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The Production and Installation Technique of Steel Plate Shear Wall

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Abstract. The processing and production of Steel Plate Shear Wall (SPSW) is introduced first in this paper. Taking a typical SPSW unit as the example, this paper states the classified principles of SPSW in the production and the basic processing of SPSW. Moreover, the common installation approaches and the axial compression occurrence due to different construction sequences are proposed in this paper. The reduction coefficient formula of the compression steel sheet wall shear capacity could be obtained by the finite element computation. The welding is the major SPSW connection way.

1. Introduction

The proper classification of SPSW is fundamental to the SPSW installation in super high-rise buildings. This comes from the fact that larger SPSW units may pose the challenge for the job-site installation; however, smaller SPSW units may result in the waste of materials but also transform the stress of SPSW itself due to the much splicing welding joints. Therefore, the basic production procedure is the crucial for the SPSW production.

The axial compression occurs in the production of SPSW owing to different construction sequences, which may reduce the loading capacity of SPSW in the super high-rise buildings. By the finite element computation, the reduction coefficient formula of the compression steel sheet wall shear capacity is obtained in this paper.

2. The Basic Production Procedure of SPSW

The production is an important component of the SPSW structure. For this point, this paper proposes the basic production procedure based on a single SPSW unit.

The classification principles. SPSW is mainly applied to the core tube structure of super high-rise buildings, which is the thick and mid-thick composite steel plate wall outsourcing

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by the reinforced concrete. In the case of Tianjin 117 Building, the steel plate thickness of SPSW is from 70mm on the ground floor to 35mmm on the top floor, the self-weight of SPSW is roughly 30tons. Consequently, the reasonable classification may ensure the production, installation and occurrence of stress on the main structure of SPSW.

To meet the requirements of SPSW mentioned above, the following principles adopted in the production of SPSW are: 1) to take into account of hoisting height and the maxims hoisting capacity in the installation of SPSW; 2) to conduct SPSW classification in accordance with its structure features and lifting point location. In this process, single-plank wall usually could not be used in the production of SPSW as well as the corner wall, stiffener and other affiliated components may be classified into the SPSW units to strengthen the lateral stiffness of the SPSW components. 3) to consider whether split joints (except for the place with big opening) in the construction site could bear the stress of SPSW structure. 4) to analyze the influence of construction platform on the SPSW units from three factors. Firstly, SPSW units may be blocked by the truss members of the construction platform when they are hoisted. Hence, this may require that the units are transferred vertically by getting through the reserved hole in the construction platform. Secondly, the distance difference between the construction platform and the core tube is equivalent to one story height, which requires that the SPSW units cannot be too high. Thirdly, after the steel wall plates are placed in the floors under construction by crossing the lifting platform, they are installed and put in place by means of the slipping rail below the construction platform truss.

The basic production procedure. After SPSW units are classified, precision of components processing as well as residue stress should be controlled. Especially, the Z-direction process ability of the thick steel wall plate should be considered to prevent interlayer tearing.

Generally, thick and mid-thick SPSW require to be leveled twice, whose objective is not only to decrease steel plate deformation but also to eliminate residue rolling force of SPSW in the rolling process. Therefore, the first leveling is the priority of in the SPSW production, which is followed by the CNC (Computer Numerical Control) cutting of the thick plates without rust. The principle of cutting gap compensation should be adopted in the cutting process given the thick plates used in this study, namely, steel plates length is reduced due to cooling shrinkage of thick plates. The third step is to assemble and weld the components of SPSW on the scaffolds.

The influence of axial compression on the SPSW ultimate bearing capacity and the SPSW installation measures. SPSW features no bearing vertical load, which has been clearly defined by American codes and Canadian codes. To realize design concept mentioned above, the common regulatory measures are taken in the production of SPSW as follows: the first step is to complete the building's main structure (namely further work is continuing including the installation of plumbing, electrical wiring, interior walls and final finishing, etc.) and conduct vertically loading; the following step is to conduct welding of wallboards and the surrounding frames or to take the bolt final twisting, which is called SPSW standard construction scheme. Currently, it is difficult to put the SPSW installation in the end in super high-rise buildings under construction in China. The connection between SPSW and the main structure synchronizes with or legs behind the production of main structure, which is an unreasonable installation sequence. Therefore, the main structure is compressed and distorted, bringing about the pre-loaded pressure (see Fig. 1) [2] [3].

