

Study of deformations of building structures thin-walled elements by the method of moire strips

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Abstract. The article deals with the application of one of the experimental optical-geometric methods which is the method of moire strips with a reflected grid (according to the Ligtenberg scheme) to the study of I-beam corrugated beams with different wall configurations of constant thickness, rigidly fixed on one side and free on the other (console). The bending deformation process was observed from the action of a concentrated force at the free end with the gradual loading at different intervals of the applied force action. A model of a beam made of low-modulus material (plexiglass) with two types of wall profile: wavy and triangular was tested. The modeling process of the studied beams was developed. Virtual technique of moire patterns formation with the subsequent computer processing by standard programs was applied. The analysis of the deflections along the beam length depending on the load is given and deflections graphs are constructed in comparison with the theoretical calculation for models with corrugated and flat walls (standard I-beam).

1. Introduction

As it is known, in experimental mechanics, when studying the stress-strain state of elements of thin-walled structures, various research methods are used: tensometric, polarization-optical, the method of moire strips, holographic interferometry, physical analogy, and other methods. When analyzing the methods of experimental studies, the method of moire strips with a reflected grid (Ligtenberg method) was chosen. This method has a number of advantages, namely: simple equipment, the ability to study models of small sizes, obtaining detailed information about the deformed state, the visibility of the polarization-optical method, the ability to study elastic and plastic deformations. The moire strip method is one of the most effective experimental optical methods of deformable solid mechanics. This method makes it possible to analyze the distribution of deformations in the elements of building structures made not only of isotropic but also anisotropic materials under static loading, as well as on models made of low-modulus material [1-3].

2. Problem statement

The purpose of this work was to determine deflections by theoretical and experimental methods of cantilever I-beams with different wall configurations when working on transverse bending and to develop a methodology for the experiment [3, 4]. As a result of the experiment planning, the required number of samples ($n=3$) was determined. It is necessary for a series of tests to obtain statistically reliable results of experimental studies.

For the experiment, the most common walls outlines (wavy and triangular) in corrugated beams were adopted: (Figure 1). In order to study the effect of the corrugated wall profile on the deformation of beams, flat-walled beams (standard I-beam) were manufactured additionally. Subjective error in the manufacture of models was smoothed due to the fact that the samples preparation (one beam from each species) was



performed by different people. From the test set parameters conditions and possible values of the external concentrated force, the size of the models and the following beams were adopted as follows: beam length $L = 200$ mm, wall height $h_w = 20$ mm, flange width $b_f = 20$ mm, wall thickness shelves $t_w = t_f = 1$ mm, the height of the wave corrugated wall $f = 6,25$ mm, length of half-wave for corrugated walls $a = 25$ mm. Calculation scheme of the beam is rigidly clamped cantilever beam loaded with a concentrated force at the free end (Figure 2). The concentrated force is applied along the axis of the shelf.

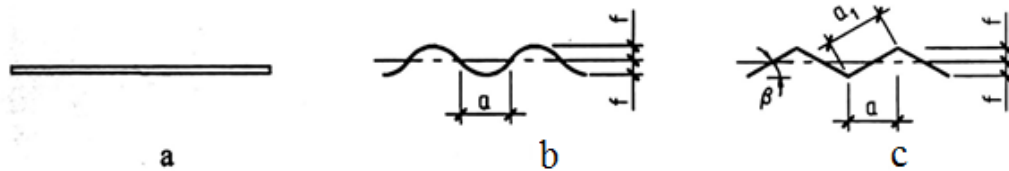


Figure 1. The beam wall profile: a – flat sheet; b – wavy; c – triangular.

