Local wisdom to a sustainable non-engineered brick building

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Procedia Engineering00 (2017) 000–000

Procedia Engineering

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Sustainable Civil Engineering Structures and Construction Materials, SCESCM 2016

Local Wisdom to a Sustainable Non-Engineered Brick Building

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Abstract

With the increase of wealth, people tend to modernize their houses by replacing the traditional wooden houses to brick buildings. Unfortunately most of these "modern non-engineered buildings" collapsed during earthquake, while the traditional wooden houses remain undamaged. In previous studies, the authors have shown that the strength of the traditional building was in the construction of the columns which were not fixed to the ground but rested on top of flat stones, hence simulating friction base dampers.

In this study a typical non-engineered brick building is used as a prototype, it is also assumed that this building is built properly. Two types of building are considered, the first one has its tie beams anchored to the foundation. While in the second one, the tie beams are not anchored to the foundation, allowing the building to slide thus simulating friction damper. Both non-engineered brick buildings are subjected to spectrum consistent earthquake excitations with several return periods. The prototype building with anchors is treated as pinned on the anchor locations, while the one without anchor is treated as friction base isolation. A third building assuming no infilling brick wall is also analyzed as a comparison. The result shows that the two buildings can stand to earthquake with a return period of 500 and 2500 year, however the one with pinned base suffers some small damages. However the bare frame already showed extensive damages due to 500 year earthquake. It is worth to note that the building with friction base attracts only 66% of the total base shear of the one with pinned base.

Peer-review under responsibility of the organizing committee of SCESCM 2016.

Keywords: Friction base isolation; non-engineered brick building; seismic performance

1. Introduction

Although the first Indonesian earthquake code was introduced in 1971 [1], after more than forty years, despite all

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Peer-review under responsibility ofthe organizing committee of SCESCM 2016.

effort to disseminate the principle of good earthquake engineering design and construction, in recent earthquake events, such as Padang, October 2009, Bengkulu, September 2007, Yogya, Mei 2006, Nias, March 2005, a lot of modern buildings collapsed (Figure 1a), while traditional building such as Northern Nias, *Omo Hada* (Figure 1b) survived without any damage [2].

Fig. 1. (a) Nias 2005: Modern Building; (b) *Omo Hada* (Lase, 2005).

Fig. 2. (a) A three story shop house (Bengkulu September 17th 2007, private documentation); (b) Wooden house (Bengkulu September 17th 2007, private documentation).

a b


Fig. 3. (a) *Uma Lengge*; (b) Base of *Uma Lengge*.

On the other hand with the increase of wealth people tend to renovate their wooden houses to modern brick houses, apparently brick house is a pride to the owner. Unfortunately the quality of work of the building is very inferior, hence during earthquake these "modern buildings" collapse (Figure 2a) while the wooden building (Figure 2b) next to the modern building in Figure 2a survived. In the previous paper, Lumantarna and Pudjisuryadi [3] reported that besides due to the light mass of the wooden house which attracts less inertia force, the traditional building survived due to the details of the columns connections to the foundation. In traditional buildings the columns are not fixed to the ground, thus simulating a friction base isolation system (Figures 3a and 3b).

2. Building Considered and Method

In this study, a typical non-engineered building suggested by Boen [4] is used as a prototype (Figure 4a). To enable slip between the upper structure and the lower structure, the anchors between the tie beams and the foundation are omitted (Figure 4b). This building (without anchor), the original building (with anchor), and a bare frame (without infilling wall) are subjected to earthquake with various return periods. SAP2000 v11 is used to perform the nonlinear time history analysis. The ground acceleration used for the excitation is a spectrum consistent ground acceleration which is modified from El Centro 18 May 1940 NS to the acceleration design spectrum [5] specific to the area where the buildings are. The modification of the earthquake record is performed using RESMAT, a software developed at Petra Christian University, Surabaya, Indonesia [6]. The original El Centro, the modified El Centro, and their response spectra compared to the design spectrum are shown in Figures 5a, 5b, and 5c respectively.

