４．Loading Experiments of Non-Engineered Houses in Marikina City, Philippines

（フィリピン・マリキナ市におけるNon-Engineered住宅の水平載荷実験）

和文要約

現在、アジア・太平洋地域の都市部における、多数の耐震基準を満たさないNon-Engineered住宅の存在は、防災上、緊急的に検討しなければならない課題の一つである。特に発展途上国においては、単に過去に建設された住宅の耐震化の問題だけでなく、現在も次々と、これら不良ストックが建設され続けている点にこの問題の深刻さがある。

本研究では、これらNon-Engineered住宅の中でも、庶民住宅として東南アジアから西アジア地域に広く普及しているRCのフレームに壁にブロックを積み上げた構造形式の住宅に焦点をあて、まず、１）その建設の全過程の観察をとおしてNon-Engineered住宅の建設プロセスの中にみられる設計・施工上の問題点の整理を整理するとともに、２）建設作業者へのインタビュー調査をおこない、改良工法普及のスキーマ形成に資する基礎情報の分析をおこなった。次に、３）これら住宅の水平載荷実験をおこない、地震時における破壊プロセスの検討と、建物倒壊という地震災害の経験のない住民に対してデモンストレーションをおこなった。さらに、４）これらの情報をもとに、現地の材料・技術で可能な改良工法を提案し、その工法に基づいて、現地の職人が住宅建設をおこなった。最後に５）この改良工法で建設された住宅の水平載荷実験をおこない、改良効果のデモンストレーションによって、住宅の耐震性確保に対するスキーマの形成を試みた。

これら一連の住宅の建設・実験をとおして、特に建設職人および市役所職員の庶民住宅の地震対策に対する意識に変化が見られた。特に市役所においては、本研究で開発された工法を、庶民住宅向け推奨工法とする事に検討をはじめた。これは、本実験が、地域の災害スキーマ形成支援の一助を担ったといえる。

なお，本研究の一部は，科学技術振興調整費「アジア・太平洋地域に適した地震・津波災害軽減化技術の開発とその体系化に関する研究（研究代表者：亀田弘行　地震防災フロンティア研究センター長)」，および，科学研究費補助金「災害情報の「情報到達度」向上のための戦略の開発（研究代表者：立木茂雄　同志社大学教授)」によるものである。

書誌情報

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Loading Experiments of Non-Engineered Houses in Marikina City, Philippines

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ABSTRACT: The RC frame with masonry wall structure is widely used not only for the residential houses but also for the commercial buildings around the world. In the past such earthquakes in Taiwan, Turkey, and Algeria, this type of structure is proved to be seismically vulnerable to cause a number of causalities due to the collapse of the structure. Since the method for the standardized structural design has not been established yet for this structure, the quality of construction varies from one construction worker to other. This is one of the key factors that this type of structure is still seismically vulnerable for earthquakes. This project is focusing on such structure for improving the quality of construction of the RC frame with masonry wall structure in the City of Marikina, Philippines. At first, this study investigates the current construction method and structural details by constructing two new houses with current construction method by the local construction workers, and the loading experiments are carried out for estimating the seismic capacity of current construction. Then, based on the experiment results, a better construction method is developed to improve their seismic capacity, and the loading experiment is carried out again for demonstrating the effects of the improvement.

KEYWORDS: loading experiment; RC frame with masonry wall structure; earthquake disaster

1. INTRODUCTION

The RC frame with masonry wall structure is widely used not only for the residential houses but also for the commercial buildings around the world. In the past earthquake disasters such as Baguio 1990, Turkey 1999, Taiwan 1999, and Algeria 2003, this type of structure is proved to be seismically vulnerable to cause a number of causalities due to the collapse of the structure. Despite such experiences, the RC frame with masonry wall structures, especially non-engineered housings, keep constructing in the urban area for Asian-Pacific countries.