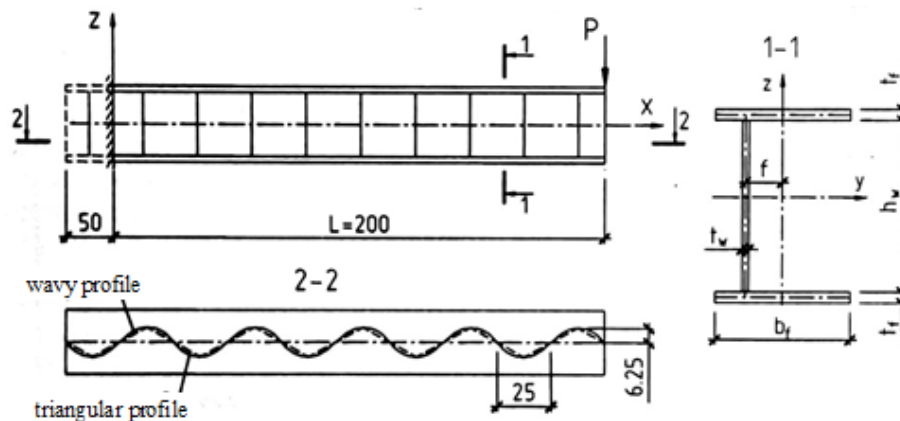


Figure 2. Beam calculation scheme.

The length of the entire model was adopted 50 mm longer to create a rigid fastening (dotted line in Fig. 2), than the length of the beam L . At testing the load was applied to one degree. During the experiment, it was necessary to choose a load that will give the number of moire strips within 6-15 lines; otherwise it will be difficult to process the results. The walls and shelves of the beams were made of sheet organic glass. The actual thickness of the sheet is 1.1-1.4 mm. modeling of corrugated wall beam samples requires careful preparation. Models are created in the following sequence:

1. Marking of details on sheet plexiglass.
2. Precise cutting of all parts.
3. Processing of edges of the cut details.
4. Making shavings or sawdust from plexiglass.
5. The production of glue based on dichloromethane.
6. Bonding a beam from the prepared parts.
7. The creation of a reference object on the basis of epoxy glue.
8. Creating a device for external load transfer.
9. Creating a mirror surface with bitumen varnish.

Wall and shelf joining is made by the glue received by complete dissolution of shavings or sawdust in dichloroethane. The glue allows receiving a strong bonding relating to the basic material durability. The glue fills all roughnesses in a joint place. The wavy wall profile is created by heating a flat sheet of plexiglass with punches forming. An additional element of rigidity is arranged in the supporting part of the beam. It is created by casting a 50 mm area with epoxy glue (Figure 2).

3. Installation for testing

The setup scheme for obtaining the moire effect is described in detail in [2,3] (Figure 3). This model was attached to the transverse steel bar using 5 clamps (Figure 4), to provide the beam rigid fix. The disadvantage of the deformations study by the moiré strip method using a reflected grid is that in a spatial structure, such as an I-beam, only the displacements of the upper flange will be determined, and the deformations of the lower flange are assumed to be similar. Although this assumption is not entirely true, since there are always imperfections in the samples which provide differences in the deformations of the upper and lower shelves.



Figure 3. Moire installation general view.



Figure 4. Fixing the beam model in the power frame of the installation.

Currently, the main problem in the development of this method is the lack of appropriate photographic materials - a special Mikrat film, which has high contrast and resolution, as well as contrast photo paper for printing moire patterns of angular deformations of model surfaces. It is proposed to use digital photo equipment in conjunction with a laptop to register the moire effect.

This technique was previously developed on separate rasters - linear, radial, concentric, cross-linear and others. The rasters were photographed and the digital image was transferred to the PC's memory, then the Photoshop program combined or superimposed it with a shift. The obtained moire pattern was processed with increasing contrast and lightening the background, then printed out for subsequent analysis [5] (Figure 5, 6, 8).

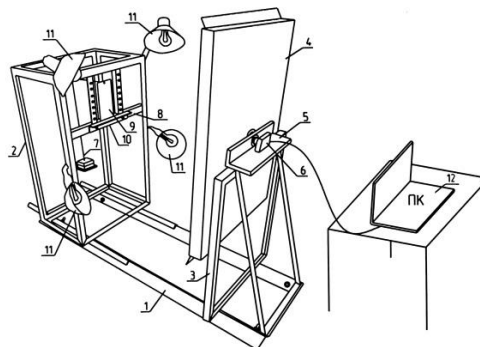


Figure 5. Schematic diagram of a joint complex of moire installation and a laptop:

1 - rigid bed; 2 - movable power (spatial) frame; 3 - a rigid flat frame with a cylindrical screen mount with a raster and a digital camera; 4 - a cylindrical screen with a linear raster; 5 - screen mounting bracket (articulated); 6 - digital camera; 7 - loading system; 8 - strap mounting model of the beam; 9 - model of an I-beam; 10 - hard jamming device; 11 - lighting devices (spotlights); 12 - laptop.

