International Journal of GEOMATE, April, 2018 Vol.14, Issue 44, pp.47-51
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2018.44.7232
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

FERROCEMENT - BRICK SANDWICH WALL APPLIED TO NON-ENGINEERED HOUSES

Febrin A Ismail[1], M Sofian Asmirza[2], *Abdul Hakam[1] and Fauzan[1]

[1]Engineering Faculty, Andalas University, Indonesia;
[2] Engineering Faculty, North Sumatra University, Indonesia

*Corresponding Author, Received: 9 June 2017, Revised: 28 Sept. 2017, Accepted: 20 Dec. 2017

ABSTRACT: Indonesian houses are generally categorized as non-engineered buildings that are constructed without any proper structural analyses. Bricks have long been used for hundreds of years as main materials to make houses for the reasons of simplicity and construction speed. Lesson learnt from the Padang earthquake in 2009 concluded many casualties are resulted from the collapsed houses made of bricks. Ferrocement as a construction material that made of wire mesh and mortar plaster become alternative to be used for retrofitting brick-houses. In this paper, structural analyses of a typical non-engineered house and a retrofitted house made of ferrocement-brick sandwich material are described. The ferrocement-brick composite material has a role as the main structure in the non-engineered house. The series of tests on that sandwich material has been done prior to the analyses. The results of the tests are then used to determine the strength criteria of the analyzed house. A structural analysis of the house is done by using the finite element computer program. As a comparison, an analysis of an ordinary brick wall house is described. As previously thought, the house with walls made of the ferrocement-brick sandwich material can withstand the given earthquake loads. It is concluded that the ferrocement-brick sandwich material is very useful to build earthquake resistant houses in seismic prone areas such as the West Sumatra.

Keywords: Ferrocement, Masonry brick wall, Composite, Non-engineered house, Earthquake engineering

1. INTRODUCTION

The earthquake safe house can be defined as a house that provides security to its occupants in the event of an earthquake whether a weak earthquake or a very strong earthquake. The actual earthquake does not directly cause the victim but the house that collapsed when the earthquake that can cause casualties. This house should be made in such a way that it does not cause accidents or casualties to the inhabitants in it and the people around it. Psychologically secure homes also provide a sense of security to the inhabitants at all times. Small cracks that occur due to small or moderate earthquakes in a house will be very psychological disturbing the people in the house. So the main principle of earthquake safe house may be able to provide security to the occupants at any time, both psychologically and physically.

The earthquake safe house should not have any damage even in case of a weak earthquake (Fig.1). Minor damage is like the small cracks in the wall or loose roof arrangement must be avoided. This should the main the criterion of earthquake safe houses because since the minor damage may cause bad feeling to residents of the house. The earthquake safe house also must not suffer from heavy damage such as the collapse of the wall or the fall of roof construction due to the very strong earthquake. Due to the collapse of the wall and/or the fall of the roof construction can hurt the occupants of the house and even take a life. During the very strong earthquake, the seismic safe house should remain to stand and may suffer from minor damage to the construction materials such as wall cracks on the wall. Each element of the earthquake safe house must remain in original place and still be in tied to each other during a very strong earthquake.

The earthquake safe house as well as other buildings can be presented as a good team work of human collaboration between owner, designer and a group of workers. An earthquake safe house in general is an ordinary house that may not be analyzed with the good science procedures that use of engineered mechanics knowledge, but adopt the principles of earthquake resistance. Dimensions and cost of making a house depend on the desire and ability of the house owner. The final quality of physical engineering work is determined by the builders of the house as a group of workers who create the house from its raw materials. The role of the house builder has enormous value in generating earthquake safe house. By providing additional knowledge and skills to the builders to create a safe house, earthquake risk reduction can be realized [1].

a. House before earthquake

b. Safe house after big earthquake

c. Un-safe house collapse after earthquake

Fig.1 Earthquake safe house definition

The people still think that the earthquake safe house is a concept of applying advanced technology that is complicated. In addition, earthquake safe house is also a masterpiece of the application of expensive engineering science. That opinion is not entirely wrong, because of some earthquake safety guidelines circulating in the community, tend to feature an addition to the ordinary house so it looks more complex and expensive [2] [3]. The transformation of a house into an earthquake safe house may need up to one third of the overall cost of construction. The extra cost depends on the concept of the earthquake safe house to be adopted. In terms of mechanical engineering, reinforcement in a house logically provides additional resistance to earthquakes. So the concept of applying additional reinforcement can be justified and applicable to traditional buildings.

Although earthquake-safe houses have the primary mission to avoid casualties from the collapse buildings during the earthquake, people still want a simple and inexpensive concept to be adopted. There is some earthquake-safe housing guidelines that nearly to eliminate the traditional procedure of building a house that is common in society. Some of these concepts have been used in some community in a few sample buildings [4].

