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Experimental study on hysteretic behavior of aluminum alloy gusset joints

Xiaonong Guo, Shaojun Zhu*, Xian Liu, Linlin Liu

College of Civil Engineering, Tongji University, Shanghai 200092, China

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ABSTRACT

This paper presents the hysteretic behavior of aluminum alloy gusset (AAG) joints by means of experimental study. Eight AAG joint specimens are tested under cyclic load. Initially, the test program is introduced, and the test phenomena and failure modes are demonstrated. Subsequently, the hysteresis curves, skeleton curves of the specimens are plotted and discussed. The experimental results reveal that there are two kinds of failure modes of AAG joints under cyclic load. The deformation process and mechanical behavior under cyclic load can be summarized into four stages and five phases, respectively. Finally, based on the hysteresis curves and skeleton curves, the deformation ability, energy dissipation capacity, bearing capacity and stiffness degradation of the AAG joint specimens are evaluated, and the following conclusions can be drawn: (1) due to the existence of the gap between the bolt hole and the bolt shank, AAG joint specimens experienced bolt slipping during the experiment, hence the hysteresis loops of the AAG joint specimens are not very plump; (2) judged by the load-displacement hysteresis curves, the AAG joint has good deformation ability but poor overall energy dissipation capacity, which can be further improved; (3) the moment-relative rotation hysteresis curves are plumper than the load-displacement hysteresis curves, indicating that the joint zone has better energy dissipation capacity than the whole specimen; (4) with the increase of the thickness of the gusset plate, the AAG joint performs better hysteretic behavior including bearing capacity, deformation ability and energy dissipation capacity; (5) all of the specimen performed stiffness degradation under cyclic loading.

1. Introduction

Nowadays, single layer reticulated shells made up of aluminum alloy are becoming increasingly favored in spatial structures, owing to their lightness, high strength and ease of construction. Gusset joint is the most common joint system in aluminum alloy reticulated shells, which can avoid the strength reduction caused by welding [1]. It is essential for load transfer and its internal forces are complicated, hence much attention has been paid to its hysteretic behavior in various structural types [2–4]. As a key component of aluminum alloy reticulated shells, the hysteretic behavior of aluminum alloy gusset (AAG) joints urgently needs to be investigated, because it is directly linked to the safety of the whole structure under exceptional loading conditions like severe earthquakes.

Researches on typical aluminum alloy joints, such as bean-to-column joints [5,6], T-stub joints [7–9], ball joints [10,11], and gusset joints [12–14], have already been conducted to investigate their static behavior, including the bearing capacity and the bending stiffness, by means of experimental and numerical analysis. Based on these studies, researches on the behavior of aluminum alloy structures were carried out [15–19], and it was found that the bending stiffness of the joint will greatly influence the overall static behavior of the structure. However, compared with the abundant research findings on the static behavior of aluminum alloy joints, study on their hysteretic behavior has just started, and the productions are limited. Only Xu [20] carried out an experiment on 1 AAG joint specimen. The hysteretic curve of the joint was stable but not very plump, while no stiffness degradation of the hysteretic curves was observed. It was concluded that the joint is able to play a role in energy dissipation, evaluated by the hysteretic curve, ductility ratio and the energy dissipation ratio. However, in order to apply the cyclic load, Ref. [20] attached two large steel plates to the aluminum alloy gusset plates, which would bring extra stiffness to the joint zone. This problem could influence the results of the experiment to a certain degree. Besides, the number of specimens was limited.

On the other hand, the hysteretic behavior of typical steel connections has been studied by many scholars. For moment connections, Tsai [21] conducted cyclic loading tests on 3 extended endplate joints. The test results revealed that stiffening the beam flanges and increasing the bolt strengths can improve the ductility of the joint, and the failure modes are turned into buckling of the flange or the web. As for semi-rigid connections, Azizinamini [22] investigated the cyclic behavior of semi-rigid beam-to-column joints under cyclic load by means of

* Corresponding author.
E-mail address: zhushaojun@tongji.edu.cn (S. Zhu).

