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by Jafril Tanjung

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PLASTERED WIRE-MESH BANDAGED: AN EFFECTIVE ALTERNATIVE TECHNIQUE FOR SEISMIC STRENGTHENING OF THE UNCONFINED BRICK MASONRY HOUSING IN PARIAMAN CITY, WEST SUMATERA, INDONESIA

Febrin Anas Ismail
Civil Engineering Department, Engineering Faculty
Andalas University, Padang, 25163, Indonesia

Jafril Tanjung
Civil Engineering Department, Engineering Faculty
Andalas University, Padang, 25163, Indonesia

Abdul Hakam
Civil Engineering Department, Engineering Faculty
Andalas University, Padang, 25163, Indonesia

Fauzan
Civil Engineering Department, Engineering Faculty
Andalas University, Padang, 25163, Indonesia

Teddy Boen
Senior Advisor
World Seismic Safety Initiative

ABSTRACT

In Pariaman city, West Sumatera, INDONESIA, most of the masonry housing are made of unconfined burnt brick masonry walls. As is located in the area with high seismic activity, this type of housing may be suffering significant damage in the event of strong earthquake. Therefore, a strengthening technique of the masonry housing prior to the enactment of current seismic codes plays an important role in the seismic risk mitigation. This paper reports the application program of the plastered wire-mesh bandaged (ferrocement layers) technique for strengthening the unconfined brick masonry house in Pariaman region. The strengthening technique was applied based-on the shaking test results which was conducted by National research Institute for *earth science and Disaster prevention (NIED) and Mie University, Japan. In current proposed technique, the additional pseudo-confinement was pasted to the existing unconfined brick masonry house. Before mortar was plastered, at first, the galvanized wire-mesh sheet had to nailed to selected-position, such that all unconfined brick masonry walls were connected and tied by the plastered wire-mesh bandaged. Application of the strengthening technique to a house in Pariaman City by trained local labor has been shown the effectively of the current technique due to simple it application and cheaper of the construction material price. It seems that the presence technique may be applied to strengthen and/or to retrofit all unconfined brick masonry housing in Pariaman city.*

Keywords: plastered wire-mesh bandaged, unconfined brick masonry housing, seismic mitigation, Pariaman city

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1. INTRODUCTION

Burnt brick masonry is considered as one of the most important housing material in the history mankind. It has been used as the construction material for several hundreds of years in Indonesia. Recently, the reinforced concrete has been frequently used and thus replacing the brick masonry as the structural material. This situation presents almost all new landed-housing are constructed by applied reinforced concrete as the structural material, i.e. in the type of confined brick masonry housing. Unfortunately, particularly remarkable di Pariaman city, about 60 kilometer west-north part of Padang a capital city of West Sumatera Province, the unconfined brick masonry housings are still used and built as the residential, especially in the type of landed-housing as it is shown in Figure1.

Seismic hazard and risk assessments have become an important issue in high seismic-prone such as West coastal of Sumatera Island, especially after the 2004 Aceh-Andaman M9.2 earthquake. Significant risk mitigation efforts have been made in recent years. Preparedness systems against the earthquake hazards need to be improved to reduce the economic and social impact due to future earthquakes. Pariaman city is located in the front of the unruptured segment of the Sumatra subduction as is shown in Figure 2.

Figure 1 Unconfined brick masonry house

In past investigation indicate that Mentawai segment of Sunda subduction may be host of a large earthquake (>M8.5) with a recurrence period of about 200 years. The last major earthquakes in this region were the 1797 and 1833 events, while two recent events, M8.4 and M7.9, occurred near Bengkulu on 12nd and 13rd September 2007 [1]. An earthquake of M7.6 occurred on the Sumatran subduction, right in front of the Pariaman city, on September 30th 2009. This event takes place in a long list of earthquakes occurring in this area, in particular since the mega-thrust earthquake of December 2004 as shown in Figure 2.According to geologists' prediction, a segment about in 300 km long between Nias segment and Bengkulu segment, called seismic gap as is shown in red-shading area in Figure 2, has potentially to trigger big earthquake in near future.

Unconfined brick masonry housing represents a significant portion of the residential house in Pariaman city. The primary disadvantage of these unconfined brick masonry located in active seismic regions is the fact that usually they have been constructed from inhomogeneous material and mainly designed to support vertical loads only. Those houses are particularly vulnerable to seismic actions and therefore susceptible to extreme damage. Their vulnerability is caused by the failure of unconfined the masonry walls due to the in-plane and/or out of plane seismic loading. Field investigation after Sumatera earthquake 2007 by Madiawati and Sanada [2] showed the vulnerability of such kind of brick housing.