The building considered is modeled as a three dimensional frame (Figure 6). Three-strut model [7] is used to model the infilling brick wall with the width of strut is one-quarter of the diagonal length. The plastic hinge properties and the shear capacity of the beams are obtained using Cumbia [8]. A typical input to SAP2000 Nonlinear is shown in Figure 7 and 8. The building is arbitrarily assumed to be built on soft ground, in Palu, Sulawesi, Indonesia.

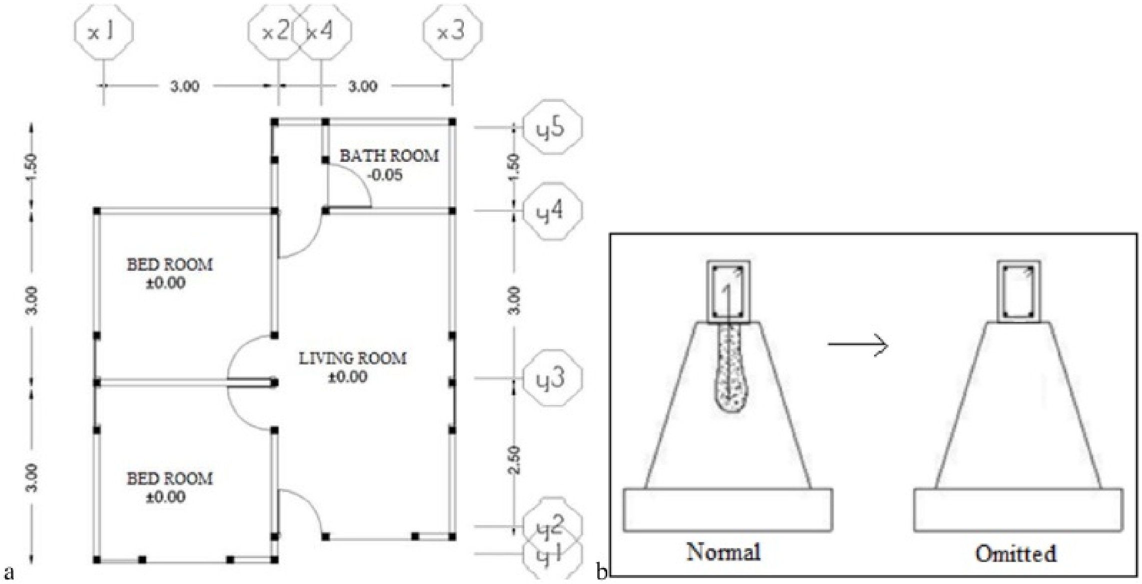

Fig. 4. Typical non-engineered brick building: (a) Plan of the building; (b) Anchors between tie beams to foundation (spaced every meter).