The essence of the method for determining deflections was the differential dependence of the deflection on the rotation angle. Having integrated along the length, we obtained the product of the serial number of the moiré strip and the scale factor λ , which is found from the ratio of the grid pitch of the raster to the doubled distance between the camera lens and the beam. The trapezoidal method was used to determine the maximum deflection in the console.

4. Testing

In the installation the models were stepwise loaded after fixing. When superimposing two amplitude grids and illuminating them with diffused light, clear moiré stripes will be visible. The grid applied on the screen is reflected from the mirror surface of the studied object and is photographed by a digital camera in loaded and unloaded states. The computer processes the images using the graphics editor Adobe Photoshop - the combination of loaded and unloaded raster, the definition of the moiré pattern, bringing the image to monochrome. The AutoCAD program determines the distance between the centers of the nearest light or dark stripes of a raster by the monochrome form of the moiré pattern. The results are processed and the deformations and stresses are determined using the Mathcad mathematical package. As a result of the experiment, five patterns of moiré stripes were obtained for a beam with a flat wall (Fig. 6) and for a beam with a wavy wall (Figure 7).

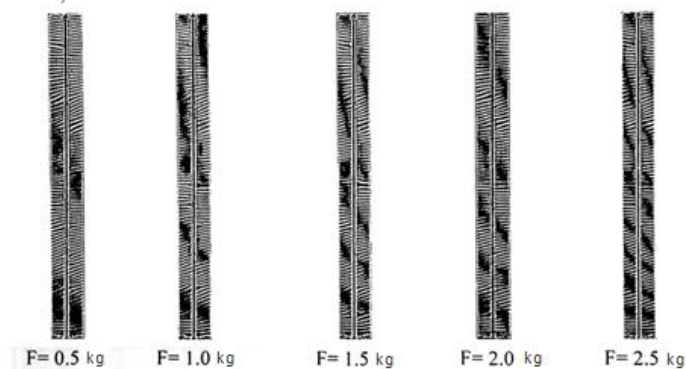


Figure 6. Moiré strips for a flat-wall beam.

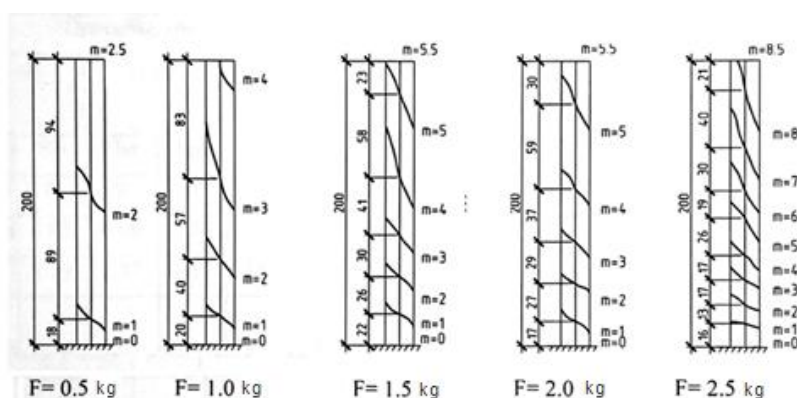


Figure 7. Processing of moiré strips for a flat-wall beam.

It follows from the graph (Figure 10) and table that the most rigid model is the model of a beam with a flat wall.