In order to overcome the weakness of the brick masonry housing as was mentioned above, indeed, the researchers have been developed several strengthening techniques by using different approaches and materials. These include on the use of Fiber Reinforced Polymer (FRP) sheet, strengthening by using FRP sheet and anchors and strengthening by using Reinforced Plastering Mortar. Different configurations, such as diagonal strips, grids, and entire surface coverage and mostly uses the FRP-based materials, were considered to improve shear behavior of brick masonry as are well-documented [3,4,5,6,7,8,9]. Although overall strength of the brick masonry walls was increased by these strengthening techniques, unfortunately due to the high-price of the materials, difficultly to find in local market, needs special tools and requires a skill and professional applicator, these techniques become not effectively when apply to strengthening the brick masonry house in local area such as Pariaman city. Instead of these techniques, the simple and cheaper of the strengthening technique was recommended, namely the plastered wire-mesh bandaged technique (ferrocement bandaged layers).

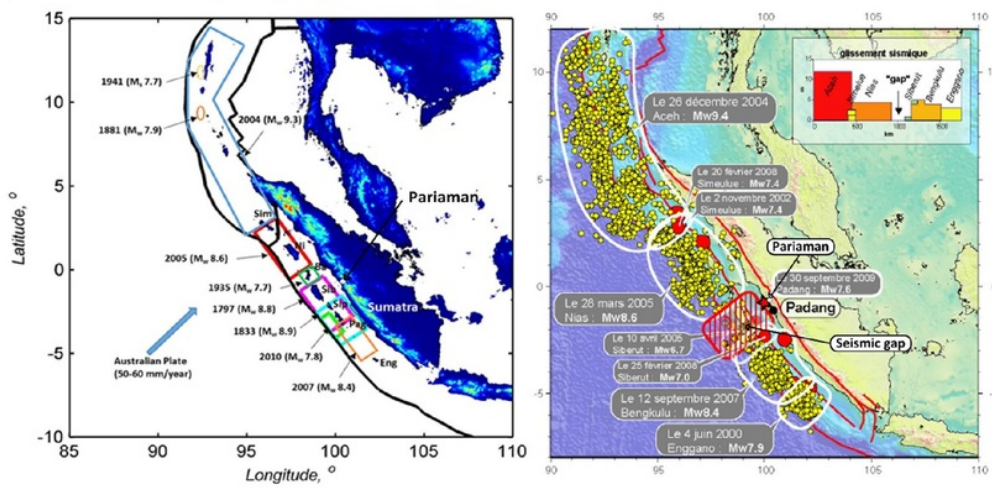
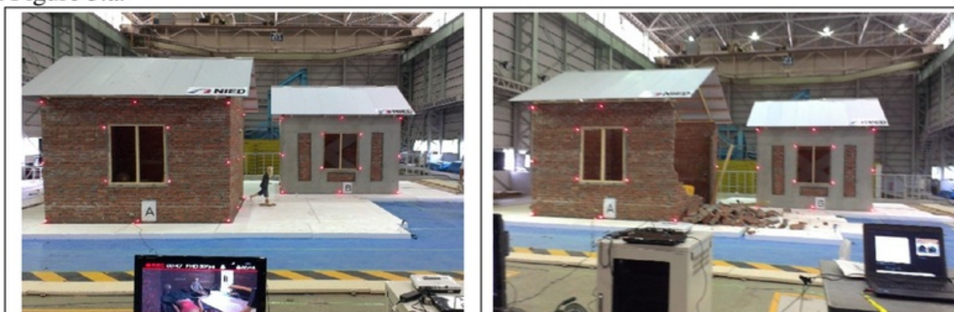


Figure 2 Historical seismic event in Mentawai segment

In this paper, the application program of the usage of the plastered wire-mesh bandaged technique for strengthening an existing unconfined brick masonry house in Pariaman city is reported. Actually, the effects of strengthening unconfined brick house by using this plastered wire-mesh bandaged technique has been experimentally investigated by Boen et.at. [10] through the shaking table test of a full-scale model test of the unconfined brick masonry houses. The experimental results showed that the plastered wire-mesh bandaged layers improved the lateral capacity and reduced the vulnerability of the housing specimens when subjected to the lateral loading. The application program which is reported in this paper was conducted based on the shaking table test results above.

2. REVIEW OF EXPERIMENTAL WORKS

The shaking table test was conducted in National research Institute for earth science and Disaster prevention (NIED) laboratory, Tsukuba, Japan and collaborated with the Mie University, Japan. Two full-scale brick masonry houses were prepared by using imported construction materials from Indonesia, such as burnt brick masonry, galvanized wire-mesh and umbrella-head-roofing-nail. The dimension of housing models was 3.60 m x 3.60 m base and 2.60 m high. One of brick masonry housing model was keep unconfined, while another one was strengthened by applying the plastered wire-mesh bandaged technique as it is shown in Figure 3.a.



(a). The Model Before Tested | (b). The Model After Tested

Figure 3 Shaking table test of brick masonry house

The brick housing models were shaken by recorded JMA Kobe earthquake 1995. As the results, the model of unconfined brick masonry house collapsed by the end of shaking table test, whereas the strengthened model remains survived. The final condition of the models is shown in Figure 3.b. These experimental results demonstrate the effectiveness of the current technique for strengthening the unconfined brick masonry house.