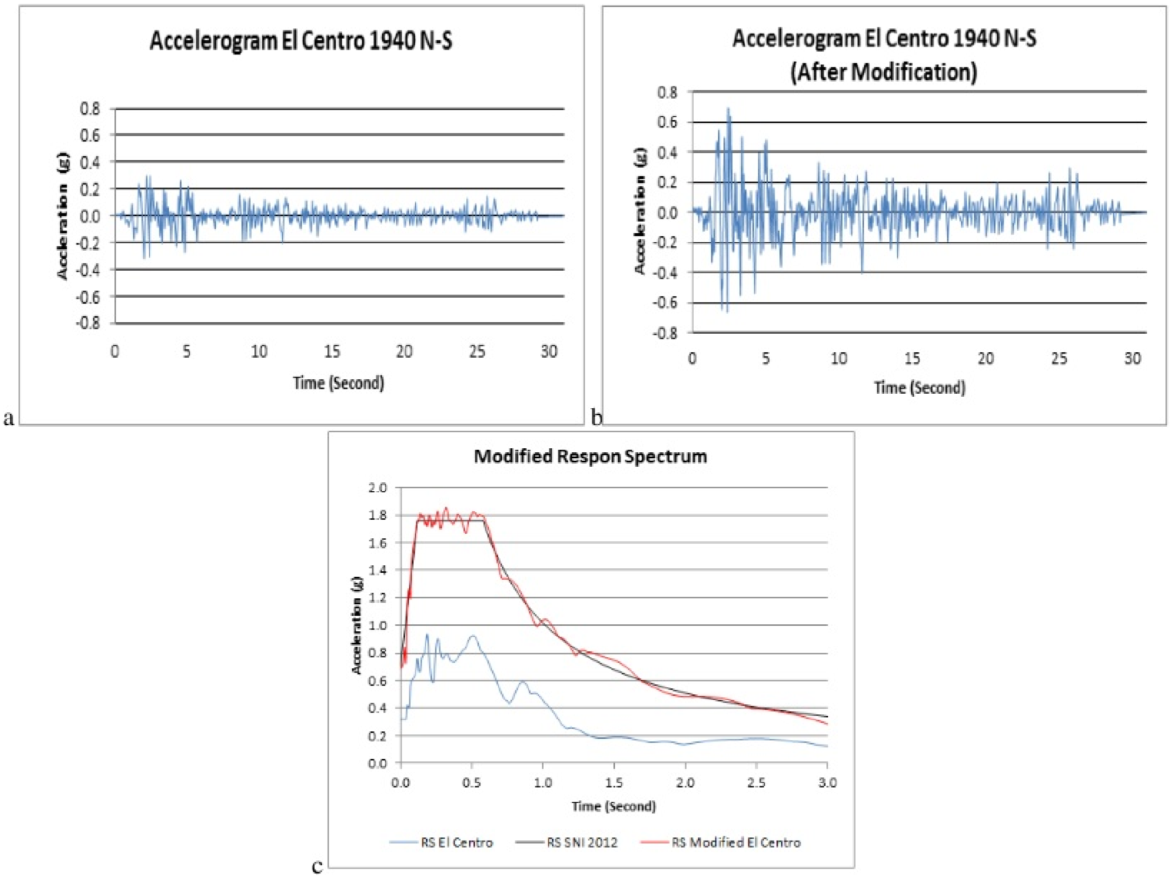

Fig. 5. El Centro 1940 N-S Component: (a) Original acceleration; (b) Modified acceleration (2500 years return period, Palu, Sulawesi, Indonesia); (c) Response Spectra

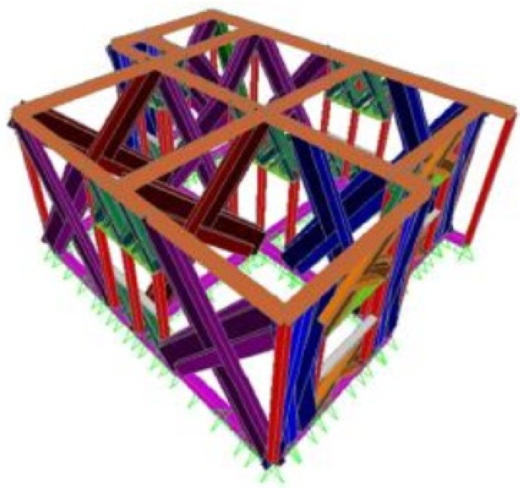

Fig. 6. Three dimensional structural model of the building (extrude view).

