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Experimental research of beams with corrugated web

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Abstract. The paper presents an experimental methodology, measuring instruments, equipment and results of an experimental study of beams with corrugated sinusoidal-shaped web. It also investigates the influence of parameters on the beams load bearing capacity. The researchers obtained data on critical loads and types of the extreme limit state at action of concentrated forces with various width of a load transmission section. They also assessed load bearing capacity of beams with different length and section height when work according to single-span jointed scheme.

1 Introduction

Beams with corrugated wall are most commonly used in floors and roofings of buildings [1-16]. The load on the beams can be transmitted in the form of concentrated forces or can be evenly distributed along their length. The beam corrugated web is known to work better at equal load distribution. Concentrated load causes local stresses in the thin web. Local stresses together with load stresses cause an early loss of stability of the beam thin web. Studies conducted by A.G. Azhermachev, A.N. Stepanenko, S.G. Baranovskaya, A.N. Kretinin [17], M.V. Laznuk [18], S.F. Pichugin, K.V. Chichulinaj [19, 20], H. Pasternak, G. Kubieniec [21], J. Gao, B.C. Chen [22] as well as by other authors [1-16] are devoted to steel beams with corrugated web. Meanwhile, the question of load bearing capacity under concentrated loads remains under-explored.

That is why experimental research of steel beams with corrugated web under concentrated static load has recently been carried out in the laboratory of Samara State Technical University.

2 Materials and methods

This study attempts to experimentally analyze the stress-strain behaviour of a beam with corrugated web under different working conditions. During experiments the influence of height and span of the beam as well as width of the platform of concentrated load transmission up to the level of stresses in the corrugated web was studied.

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Six I-Beams (see Table 1) were manufactured for testing. The beams differed from each other by the size of the span and the web depth. The flanges of all the beams were the same. The flanges were made of 200 × 12 mm flat-rolled steel. The webs were made of 2.5 mm thick sheet steel. The steel sheet of the beam web was bent during the rolling process. The geometry of the web bending was a sine wave with a wavelength of a = 155 mm. The height of the corrugation web was F = 20 mm (see Figure 1).

Table 1. Corrugated beams characteristics

Symbol*	Span L, m	Beam web height h_w, mm	Beam flanges width b_f, mm	Beam flanges thickness t_f, mm	Width of the concentrated load transmission area, mm
6.1	6.0	500	200	12	100
6.2					200
9.1	9.0	750			100
9.2					200
12.1	12.0	1250			100
12.2					200

* In the beam symbol column, the first figure indicates the span of the beam, the second figure indicates the width of the concentrated load transmission section.

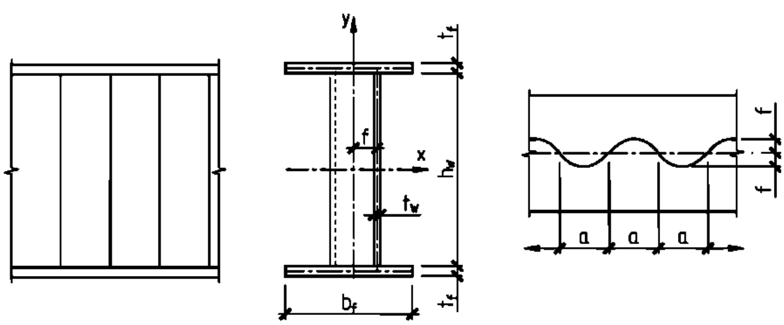

Fig. 1. Corrugated beams characteristics.

The exact values of stress-strain properties of the beam elements were determined by the experimental test. Tests of samples of metal elements of beams were tested on stretching up to fracture. In the course of the samples tests, steel mechanical characteristics were also determined (see Table 2).

Table 2. Mechanical characteristics of materials

N	Name	Steel	Dimensions, mm	Yield strength , MPa	Ultimate strength, MPa	Strain, %
1	Web	Cold-rolled	400×30×2,5	235	373	30
2	Flange	Hot-rolled	400×30×12	260	431	30

Figure 2 shows the calculation scheme of beams, taken at experimental tests. The upper flanges of the beams in the places of concentrated forces application were fixed from the offset into the horizontal plane.

