Construction

Savytsky M.V., Zinkevych O.G., Zinkevych A.M.

INFLUENCE OF CONSTRUCTIONAL FEATURES ON SHEAR WALLS' STIFFNESS IN A LIGHTWEIGHT STEEL FRAMING BUILDINGS

Abstract. Dependences of constructional features' influence on shear walls stiffness in a lightweight steel framing buildings are received. On the basis of dependences approach for any configuration's shear wall stiffness estimating is developed, allowing to make decisions for providing spatial stiffness of the building.

Key words: *lightweight steel framing buildings, stiffness of shear wall, sheathed cold-formed steel walls, stud-fastener-sheathing interactions.*

I. Introduction

For low-rise buildings frame technologies have got significantly widespread. One of the directions is using lightweight steel thin-wall constructions (LSTC).

Feature of such frames is that in most cases all connections of structural elements are pivot-hinged. Thus, the main influence on building's spatial rigidity under the lateral forces is taken by diaphragms (horizontal – floors and vertical – shear walls).

Shear stiffness (further - stiffness) of shear walls is provided by the following: using cross bracing of steel stripes; accounting frame-sheathing interactions.

According to preliminary results, the cross bracing's disadvantage is in significant value of force in its connections with frame, that can cause local distortion of elements' section and leads to necessity of junctions' complication.

Thus, cross bracings are taken as the stiffness elements of only for the period of assembly. Needed frame's stiffness in operation is provided by shear walls accounting frame-fasteners-sheathing interactions.

II. Problem statement

For providing spatial rigidity of building shear walls have to satisfy prescribed requirements to their stiffness. Shear walls' stiffness can significantly change depending on its constructional features. Therefore, necessary stiffness can be received by setting definite constructional parameters which are selected according to the design approach.

In [1, 2] there are given methods of shear walls' stiffness estimation through their comparison to model shear wall which consider limited number of factors and don't reflect the features of considered frames.

Purposes of work are to receive the dependences of constructional features' influence on shear walls stiffness (using FEM models) and to set the value of any configuration's shear wall stiffness linking its parameters with correspondent parameters of the standard shear wall through the established dependences.

III. Results

Factors influencing on shear walls stiffness

On the basis of FEM there was accomplished preliminary analysis of constructional features influence on shearwall's operability, for further analysis the following factors were taken:

- fastener stiffness ν_c, kN/sm (is defined experimentally [3, 4] and depends on width, elastic modulus, sheet material, diameter of joint elements);

- correlation of shearwall dimensions h/L (height / length);

- stud spacing;

- fasteners' spacing;

- presence of openings in shearwall.

Shearwall stiffness (ν, kN/sm) was estimated according to the value of top chord displacement under lateral load

$$\nu = P/f \text{, kN/sm} \qquad (1)$$

where: P – concentrated horizontal load (wind, seismic) applied to shearwall's top chord, kN; f - top chord horizontal displacement, sm.

To estimate shearwall's stiffness of any sizes the value taken to length is used:

$$\nu_0 = \frac{\nu}{L} = \frac{P}{f} \cdot \frac{1}{L} \text{, kN/sm·m} \qquad (2)$$

where L - sharewall length.

Influence of openings in shearwall

As most sharewalls (inner and outer walls of buildings) are exploited with openings, influence of their number and configuration has been estimated.

Models with equal total length of segments (part of shearwall on the entire height) with different length of particular segments were considered. Besides, influence of modeling approach was estimated for the following cases:

a) continuous sheeting with cutout openings (fig. 1a)

b) only segments of shearwall with sheeting on the entire height were taken into account (fig.1b)

c) sheeting consists of segments and parts above and below openings (fig. 1c).

