The 5th Sustainable Future for Human Security (SustaiN 2014)

Seismic vulnerability on structural proportion of traditional Javanese wooden houses (Joglo)

Yulianto P. Prihatmaji\textsuperscript{a*}, Akihisa Kitamori\textsuperscript{b}, Kohei Komatsu\textsuperscript{b}

\textsuperscript{a}Department of Architecture, Islamic University of Indonesia, Jalan Kaliurang km 14, Yogyakarta, 55584, Indonesia
\textsuperscript{b}Research Institute for Sustainable Humanosphere, Kyoto University, Gokasho Uji, Kyoto, 611-0011, Japan

Abstract

Due to major recent major earthquake, many traditional Joglo buildings have been damaged. In order to preserve Javanese wooden house against earthquake attack, as tangible culture, an evaluation and improvement of timber structures is indispensable. Joglo is the most complicated and sophisticated roof type in terms of the construction and techniques of Javanese wooden houses. The Joglo use teak wood as the primary construction material for both the building’s structure and the ornaments. The house is use a knock down construction method, using mortise and tenon. Joglo-style for high-class society e.g., sultan place. The Joglo structure consists core and side structure. In term vertical and horizontal direction, they have different proportion and performance against lateral force. Structural proportion has role with seismic vulnerability. Here, investigation of the structural proportions of Javanese wooden house was carried out associated with earthquake structural damages. It shows the level of vulnerability of Joglo buildings against earthquake attack. A total of 29 Joglo buildings were estimated; the estimation can be used for earthquake mitigation in the future. In this paper, we report the results of investigation and objective to verify the contribution of structural proportion to the damage level of Joglo.

© 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Peer-review under responsibility of Sustain Society

Keywords: Seismic vulnerability; structural proportion; traditional Javanese house; wooden house

1. Introduction

In this study, twenty-nine Joglo buildings were observed through purposive random sampling method. Twenty-four Joglos were representing common houses and five Joglos represented royal houses [1]. Four types of damages...
of Javanese wooden house were categorized according to the degree of damage: damage on the base joint, damage on the side-structure, destroyed main structure, and totally collapsed main structure [2]. Figure 1 shows degrees of damages of Javanese wooden houses. The first degree of damage involved broken mortise of columns, and slip between columns and stone foundations. In the second degree, joints between outer ring beam and column deformed or broke, and joints between inner ring beam and rafters broke. In the third degree severe damage on core structure were observed besides second degree of damage. The main structures were totally collapsed including roof structures in the fourth degree [3].

From Figure 1.b. it can be seen that the core structure inclined due to lateral force, but still standing. The condition shows that the joint at core structure is very important and significant to secure human life when earthquake come. Figure 2 shows detail the mortise tenon joint at the core structure of Joglo building.
2. Result and Discussion

Structural proportions of Joglo type are investigated based on the comparisons of structural dimension. Figure 3 shows the subjects of measurement on vertical dimensions on core structure (a) and horizontal dimensions on plan (b) of Joglo house.

From structural proportion as described at Fig. 3, it can be obtain the result of dimension measurement of structural component of thirty-one Joglo houses performed and the proportion of the ratio of structural elements. Fig. 3 in left shows the relationship between the ratios of the main column’s dimension and short span of the core structure and level of damage.

Fig. 4a-b shows a pretty linear relationship between main column dimension (a) and beam height (b), as well as between height of main column (c) and height to center of beam (d).

The later data verify earlier result. This indicates that the carpenter have followed a common rule in construction to determine the dimensional proportion of the joints on the main column and its position in height. The proportion of the joints at the main column is about 1 to 1, and is located at almost 92% of the height of the column. A minor relationship between the ratio of the beam’s height and the short span of the core structure and the levels of damages. There is no apparent relationship between ratio of height-to-beam center and span of side structure and the levels of damage.
Fig. 5 shows a declining tendency, which indicates that the smaller the ratio becomes, the more damaged the structure is. The ratio of the vertical area of the main column and the horizontal area of the core structure could give better correspondence on the level of damage (Fig. 5 in right). Therefore the ratio of the vertical section area (height of the main column) of the main column and horizontal area of core structure is a reliable indicator to estimate the earthquake resistance of Joglo structures. It can be used for self-checking the Joglo structures (e.g. by the owner).

Figure 6 shows vulnerability of Joglo building against earthquake. Vulnerability of Joglo buildings is mainly estimate on second level of damage. From the estimation, the Joglo buildings need some structural improvement to strengthen it against the future earthquake attack.

Note: No. 1, 2, 3 and 4 are types of damage. No. 0 is no damage.
3. Conclusion

The dimensional proportion of the joint at the main column and its position in height follows traditional carpenter’s common rule. A strong relationship exists between the ratio of the vertical section area of the main columns and horizontal area of the core structure and level of damage; the smaller the ratio, the more extensive is the damage.

These samples of earthquake damaged wooden houses verify that structural proportion significantly contributes to simple estimation of earthquake-resistance performance of Joglo buildings. Structural proportion will affect seismic vulnerability. From the estimation, Joglo buildings are most vulnerable at second level damage. Hence, Joglo buildings need some structural reinforcement to counter against future earthquake attacks.

References