Literature Review of Shear Performance of Light-weight Steel Framing Wall Panels

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Abstract. In this paper, a comprehensive review of light-weight steel framing wall panels was carried out. The structure and force characteristics of light-weight steel framing wall panels were introduced. The testing and theoretical research results on the shear behaviour of light-weight steel framing wall panels were summarized in the domestic and foreign. And combined with the existing standards in China, the author's views and ideas are put forward to the problems in the research field of this kind of structural system.

1. Introduction
Light-weight steel framing structures have many advantages, including light weight structure, saving material, environmental protection, being conducive to the housing industry, good comprehensive economic benefits, good seismic performance advantages [1]. In recent years, the system developed rapidly in the international. And in developed countries and regions, the system has been extensive application in low-rise steel structure residential system.

The light-weight steel framing residential structure is a late-model housing with light-weight steel framing structures steel members, light-weight slab, for instance gypsum wall board (GWB), oriented particle board (OSB) as a load-weighting and protecting structure. This class housing system conforms to our country's strategic policy that constructs the economical society and achieves the sustainable development. Although there are still many constraints, but with the economic and social development and with the change of people's concept, the house will have a very broad application prospects. Therefore, it is great practical significance to speed up the study of cold-formed steel structure.

2. The Constitution of Light-weight Steel Framing Wall Panels
Light-weight steel framing wall panels is the main part of light-weight steel framing architecture residential. Light-weight steel framing wall panels is composite building parts that is composed with light-weight steel framing components of wall frame (Fig.1), and filled with insulation and sound insulation materials, and covered by the composite panel. It can be applied with main walls or non-main walls. It also can be used as low-rise buildings inside and outside the load-bearing walls, as well as the general building of the light-weight external walls and indoor partitions [2].

Light-weight steel framing wall panels is mainly composed of top track, bottom track, stud, wall panels, plate strip, K-strap bracing, noggin and other components (Fig.2). As the main force of the shear wall components, stud can be used in a variety of cross-section of the light-weight steel framing, for instance channels, crimping channels, angle, hat shape, I-shaped. Top track and bottom track are generally U-shaped light-weight steel framing section girders. Different materials could be used in wall panels, such as profiled steel sheet, OSB board, plywood, gypsum board, fiber cement plate,
calcium silicate board, etc., and it need connect to steel frame through the screw. Top track, the bottom track and stud connect through the tapping screw, and the side stud which withstands the larger vertical load often used double column with back to back. In the bottom of the column, it is usually set up the hold-down. A shear connector is provided between the top and bottom guide beams and the floor or foundation. The panels on both sides on the frame play the role of skin effect, and can effectively support the frame components to prevent the plate plane of the global buckling of the stud, thereby effectively improving shear performance of the shear wall [3].

3. Research Status of Combined Walls at Home and Abroad

In the last few years, with the increasing application of light-weight framing structure system on the building and the increasing national energy-saving standards, many experts and scholars have studied the low storied cold-formed thin-walled steel composite walls. Because many factors can affect the shear behavior of light-weight steel and keel combination of walls, the derivation of bearing capacity formula is very difficult. Therefore, the study on shear behavior of the composite walls is mostly based on the test, supplemented by the finite element software simulation analysis. And finally, according to different failure modes, the calculation formula of shear capacity of composite walls is obtained. The United States, Australia, Canada, New Zealand, Japan are in front-runner status in this field. In our country, on the basis of the existing theory in foreign countries, we also carried out a series of testing and theoretical research, and achieved some results.

3.1. Experimental study

From 1978 to 2014, some scholars [4-6] conducted a battery of experimental on shear resistance of cold formed thin-walled steel frame wall. They mainly studied the type of load, height to width ratio, the type of wall panels, stud spacing to the impact on the shear behavior of composite wall. The outcome indicated that the sheathing has a great influence on shearing behavior of combination of walls; the reduction of the column spacing can improve the shear capacity; the damage of the wall is usually caused by buckling of the side column or the break of the ancho.

In 1994, Serrette used double studs instead of one stud in the side stud in the monotonic horizontal loading shear test, that is, two single stud with back to back make up the cross-section of the side stud [7]. The experimental study fully proved that the double studs can ensure that the shear capacity of the
wall was fully utilized, which further showed that the section size and strength of the side stud were critical to the shear capacity of the whole wall. In addition, Serrette [8] and other scholars conducted a series of experiments; they studied the screw spacing, loading type, paving direction of wall panels and other factors on shear performance of cold-form light-weight combination wall in 1996-1997. The following results are obtained: the reduction of screw spacing can obviously enhance the shearing strength of combination wall; shear capacity increased with the height-width ratio reduction; but when the screw spacing is reduced to a certain extent, the aspect ratio has little effect on the shear performance; the monotonous loading is taller than shearing resistance of combination wall under cyclic loading.

In 2003, shear experimental of full size former of light steel and keel combination wall (OSB+GWB) was conducted [9]. This experimental aimed at to find the effect on shear strength from different height-width ratio, and to get the shear resistance limit by static and cyclic loading. On this basis, Shi Yu [10] carried out the second batches of experiments in 2004, and got the conclusion that the shear capacity of the composite wall of double side panel (GWB+OSB) is approximately equal to sum of shearing resistance of single plasterboard or the one side OSB wall. But through reading and studying, the writers thought which shearing resistance of double-sided board wall are approximately equal to sum of the corresponding single panel wall just under monotonic loading conditions, but the conclusion is debatable under the condition of low cyclic loading. Zhou Tianhua [11] pointed out that through the experimental study: the panel seams are the weak parts of combination wall; the wide and holonomic steel strip in level joints can improve the shear bearing strength and side stiffness of wall effectively.

