Experimental research on the opening frames with bamboo sheets under horizontal loads

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Abstract

The center support frame structure and the open center support frame structure were designed and manufactured with bamboo paper as the raw material. The performance difference between the central support frame and the open center support frame was studied by means of comparative analysis. The horizontal loading test was carried out, and the displacement of the model during the loading process was measured using a total station. The test results show that the ductility and bearing capacity of the structure will increase after the opening of the web. The structure of the open-cell support frame can improve the ductility of the structure to some extent and improve the bearing capacity of the structure.

Keywords

Frame structure; central support; bamboo paper; horizontal load; opening.

1. Introduction

Frame-brace system is an important dual lateral resistance system, which is widely used in practical engineering. According to the different types and settings of supporting members, braced frames can be divided into central braced frames and eccentrically braced frames[1]. Eccentrically braced frame can keep the structure in elasticity in moderate earthquakes, and the stiffness is large, energy-dissipating beam section can absorb most of the seismic energy, the structure has good ductility, but its joint area is complex, construction is difficult, the overall beauty of the building is poor, the bracing arrangement will also affect the layout of doors, windows and openings, and play a negative role in the overall layout of the building. The central braced structure has the characteristics of large lateral stiffness, simple structure, small horizontal displacement and scientific internal force distribution. However, under rare earthquake, the bearing capacity of braced inclined bars will decrease sharply after repeated compressive buckling, which will lead to serious degradation of floor shear capacity and lateral stiffness. At the same time, the low cycle fatigue cracking caused by local buckling of plates will cause the bracing to withdraw prematurely. In order to prevent the serious consequences of the buckling of the central brace under compression, it is proposed to open the brace to make the section yield before the whole buckling of the member[2].

In this paper, bamboo paper is used as raw material, and the unbroken and perforated central bracing frames are manufactured respectively. Horizontal loading tests are carried out to compare and analyze the mechanical properties and failure modes of the models.

2. Test scheme

2.1 Model Design and Making

The three-storey central braced frame structure model shown in Fig. 1 is used in the test, with a storey height of 23 cm and a span of 40 cm. All connections are rigid, the column is box-shaped section, the beam is I-shaped section, supporting I-shaped section, the opening position of the hole support is located on the web of I-shaped support, and a rectangular hole is opened in the middle of the web. The section size is shown in Table 1.

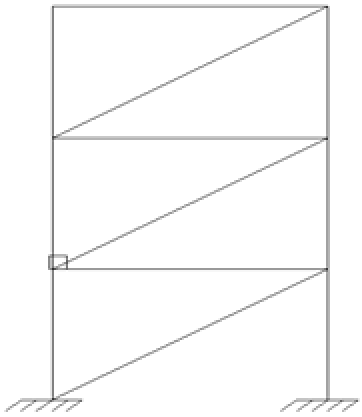
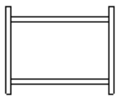
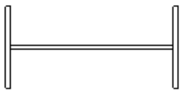


Figure 1 the three-storey central braced frame structure model

Table 1 Section Size of Component

component	Section pattern	section size
column		flange web 18㎜×1㎜ 1㎜×18㎜
beam		flange web 15㎜×1㎜ 0.85㎜×30
brace		flange web 10㎜×0.85㎜ 20㎜×0.85㎜

Components are made of bamboo paper and their material properties are shown in Table 2. 502 glue is used to bond the components, evenly and symmetrically wipe the surface, and dry them to ensure the bonding strength. The support and the main structure are connected by a joint plate. In order to ensure "strong nodes, weak components"[3], 502 glue mixed bamboo paper debris was used to strengthen the connection at the joints.

Table 2 Performance parameters of bamboo paper

density （g/cm^3）	Modulus of elasticity (GPa)	Ultimate tensile strength （N/mm2）	Ultimate compressive strength（N/mm2）
0.8	10	60	30

2.2 Loading scheme design

2.2.1 Test device

In this paper, a loading device is designed as shown in Fig. 2. The model and weight are connected by rope and fixed pulley, and the vertical load is transformed into horizontal load by fixed pulley. The whole model is bonded to the flat solid wood board, and the column foot is connected with the board by the structure similar to boot beam to ensure that the column foot has sufficient bonding strength and prevent the whole collapse caused by the destruction of the column foot. A steel tripod is placed on one side of the model, and a pulley is suspended in the center of the tripod. On the other side, KTS-482Rm total station is used to measure the lateral displacement of the top of the frame. The displacement is determined by calculating the change of two horizontal distances after the first stage loading.

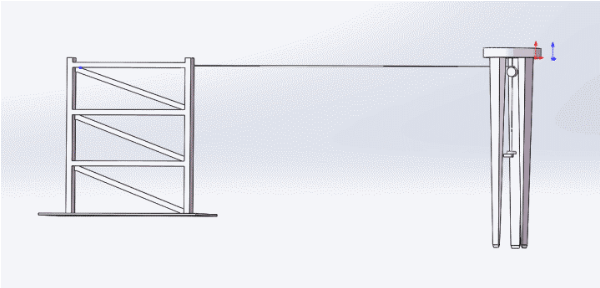


Figure 2 the loading device

2.2.2 Load exertion mode

The structure is loaded by stages, and the duration of each stage is 30s[3]. When the structure begins to fail, in order to approach the ultimate load of the structure failure, the load of each level will be reduced appropriately. It is easy to observe the deformation of the brace and the change of the displacement of the top floor of the frame. Hierarchical loading steps are shown in Table 3.