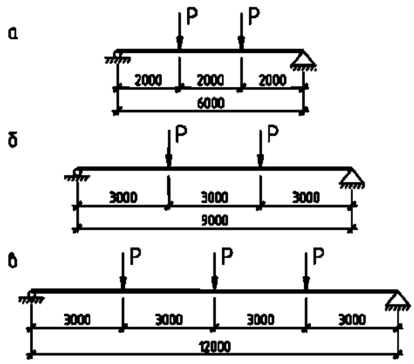

Fig. 2. Beam diagrams

Fig. 3. Testing bed diagram

The concentrated load was created by hydraulic jacks (see Figure 3). The number of jacks and pumping stations corresponded to the number of forces that loaded the beam. The loading of beams was carried out by steps, with 10 minutes time intervals at each stage. The size of the steps for all beams was accepted equal, P = 10 kn.

The following parameters were controlled when during the tests: concentrated forces value; flanges deformation in the middle of the span and in places of concentrated force application; beam deflection; supporting structures settlement.

The value of the applied load was controlled by pressure gauges.

Deformations of flanges and webs were determined by electro-strain-gauge measurement. Strain-gauge sensors with a base of 20 mm were used. A strain-gauge complex allowing to measure the deformation with theaccuracy up to 10-6 units was applied.

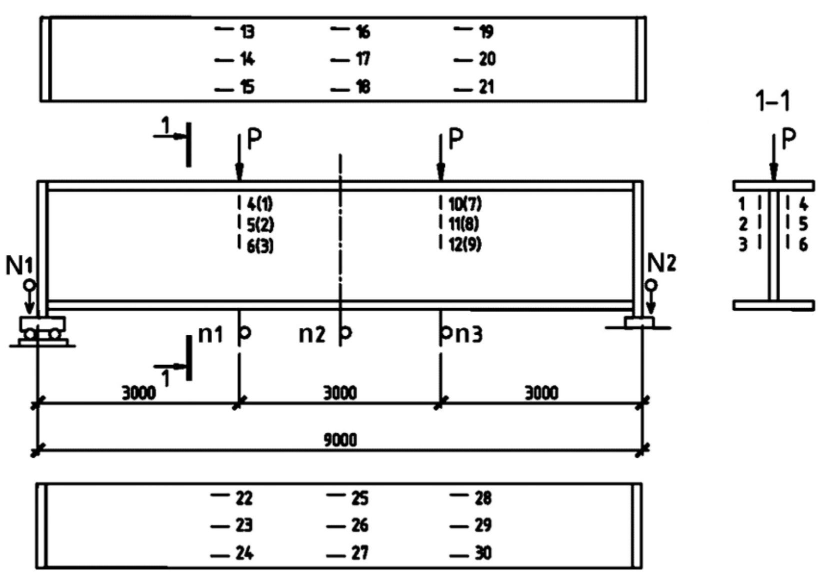

Fig. 4. Arrangement of devices

Deviation of cross sections of beams were measured by means of deflection indicators. The supports settlement was controlled by the clock type indicators. The accuracy of the displacement was 0.01 mm. Figure 4 shows the devices allocation scheme and the numbers of the sensors.

The data analysis obtained as a result of the experiment showed that the greatest tension occurs at the area of the web section under the concentrated force. The specified section is located 40-50 mm below the top flange. The destruction of the beam begins with its web in the places of concentrated forces. The steel of the web of the beam reaches the yield limit earlier than other sections of the beam.

It is proved that at the moment of achieving the yield strength on the specified sections of the webs, the tension the flanges was only 60-70% of this value (see Table 3).

Table 3. Beams test results

Symbol	Load corresponding to the beginning of metal yield (p), kN	Yield strength , σloc.y= σt, MPa	Flanges tensions (σx), MPa	Maximum beam deflection (f), mm	Relative stress level in beam flanges,%
6.1	90	235	165	15.4	68.8
6.2	92.3		150	15.05	62.5
9.1	80		135	18.2	56.3
9.2	109		229	25	95.4
12.1	84		169	24.5	70.4
12.2	97		164	26.4	68.3

3 Results

The tests showed that under the action of concentrated forces the exhaustion of the load capacity of corrugated beams occurs either because of the loss of local stability of the corrugation, or due to the achievement of metal yield limit in the flanges. It is proved that the web local destruction is not the criterion of total destruction of corrugated beams. That is, after the buckling failure, the beam is still able to take up some additional load.

