BASE ISOLATION in TRADITIONAL BUILDING LESSON LEARNED from NIAS MARCH 28, 2005 EARTHQUAKE

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ABSTRACT: While modern buildings in Nias collapsed due to the March 28, 2005 strong earthquake (8.7 on Richter scale), the traditional northern Nias house (*omo hada*) survived without any damage. *Omo hada* has an oval plan with a raised platform consisting of wooden beam and plank supported by a complex arrangement of posts (*ehomo*) and x type bracing (*diwa*). The posts are not fixed on the ground, but rest on top of stone foundations. This kind of friction type support is also evident in other traditional houses in Indonesia. In this study, the behaviour of *omo hada* under spectrum consistent ground acceleration is studied. The supports of the traditional house are modeled as coulomb friction model and fixed support. Results of analysis show that the friction type support acts as base isolation. The presence of sliding at the friction type support significantly reduces the internal forces in the structure.

KEYWORDS: Omo Hada, Stone Foundation, Coulomb Friction, Ground Acceleration

1. INTRODUCTION

The recent Nias Earthquake (March 28, 2005 – 8.7 on Richter scale as seen in Fig.1) destroyed many buildings in Nias Island. Most of these building are conventional reinforced concrete with masonry walls (Fig. 2). The strong ground shaking, inadequate reinforcement detailing and heavy material are the main factors of the structural failures.

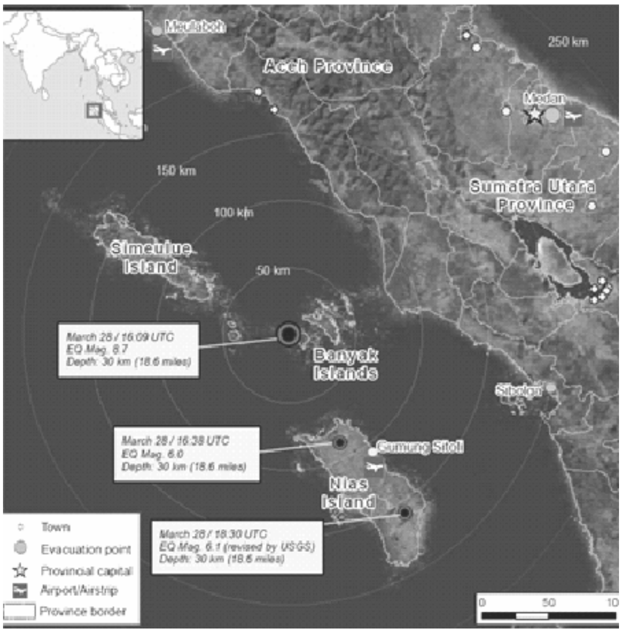

Figure 1. The Nias Earthquake, March 28 2005

On the the other hand, all wooden traditional buildings (*omo hada*) survived without any damage. *Omo hada* has an oval plan with a raised platform consisting of wooden beam and plank supported by a complex arrangement of posts (*ehomo*) and X type bracing (*diwa*). Pictures of *Omo hada* can be seen in Figs. 3, and 4. One factor that might cause *omo hada* to survive the earthquake is probably the non-fixed base support. The posts are rested (not-fixed) on stone foundations, thus act as base isolation. This study explores the behaviour of this traditional base isolation as compared to fixed based subjected to lateral ground motion.

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(a) (b)

Figure 2. (a) A Totally Collapsed Reinforced Concrete Building, and (b) Collapsed Masonry Walls Inside a Modern Building.

2. STRUCTURE CONFIGURATION AND MODELING

In this study, the *omo hada* is modeled and analyzed using SAP2000 software. All line members are modeled as frame element with 6 degrees of freedom (6DOF). The wooden wall is modeled using 4 noded shell elements with 6DOF in each node, while the roof is modeled using 4 noded membrane elements with 3 DOF in each node. The perspective view, floor plan, and the three dimensional frame of the *omo hada* model are shown in these Figs. 5, and 6.