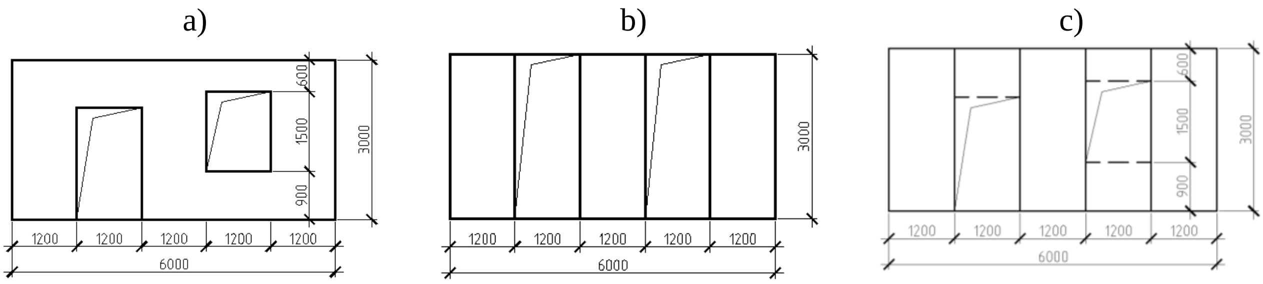

Fig. 1. Ways of accounting openings in modeling work of shearwalls

Shearwall with continuous sheeting (cutout openings) has the highest rigidity, but due to limitations for sheet size is impractical. As a rule, sheeting above and below openings is made of separate parts, fastened to the frame (method c).

According to results, shearwalls stiffness in modeling through the ways b and c slightly differ (some decrease for way b), therefore, to simplify modeling it is recommended to set shearwalls only considering their segments (way b).

As in further the shearwall with openings is considered as the whole set of separate segments it is supposed that stiffness of a particular segment will depend on correlation of its dimensions (h/L) and can be defined on the same dependences as for shearwalls with the particular h/L.

Influence of shearwall dimensions and fastener stiffness

Dependences of shearwall stiffness taken to the unit of its length (1 m) on correlation of dimensions h/L and fasteners stiffness are given in the fig. 2.

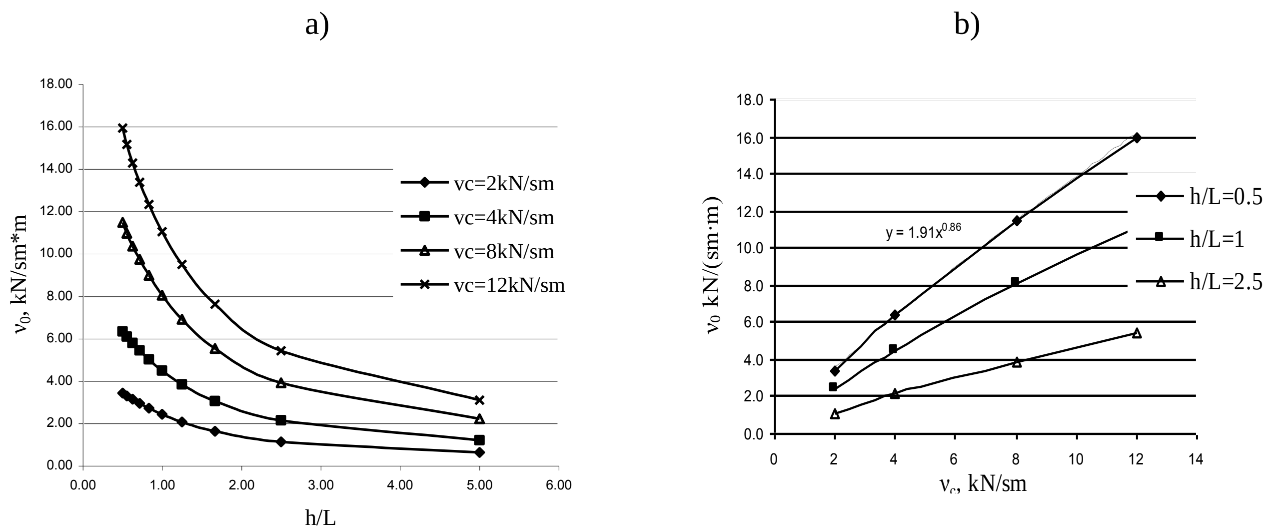

Fig. 2. Dependences of sharewall stiffness on correlation of sharewall dimensions with different fastener stiffness (a) and on fasteners stiffness (b)

As dependences of shearwall stiffness on the analyzed factor are isoperimetric, approximate equation are given for models with its definite value. Changing value of factor is considered with the correspondent coefficient.