In the above study, the effect of wall opening against shear capacity is not considered. In order to solve the practical problems, the National Association of National Building Association conducted the four light-weight steel keel combination wall with the size 2440mm × 7320mm in the horizontal monotonic loading test. The experimental aimed at to study the doors and windows on the stiffness and bearing capacity of the wall [12]. At the same time, they studied the hold-down to analyse the shearing resistance of combination wall. It can be found which with the increase of opening rate, shearing capacity and stiffness of the wall were obviously reduced; the hold-down can resist the wall from pull out, and the position of the final failure of the wall occurs at the screw connection of the OSB board. Compared with the shear wall of wooden structure, it is found that the shear wall of the wood structure and the cold-formed steel composite walls were in the same shear mechanism. And the "the method of open-hole shear wall" in the wood structure design method applied to the cold-formed thin-walled composite structures was effective in shear, but the shear capacity towards conservative. Therefore, the applicability of the theoretical analysis method and research results of the wood structure in devise of light-weight steel structure need further study. Salenikovich et al. conducted the test on the composite walls with opening under horizontal monotonic loading and reversed cyclic loading [13]. The experimental outcomes show which shearing resistance and rigidity of combination walls without holes are all taller than those combination walls with hole, but the ductility is lower than that of combined walls with openings. Cyclic loading has almost no effect on the elastic properties of the walls, but its deformation capacity has decreased. The test outcomes indicated which the shearing resistance and rigidity of the combination walls were taller than the combination walls with opening, but the ductility was lower than the composite walls with opening; the wall under cyclic loading has almost no impact to the elastic properties, but its deformation capacity has declined.

The 4 full-scale light-weight steel keel combination walls with openings were experimented in level loading and shear resistance behaviors of specimens were obtained by Nie Shao-feng [14]. The outcome indicated that the main destruction of composite wall with opening take place around the opening; the sheathing was crushed and torn along the direction of 45 degree around the door or window opening.

The influence of opening on seismic behaviour of the shear wall is not clear, and there is no basis for the size of the hole and the location of the hole. The model of the restoring force of the wall with opening needs to be further studied.
3.2. Theoretical research

Telue Y.K et al. [15, 16] firstly researched mechanical behavior of light-weight steel frame wall. The hysteretic performance of light-weight steel frame in low cyclic loading was studied in the boundary condition of line constraint. And under the condition of unilateral and bilateral cladding, the axial pressure properties of the cold bending steel frame are researched. It is proved that the bearing capacity of frame was improved due to the skin effect.

Based on seismic research, L.A. Fulop [17] proposed hysteretic performance equivalent numerical model of the wall, and applied to the three-dimensional nonlinear dynamic analysis with cold-formed steel framing wall. The model was a single degree of freedom, and sheathing was simplified to a cross strut and tie models (Fig. 3). Considering the hysteretic behavior of the wall through assumed fibre hinge in the finite element program, and a preliminary conclusion of the strength and ductility of the light-weight steel framing wall was obtained under the possible seismic loading.

In 2008, Guo Peng [1] put forward the simplified calculation model (Fig 4.) of the sideways stiffness of light-weight steel framing walls. He also analysed the failure modes of the sheathing wall and the X-strap bracing on both sides, and calculated the shear capacity in different failure modes. The shear capacity of the wall under different failure modes was compared, and the minimum shear capacity mode was selected as the ultimate shear capacity of the wall. This method provides a good idea for finding the shear capacity of the wall, there are some limitations because it only applies to two kinds of walls which were mentioned, and the specific problems should be analysis specifically.

Besides, Guo Peng calculated approximately the resistance partial coefficient and seismic adjustable coefficient of walls by using the allowable stress design method about this kind of wall in American code and combining American code with Chinese code. It can be used as design reference in the practical project at home. However, its applicability still needs further study. At the same time, it is necessary to determine the resistance partial coefficient of wall by reliability analysis.

![Figure3. The hysteretic model of shear wall](image)

![Figure4. Simplified calculation model](image)
Li Bin et al. [18, 19] used finite element software to analyse the composite wall in the case of opening and no opening. The simulation process considered the influence of the material nonlinearity and geometric nonlinearity. In order to facilitate the calculation easily, he made the tapping screw connection of the sheathing and the frame, track and stud simplify coupling simulation of point and point. Through the comparison of two types of walls, it is found that the wall with opening showed a ductile failure and the wall with no opening showed a brittle failure; the shear resistance and shear stiffness declined more obviously with the width of the door and window openings increased; the shear capacity and shear stiffness declined little with the height of the opening increased. Great progress has been made in the study of the mechanical behaviour and design theory of light-weight steel framing structures.

4. Conclusion

The research progress of shear performance of the light-weight steel framing wall panels was summarized in the domestic and foreign in this paper. Representative experimental study and theoretical research were listed; the main elements affecting shearing performance of composite wall were analyzed; and suggestions for the research and development of the shear performance of composite wall were put forward.

Acknowledgments

This work described in this paper was supported by Natural Science Foundation of Liaoning Province (201602636) and Shenyang Jianzhu University Discipline Content Education Project (XKHY2-16), their supports are gratefully acknowledged.

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