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Ductility Improvement of Brick Masonry Wall Using Local Materials for Anticipation of Earthquake Forces

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ABSTRACT

Settlement infrastructure in Indonesia, either building or housing mostly using masonry brick wall. In fact this masonry serves as a bearing wall both for gravity and horizontal loads. This research was conducted with the aim to improve the ductility of the masonry wall structure, because of the strength and stiffness difficult to increase. By increasing the ductility is expected that greater energy absorption before the masonry walls collapsed. Taking into account the economic condition of the dwelling owner in Indonesia, the selected local materials are easily available and cheap. This research was conducted by creating a confined masonry wall model in the laboratory. There are two kinds of confined masonry models of the wall, which has been damaged and not damaged. Materials are brick walls of the local area around Malang that generally have low strength characteristics. Efforts to improve the ductility by using the reinforcing bamboo 2 sides in a diagonal direction with shear connectors from the local steel wire and bamboo wedges. Monotonic loading is given in the direction of the inplane masonry wall. To facilitate designing of the actual wall structure is used an analogy truss model framework by reviewing the condition of non-elastic. The results showed an increase in ductility of both the structures that have been damaged and undamaged. The energy absorption also occurs in the wall that has been given bamboo reinforcement. With this result the system of bamboo reinforcement can be used as a retrofit model for local brick confined masonry to increase ductility.
KEY WORDS: local brick, retrofit, bamboo reinforced system, ductility.

1. INTRODUCTION

Settlement infrastructure in Indonesia, both building and housing made of the masonry brick wall. Brick material used comes from the locale around the area where building will be erected. The structures of this masonry brick wall resist gravity loads and horizontal loads from wind and earthquake. Evidence of this can be seen from the pattern of wall collapse when hit by an earthquake recently.

This research was conducted because of the fact that the strength of local brick mostly located in the lowest class of the code in Indonesia [1] and the brick walls are produced at a low level of quality as well [2]. This condition is shown in Table 1. Because of this the strength and stiffness of the masonry wall structures of the local materials is difficult to increase. Table 1 also shows the increasing strength of mortar no significant effect on increasing strength of the masonry wall. One effort that can be done is to improve the ductility of the structure so that the energy that is absorbed into the wall more bigger before the structure collapse under the earthquake load.

Based on Table 1 the compressive strength of masonry wall (f'm) can be determined from the mortar strength (f'c). This is shown in Equation 1. It can be seen that the strength of mortar (f'c) has a small effect on the strength of masonry wall (f'm).

$$f'm = 16.736 + 0.053 f'c \tag{1}$$

Many proposals concerning new materials and new methods that can be used to increase strength and ductility of the wall structure. This can be obtained from the literature [3,4]. If these methods will be used for the existing wall structure in Indonesia it is still needed further study considering the characteristics of masonry structures from local materials that different from those countries [5,6]. The difference between the quality of bricks and mortar as well as interfaces between them affect the strength of the resulting masonry wall.

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Table 1. Summary of brick masonry characteristic test from Malang region

Year of test	Local brick strength		Mortar (kg/cm^2)	Prism ASTM C1314	Masonry wall model	
	Cube (kg/cm^2)	SNI (kg/cm^2)		Compress. (kg/cm^2)	Compress. (kg/cm^2)	Shear (kg/cm^2)
2001	20.91	--	149.59	--	24.08	3.23
			53.86	--	20.71	2.75
			30.62	--	17.74	2.92
2002	--	25.56	86.79	26.29	--	--
			64.76	20.09	--	--
			30.04	16.03	--	--
	--	22.24	61.42	--	--	2.86
			41.72	--	--	2.51
			30.60	--	--	1.96
2007	30.03	21.73	131.57	20.26	--	--
			67.84	19.50	--	--
			38.74	14.95	--	--
	23.59	20.46	93.98	21.04	--	2.20
2008	27.27	20.81	113.63	--	19.73	2.31
2009	40.45	46.75	82.21	32.65	29.70	2.84

Many materials that can be used for this effort, but given the economic condition of the house owner, then the need to look for local materials that are cheap, strong and easy to obtain. In Indonesia, bamboo widely spread throughout the region. Other materials such as wire clothesline can also be used to shear connector to prevent interface sliding. Simple reinforced concrete can also be used to form a confined masonry. Confined masonry structures has been widely known in Indonesia and proved able to resist the earthquakes as long as having good detailing [7,8].

The purpose of the addition of bamboo reinforcement system in this research is to improve the ductility of the structure of the masonry wall of local brick material. Another thing that can be expected is the time of the collapse of the structure which would be longer for non-engineered building structure when subjected to earthquake loading [9].

2. MATERIALS AND METHOD

Wall structure that is recommended for areas with high seismicity is confined masonry. The structure may also be non-engineered structure that was not done by the engineered. The behavior of confined masonry wall structure is different from infill frames. To be able to model these characteristics the reinforced concrete frame is made as small as possible and concrete quality is made as low as possible. This is done to minimize the influence of the flexural stiffness. Thus the truss analogy approach can be used to perform simple calculations for practical purposes.