In the field of international aids and supports to the developing countries, lots of works have been done for the disaster mitigation. However, they are mainly focusing on the engineered structure, not focusing on the non-engineered structure such as adobe, wood, and RC frame with masonry wall structure. Since the method for the standardized structural design has not been developed yet for this structure, the quality of construction varies from one construction worker to other. This is one of the key factors that this type of structure is still seismically vulnerable for earthquakes.

The Objectives of this study are to improve the construction quality of the RC frame with masonry wall structure in the City of Marikina, by

1) identifying the current construction process by the interview to the construction workers and residents

2) investigating the current construction method and structural details by constructing two new houses with current construction method
3) estimating the seismic capacity of current construction by loading experiments
4) developing and disseminating a better construction method to improve their seismic capacity with minimum cost increase and applicable for the local worker's skills and techniques.
5) demonstrating the effects of the improvement through loading experiment

The research field of this project is the resettlement site in the city of Marikina, Philippines, where is the riverbank of the Marikina river. The location and its earthquake thread is shown in Figure 1

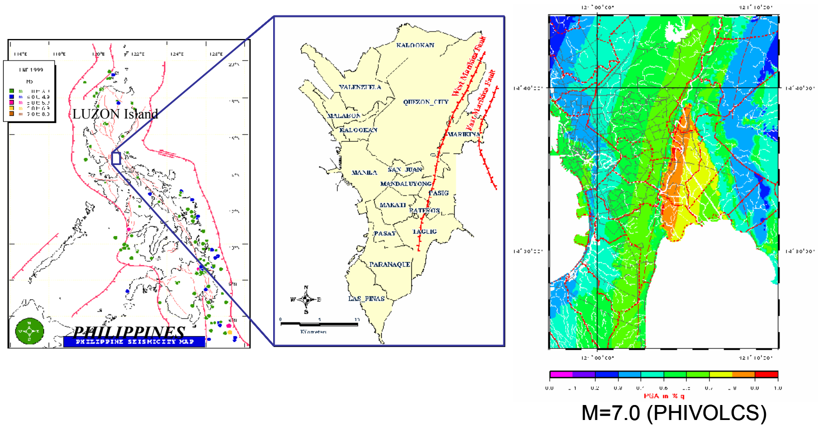

Figure 1. Marikina City and Its Earthquake Thread

The basic size of the house in this area is 3m x 8m, and 2-3 stories RC frame with masonry wall structure as shown in Figure 2.

Figure 2. RC Frame with Masonry Wall Structure in the Resettlement Site of Marikina

2. INTERVIEW SURVEY

The basic model of the housing construction process is shown in Fig. 3. Since it is not clear to us for the relationship of the stakeholders in the process of the housing construction at this site, the interview survey is carried out to the local stakeholders such as engineers, construction workers, residents, etc. as shown in Fig. 4. It is a structured interview using the questionnaire sheet, and takes about 40min per person.