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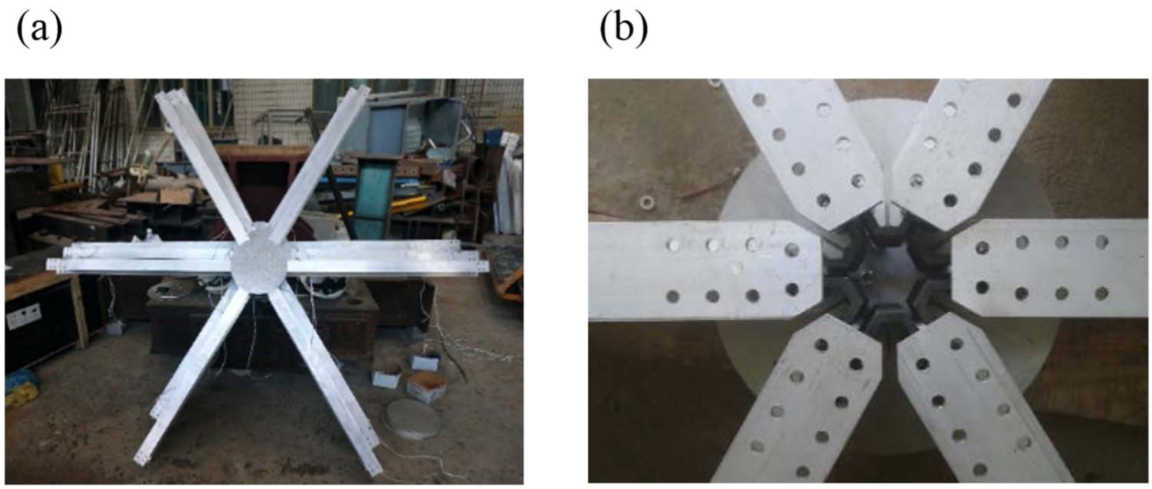

Fig. 1. AAG joint specimens. (a) Configuration. (b) Specimens with shear connectors.

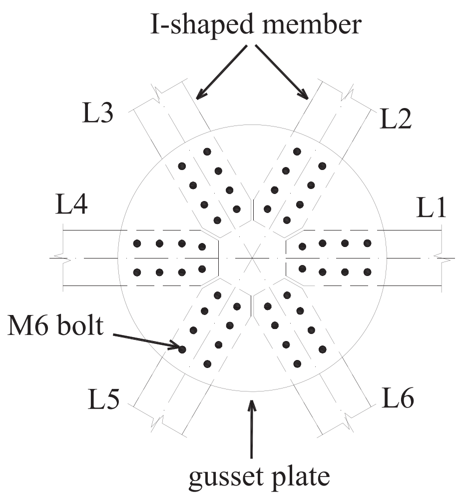

Fig. 2. Labelling of the members.

experimental study, and the formulae to estimate the cumulative damage in variable amplitude loading were proposed. Bernuzzi [23] highlighted that the cyclic response of semi-rigid connections is quite satisfactory in terms of stiffness, strength and rotational ductility, and a mathematical expression to approximate the deterioration of flush end plate connections was proposed. Through hysteretic experimental results of semi-rigid double web angle steel connections, Abolmaali [24] summarized two kinds of failure modes of the specimens, i.e. yielding of the angle and bearing failure of beam web. Pinching phenomenon was observed in the experimental hysteretic curves, and it was concluded that the overall behavior proved the energy dissipation capability of the connection. From aforementioned researches, it can be concluded that the failure modes and energy dissipation capacity of the joints were the focuses of the researchers, and semi-rigid steel joints presented quite good seismic performance. Besides typical steel connections, steel gusset connections are also introduced in concentrically braced frames (CBFs) in seismic design. In addition to tensile yielding and compressive buckling of a brace, many researches on the hysteretic behavior of CBFs [25–27] reveal that the out-of-plane deformation of gusset plates can also participate in dissipating energy. Therefore, a deeper research is

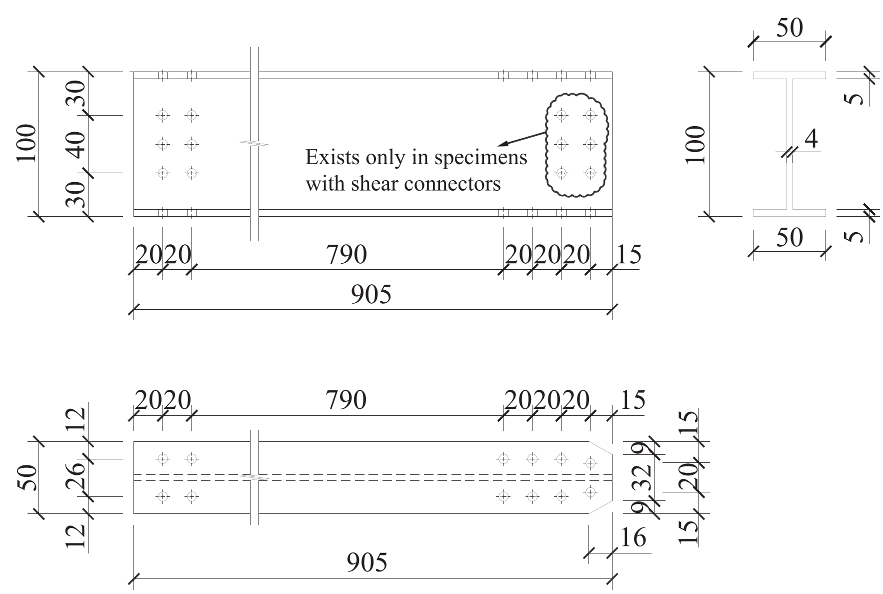

Fig. 3. Detailed information of the members.