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SHEARWALLS IN A LIGHTWEIGHT STEEL FRAMING BUILDINGS

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Introduction

For building low-rise buildings frame technologies have got significantly widespread. One of the directions is making elements of building frame from light steel thin-wall constructions (LSTC) – thin-wall metal galvanized sections.

Peculiarity of such frames is that in most cases all junctions of constructional elements are pivot-hinged. Determinative influence on spatial rigidity under the impact of horizontal strength is taken by shearwalls (horizontal – ceilings, coverings and vertical - walls).

Shear rigidity (further - rigidity) of shearwalls receiving force in its plane is provided with the following ways:

- using cross bracing of galvanized steel stripes in wall panel;
- accounting work of wall panel sheets.

According to the results of preliminary calculations the biggest disadvantage of shearwalls with cross bracing is in significant amount of force in junctions of bracing with frame. As the elements are thin-wall, received force can cause local deformations of sections and sheet mutilation. Making junctions with fulfillment of constructional requirements leads to their complication and decreasing produceability.

On the assumption of this cross bracings are taken as the element of rigidity of shearwalls as well as the entire frame only for the period of assembly. Needed rigidity of LSTC frame in operational process is provided by shearwalls considering work of junctions of frame elements with wall panel sheets (gypsum plasterboards, OSB etc).

Problem statement

For providing spatial rigidity of building constructional elements fulfilling the function of shearwalls have to satisfy prescribed requirements to their rigidity. In its turn shearwalls rigidity can significantly change depending on its constructional peculiarities. Therefore, necessary rigidity can be received by setting definite constructional parameters which are selected according to the calculation method.

In [1, 2] there are given methods of estimation of shearwalls rigidity through their comparison to model shearwall which consider limited number of factors and don't show the peculiarities of shearwalls in frames of LSTC.

Purpose of work

To receive the dependences of influence of constructional peculiarities on their rigidity on the basis of calculation results for model shaerwalls by the method of finite element method (FEM).

To set the value of rigidity for shearwall of any configuration linking its parameters with correspondent characteristics of the standard shearwall through the established dependences.

Factors influencing on shearwalls rigidity

On the basis of FEM there was accomplished preliminary analysis of influence of constructional peculiarities on the operability indices of shearwall, for further modeling and account significant values were taken in dependences.

According to the results of the previous analysis type of frame section (flexural rigidity), thickness and rigidity of panel sheets don't influence significantly on shearwall rigidity (conventionally their direct impact on shear rigidity of boarding bracing with frame elements wasn't considered). Therefore, type of section, width and rigidity of sheets can be not considered as factors influencing on shearwall rigidity (change of value to 5%).

For further analysis the following factors were taken:

- rigidity of junctions between boarding and frame elements 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);
- step of brace to frame;
- step of wall panel sheets junction to frame elements;
- presence of openings in shearwall.

Shearwall rigidity (ν, kN/sm) was estimated according to the value of shifting upper fascia under horizontal load

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

With P – concentrated horizontal load (wind, seismic) applied to upper fascia of shearwall kN;

f - shifting upper fascia of shearwall in horizontal panel, sm.

To estimate rigidity for shearwalls of any sizes the value taken to length is used:

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

with 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 ways of modeling sheeting in shearwall on calculation results was estimated for the following cases:

a) continuous sheeting with cutout openings;

b) only segments of shearwall with sheeting on the entire height were taken into account;

c) sheeting consists of segments on all the height and parts above and below openings each of which is connected with the frame.

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

According to received results of shearwalls rigidity in modeling sheeting through the ways b and c slightly differ (some decrease for way b), therefore, to simplify calculation scheme in general it is recommended to set shearwalls only considering segments on the entire height (way b).

As in further the shearwall with openings is considered as the whole set of separate segments with sheeting on the entire height it is supposed that rigidity 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 rigidity of sheeting brace with frame

Dependences of shearwall rigidity taken to the unit of its length (1 m) on correlation of dimensions h/L and rigidity of sheeting brace with frame elements are given in the fig. 1.

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

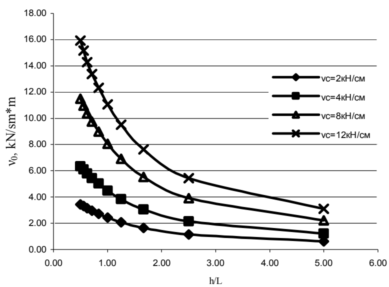

Fig. 1. Dependences of given sharewall rigidity on correlation of sharewall dimensions with different bracing rigidity

Influence of step of frame member and step of junctions of sheeting planes to the element of frame

Estimation of influence of step of frame members and step of junctions of sheeting planes to the element of frame on contour and in the middle part of shearwall was accomplished on the sharewall models with the following parameters: sharewall length L=6000 мм, height h=3000 мм, rigidity of sheeting bracing with the frame $v_c = 2$ kN/sm, step of junctions of sheeting planes to the element of frame on sharewall contour S_{ce} =100; 200; 300 mm, in the middle part of shearwall S_{ci} =100; 200; 300 mm. Corresponding dependences were obtained.

Defining sharewall rigidity

On the basis of received correlation dependences there was developed the method of estimation of shear rigidity for sharewalls, that enables to consider the influence of their constructional peculiarities.

Rigidity of length unit of sharewall (1 m) considering constructional peculiarities is defined as

$$v_n = v_0 \cdot k_i \text{, kN/sm·mp} \qquad (3)$$

with v_0 - rigidity of length unit of standard sharewall kN/(sm·m);

k_i - coefficients considering constructional differences of analyzed sharewall from standard sharewall;

k_c - coefficients considering influence of rigidity of junctions of sheeting planes with frame elements of the sharewall;

k_s - coefficients considering influence of step of frame members;

k_{ci} - coefficients considering influence of step of inner junctions of junctions of sheeting planes with frame elements of the sharewall;

k_{ce} - coefficients considering influence of step of junctions of junctions of sheeting planes with contour frame elements of the sharewall.

Sharewall rigidity of any configuration is defined as:

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

with v_{ni} - rigidity of length unit of the particular segment kN/(sm·mp);

L_{si} - length of sharewall segment (part of the sharewall with sheeting on the entire height), m;

k_{ar_i} - coefficients considering correlation of dimensions of sharewall segments (height/length).

Values of the coefficients are taken on relation of correlation dependences for analyzed sharewal and standard sharewall.

For example, general definition of the coefficient k_c, coefficients considering influence of rigidity of junctions of sheeting planes with frame elements of the sharewall is made in the following way:

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

with v_{c_e} - rigidity of junctions of sheeting planes with frame elements of the standard sharewall.

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

Rigidity of standard sharewall was defined experimentally (in the given work with a numerical experiment) and used as basic data for calculation.

There were defined movements of upper fascia of sharewalls in horizontal plane under horizontal load.

Deviations of the results received with the developed method and calculations of models doesn't exceed 15 %.

Conclusions

There was developed the simplified method of estimating influence of major constructional peculiarities 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 calculation method is reliable enough for estimation of rigidity of sharewall and the whole frame of construction.

Received dependences of influence of above-mentioned factors and the method of estimation of sharewalls rigidity can be used for providing spatial rigidity at the expense of:

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

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