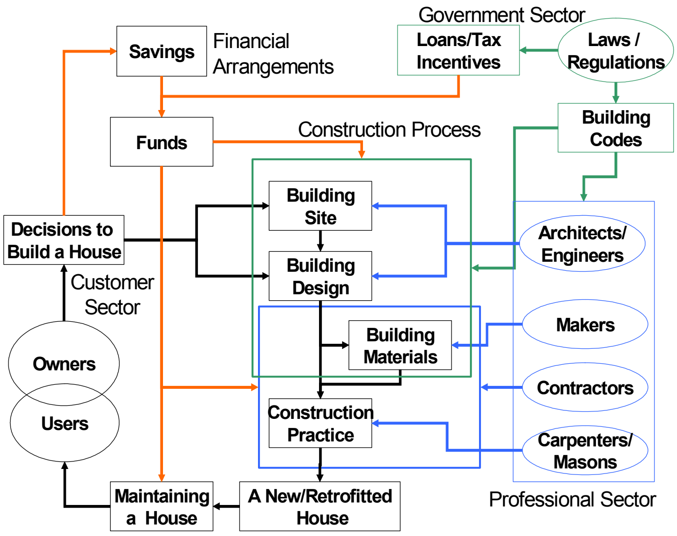

Figure 3. Process of the Housing Construction

Figure 4. Interview Survey

3. CURRENT CONSTRUCTION METHOD AND STRUCTURAL DETAILS

The current construction method and structural details of the RC frame with masonry wall house at this site is investigated by constructing two new houses, which is named House N1 and House N2. They take the same design as an existing house in the site, named House E (Fig. 5), which is about 2 years old and the non-engineered RC frame with masonry wall structure. In addition, House N1 and N2 are constructed by the same foreman as House E. Therefore, House N1 and N2 are expected to have the same structural details and seismic capacity as House E.

The construction for these two houses was started on September 29, and finished on October 31. During the construction, the construction method and structural details are monitored, measured and recorded by the EqTAP researchers (Figs.6-7).

Figure 5. Existing House E

Figure 6. Structural Details and Method of the Construction for House N1 and N2

Figure 7. Construction of House N1 and N2 with Current Construction Method

4. ESTIMATION OF THE SEISMIC CAPACITY

To estimate the seismic capacity of the non-engineered RC houses with the current construction method, the lateral loading experiments are carried out for 3 houses, House E, House N1, and House N2. The experiments are carried out at Camacho and Balubad Resettlement Site in Marikina. The site map and loading direction are shown in Fig. 8.

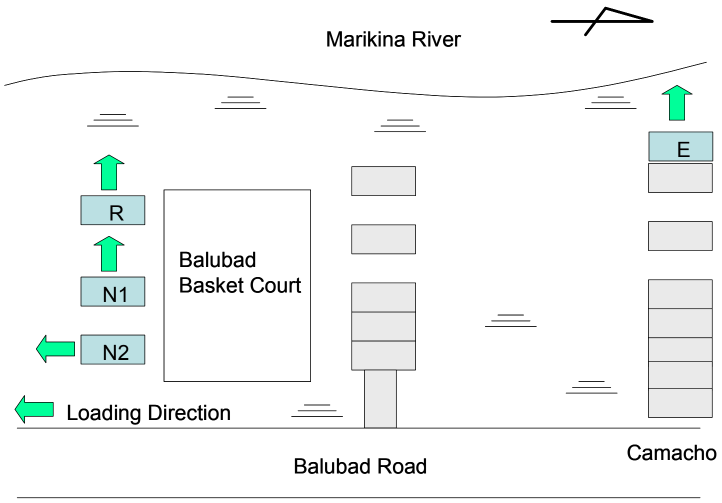

Figure 8. Experiment Site and Loading Direction

The schedule of the experiments is as follows: 1) House E on November 25, 2003, 2) House N2 on December 5, 2003, and 3) House N1 on January 16, 2004.

The loading method is to pull the second floor slab by the jacks as shown in Fig. 9. The applied load and displacement of the second floor are monitored during the experiment. In addition, for House N1, N2, the strain gauges installed on the beam and column rebar are also monitored.

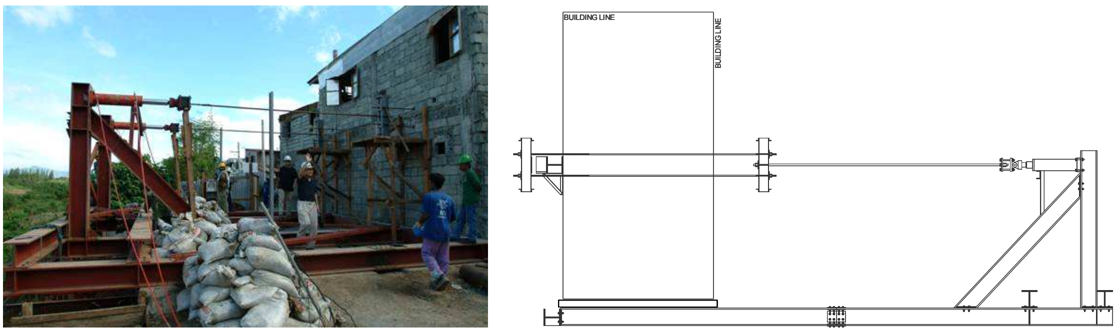

Figure 9. Loading Method

The loading experiment for House E was carried out on November 25, 2003. The preliminary result and P-δ relationship are shown in Fig 10 and Fig. 11, respectively.