Influence of stud spacing and fastener spacing

Estimation of influence of stud spacing and fastener spacing on contour and in the middle part of shearwall was accomplished on the sharewall models (fig. 3) with the following parameters: sharewall length $L = 6000$mm, height $h = 3000$mm, fastener stiffness $\nu_c = 2$ kN/sm, stud spacing $S_s = 200;400;600;1000$ mm, fastener spacing on sharewall contour S_{ce}=100; 200; 300 mm and in the middle part of shearwall S_{ci} =100; 200; 300 mm.

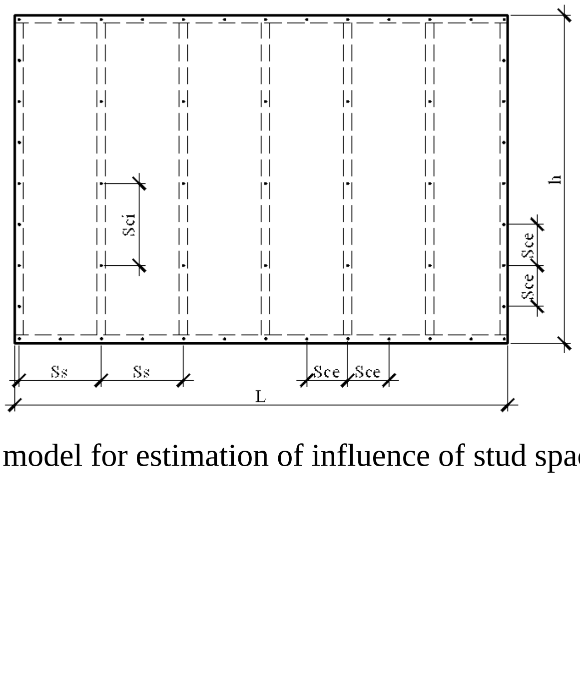

Fig. 3. Scheme of sharewall model for estimation of influence of stud spacing and fastener spacing

Dependences of the sharewall stiffness on stud spacing are shown in fig. 4 (in designation of lines the numerator is inner fastener spacing, denominator – contour).

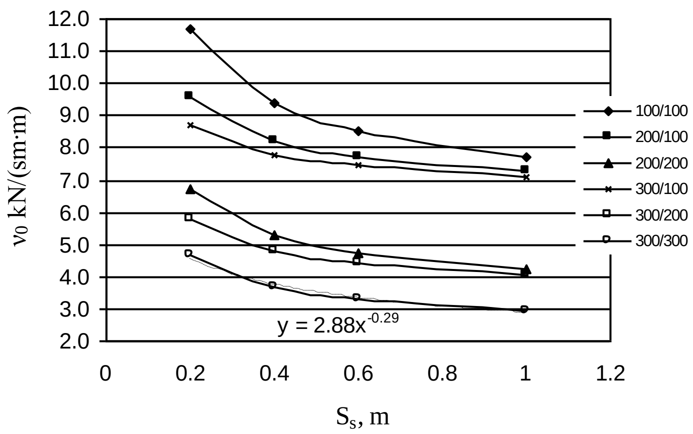

Fig. 4. Dependences of the sharewall stiffness on stud spacing with changing fastener spacing

In fig. 5 there are given dependences of sharewall stiffness on inner fastener spacing and contour fastener spacing for the sharewall with stud spacing $S_s = 600$ mm. In construction of dependences the following conditions were taken:

- dependence of sharewall stiffness on inner fastener spacing is constructed in consideration of contour fastener spacing of 300 mm (line – inner fasteners);

- dependence of sharewall stiffness on contour fastener spacing is constructed in consideration of inner fastener spacing of 300 mm (line – contour fasteners)

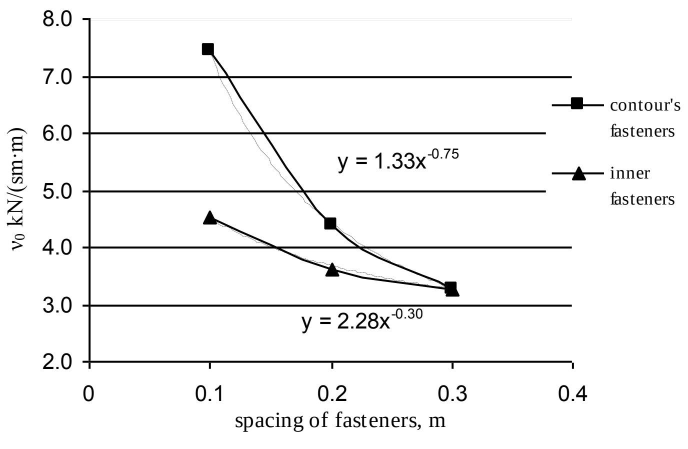

Fig. 6. Influence of fastener spacing (contour and inner) on sharewall stiffness

It is possible to conclude that contour fastener spacing has more significant influence on sharewall stiffness comparing to inner fastener spacing.