For example, the web tension at the force application area in Beam 6.1 reached the yield limit at P = 90 kN (see Table 3), but the buckling failure occurred only at P = 110 kN (see Figure 5), and complete destruction of the beam started at P = 130 kN. For Beam 9.1, a similar pattern was observed under the following load values: P = 80 кN, P = 120 кN, P = 140 кN.

For Beam 6.2, the criterion of destruction was the achievement of metal yield strength in the flanges (see Table 4).

For Beams 12.1, 12.2 the criterion of destruction was the achievement of metal yield strength in the webs. Here, the tension in the webs was about 90% of the metal yield strength.

Fig. 5. Web buckling failure in beams.

Fig. 6. Beam buckling failure.

It is experimentally determined, that the quality of beams manufacture significantly influences the final load bearing capacity of corrugated beams. Deviations from the ideal geometry of beams significantly affects their load carrying capacity. For example, the longitudinal axis of Beam 9.2 top flange was shifted from thew web longitudinal axis for 8 mm. This led to the fact that under the load of 75 kN the upper belt of the beam began to deform in its horizontal plane (see Figure 6).

The offset of the web axes and the beam flange results in the eccentricity of the load application. Eccentricity causes the phenomenon of the beam twisting. Beam twisting causes the early failure of the bent corrugated beam.

In beams with a wide area of concentrated load distribution (200 mm) local buckling failure of the web was not observed. This result confirms the known fact, that at the increase in width of load distribution, local tensions in a web decrease.

For all beams, the researchers observes a linear dependence between the size of the deflection and a load intensity up to the destruction of beams. Deflection graphs for beams with a concentrated load distribution width of 100 mm are given in Figure 7.

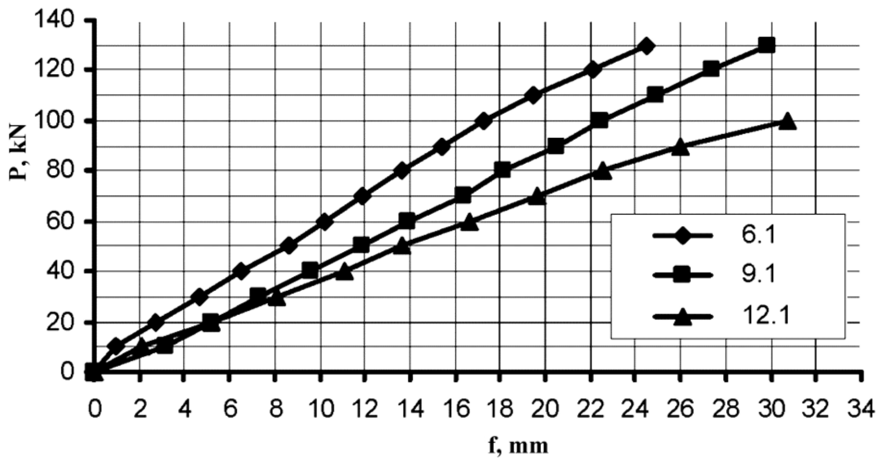

Fig. 7. Beam deflection graphs.

4 Conclusions

1. It is proved that the web local destruction is not the criterion of total destruction of corrugated beams.
2. The tests showed that under the action of concentrated forces the exhaustion of the load capacity of corrugated beams occurs either because of the loss of local stability of the corrugation, or due to the achievement of metal yield limit in the flanges.
3. When metal yield strength in the web of beams is achieved, flanges tension is only 60-90% of this value.
4. The load bearing capacity of corrugated beams is significantly influenced by eccentricity between the axes of flanges and webs.
5. Up to the destruction of corrugated beams, there is a linear correlation between deflection and load.

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