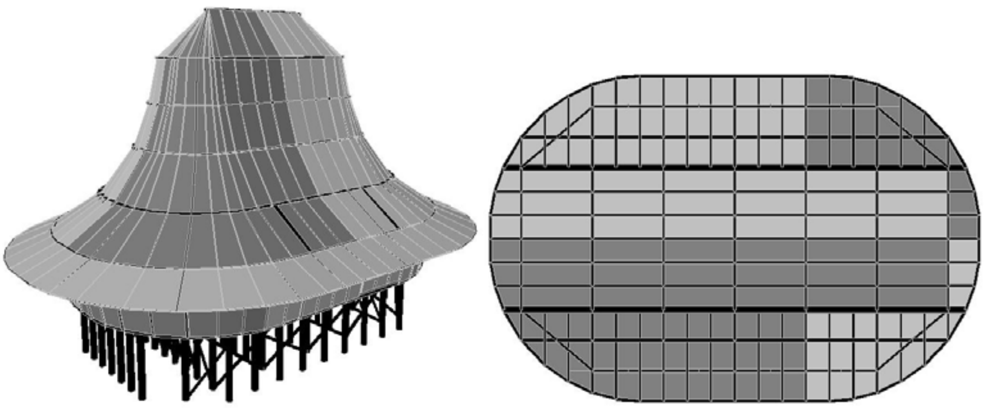
Figure 3. The *omo hada*, Nias Traditional Wooden House

Figure 4. The Lateral Force Resisting System of *omo hada*.

From Fig.4, it can be seen that the platform of *omo hada* is relatively very stiff if subjected to lateral force. Practically the lateral resisting system of *omo hada* is only the *ehomo*s, the vertical posts, and the *diwa*s, the diagonal bracing, below the floor. Only six of these vertical posts (*taru mbumbu* and *silalo yawa* as seen in Fig. 6) are lengthened to support the roof structure of the house. The dimension of *ehomo* is varied from 20 cm to 25 cm, with distance separating one *ehomo* to another about 1 to 1.5 m. The length of these ehomos is approximately 1.6 to 2.1 m (Lase, 2005).

The floor of the *omo hada* itself has an oval shape with the dimension about 12 m x 8 m. The orthogonal beam grid is used as the floor structure, and the grid is covered by 3 cm wooden floor. The height of the wall (*tuwu tuwu buato* as seen in Fig.6) is about 1.6 m.

The structure of the roof is about 6 m high, consists of vertical members (*taru mbumbu* and *silalo yawa*) and horizontal members (*alisi1*) that are oval in plan. The roof is covered only with dried leaves, thus makes it very light.



(a) (b)

Figure 5. (a) Perspective view of *omo hada*, & (b) Floor Plan of *omo hada*

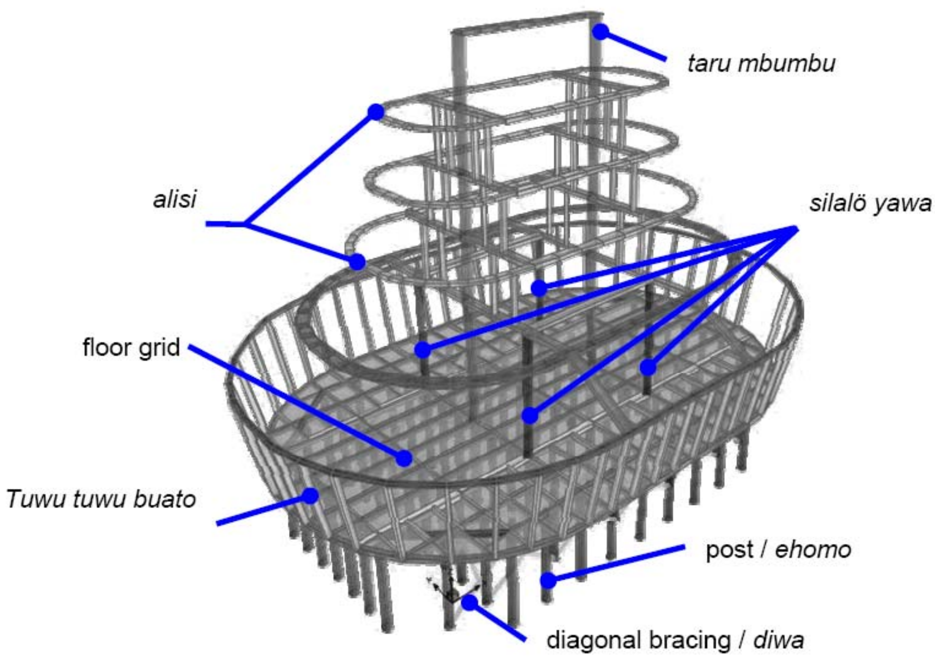


Figure 6. The three dimensional frame system of omo hada (Lase, 2005).