Figure 10. Result of the Loading Experiment for House E on 11/25/2003

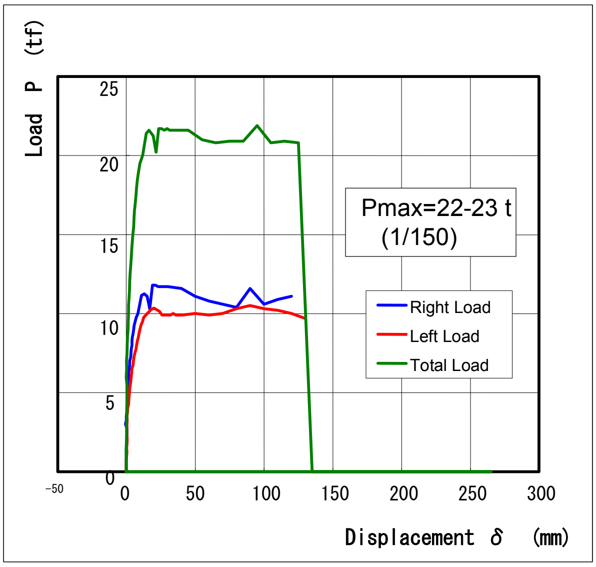

Figure 11. Preliminary P-δ Relationship for House E Experiment

As the result, the maximum load is about 21.6 ton, and its displacement (δ/h) is about 1/150.

5. DEVELOPMENT OF THE IMPROVEMENT

Based on the information obtained from the results of the investigation and experiments, the seismic capacity of the structure is analyzed and the points of improvement are identified. The concept of the improvement is to reinforce the strength of the RC frame of the house with minimum cost increase. The proposed improvements are listed in Table 1.

Table 1. List of Improvements

Item	Part	Current Situation	Improvement
Design	External Wall		Install within beam and column frame
	Beam Starlap	90°hook, @200mm	135°hook, @200mm
	Column Hoop	90°hook, @200mm	135°hook, @100mm
	Anchorage of Column Rebar	insufficient	35d
	Anchorage of Beam Rebar	insufficient	35d
	Rebar Lapping Length	insufficient	40d
	Size of Column	250 x 170	300 x 250
	Size of Beam	B=160	B=180
	Size of CHB	t=100	t=150
Construction	Concrete Mixture	1:3:3	1:2:3
	Joint Mortar for CHB	about	Fill up completely
	Concrete Covering	about	40mm
	Column Concrete Placing	Pouring at once	Placing separately

Although it refers to a wide range of the structural details, the key points of the improvement are as follows;

1) Enlarge the size of the column
2) Increase the strength of the concrete by controlling the concrete mixture and the amount of water
3) Modifying the rebar arrangement for the beam-column joint section
4) Placing the column concrete separately and well compaction
5) Adequate rebar joint lapping length
6) Use 12mm ϕ rebar to minimize the cost increase

These improvements are applied to the construction of a new house named House R. The construction of House R is started on November 28 and finished on December 22. During the construction time, it dose not have any major troubles to apply the improvements.

Figure 12. Construction Process for House R

To demonstrate the effects of the improvements, the loading experiment will be carried out on January 27, 2004.

6. CONCLUDING REMARKS

This paper presents the loading experiment for the non-engineered house at the resettlement site of Marikina City, Philippines. Although the experiment result is still preliminary, the information obtained here is useful for analyzing and upgrading the seismic capacity of the non-engineered RC frame with masonry wall house.

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http://eqtap2.edm.bosai.go.jp/phase2/project/section5/3/