Experimental study of an I-beam reinforced steel sheet pile under axial tension

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Abstract. This article discusses the connection of a steel sheet pile to an I-beam by welding to increase the horizontal load-bearing capacity. The connection to the I-beam is checked during an experimental study for axial tension. Deformations at reference and maximum loads, as well as stresses in the weld metal and I-beam metal, are recorded. During the tests, the bearing capacity of the welded joints was confirmed, data on plastic deformations of the sheet pile walls under various loads were obtained.

1 Introduction

Sheet piling is often necessary for the construction of fences in deep pits of various buildings and structures. Among the main areas of use of sheet piles are: strengthening the walls of pits, protecting pits from filling with ground water, arranging caissons, piers, locks, dams, etc., strengthening the walls of tunnels, strengthening eroded coastlines [1].

In some situations, even heavy sheet piles such as L4 and L5 lack the load-bearing capacity. This may be due to various reasons, but all of them are united by the fact that the bending strength of the sheet pile is insufficient. There are various ways out of this situation, but almost all of them significantly increase the cost of building a fence [2]. An alternative to the above-mentioned measures may be to strengthen the sheet pile, that is, to increase its load-bearing capacity.

One of the reinforcement methods is to connect the tongue and groove to the I-beam using welds [3]. The choice of I-beam is explained by the fact that it is the most effective type of cross section, working on bending. The relative position of the tongue and groove ensures the transfer of pressure from the ground to the plane of the I-beam wall.

Due to the fact that the tongue and I-beam are connected using a welded joint, there is a possibility of various defects during welding, and, accordingly, it is necessary to control welds, as well as non-destructive testing of the finished tongue reinforced with an I-beam [4]. Also, this topic is found in the sources [5-9].
2 Materials and methods

As part of the test of the tongue reinforced with an I-beam, the following were carried out:
visual and measuring inspection of welds, capillary control, laboratory testing of the physical and mechanical characteristics of the seam, experimental study of tensile samples. Next, full-scale tests of sheet piling for axial tension are considered.

The sample was loaded with 4 hydraulic cylinders, in accordance with the scheme of applying the load in a tensile test (Fig. 1).

During the tests, strain monitoring was performed using strain gauges installed on the weld and separately installed strain gages in accordance with the scheme of the recording equipment installation (Fig. 2).

Fig. 1. Scheme of tensile test.

Fig. 2. Installation diagram of strain gages during testing.
The strain resistor data obtained during the test (µm/m) was converted to stresses using the elastic modulus ($E$) for steel equal to 206 GPa. The voltage at the point ($\sigma_i$) was determined by the formula (1):

$$\sigma_i = \varepsilon_i \times E$$

For strain, grids consisting of 3 strain gages, the main deformations ($\varepsilon_{e1}$ and $\varepsilon_{e2}$) and shear deformations ($\gamma_{xy}$) are determined. In this case, the values of the main and shear stresses are determined by formulas (2) and (3) in accordance with GOST R 52728-2007.

Here, the Poisson's ratio ($\mu$) is assumed to be 0.3 for steel, and the shear modulus ($G$) is 79 GPa.

$$\sigma_{1,2} = \frac{E}{1 - \mu^2} \cdot (\varepsilon_{1,2} + \mu \cdot \varepsilon_{2,1})$$

$$\tau_{xy} = \gamma_{xy} \times G$$

Additionally, during the test, the amount of "opening" of the sheet pile walls was recorded by monitoring the movements of I-beams relative to each other using indicators. Figure 3 shows a general view of sample No. 1 and tooling before testing from two angles.

Fig. 3. General views of the sample before testing a) view 1; b) view 2.
3 Results

Previously to the axial tension tests, the welds were inspected. At the same time, visual and measuring inspection of welds, capillary control and testing of control samples were performed to determine the characteristics of an H1 type weld. During the inspection, it was found that the detected defects do not exceed the permissible values, the welded joints comply with GOST 23118-2012, GOST 14771-76.

Full-scale tests of a series of 3 samples were performed. During the tests, it was possible to achieve a maximum total load of 2360 kN for each of the samples. At the specified load value, no failure of the samples occurred, but significant sheet pile deformations were recorded, associated with the convergence of the sheet pile walls (Fig. 4). After the load was removed, the remaining deformations of the sheet pilings were about 28 mm, when they were moved at a maximum load of about 32 mm.

The values of changes in the distance between beams depending on the external load are shown in Figure 4. The red horizontal line on the diagram shows the value of the control load equal to 392 kN.

Fig. 4. Changing the distance between beams depending on the load.

The results of strain monitoring using strain gauges in the form of dependences of voltage changes on the total load on the sample are shown in Figures 5, 6.
Fig. 5. Voltage dependence on the load value for:

- a) strain gages 1-3
- b) strain gages 4-6
- c) strain gages 7-9
- d) strain gages 10-12
- e) strain gages 13-15
- f) strain gages 16-18.
The stresses in the welds do not exceed 170 MPa when the reference load is reached. Deformations do not exceed 2 mm. With a subsequent increase in the load, there is a significant increase in movement between the I-beams (Figure 4) due to the bending of the sheet pile walls. At the same time, deformations occur in the area of the location of welds H1, which significantly exceed the elastic limit deformations for steel (2000 microns/m), so many strain gages have become inoperable. This is especially noticeable at loads above 1520 kN.

4 Conclusions
the reference load is reached, no stresses occur in welds that exceed the limit of proportionality of the weld metal equal to about 400 MPa.

References