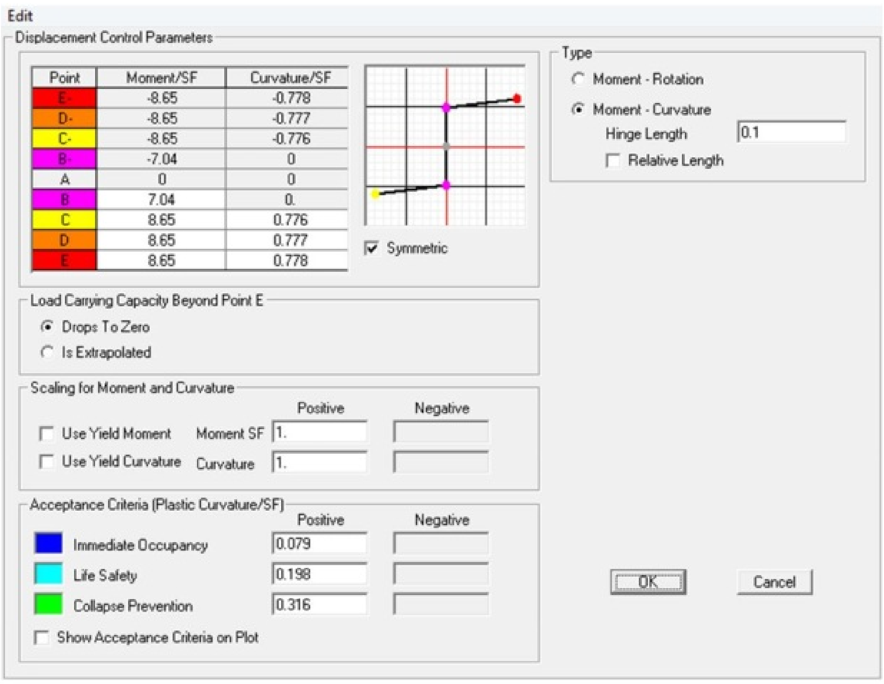

Fig. 7. Typical plastic hinge properties (bending capacity).

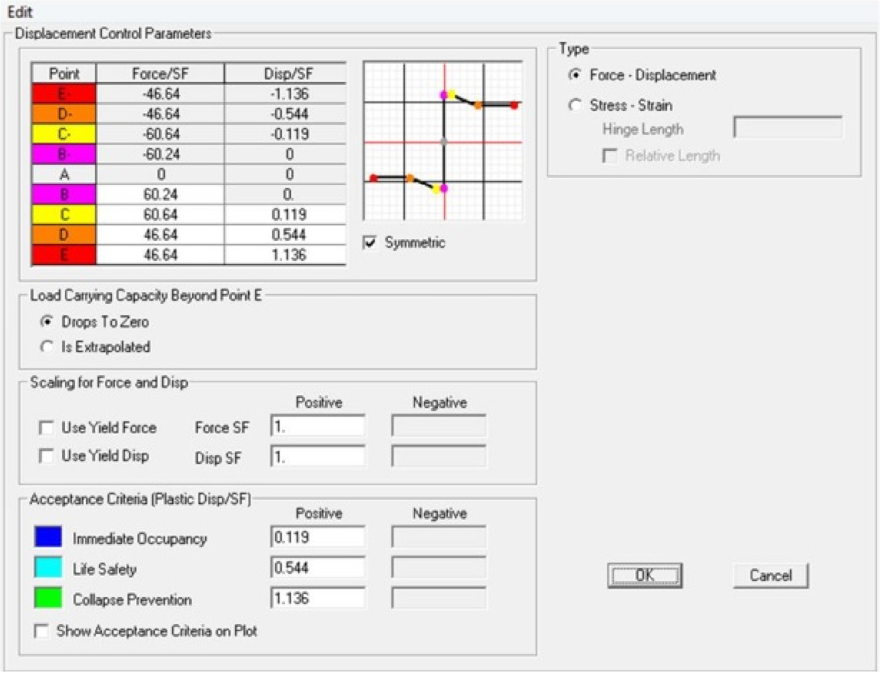

Fig. 8. Typical plastic hinge properties (shear capacity).

Friction base isolation relies on friction between the upper structure (in this case the tie beam) with the foundation. Friction is defined as (Figure 9):

$$f_s = \mu_s N \quad (1)$$

$$f_k = \mu_k N \quad (2)$$

In which, f_s, f_k, μ_s, μ_k, and N are the static friction force, kinetic friction fore, static friction coefficient, kinetic friction coefficient, and normal force, respectively. To model the friction base damper, Friction Pendulum Isolators with radius is equal to zero (flat base) in SAP2000 v11 [9] are used, while for building with anchors, the anchors are assumed as hinges (pinned). The coefficients of static friction and kinetic friction for this research are set as much as 0.4.