The posts are rested (not-fixed) on stone foundations. To study the effectiveness of this type of foundation as a base isolation, the supports are modeled as Coulomb friction with friction constant equal to 0.4 (Lase, 2005) and fixed supports as a comparison. Illustration of the Coulomb friction support model is shown in Fig. 7.

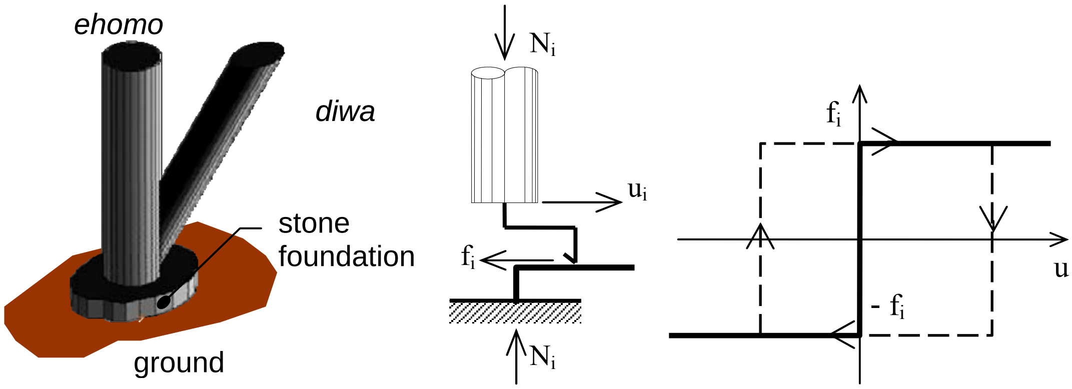


Figure 7. The Coulomb friction support.

The friction force (f_i) is proportional to the product of frictional constant (μ) and the axial force (N_i), acting at the same direction of velocity $\dot{u}_i$.

$$f_i = -\mu . N_i . \text{sign}(\dot{u}_i) \quad (1)$$

Taking into account the effect of friction force leads to modification of the equation of motion as follow:

$$M\ddot{u} + C\dot{u} + Ku + f = -M\ddot{u}_g \quad (2)$$

where M, C, and K are the mass, damping, and stiffness matrices respectively, while $\ddot{u}_g$ is the ground acceleration.

3. LOADS CONSIDERED

The loads considered to test the *omo hada* are the gravity loads and earthquake loads. Gravity loads consists of self weight dead load, and 200 kg/m^2 uniform live load. Earthquake load used is a spectrum consistent ground acceleration (Fig. 8) which is modified from El Centro 18 May 1940 NS ground acceleration using RESMAT a software created at Petra Christian University, Surabaya (Lumantarna, 1995). Response Spectra of the modified and the original El Centro 18 May 1940, NS component ground acceleration along with the target response spectrum is shown in Fig. 9.

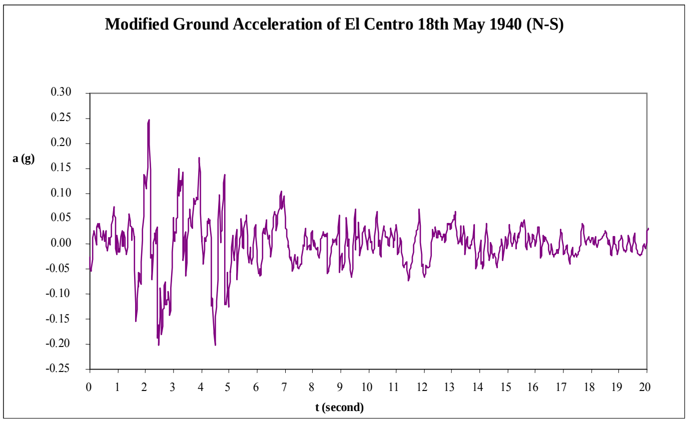


Figure 8. Modified Ground Acceleration of El Centro North-South Component.