Defining sharewall stiffness

On the basis of received correlation dependences there was developed the approach of sharewalls' stiffness estimation, that enables to consider the influence of their constructional features.

Sharewall stiffness per unit of length (1 m) considering constructional features is defined as

$$\nu_n = \nu_0 \cdot k_i \text{, kN/sm·m} \qquad (3)$$

where: ν_0 - standard sharewall's stiffness per unit of length, kN/(sm·m); k_i - constructional factors adjustment differences of analyzed sharewall from standard sharewall: k_c - factor reflecting influence of fastener stiffness; k_s - factor reflecting influence of stud spacing; k_{ci} - factor reflecting influence of inner fastener spacing; k_{ce} - factor reflecting influence of contour fastener spacing.

Sharewall rigidity of any configuration is defined as:

$$\nu = \sum \nu_{ni} L_{si} k_{ar_i} \text{, kN/sm} \qquad (4)$$

where: ν_{ni} - stiffness per unit of particular segment's length, kN/(sm·m); L_{si} - length of sharewall segment (part of the sharewall with sheeting on the entire height), m; k_{ar_i} - factor reflecting influence of segment's height/length ratio.

Values of the factors are taken on ratio of correlation dependences for analyzed sharewall and standard sharewall.

For example, factor k_c (reflecting influence of fastener stiffness) is defined:

$$k_c = \frac{1.91 \cdot \nu_c^{0.86}}{1.91 \cdot \nu_{c_e}^{0.86}} = \left(\frac{\nu_c}{\nu_{c_e}} \right)^{0.86} \qquad (5)$$

where ν_{c_e} - fastener stiffness of the standard sharewall.

Reliability of the developed design approach was estimated trough comparison of the results received in calculation of test sharewalls (design value) with the results of calculation of sharewall FEM models.

Standard sharewall's stiffness was defined experimentally (here, by FEM modeling) and used as initial data for calculation.

There were defined displacement of sharewall's top chord under horizontal load.

Deviations of the results received with the developed approach and calculations of FEM models don't exceed 15 %.

IV. Conclusions

There was developed the simplified design approach of estimating influence of main constructional features of shearwalls on their rigidity, enabling definition of requirements to the construction on the preliminary stage of forming space-and-planning decisions for frame building of LSTC.

Received results enable to conclude that developed design approach is reliable enough for estimation of sharewall stiffness.

Received dependences of main constructional factors' influence and sharewalls stiffness design approach can be used for providing spatial rigidity by the following:

- setting requirements to construction of sharewalls;
- limitation of the distance between sharewalls (decreasing load space);
- limitation of the number of openings in sharewalls.

References

1. Рекомендации по учету жесткости диафрагм из стального профилированного настила в покрытиях одноэтажных производственных зданий при горизонтальных нагрузках [Текст] – М., 1980. - 25 с.

2. Residential structural design guide: 2000 Edition [Text] – W., 2000. – 434 p.

3. Iuorio, O. Compilation of k values [Электрон. ресурс] / O. Iuorio, B. W. Schafer; Johns Hopkins University. – 2008 – Режим доступа: http:// www.ce.jhu.edu/bschafer/sheathedwalls.

4. Савицкий, Н. В. Влияние жесткости обшивки на расчетную длину сжатой стойки каркаса из ЛСТК между узлами закрепления [Текст] / Н. В. Савицкий, О. Г. Зинкевич, А. Н. Зинкевич // Вісник Дніпропетр. нац. ун-ту залізн. трансп. ім. акад. В. Лазаряна. - Вип. 32. - Д.: Вид-во ДНУЗТ, 2010. - С. 115-117.