Model of confined masonry is made in a laboratory to get the objective of research. Type and description of the research model shown in Table 2. Treatment of group is made 4 types. The first group is the comparison group (Origonal). Another group was treated to see the effect when the wall structure has been damaged by the imposition of 50% and 75% maximum load.

Table 2. The models and their treatment

Specimen code	Treatment I	Treatment II
Original (3 specimens)	Monotonic load until collapse; Maximum load = P0	---
50%P0 (3 specimens)	Monotonic load until 50% P0	Given the bamboo reinforcement system, loaded again until it collapsed
75%P0 (3 specimens)	Monotonic load until 75% P0	Given the bamboo reinforcement system, loaded again until it collapsed
F S (3 specimens)	Given the bamboo reinforcement system, loaded until it collapsed.	---

The wall materials were obtained from the area around Malang. Characteristics of materials to make the masonry wall models shown in Table 3.

Table 3. General characteristics of materials

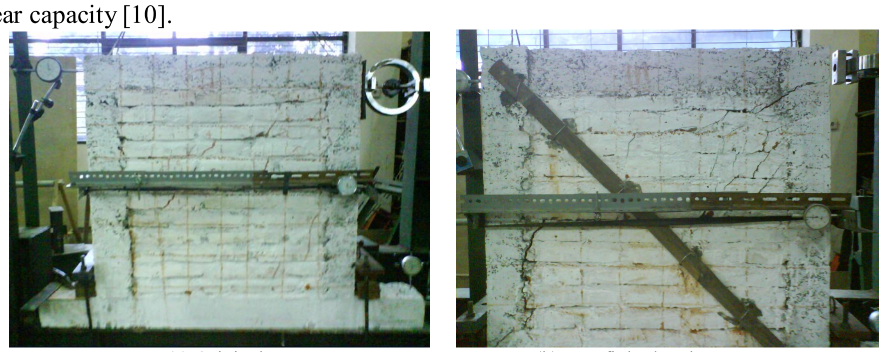
	Compressive strength of mortar 1:4 (kg/cm^2)	Compressive strength of brick (kg/cm^2)	Tensile strength of bamboo (kg/cm^2)	Compressive strength of concrete (kg/cm^2)
Average	72.70	24.86	1423.48	72.16
COV	23.50%	50.27%	24.57%	42.59%

The model confined masonry walls using bamboo reinforcement system installed at two sides of the diagonal direction. Shear connectors made of 1.3 mm diameter steel wire that is placed every 20 cm. At the end of a bamboo rod attached bamboo pegs 5 mm in diameter that connects bamboo to reinforced concrete frame. Dimensions bamboo stems are used as the reinforcement is 0.5 cm X 3.0 cm. This dimension is made because of the strength and modulus of elasticity of bamboo higher than the strength and modulus of elasticity of brick walls. This condition will be used as a scale model for the actual building construction. Species of bamboo is bambu apus (*Gigantochloa apus*).

Loads are given in the form of monotonic load in the direction of the inplane masonry wall. Loading is provided using two methods, the load control and the deformation control, so it can be obtained the ductility.

3. RESULTS AND DISCUSSION

The mode of failure indicates the wall stiffness is higher than reinforced concrete frame stiffness. These conditions appropriate for the category of confined masonry. Crack pattern and mode of failure can be seen in ***Fig. 1***. If infills are stiff and/or strong, then the frame is the weaker component. Cracking is not across a corner-to-corner diagonal, but on a flatter angle. Column cracking over a length equal to two member widths is severe and a sign of low frame shear capacity [10].



(a) Original (b) retrofit by bamboo

Fig. 1. *Crack pattern and modes of failure*

What happened to the bamboo reinforcement can be observed from the strain gage. These results can be seen in ***Fig. 2***. It can be seen bamboo reinforcement system capable of providing the composite action until shear connectors did not work due to crack on the brick wall on the loading of about 75% of maximum load. This example is taken on the model wall with full reinforcement (FS Type).

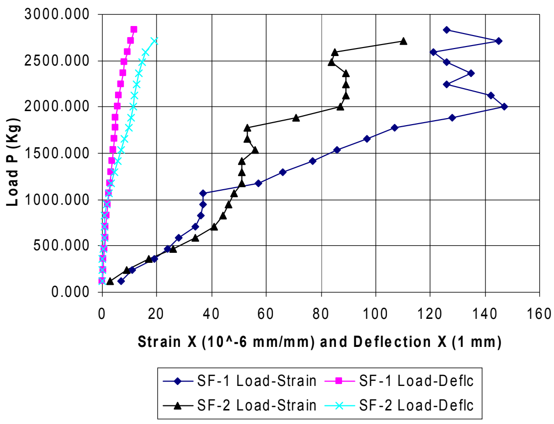


Fig. 2. *Typical load-deflection and load-strain at bamboo for FS type*

Load deflection graph from ***Fig. 3*** shows 3 results that can be observed. First: if the wall structure has been severely damaged (75% of maximum load) the ability of the structure can be returned back as the ability of wall that is not broken. Second: to the wall structure with minor damage the ductility can still be improved again with this improvement. Strength obtained no increase significantly. Third: the structure of the wall that was immediately given reinforcement (FS), an increase in ductility approaching twice.

