake	Cohesion	friction coefficient	max acceleration	max. relative velocity	max. relative displacement	residual displacement
0.93 g	0.0	0.20	0.20 g	48.84	21.10	3.79
0.93 g	0.25	0.20	0.44 g	49.47	21.64	4.34
0.93 g	0.50	0.20	0.70 g	48.90	19.39	2.10

Table (2): Effect of material cohesion on different parameters for Tabas earthquake

Table (3) shows the effect of different inclined angle on maximum acceleration, velocity, displacement and residual displacement of the structure. It can be seen that for 1% slope, acceleration has 5%, velocity 4.8% and displacement 20% increasing. Since in practice 1% slope as an error for construction is expectable and this amount of slope does not have any affect on basic results, therefore this system of sliding layer works in acceptable way.

PGA of earthquake	inclined angle	friction coefficient	max acceleration	max. relative velocity	max. relative displacement	residual displacement
	rad		cm/sec^2	cm/sec	cm	cm
0.93 g	0.0	0.20	0.200 g	48.84	21.10	3.79
0.93 g	0.005	0.20	0.205 g	50.06	23.14	8.41
0.93 g	0.010	0.20	0.210 g	51.19	25.27	12.86

Table (3): Effect of inclined angle on maximum and residual displacement for Tabas earthquake

In table (4) the effect of peack ground accleration for El-Centro earthquake has been shown. Increasing PGA more than μg would not have any affect on applied acceleration to structures, but may change the amount of maximum velocity and displacement in faster rate. It can be seen from table (2) that with increasing of PGA by twice , maximum relative and displacement increase more than 250% and 50% respectively.

According to table (5) it can be see that up grading of the period of applied acceleration results approximately linear increasing in the maximum of relative velocity and displacement. Therefore it can be concluded that this system of sliding layer would not suitable for long period of earthquake loading.

5- Experimental method

For cosidering the behavior of different materials for sliding layer which will be supported by supersrtuctures and foundation and also measuring of coulomb's law of friction parameter, the model of Fig (4) has been Considered. This system may be subjected by two forces in perpendicular direction as shown. These two forces can be considered as verical loads of structure and frictional forces of differnet materials. Vertical loads apply to the model by a system of air pressure horizontaly and vary between. 0.7 to 1.7 kg/cm2 to a brick with area of 200 cm2. Velocity of applied loads may be controled between 1.27 mm/min and 50.8 mm/min by hydraulic machine.

PGA of earthquake	friction coefficient	max acceleration	max. relative velocity	max. relative displacement	residual displacement
		cm/sec^2	cm/sec	cm	cm
0.32 g	0.20	0.20 g	10.49	1.24	0.84
0.64 g	0.20	0.2 g	40.68	5.57	3.02

Table (4): Effect of PGA on maximum and residual displacement

PGA of earthquake	Period	friction coefficient	max acceleration	max. relative velocity	max. relative displacement
	sec		cm/sec^2	cm/sec	cm
0.5 g	0.1	0.20	0.2 g	7.06	0.26
0.5 g	0.2	0.20	0.2 g	14.13	1.00
0.5 g	0.5	0.20	0.2 g	35.34	6.26
0.5 g	1.0	0.20	0.2 g	70.68	25.17
0.5 g	2.0	0.20	0.2 g	141.38	100.51

Table (5): Effect of time record acceleration period on maximum relative displacement and velocity

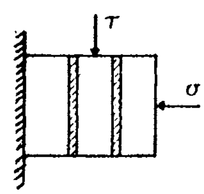


Fig (4): model for material test

6- Experimental results

sand-clay mortar is one of the material which has been tested under different vertical loads. Friction coefficient for a layer with, 1.0 cm tickness for two cases of velocity 1.27 mm/min and 50.8 mm/min are .312 and .299 respectively. For a layer with 2 cm thickness friction coefficient at velocity of 50.8 mm/min will be .203. Mohr. columb's model has been shown for this material in Fig(5). Another material which has been tested is clay mortar which does not have any compression strengh, friction coefficients for two cases of velosity 1.27 mm/min and 50.8 mm/min have been obtained .31 and .22 respectirely. This result show that friction coefficient decreases while velocity of applied load increase.
Another type of material which has been tested with the same method is **Pozzuolana**. The friction coefficient for this material is obtaind .25, table (6) shows the friction coefficient for different materials.

