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Rotation Performance of Javanese Traditional Timber Joint

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Abstract

Many Javanese traditional timber structures have been destroyed by major earthquake. A lot of them tend to be dismantled due to a high cost of reconstruction and a demand for more reliable structures. In order to preserve this disappearing building as valuable and tangible culture, a deeper understanding on these traditional timber structures is necessary. Especially the restoring force of the traditional joints, which are the major earthquake-resisting elements has to be investigated. The static characteristic of these structural components has been investigated experimentally. A total of 12 full-scale specimens of 2 types made from glued Acacia-mangium were tested. The specimen simulated joint at middle part, which is a joint of column-tie beams interlocked each other. The horizontal cyclic load was applied on the specimen placed in pin joint frame from two mutually perpendicular directions. The cyclic loading protocol consists of 7 increasing target deformations from 1/200 radian to 1/15 radian, and finally until failure. As the test result, failures were caused by embedment, crack, and split in beams parallel to the load direction. All crack of beam started from corner of beam mortise and resulted in the split. From the curve of load and rotational relationship, occurrence of initial slip leaded to the larger deformation. It revealed the importance of joint tightness against future earthquake.

Keywords: Javanese wooden structure, traditional timber join, rotation performance

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1. Introduction

The recent earthquakes inflicted massive damage to build environment in Java, Indonesia. Especially many Javanese traditional timber structures have been destroyed, as shown in Figure 1-a), b) and 2. Many of them tend to be dismantled due to a high cost of reconstruction and a demand for more reliable structures [1].

![Fig. 1 (a) Damage types of Javanese wooden houses by earthquake, (b) Damage types on the joint](image)

Figure 2 shows four columns are severely inclined but still standing and it will be secure the human life. Hence, it is the role of joints is very important and significant. Safeguarding and conserving Javanese timber structures and its construction techniques mean preservation of the rich historic and cultural values of Javanese culture [2]. Conservation efforts are very important, especially for the next generation, so that they can understand and appreciate the origin of their history and culture.

![Fig. 2 Status of core structures by earthquake](image)

In order to preserve these disappearing buildings, a deeper understanding on their structural behavior is necessary. Especially the restoring force of the traditional joints has to be investigated. This is because the load-carrying property of a complicated traditional join based on interlocking of members made of hardwood has not clarified very well although they are the major earthquake-resisting elements.
2. Material and method

A total of 12 full-scale specimens of 2 types of joints made of glued *Acacia-mangium* (200x200x250 mm for beam and 250x250x250 mm for column) were tested. The specimens simulated a joint in different directions at middle part of Javanese wooden core structure as shown in Figure 3.(a) and (b), which is a joint of column-tie beams interlocked each other(type-A in x direction and B in y direction).

The first type specimen (A) was named as JLB-1 to 6, a beam with broad tenon with a mortise at the middle, and the second type specimen (B) was named as JLB-7 to 12, a beam with narrow tenon which penetrates type-A in the joint. Figure 3 shows dimensions of specimen. Specimens consist of three mutually perpendicular members; column, beam and short beam. The short beam was simply inserted into the joint without any restraint to correspond the actual situation.

Figures 4.(a) and (b) show test set-up of traditional beam-column join specimen which represents a joint placed upside-down. The horizontal static push and pull cyclic load were applied on the specimen supported in pin joint frame from two mutually perpendicular directions by controlling oil jack movement. The cyclic loading protocol consists of 7 increasing target deformations to give apparent rotation angles of 1/200, 1/150, 1/100, 1/50, 1/30 and 1/15rad respectively, and finally until failure. In each cyclic loop, three cycles loading were applied.
3. Result and discussions

3.1. Failure modes

Figure 5 shows condition of short beams after test, which is beam located perpendicular to the loading plane in test process. In this figure, all of short beam has no significant damage by cyclic loading. It can be said that short beam gives few influence on the rotational behavior. Figure 6 shows the status of the beam of type-A after the loading test.

Failures were caused by embedment, crack, and split on beams parallel to the load direction. All crack of beam started from corner of beam mortise and resulted in the split. Figure 7 shows the failure modes in long beam with tenon caused by embedment and split in beams parallel to the load direction (bending failure). All split of beam is started from corner of edge cutting. Figure 8 shows the condition of column after test. In this figure, all of column has no significant damage by cyclic loading.
Figure 9 shows specimens type-A and B in maximum loading at deformation of 1/15 radian. The different amount of deformation angle was observed between those at inner and outer side of the frame. This was due to the deformation of beam inside of the joint.

3.2. Moment-Rotational Angle Relationship

3.2.1. Initial slackness

Hereafter, the moment-rotation relationships will be discussed using their skeleton curves. In general, the moment-rotation relationships showed large initial slackness due to insufficient tightness of the joint. In order to evaluate their fundamental behavior, the influences of initial slackness were eliminated so that curves start from origin. Figure 10 indicates how to treat initial slackness becoming appropriate curve [3]. From these curves of moment and rotational relationship, occurrence of initial slip leaded to the larger deformation. It revealed the importance of joint tightness.

3.2.2. Skeleton curve

Figures 11 and 12 show the moment-rotational angle relationship of specimens type-A (JLB1-6) and type-B (JLB 7-12) respectively.
From these figures, it can be seen that type-A and B has quite small variation between them especially in terms of stiffness. Figure 13 shows comparison of average curves between type-A and B.

As it is seen in this figure, the moment-rotational angle relationships of long beam with mortise and long beam with tenon were not significantly different though Type-B showed about 14% smaller value than type-A. It indicates that both of beam in parallel in load direction are quite equal.

3.2.3. Inside beam deformation

Figures 14 and 15 show the comparison of the result taken from inner side of the frame with that taken from outer side. In both type, the inner side deformation showed much larger value than outer side deformation at the same moment level. This indicates the deformation of beam in bending and shearing inside of the joint except the deformation caused by embedment. On the other hand, it can be seen the difference of component of deformation...
inside of the joint between directions, i.e. the inside beam deformation give much larger influence on type-B than type-A.

Figure 14 shows the comparison of the ratio of inside beam deformation between type-A and Type-B has almost twice ratio of deformation than type-A. It can be said that type-A has influence of embedment bigger than type-B. The influence of bending type-A is smaller than type-B.

3.2.4. Other expected factors to be evaluated

Javanese timber structures have been built by using typical timber character traits integrated together. Thick column and beam, joins of column-tie beam and bracket complexes are typical examples of the character traits, and are the most important structural elements. When the structures deformed by earthquake, embedment in join occurs, and generates force moments to all jointing component.

4. Conclusions

Results presented in this paper are the initial findings of an on-going investigation on the evaluation of Javanese traditional beam-column join. Main findings from the work may be summarized as follows:

- Columns and beams located in perpendicular to the loading plane, have few influence of the rotational property by cyclic loading.
• Failure modes for long beam with mortise were caused by embedment, crack, and split in beams parallel to the load direction. All crack of beam started from corner of beam mortise and resulted in the split.
• Failure modes for long beam with tenon were caused by embedment and bending of beams. Bending failure started from corner of cutting edge.
• Initial slackness leaded to the larger deformation. It revealed the importance of join tightness.
• 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, even though the deformation mechanism inside of the joint showed a large difference. It indicates that traditional carpenters have chosen a proper ratio of dimension of two-directional join to achieve uniform structural behavior against lateral force.

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References