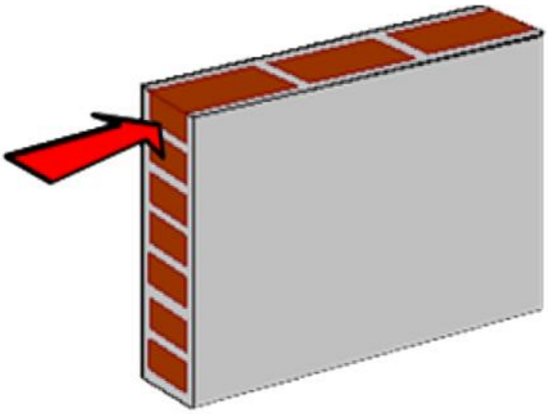
Ferrocement as a construction material that made of wire mesh and mortar plaster become alternative to be used for retrofitting brick-houses to resist the seismic load. The concept of ferrocement material has been applied to almost all structural elements of a building such as floors, roofs, water thanks including beams [5]. More advanced application of ferrocement composites also has been studied by some researcher [6]. In this study an application of ferrocement to ordinary brick walls is done to gain a seismic resistant to the house. In this paper, the tests of brick walls including ferrocement-brick sandwich wall and the structural analyses of a typical non-engineered house are described.

2. BRICK-FERROCEMENT WALL TESTS

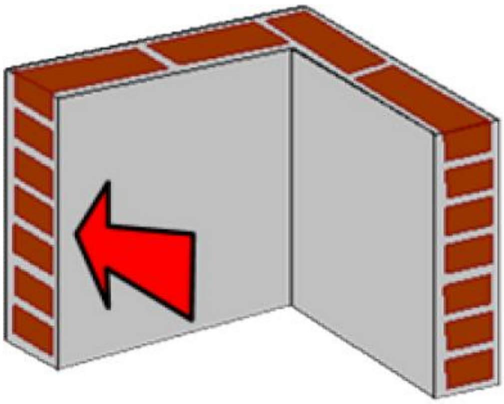
In order to obtain the engineering strength value of ordinary and ferrocement composite brick walls, a series of laboratory tests had been conducted. The specimens included in the tests were:

1. Masonry brick wall
2. Brick wall with wire mesh (Brick wall covered by wire mesh without mortar)
3. Mortared brick wall (Brick wall covered by mortar plaster)
4. Ferrocement brick wall (Brick wall with wire mesh covered by mortar plaster)

The tests were performed by applying single axial force in two different directions, one was parallel to the wall surface, and secondly perpendicular to the wall plane surface (Fig.2). The first one was purposed to obtain the shear strength of the wall in the direction of the wall cross section, and the second direction was for the resistant moment as well as shear strength in the wall surface direction.



a. Force on the wall cross section



b. Force on the wall surface

Fig.2 Wall specimen test directions

During the tests, the damages to the specimens in term of crack were monitored. There were two different patterns observed on the tests depend on the direction of applied forces as plotted in Fig.3.

The applied forces and displacement in the same direction are recorded. The results in the terms of forces versus the displacements are shown here (Fig.4 and 5).