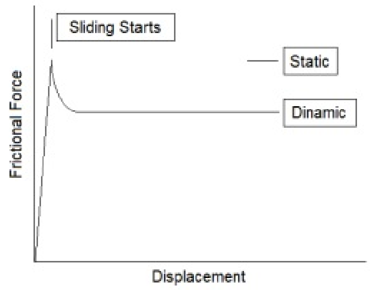

Fig. 9. Frictional force.

3. Analysis Results

3.1. Base Shear

Figures 10 and 11 show the total base shear of the two buildings due to earthquakes with 500, and 2500 years return period in X direction. While Table 1 shows comparison of maximum total base-shear in the two buildings due to earthquakes with 500 and 2500 years return period in the X direction.

It can be seen from Table 1, Figures 10, and 11 that the total base shear in the building with friction base is always smaller than the one with anchor. Comparison between the 500 and 2500 years shows that while the maximum base shear of the anchored base increases by 1.5, the friction base only increases 1.19 time. This indicates that the base of the friction base building already slips.

Table 1. Comparison of maximum Base-Shear in X direction for 500 and 2500 years.

Base Shear (N)	Earthquake in X direction					
	500 years			2500 years		
	Friction	Anchored	Anchored/ Friction	Friction	Anchored	Anchored/ Friction
Min (-)	-78,559	-84,210	1.07	-92,020	-129,833	1.41
Max (+)	99,727	132,455	1.32	118,254	199,801	1.67

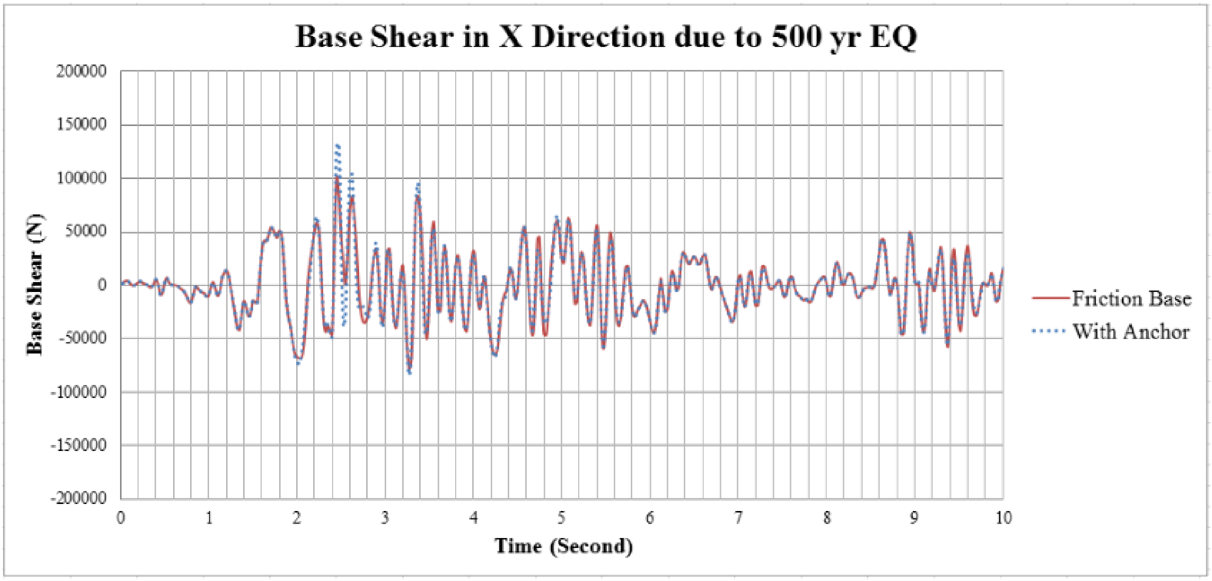

Fig. 10. Total Base Shear in X direction due to 500 years earthquake.

