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Study on Wind Vulnerability of Non-engineered Houses in Leyte Island, the Philippines

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1. Introduction

The Typhoon Haiyan, locally called Yolanda, struck islands in the Philippines, including Leyte Island, on November 8, 2013. It brought about the significant number of fatality and major damages to infrastructure in those islands. According to the report as of April 3, 2014, by NDRRMC (National Disaster Risk Reduction and Management Council, the Republic of the Philippines), the number of fatality amounts to 6,293, the injury to 28,689, the missing to 1,061, the number of totally damaged buildings to 550,928, partially damaged buildings to 589,404.

Following this event, the team at DPRI, Kyoto University, conducted surveys two times. The first one was conducted between January 23 and 31, 2014, and the second one was conducted between June 23 and 29, 2014. The second survey was conducted together with a team from the University of the Philippines, Diliman. The objectives of the surveys are (1) to observe wind damages to buildings and (2) to collect information of typical buildings in Leyte Island, which were damaged by the typhoon.

The present study investigates, on the basis of these surveys, the wind vulnerability of non-engineered houses in Leyte Island in order to analyze the weak points of this type of buildings, and thereby, to facilitate the proposal of measures in improving their wind-resistant performance.

2. Model building

A residential house located along the east coastline of Leyte island is considered as the model building in the study. It is built by non-experts, who do not rely on engineering knowledge and skills and hereby classified as non-engineered house. The appearance and its details are shown in Fig. 1. Its geometry and employed construction materials are listed in Table 1.

Fig. 1. Model building and its details.

Table 1. Geometry and construction material.

Geometry	
$W \times D \times H$	$4 \times 4.4 \times 3.2[m]$
Construction material	
Roof coverings	Galvanized iron (GI) sheet
Structural components	Coco lumber
Connections	Nail
Upper wall	Coco lumber
Bottom wall	Concrete block

3. Wind-resistant performance assessment

3.1. Failure modes

Having inspected the details of the model building three parts are identified as weak points. These are (a) attachment of GI sheet to roof structure, (b) connection between roof structure and column and (c) connection between column and foundation, see the right photos in Fig 1. For part (a), three failure modes are considered in the following assessment; i.e. (a-1) nail pull-out, (a-2) nail pull-over, (a-3) GI sheet shear tear-out. These are illustrated in Fig. 2.

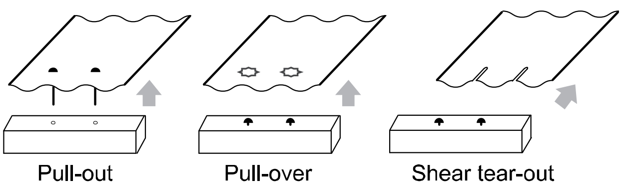

Fig. 2. Three failure modes at attachments of GI sheets to roof structure.

For part (b), one failure mode is considered; i.e. (b-1) failure by shear, see Fig. 3 (left). For part (c), one failure mode is considered; i.e. (c-1) failure by shear, see Fig. 3 (right).

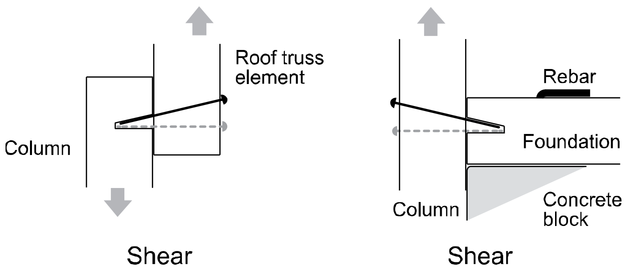

Fig. 3. Failure modes at connections between roof structure and column (left), and between column and foundation (right).

3.2. Models for analysis of failure modes

For the purpose of analyzing the failures identified in the previous section, the three structural models are assumed; one for part of the roof, one for the whole roof and one for the whole structure, see Fig. 4.

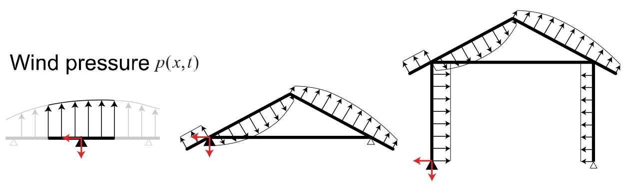

Fig. 4. Structural analysis models for part of roof (left), whole roof (middle) and whole structure (right).

3.3. Experiment for model parameter estimation

The following model parameters, which are required in the analyses in section 3.2, are estimated from wind tunnel experiment and material tests:

- external and internal wind pressure coefficient distribution,
- strengths of the attachment for pull-out and pull-over failures,
- strength of the GI sheet for shear tear-out failure,
- shear forces that the connections can carry.

4. Lizard-tail model for overall performance analysis

A mathematical model for the analysis of the whole structural system is employed, which is called a "lizard-tail" model, see Nishijima (2014). A lizard tail system consists of objects and links. The objects are assumed not to fail and only links can fail. When a link fails, the objects at the upper level are lost, see Fig. 5 (right). The consequences of the failures are evaluated based on the loss of the objects only; i.e. the links are of no value.

The model for the model building within the lizard tail modeling framework is illustrated in Fig. 5 (left). The objects are GI sheet, roof and column (and wall attached to them). The links are attachment of GI sheet to roof, connection between roof and column, and connection between column and foundation. The resistances and the load effects are modeled based on the models for the analysis of failure modes as described in section 3.2.

The overall performance of the model building can then be assessed using the developed lizard tail model. It is capable of computing conditional probabilities of failures at the respective links; hence, conditional risk, as a function of the given wind speed. By combining the output from a hazard model for strong wind (such as annual maximum wind distribution), the unconditional probabilities of failures as well as risk are assessed.

Finally, by utilizing the hazard model and the lizard tail model, the effectiveness of the improvement of each of the components is quantified.

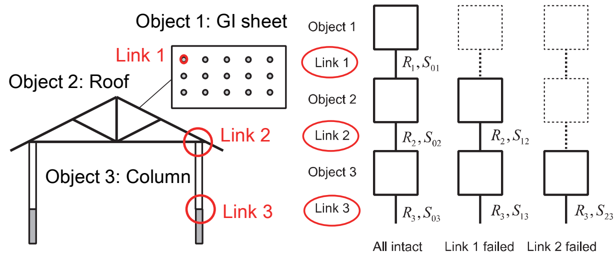

Fig. 5. Modeling of the model building by lizard tail model.

5. Summary

A model for the wind resistant performance of non-engineered house is developed. The model is developed on the basis of the surveys, wind tunnel experiment, material tests and structural analysis. By utilizing the model, the effectiveness of various measures for improving the wind-resistant performance is investigated.

References

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Nishijima, K. (2014). Building Design: Research Relevance, Practical Needs and Unique Development of in Southeast Asia, Proceedings of the 5th International Conference on Science and Engineering.