Because the connection between SPSW and the main structure legs behind the production

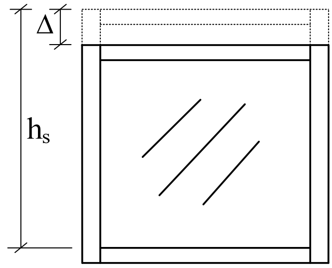


Fig.1.SPSWwhole compression diagram

of main structure, axial compression occurs in the SPSW production. This study further explores the specific reasons from two aspects. On the one hand, when the SPSW installation is conducted ahead of the schedule, the mass gravity-structure load will be accumulated, leading to the occurrence of axial compression in main steel structure, meanwhile, the steel plates are compressed. On the other hand, the axial compression is generated from floor load transferred by a beam. The calculation in this study demonstrated that the former axial compression plays a leading role in SPSW installation, which is apart from the concept that there is no vertical load in SPSW. Thereby, in this paper, ultimate bearing capacity of SPSW under axial compression is considered [1].

Ultimate bearing capacity of the main structure is assumed to reach the axial compression yield critical point, the ratio of axial compression extreme value represented by Δ_{max} to story height of one floor represented by h_s is defined as compression ratio represented by χ . This ratio can be calculated by [2]

$$\chi = \frac{\Delta_{max}}{h_s} = \frac{N_y}{EA_c} = \frac{f_y A_c}{EA_c} = \frac{f_y}{E} \tag{1}$$

Where N_y is ultimate axial force which is obtained when the main structure is under axial compression yield; A_c is net cross-sectional area of main structure; f_y is material yield strength of main structure; E is elasticity modulus of main structure.

The compression ratios of main structures with different materials are listed in Table 1.

Table1. Compression Ratio Of Main Structure

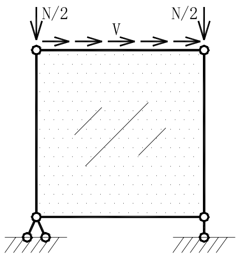
Materials of main structure	Yield strength(MPa)	Elasticity modulus(MPa)	Compression ratio
Q345	310	2.06×105	1/665
Q420	380	2.06×105	1/542
C70	44	3.70×104	1/831
C80	50	3.80×104	1/757

It can be found in Table1 that the materials selected in this study are high-strength steel and high-grade concrete, which are commonly used in the super high-rise buildings. The compression ratio of the concrete filled steel tubular is surely between that of high-strength steel and high-grade concrete. The result indicates that when the main structure reaches to critical buckling point, the conservative value of compression ratio is 1/500 of the story height by the comparing the compression ratios in Table1.

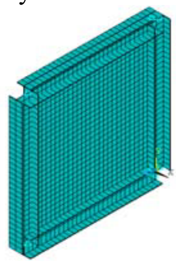
To further study SPSW ultimate bearing capacity under axial compression, this paper makes an analysis on one single SPSW by Exquisite FEM (finite element model). In this model, SPSW are surrounded by beams and columns, the node of beams and columns is defined as hinged joint, and the connection between SPSW and beams and columns is defined as the rigid connection. It can be seen in this model that the actual stiffness of steel beam (elastic-plastic materials) is used while the value of steel beam stiffness (elastic material) is infinite; element Beam188 is used for the beam and column and element shell181 is used for steel wall plate.

Two loading methods are adopted in the model. First is to increase axial compression on the upper portion of the beams in both sides; second is to drive the uniform distribution horizontal force on lateral beam end on the top of SPSW and consider the influence of initial defects on the calculation model.