Table 3 Hierarchical loading steps

step	Weight quality/kg
1	2.55
2	2.55
3	2.55
4	1.275
5	1.275
6	1.275
7	0.319
8	0.319
9	0.319
10	0.319

3. Test results and analysis

3.1 Loading experiment of central braced frame structure (without opening)

A model has been made in this group of experiments. The experimental results are shown in Fig. 3.

When the first loading step is completed, the braces buckle locally; when the second and third loading steps are completed, the braces do not change significantly except the local buckling; when the fourth loading step is completed, the braces begin to buckle integrally, leading to the decrease of the overall lateral stiffness of the structure. When the sixth loading step is completed, the whole central braced frame is destroyed.

When the structure is damaged, the load is 11.794 kg and the top displacement is 9 mm.

From the analysis of the above experimental phenomena, it can be seen that once the brace deforms, it will quickly break down brittle. The failure form of brace is overall buckling and withdraws from work immediately. Only the frame bears the load, which leads to the rapid reduction of the overall lateral stiffness of the structure and immediate damage[4].

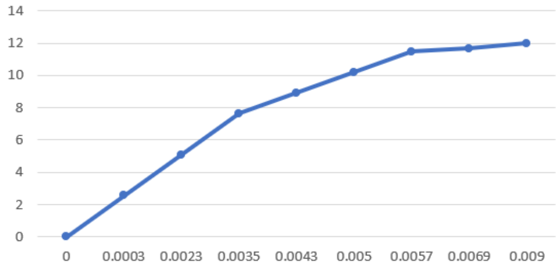


Fig. 3 General central braced frame structure

3.2 Loading experiment of frame structure with central support with openings (the area of openings is 4mm*20mm)

In the first three loading steps, there is no obvious change around the opening. It is noteworthy that visible deformation begins to occur around the opening of the supporting member in the third loading step. When the structure enters the fourth loading step, obvious local buckling occurs at the opening. When entering the eighth to ninth loading step, the braces overall buckle and the whole frame is destroyed.

When the structure is damaged, the load is 12.432kg and the top displacement is 13.1mm.

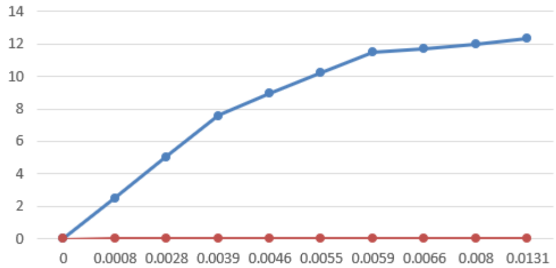


Fig. 4 Load-displacement curve of frame structures with openings and centrally braced frames

From the above experimental phenomena analysis: after opening the brace, the first failure occurs at the opening, and ultimately the brace buckling failure occurs as a whole. However, the ultimate bearing capacity of the structure with opening is slightly higher than that of the structure without opening.

3.3 Loading experiment of frame structure with central support (opening area is 3mm*20mm)

The loading and failure process of the model after changing the opening area is similar to the experiment 2.2, so there is no need to complain about it. The load-displacement curve of the model is shown in the figure 5.

When the structure is damaged, the load is 12.751 kg and the top displacement is 13.1 mm.

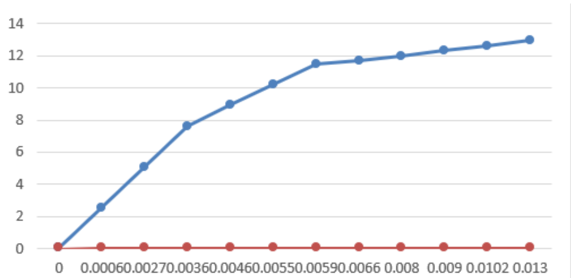


Fig. 4 Load-displacement curves of open-hole central braced frame (Model 2)

From the above experiments, it can be seen that when the area of opening decreases, the bearing capacity of the structure increases and the ultimate displacement of the top story remains unchanged.

4. Conclusion and prospect

From the above results, it can be concluded that:

The ultimate bearing capacity of the model with the opening area of 3mm*20mm is the largest, followed by the model with the opening area of 4mm*20mm, and the model without opening is the smallest. The reason is that when the support openings are made, the structure will enter the elastic-plastic stage to a certain extent, thus improving the ultimate bearing capacity of the structure.

From the top displacement point of view, in the early stage of loading, the structure is in the elastic stage, the displacement difference is not big, but the ultimate displacement of the structure is still different. The ultimate displacement of the structure with the opening area of 4mm*20mm and 3mm*20mm is the same, and the smallest without opening. The reason is that the opening ratio of the experimental support is very small, which has little influence on the overall stiffness of the structure. Therefore, when the loading weight is the same in the early stage, the top displacement of the structure is not different. However, with the increase of load, the support with the opening will yield, so that the elastic-plastic deformation accumulation of the whole structure increases, which ultimately leads to the increase of the top displacement.

In terms of the time from buckling of the support to failure of the whole structure, the longest supporting time is 3mm*20mm, the second is 4mm*20mm, and the smallest is unopened. It can be seen that the opening can increase the ductility of the structure.

It is concluded that opening the support of the central braced frame system can prevent the premature instability of the braced members in the braced frame system, and improve the ductility and ultimate bearing capacity of the structure.

In this experiment, there are still two shortcomings:

In the process of opening support experiment, yielding occurs very early around the opening. The reason is that the opening is rectangular and the stress concentration is formed at the tip of the hole. To avoid this phenomenon, the elliptical opening can be changed.

In this paper, only two model experiments with different openings are carried out, which can not quantitatively explain the influence of the openings on the bearing capacity and ductility of the structure. It is suggested that more experimental comparisons of the openings can be made.

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