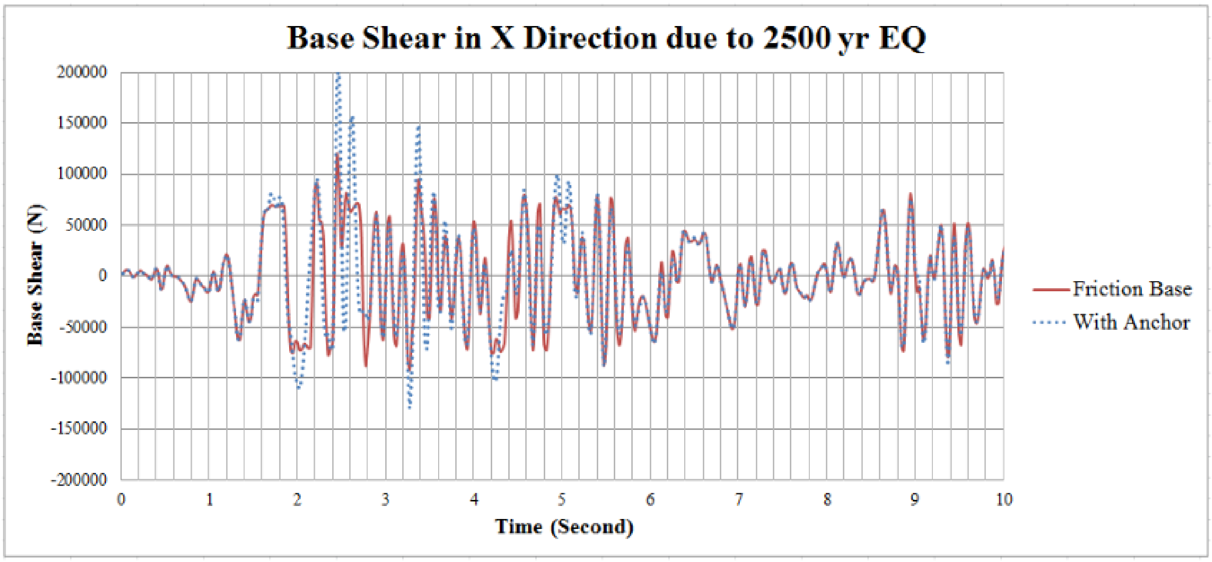

Fig. 11. Total Base Shear of building with friction base in X direction due to 2500 years earthquake.

3.2. *Drift*

Table 2 compares drift due to 500 and 2500 year earthquakes in the X direction between building with base isolation and with anchor. It can be seen that applying base isolation reduces the drift significantly.

Table 2. Comparison of driftdue to earthquake in X direction.

Column IDs	Drift (%) due to Earthquake in the X direction					
	500 year			2500 year		
	Friction	Hinge	Friction/ Hinge	Friction	Hinge	Friction/ Hinge
K1	0.151	0.168	0.899	0.19	0.257	0.739
K2	0.151	0.167	0.904	0.189	0.257	0.735
K3	0.148	0.162	0.914	0.181	0.249	0.727
K4	0.148	0.162	0.914	0.181	0.249	0.727
K5	0.103	0.134	0.769	0.124	0.205	0.605
K6	0.104	0.134	0.776	0.125	0.205	0.610
K7	0.105	0.134	0.784	0.126	0.205	0.615
K8	0.081	0.103	0.786	0.104	0.158	0.658
K9	0.081	0.103	0.786	0.104	0.158	0.658
K10	0.082	0.103	0.796	0.105	0.158	0.665
K11	0.083	0.096	0.865	0.102	0.147	0.694
K12	0.082	0.095	0.863	0.102	0.147	0.694
K13	0.081	0.103	0.786	0.104	0.158	0.658
K14	0.082	0.096	0.854	0.102	0.147	0.694

3.3. *Damages*

The Analysis only showed slight damages in the anchored building due to 2500 year earthquake as shown in Figure 12. However the bare frame already showed extensive damages due to 500 year earthquake (Figure 13).