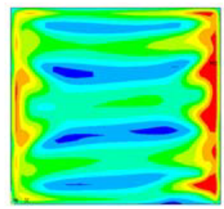
The initial defects are considered as $h_s/1000$ of first-order buckling model which is imposed in the model. The stress analysis of buckling model is presented in Fig.2.



(a)Calculation model



(b)Finite element model



(c)Deformation diagram

Fig.2.The stress analysis of SPSW under axial compression

The above calculation indicates that under the axial compression the ultimate bearing capacity will be decreased in different degree. Stress variation trend can be seen in the Fig. 3[2].

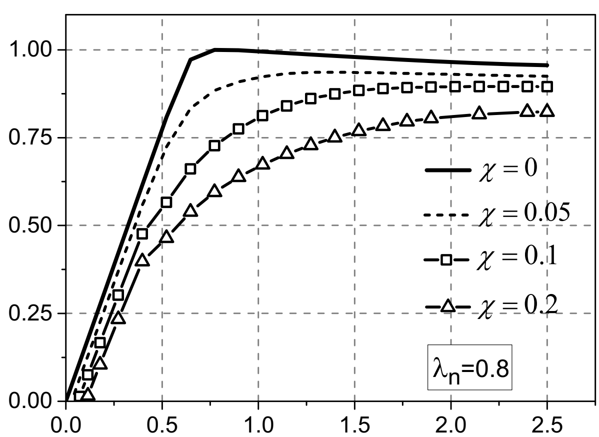


Fig.3. The load-displacement curve of wall shear capacity under the main structure compression

The above numerical analysis shows that the thinner steel wall plates are, the greater influence axial compression has on shear capacity in the production of SPSW. Under the condition of different thickness, the influence of SPSW ultimate bearing capacity is expressed by a bandwidth consisted of reduction coefficient ψ ,

$$\psi = 1 - \chi \quad (2)$$

Where the bandwidth can be represented by a reduction curve in Fig.4.

From Eq. 2, we see that bearing capacity of SPSW could be reduced according to amount of compression of edge columns in every story in SPSW installation.

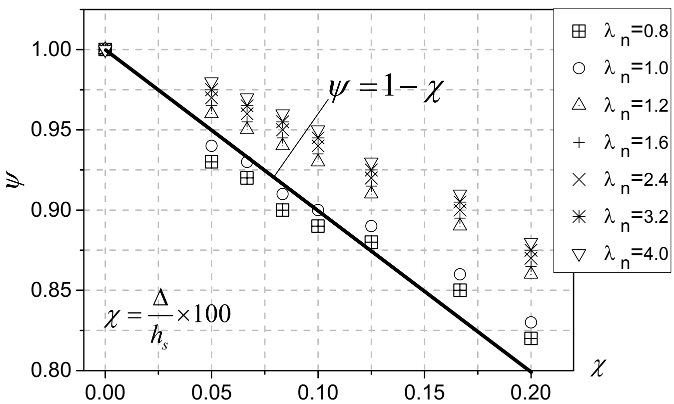


Fig.4.The reduction coefficient of steel wall shear capacity under the occurrence of compression

In production of SPSW, the share bearing capacity may be decreased by axial compression. There are two methods [4] to address above issue: 1) the construction procedures should be optimized by following the fact that in this study we should connect the upper edge of SPSW with the frame girder by welding without affecting the main structure, then deal with the welded joints in both sides and at the bottom of SPSW after completing the main structure in order to decrease the effect of axial compression on SPSW.2) After calculating amount of vertical compression, welding way above mentioned in the construction of SPSW can be used, then the oval bolt holes could be released vertically for the vertical deformation then the horizontal welted joints in the end of SPSW could be connected by welting.

3. Conclusion

The classified principles and basic production procedure in the construction of SPSW are explored by this study. Moreover, this paper offered the analysis of the common installation approaches and the reason why SPSW bears the axial compression due to different construction sequence. Targeted to the reduction of shear bearing capacity under the axial compression, this paper proposed the reduction coefficient formula of the compression steel sheet wall shear capacity, which could be instructive for the structure designers.

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