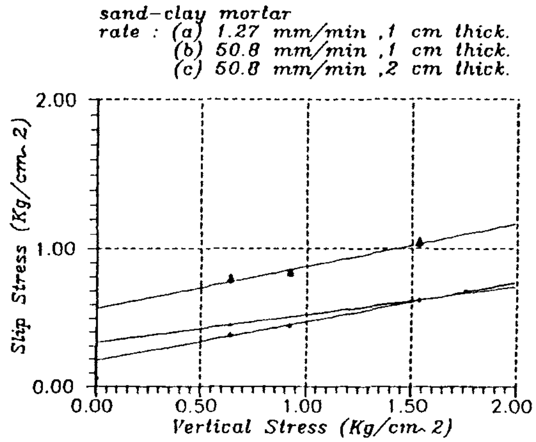


Fig (5):Result of sand-clay mortar test

material	friction coefficient
Sand - Clay mortar	.2 - .32
Silt	.23 - .31
Pozzuolana	.25

table (6): Friction coefficien for different materials

Cohesion of different materials

Form the results of sand-clay mortar test may be concluded that this material due to cohesion will transfer considerable forces from sliding layer to foundation, but the action of layer after breaking, will be similar to sliding layer. There is no such problem in grain materials e.i. sand, pozolan. This is the advantage of these materals.

Thickness of layer

Comparison of the results for different thickness of layers show that increasing the thickness will decrease the sliding forces, although this reduction in applied forces to the structure is a good effect, but there is a maximum thickness of layer for any kind of materials so that the settlement of structure will be minimum.

Velocily of loading

Velocity of loading from two points is important. 1) matereial cohesion 2) friction coefficient. From experimental results, it can be observed that when the model is subjected to zero vertical stress, sliding strength of cohesive material will increase while the velocity of loading increse.

Therefore the materials should have the minimum sliding strength while the structure is subjected to the earthquake loading. But friction coefficient decrease when the velocity of loading increase, this reduction for silt is more than sand-clay mortar.

7- Conclusion

1- Bearing isolation system for small building particularly in rural area which couldnot exist advanced technology is relatively easy to manufacture.
2- From experimental results it can be seen that behavior of the sliding layer with different materials such as silt and Pozzuolanaare more suitable than cohesive materials.
3- Dynamic behavior of sliding system for unreinforced masonary building shows that the different parameters of earthquake acceleration dosenot have so much effect on maximum and residual displacement.
4- The maximum and residual displacement have a main role for selecting the optimun friction coefficienμ.
5- With regard to results of experimental work as well as numerical analysis a sliding system for unreinforced masonary wall may be designed and constructed. Fig(6) shows details of one type of this sliding foundation.

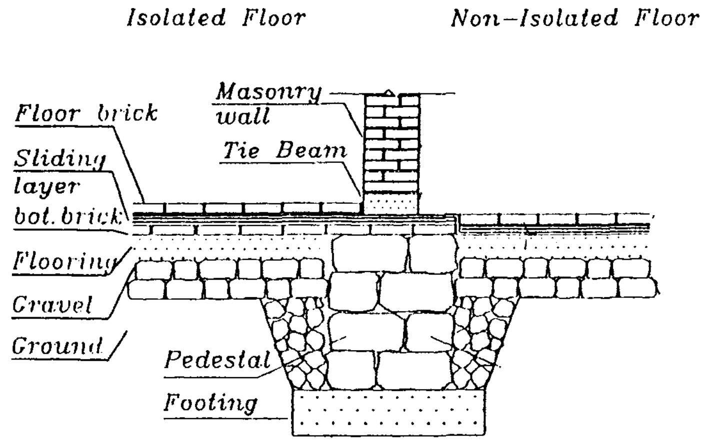


Fig (6):Sliding foundation detail

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