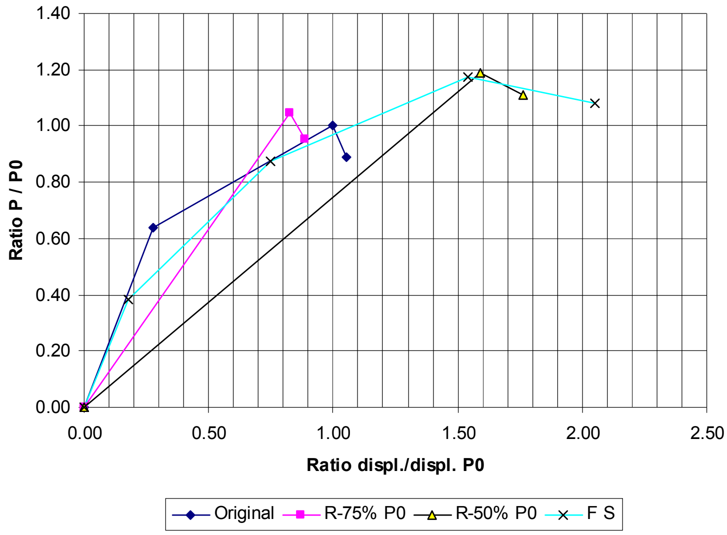


Fig. 3. *Load-deflection behaviour*

To use the analysis on the actual building used truss analogy model which has been reviewing the condition of non-elastic. This is done with the equivalence of the wall as a truss structure [8,11,12]. The equations in these references still need to be given the value of the coefficient relating the different characteristics of local brick wall.

4. CONCLUSION

The results showed bamboo reinforcement system can be used to improve the ductility and to restore and retrofit the function of wall as they are. This system does not increase the strength and stiffness of the structures, this is due to the characteristics of local brick wall. To get good results in practice requires attention about ratio of bamboo dimension to strength of brick.

5. ACKNOWLEDGMENTS

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REFERENCES

1. SNI 15-2094-1991. Specification and test methods for solid Red Brick. Department of Settlements and Regional Infrastructure, Republic of Indonesia (in Indonesian).
2. Wisnumurti; and Dewi, S.M. 2009. Characteristics Clay Brick Masonry from Malang Region. Proceeding of International Conference on Materials and Metallurgical Technology (ICOMMET 2009), Graha ITS, Surabaya-Indonsia.
3. Mayorca, P.; and Meguro, K. 2004. Proposal of An Efficient Technique for Retrofitting Unreinforced Masonry Dwellings. 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, Paper No. 2431.
4. ElGawady, M.; Lestuzzi, P; and Badoux, M. 2004. A Review of Conventional Seismic Retrofitting Techniques for Unreinforced Masonry. 13th International Brick and Block Masonry Conference, Amsterdam.
5. Wisnumurti; Dewi, S.M.; and Soehardjono, A. 2011. Behavior of Local Brick Masonry Structure as A Supporting Infrastructure in Indonesia. National Seminar Proceedings Civil Engineering VII, ITS, Surabaya – Indonesia, pp. A147-A153, (in Indonesian).

6. Korany, Y.; and Glanville, J. 2005. Comparing Masonry Compressive Strength in Various Codes. Concrete International, Vol. 27, Number 7, pp. 35-39. American Concrete Institute.
7. Brzev, S. 2007. Earthquake Resistant Confined Masonry Construction. National Information Center of Earthquake Engineering, IITK, Kanpur, India.
8. Meli, R.; Brzev, S.; Astroza, M.; Boen, T.; Crisafulli, F.; Dai, J.; Farsi, M.; Hart, T.; Mebarki, A.; Moghadam, A.S.; Quiun, D.; Tomazevic, M.; and Yamin, L. 2011. Seismic Design Guide for Low-Rise Confined Masonry Building (Final Draft). World Housing Encyclopedia, EERI & IAEE. (http://www.confinedmasonry.org)
9. Macabuag, J.; and Bhattacharya, S. 2009. Extending The Collapse Time of Non-Engineered Masonry Building Under Seismic Loading. EWB-UK Research Conference, Hosted by The Royal Academy of Engineering.
10.FEMA 306 -1998. Evaluation of Earthquake Damaged Concrete and Masonry Wall Buildings. ATC, California.
11. Paulay, P.: and Priestlay, M.J.N. 1992. Seismic Design of Reinforced Concrete and Masonry Buildings, John Wiley & Sons, New York.
12. FEMA 356 - 2000. Prestandard and Commentary for The Seismic Rehabilitation of Buildings. ASCE, USA.