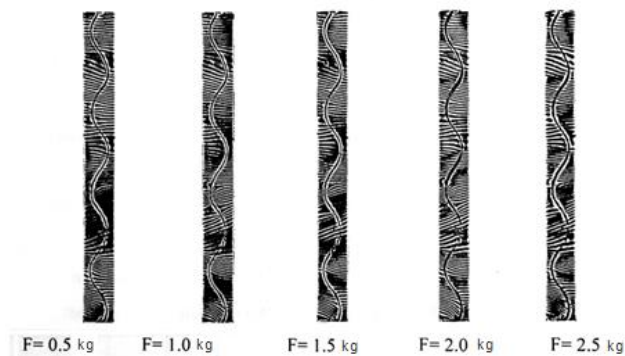


Figure 8. Moiré stripes for corrugated wall beams

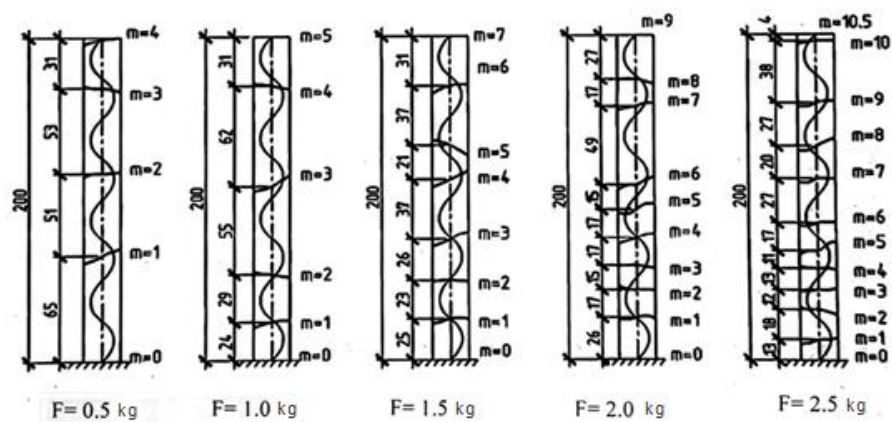


Figure 9. Processing of moiré strips for a beam with a wavy wall.

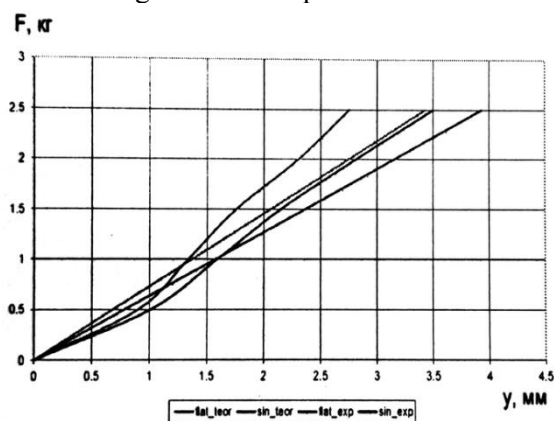


Figure 10. Graph of theoretical and experimental deflections

5. Conclusion

During the experiment the following features of beams were revealed:

1. It is experimentally confirmed that the beam with a corrugated wall is more deformable compared to the beam with a flat wall [6, 7].
2. The sin beam deflection is 12-27% higher than that of the beam with a flat wall.
3. The values decrease of experimental deflection relative to the theoretical ones is associated with the emergence of the effect of local torsion, which can be seen via the moire stripes.
4. The analysis of the position of the moire strips shows that the beam with a corrugated wall resists torsion better than the beam with a flat wall.

Table 1. Research results

Load F, kg	Deflections				Difference, %		
	Exp.		theoret.		Exp.	theoret. / Exp.	
	Flat	Sin	Flat	Sin			
0	0	0	0	0	-	-	-
0.5	0.90	1.01	0.68	0.78	12.1	32	28.9
1	1.33	1.59	1.37	1.57	18.9	-2.5	1.1
1.5	1.75	2.14	2.05	2.35	22.2	-	-
						14.6	-9.1
2	2.3	2.80	2.74	3.14	22.1	-	-
						16.1	10.7
2.5	2.75	3.49	3.42	3.93	27.2	-	-
						19.7	-11

References

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