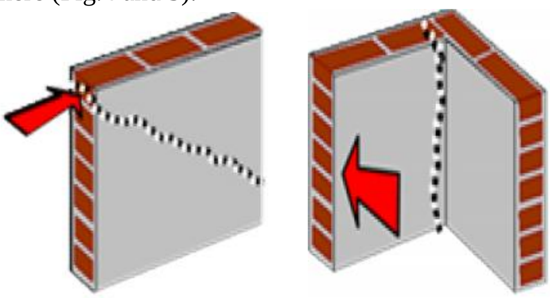


Fig.3 Crack on tested specimens

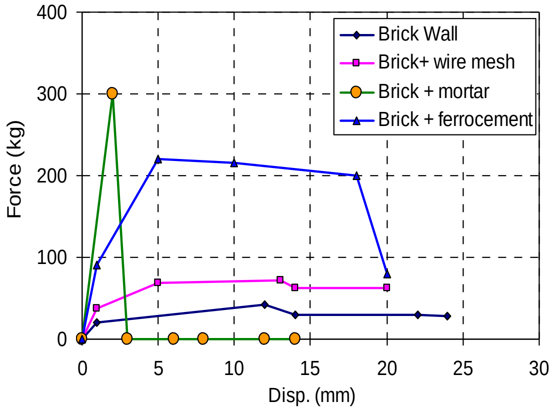


Fig.4 Test results in wall cross section direction

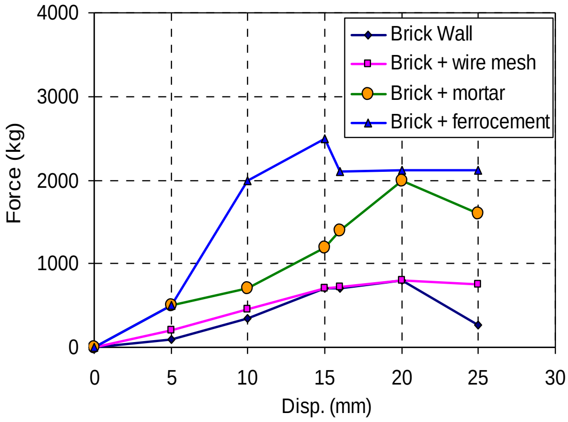


Fig.5 Test results in wall surface direction

Based on those test results, it can be taken the strength values of the walls in terms of the transversal and longitudinal shear forces as well as bending moment resistances as written in Table 1. The mortared brick wall seems almost has the same strength compared to the ferrocement-brick wall, but it is very brittle. This condition is not good for the buildings subject to earthquake load which may experience suddenly collapse. This situation does not give chance for occupants to evacuate from the building.

It also can be seen that the ferrocement-brick wall has the strength about five times compared to the ordinary masonry brick wall. The advantages of the increased strength of ferrocement-brick wall certainly can be used to retrofit brick wall houses such that the earthquake safe houses can be gained.

In order to demonstrate the application of ferrocement-brick wall to a non-engineered house, numerical simulations are performed in the next section. Those values in Table 1 are then used to determine the strength of the analyzed houses subjected to an earthquake.

Table 1 Wall strength to perform under earthquake load

Wall types	Longit. shear force (kg)	Transv. shear force (kg)	Bending moment (kg.m)
Brick Wall	42	800	240
Brick& Mesh	72	800	240
Brick& Mortar	300	2000	600
Brick& Ferroct.	220	2500	750

3. NUMERICAL SIMULATION

In this section, structural analyses of a typical non-engineered house and a retrofitted house made of ferrocement-brick sandwich material are described. During Padang earthquake on 30 September 2009, many non-engineered houses in the West Sumatra Province suffered from partially (Fig. 6) and totally collapse. This experience must not be happening in the future, thus the existing ordinary brick houses in the West Sumatra need to be retrofitted. The retrofitting model can be performed by using wire mesh and mortar plaster on the houses to present ferrocement-brick sandwich material as the wall. This wall becomes the main structure of the house to subject any forces including seismic loads.

Fig.6 Damaged house due to Padang earthquake

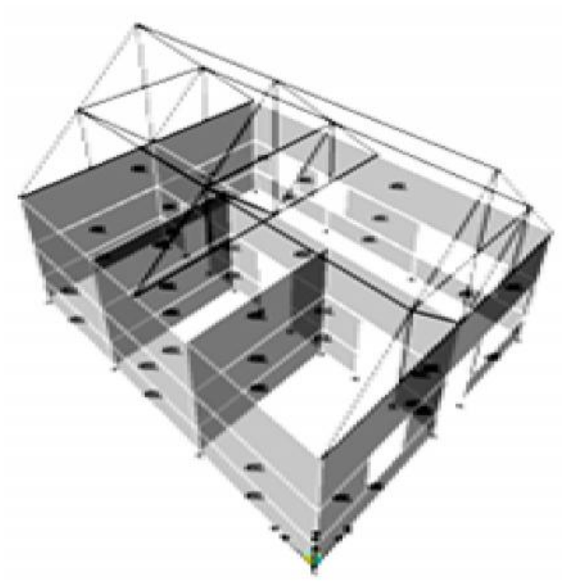


Fig.7 Numerical model of analyzed house

Numerical simulation is a tool can be used to carry out the analysis of houses subjected to an earthquake. Here, the numerical study of a typical house that has experienced the damage due to Padang 2009 earthquake is presented. The simulations are carried out first for a non-engineered house and then for ferrocement-brick sandwich material retrofitted house (Fig. 7). The seismic loads are adopted from Indonesian Code for Padang City in transversal and longitudinal to the front side of the house.