3. STRENGTHENING CONCEPT

The plastered wire-mesh bandaged technique is the strengthening technique that consist application of single or double side of the pasted ferrocement layers at the selected location or area on the brick masonry wall such that the unconfined masonry walls are connected and tied one to others. The selected location are the location of suitable columns and beams in the traditional confined brick masonry housing. The main idea of the current technique, certainly, define the technique instead on difficulty to construct the confinement columns and beams in the existing unconfined brick masonry house. The detailing of this technique is schematically drawn in Figure 4.

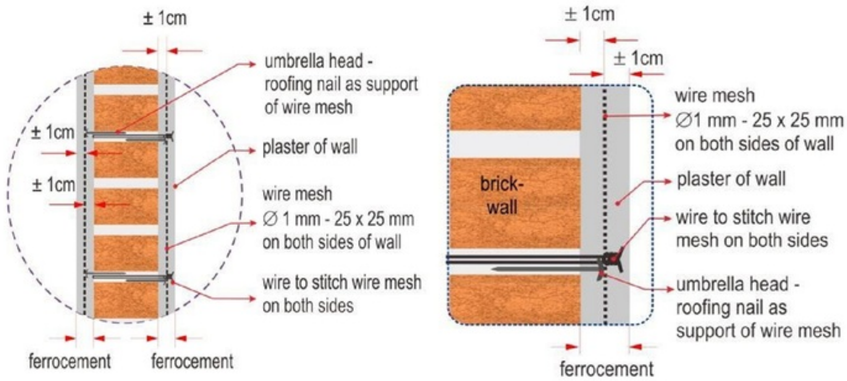


Figure 4 Detail of strengthening technique of the brick masonry [10]

Actually, the strengthening technique mentioned in this paper is adopted from the principle of sandwich structures, i.e. having brick masonry wall as the core and paste covered both sided with the ferrocement layer. The strengthening technique uses 500 mm wide of the ϕ1 mm 25 mm x 25 mm galvanized wire-mesh. The position of the wire-mesh in the cement mortar layer is controlled and supported by umbrella head roofing nail. Finally, the wire is fastened by stitching the wire-mesh to the brick masonry. This ferrocement layers are expected to oppose the shear and tensile strengths which is induced by the lateral forces, such as earthquake. After that, the cement mortar, i.e. a blend of Portland cement and graded sand, is pasted to entire of wire-mesh surface. The reason for choosing the galvanized wire-mesh as the construction material to strengthening the unconfined brick masonry house is the availability of it material in local market and provide in low price and become suitable for the community in low-income in Pariaman city.

4. APPLICATION PROGRAM AND DISCUSSION

The above presented strengthening technique has been applied to strengthen an unconfined brick masonry house in Pariaman city. One of unconfined house was taken as a pilot project. The strengthening works were conducted by local labors. Previously, applicants of the local labors were introduced and trained by the experts from Centre of the Disaster Study, Andalas University about what is and how to apply the current simple strengthening technique as it is show in Figure 5.

Figure 5 Technical Training for the Local Labors in Pariaman City

Figure 6 Detail of attach of the wire-mesh

Figure 6 shows the installed wire-mesh on the brick masonry wall of the unconfined brick masonry house. The sequential work of this strengthening technique was done as follow, nailed the umbrella head-roofing in meshing about 300 mm x 300 mm, leave about 10 mm above the brick's surface, use the head of the umbrella head-roofing as a base of the wire mesh and after that use the steel wire to stitch both sides of the wire mesh. Place the wire mesh in corner, top, and bottom of the brick wall about 300mm-500 mm width as it is shown in Figure 7.

Figure 7 Location of the wire-mesh

Figure 8 Construction and plastering the wire-mesh

Finally, the cement mortar was pasted into installed wire-mesh as it is demonstrated in Figure 8. The technique is quite simple and easy to apply under minimal supervision. Based on the short training to local labors with have experience constructing the traditional housing in Pariaman conclude that these local labors may apply this technique without difficulty. Besides, this innovated technique only requires cheaper and offering in local market in Pariaman city and make this technique effective and valuable for applying to strengthening the existing unconfined brick masonry housing and new construction as well.

5. CONCLUSION

The technique presented in this paper has been successfully applied to strengthen an unconfined brick masonry house in Pariaman city with minimum supervision. The technique quite simple to apply. Short training to local labors whose experience in constructing the traditional housing imply the technique easy to understand even by non-educated local labors. The effectiveness of this technique was demonstrated by the full-scale shaking table test of the unconfined brick masonry houses subjected to recorded JMA Kobe earthquake. One of advantages of this technique is the used construction materials easy to find in local market with reasonable price. Therefore, this technique become useful and valuable for strengthening the housing of the low-income community in Pariaman city.

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