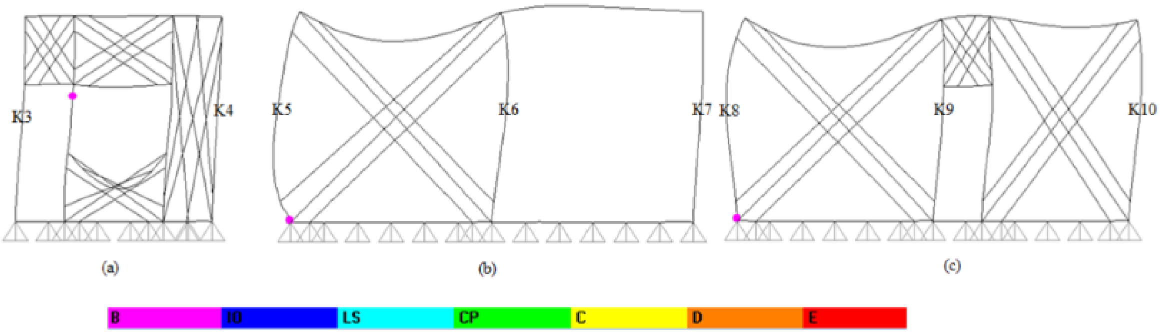

Fig. 12. Damages in (a) Frame Y2 (b) Frame Y3 (c) Frame Y4 due to 2500 year earthquake in the X directionBase Shear of building with anchor in X direction.

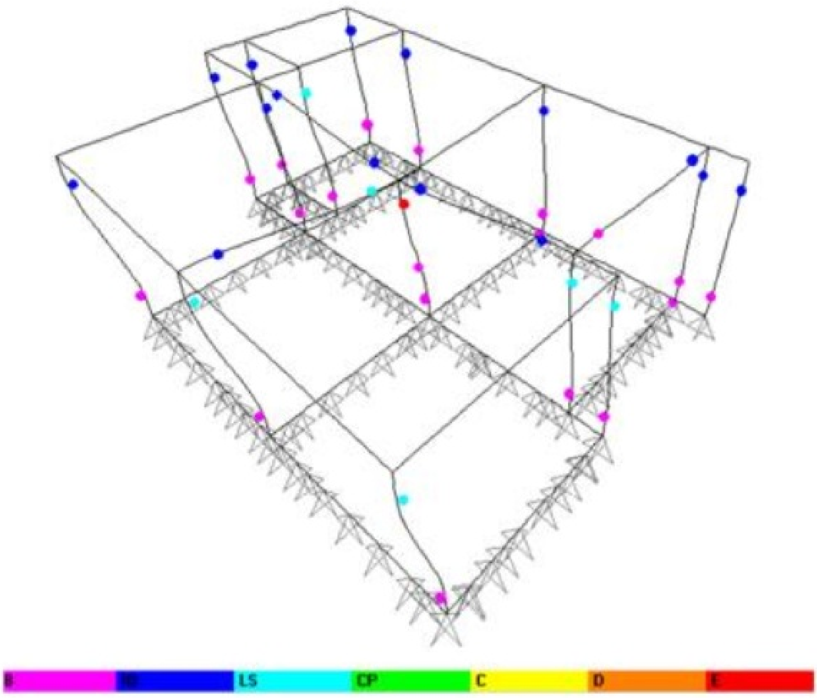

Fig. 13. Damages in bare frame due to 500 year earthquake in the X direction (at t=6.6 sec).

4. Conclusions

This study did not consider earthquake going in two directions, thus eliminating the possibility of walls already damage due to load perpendicular to the wall (face load). If the infilling wall was damaged due to the face load, there is a possibility that the structure behave as bare frame and will possibly collapse.

It can be concluded that the non-engineered building suggested by Boen [4] will survive with very minimal damage to 2500 year earthquake if the structure is constructed soundly. However the friction base building behaves better by attracting only 66% of the total base shear and 68% of the average drift due to 2500 year earthquake of the traditional fixed base (anchored) building.

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