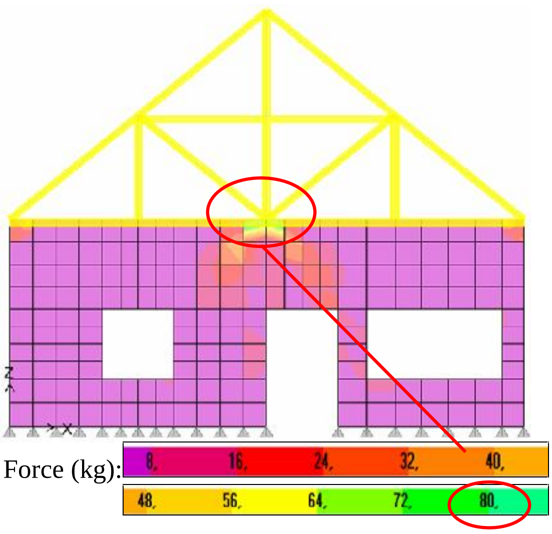


Fig.8 Numerical result for shear forces

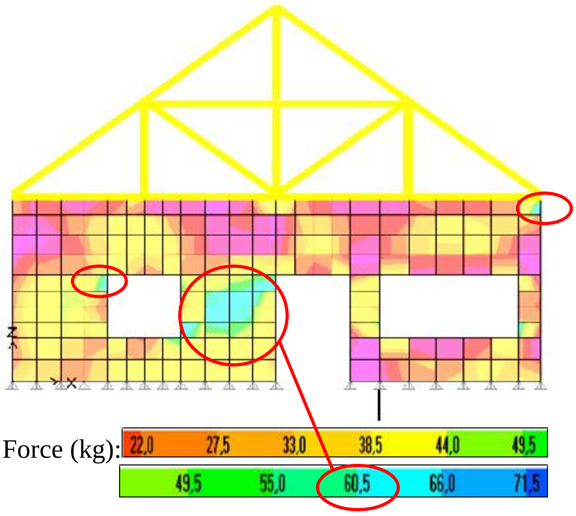


Fig.9 Numerical result in longitudinal shear forces

The simulation results in terms shear forces due to of transversal and longitudinal seismic loads are shown in Fig.8 and Fig.9. In this paper only the internal shear forces on the front side of the house are presented since they have the less strength based on the laboratory tests.

The numerical results are then compared with the results of laboratory testing which are used as strength criteria analyses. The maximum forces acting on the house exceed the strength of ordinary brick wall and this indicates a damage in reality. The internal shear forces due to seismic loads are about 60 kg and 80 kg which are more than 42 kg for the brick wall. Those internal forces are still under the maximum ferrocement-brick wall strength that is 200 kg.

Thus, the ferrocement-brick sandwich material is very useful to build the strength of the ordinary house due to the earthquake. The seismic resistant of houses may increase by applying mortar plaster to the wall, but this way make the wall in a brittle condition which may collapse suddenly during the earthquake.

4. CONCLUSION

Analyses of main structural components of non-engineered buildings have been studied in this paper. The series of tests on that sandwich material has been done. The tests showed that the ferrocement-brick sandwich material can increase the strength up to three times compared to the brick wall. The results are used to determine the strength criteria of the analyzed house. Based on comparison study using numerical results and laboratory tests, the ferrocement-brick sandwich material is very useful to build earthquake strength of ordinary brick houses in seismic prone areas such as the West Sumatra.

5. ACKNOWLEDGEMENTS

Thanks to our students: Mangara, Rido and Siska who have generously involved in this study. Authors also would like to express a special thank to Engineering Faculty of Andalas University in which has provided in publishing budget for this paper.

6. REFERENCES

[1] Hakam A., Fauzan, Ismail F.A. and Istijono B., “Capacity Building of Local Home Builders on Application of Earthquake Safe House for Disaster Risk Reduction”, 4th Annual meeting of Indonesian Disaster Expert Association, will be published in the Proceeding, May 2017, Jakarta

[2] Boen T., et al., “How to Fix Simple Buildings Damaged by Earthquakes” (in Indonesia: Cara Memperbaiki Bangunan Sederhana yang Rusak Akibat Gempa Bumi), Jakarta: Boen Conslt., 2010

[3] DirJen Cipta Karya, Indonesian Code No: 111/Kpts/Ck/1993: “Guidelines for Building Earthquake Resistant Construction” (in Indonesia: Pedoman Pembangunan Bangunan Tahan Gempa), Jakarta 28 September 1993

[4] Imai H., Okubo N., Jamal A.U., Purwoko A., Zahrudin, Hamimie A., Setiyaningsih H., Satyarno I., Manual For Retrofitting Of Brick Masonry Houses For Earthquake Safety: 1st Edition, Jogja, Publisher: Kaliwangi Offset, August 2009

[5] Paramasivam P., “Ferrocement structural applications, 26th Conference On Our World In Concrete & Structures: 27 - 28 August 2001, Singapore, pp. 99-107

[6] Sakthivel P.B. and Jagannathan A., “Fibrous Ferrocement Composite with PVC-coated Weld Mesh and Bar-chip Polyolefin Fibers”, Int. J. of GEOMATE, Dec., 2012, Vol. 3, No. 2 (Sl. No. 6), pp. 381-388

Copyright © Int. J. of GEOMATE. All rights reserved, including the making of copies unless permission is obtained from the copyright proprietors.