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# ABSTRACTS (PH D THESIS)

## Investigation of "Joglo" Structure Damaged by Earthquake and Development of Technical Conservation Method for Damaged Structural Members

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A post-earthquake survey and experimental evaluation were performed on Joglo Javanese wooden houses. Aims of study are to preserve Joglo as a tangible culture through study on seismic vulnerability, timber mechanical properties, structural performances and repair-strengthening methods.

### An Investigation of Traditional Javanese Wooden Houses 'Joglo' Damaged During the May 2006 Yogyakarta Earthquake, Indonesia

Investigations on 20 damaged Joglo buildings reveal that the structure's damage can be classified into three categories: slip between columns and stone foundation, broken joints between outer ring beam and column, and collapse of core structure. Four damage levels were defined: I) damage on the base joint of side structure, II) fatal damage on the side-structure, III) destroyed core structure, and IV) totally collapsed core structure. The dimensional proportion of the joint at the main column and its position in height follows traditional carpenter's common rule, while they have nothing to do with the scale of the building in plane. 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 higher the damage is extensive. A distinct relationship was identified between the levels of structural damage and the area ratio of core structure and the main column projection. It was verified that structural proportion significantly contributes to the assessment of damage.

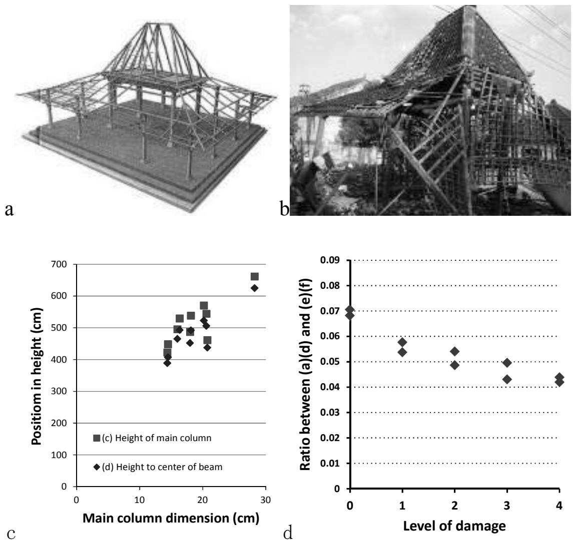



Figure 1. a. Joglo wooden structure; b Joglo damage by earthquake; c. Position in height against main column dimension; d. Ratio between column width/column height and short span/long span of core structure against level of damage.

### In Search of Substitution Material for Traditional Javanese Wooden Houses

Due to preserve beautiful wooden art, lack of big Teak stock, and high price of Teak, searching of substitution material for repairing, reinforce and reconstruction of Joglo by compression test, 3 PB test, 4 PB test and 4 PS test for 9 tropical timbers have been done (Fig. 2.a, b and c). As traditional joint construction use mortise and tenon system, the yield stress at intersection of members is important.

From compression test, all of tropical timber species showed that MOE and Yield stress has strong relationship with densities (Fig. 2d). There were clear tendency that the smaller density indicates the smaller MOE. Acacia, Teak, Ketepeng and Jackfruit has similar trend of increasing MOE and yield stress (Fig. 2.e). From 3 PB test, 4 PB test and 4 PS test, all

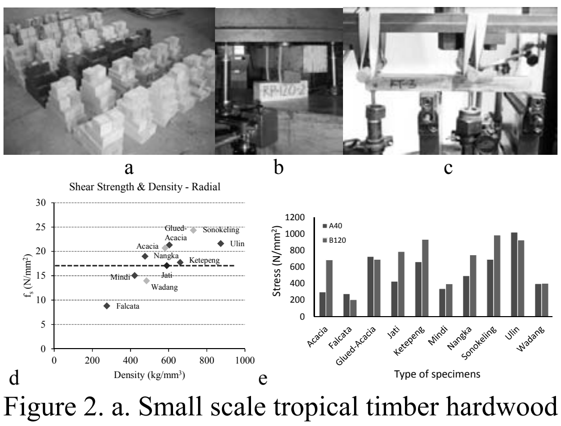



Figure 2. a. Small scale tropical timber hardwood specimens; b. partial compression test; c. 4 PB test; d. Relationship between Shear strength and density; e. Difference of increase ratio among the specimens.

specimen showed that MOE and MOR has no relationship with densities. Shear strength and shear modulus showed quite strong relationship with densities. In terms of shear modulus, Ketepeng, Acacia, Teak and Jackfruit have quite similar mechanical properties. Considering those results, Ketepeng, Acacia, Teak and Jackfruit are considered to substitute Jati (Teak) to be used in Javanese wooden house reconstruction.