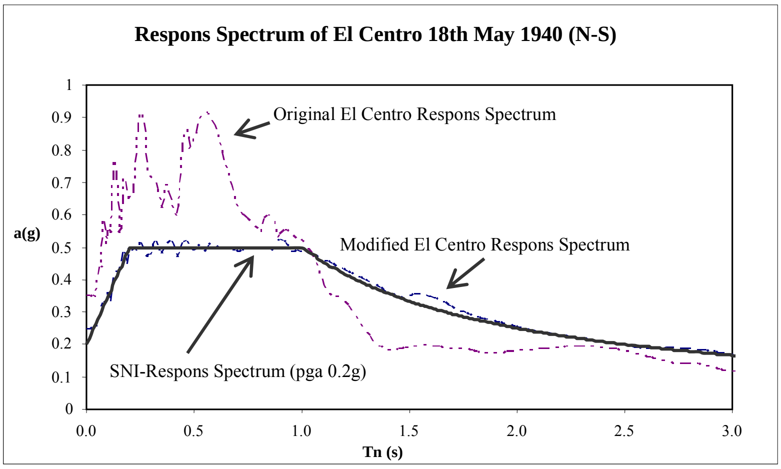


Figure 9. Response Spectrum of El Centro North-South Component

The ground acceleration shown in Fig.8 is constructed to a design spectrum with maximum peak ground acceleration (pga) of 0.2g. Since pga for 500 years return period in Nias Island is 0.38g, in this study the ground acceleration shown in Fig. 8 is scaled up by 1.9.

4. ANALYSIS RESULT

The member internal stresses due to load combination 1Dead+1Live+1Quake of the two models are checked with respect to allowable stresses of the wood according to Indonesian standard (Departemen Pekerjaan Umum, 1961). The result of the analysis is presented in Table 1.

Table 1: Analysis Results

Element Section	ratio of stress to allowabe stresses			
	Q_F	Q_BI	GQ_F	GQ_BI
2XSIBA	0.5959993	0.6013056	0.9695314	0.7638139
ALISI1	0.255724	0.1476885	0.2687445	0.1592661
ALISI2	0.5529371	0.2336859	0.6032051	0.2950107
BOTOMBUMBU	0.3349022	0.1248239	0.3838718	0.2226901
BUATO	0.2408238	0.0944253	0.3956993	0.2524556
DIWA	**0.8890279**	**0.2119915**	**0.9354378**	**0.2563155**
EHOMO	**0.1844726**	**0.2874179**	**0.2922483**	**0.3472276**
GASO	0.275492	0.2743321	0.456453	0.5120431
HENEDEU	0.0837727	0.0724827	0.091155	0.0778071
LALIOWO	0.3865637	0.485873	0.8788999	0.9253428
SANARI	0.2336954	0.0856379	0.2886142	0.2204512
SIBA	0.5322468	0.8883584	0.7933298	0.9632103
SILALOYAWA	0.1538898	0.0966877	0.1730171	0.1137965
SILOTO	0.134505	0.5693557	0.2510895	0.6903573
TERUMBUMBU	0.6208147	0.2585004	0.6436129	0.2638488
TUWU TUWU BUATO	0.6247302	0.3204547	0.7429177	0.4620882

where Q_F : due to 1Quake – Fixed Support

Q_BI : due to 1Quake – Base Isolation Support

GQ_F : due to 1Dead+1Live+1Quake – Fixed Support

GQ_BI : due to 1Dead+1Live+1Quake – Base Isolation Support

5. CONCLUDING REMARKS

Observing the results presented in Table 1, the following conclusions can be made:

1. The *omo hada* can be considered to be a very stable structure.

   Even with fixed support model, during occurrence of 500 years return period earthquake (pga=0.38g, most severe seismic zone in Indonesia), the stresses in all frame elements are still below the allowable stresses (the maximum ratio is about 0.94 for diagonal bracing diwa).

2. The base isolation of *omo hada* performs very well in reducing internal forces.

   The ratio of stresses Coulomb friction base isolation model is significantly decreased to only 0.26.

6. REFERENCES

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