**Mechanical Analysis of Rotation Performance of Javanese Traditional Timber Joint**

To confirm the most effective criteria on strength of the building, the static characteristic of these structural components has been investigated experimentally for each joint (Fig. 3.a and b). A total of 12 full-scale specimens made of glued *Acacia-mangium* were tested. The horizontal cyclic load was applied on the specimen placed in pin joint frame from two mutually perpendicular directions. As the test result, columns and beams located in perpendicular to the loading plane have few influences on the rotational property by cyclic loading. Failure modes were caused by embedment, crack, and split in beams parallel to the load direction. From the curve of load and rotational relationship, occurrence of initial slackness leaded to the larger deformation.

The curve of moment-rotational angle relationship between long beam with mortise and long beam with tenon didn't show a significant difference as a result (Fig. 3.c, d, e and f). It indicates that traditional carpenters have chosen a proper ratio of dimension of two-directional joint to achieve uniform structural behavior against lateral force. Assuming the rotation center is located at geometrical center view of each member, the prediction meets fairly good experimental results.

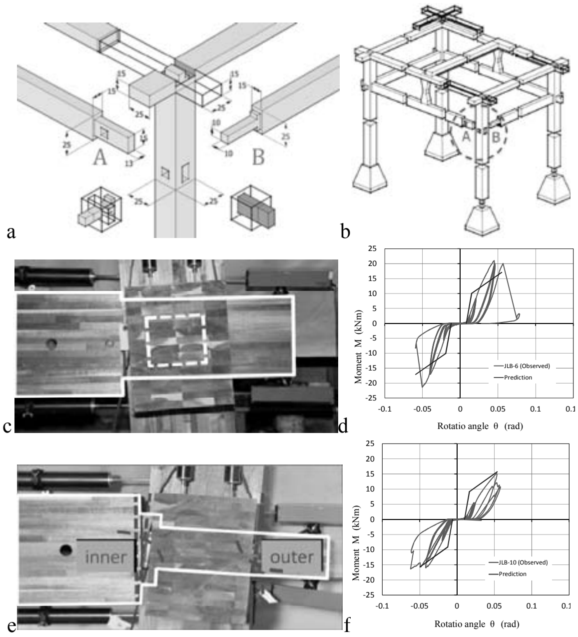
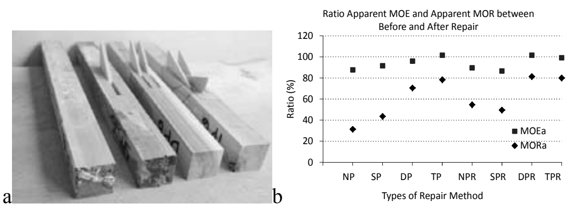



Figure 3. b. Joglo joint construction; b. Core structure of Joglo; c and d. Joint detail type A and it's curve deformation; e and f. Joint detail type B and it's curve deformation.

**Repair Technique of Damaged Timber Beam by Insertion of Compressed Wood Plate and Adhesive-Vacuumed Method**

To provide an appropriate technical conservation method for damaged structural members, we purpose repair technique by insertion of compressed wood plate and adhesive-vacuumed method (Fig.4.a). There was relationship between strength of Falcata compressed wood (FCW) and their compression ratio. Bigger compress ratio of FCW leads higher strength. Vacuumed method shows the highest recovery ratio of apparent MOE and MOR. Insertion of FCW plate increased the $P_{max}$ and the stiffness. Application of triple compressed wood plate insertion cover 83 % of original strength (Fig.4.b).




NP: no plate, SP: single plate, DP: double plate, TP: triple plate, R: re-bending action

Figure 4. a. Repair technique by insertion of FCW; b. Comparison ratio apparent MOE and apparent MOR between before and after repair among repair methods applied.

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