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Modern Methods of Box-Shaped Crane Beams Design

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Abstract: A box-shaped crane beam has been developed with transverse diaphragms that change the positionning pitch along the beam and the angle of horizontal inclination in accordance with the orientation of the waves of the local wall resistance loss.
Keywords: box-shaped crane beams, walls of beams, local loss of resistance, diaphragms.

1. Problem Statement

Stringers of the crane bridges (Fig. 1) during operation are loaded with external stationary and moving forces leading to arising internal forces, Q being transversal force and *M* being bending moments. The transversal forces have the largest values in the supporting parts and then decrease to a minimum in the middle of the beam run. These forces cause a local stability loss in the beam walls arising as diagonal waves of wall deformation 7.

On the contrary, the bending moment increases from the minimum on the supports to the maximum value in the middle of the beam run. The bending moment causes a local stability loss in the compressed upper portions of the beam walls arising as longitudinal waves of wall deformation 8.

In existing stringers of a box-shaped structure, especially heavy-loaded ones, transversal vertical diaphragms 5 are placed with a uniform pitch. In addition, at the distance of 0.25 Ns from the upper belt at least one longitudinal rib 6 is welded to each wall. For manufacturing such beams a large number of different types of welding operations is needed, a variety of ribs and diaphragms being available, the direction of placement of which does not coincide with the direction of possible occurrence of the waves of local loss of wall resistance.

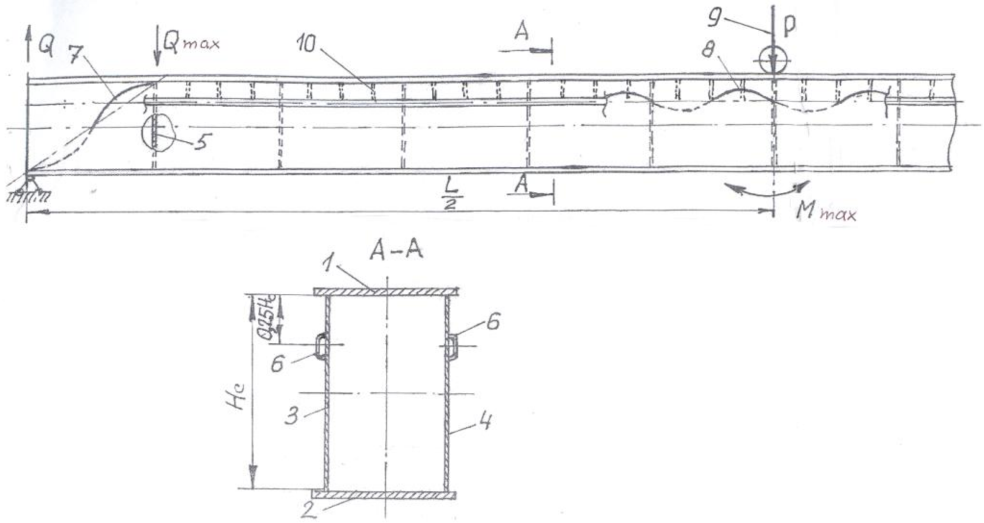

Figure 1 – Common stringer design

2. The Aim of the Work

In order to simplify the design and increase the productivity the task was to develop a stringer of a load-lifting crane, which would ensure the local stability of the walls.

3. Statement of Basic Material

For the most effective prevention of the occurrence of waves of local loss of walls stability in the beams of heavy loaded cranes, the diaphragm it is proposed to be placed along the possible direction of occurrence of deformation waves, the beam being equipped only with transversal diaphragms, the placement of which decreases from the supports to the middle of the beam. The angle of the diaphragm corresponds directly to the possible occurrence of waves of local loss of wall resistance in different sections and increases to the middle of the beam. The placement pitch and the diaphragm angle corresponds to the known ratio of the free height of the wall in the middle modules of the beam to the thickness of the wall

$$\frac{h_i}{\delta_c} \leq 200\sqrt{\frac{210}{R}},$$

where R is the design resistance of the wall steel, MPa;
h_i is the free height of the wall, m;
δ_c is the thickness of the wall, m.

The beam (Fig. 2) which includes transversal diaphragms 5 installed in the beam, the pitch of placement being evenly reduced from the supports ($l_i = H_c$) to the middle of the beam, is recommended. The angle of their horizontal inclination increases uniformly from $\alpha_i = 45°$ in the supporting ones to $\alpha_i = 135...150°$ in the middle modules of the beam according to the direction of possible walls deformation waves which lead to a local loss of walls stability.

Consequently, the application of only transversal diagrams, the placement pitch being evenly reduced from the support modules to the middle of the beam and the change in the angle of their inclination to the horizontal, provides stability of the wall, and, thus of the whole structure.

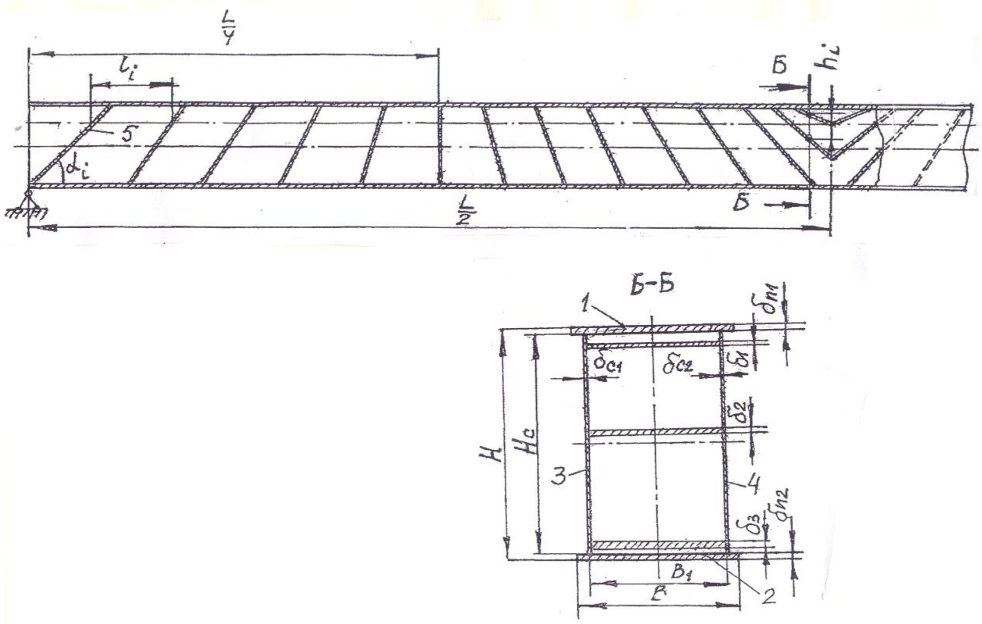

Figure 2 - The proposed construction of a stringer with inclined diaphragms

Beams corrugated walls can be an alternative to two-sided beam, they ensure the local stability of the walls and the ease of technology for the manufacture of single-paneled structures. The technology of corrugated wall manufacture and its joint with the upper and lower belt is well-worked out and has no problems in automation which ensures high-quality connection and lower production cost.

Such beams are well-known and widely used in civil engineering. The most common beams with corrugated walls are Sin-beams. Sin-beam (Fig. 3, a), hereinafter corrugated beam, is a kind of welded I-beam with a wavy-profiled sheet wall and flanges of strip steel.

Previous domestic and foreign experimental studies of corrugated beams proved that normal bending stresses σ_x are perceived almost only by the beam flanges and very rapidly fall practically to zero, the wall across the corrugation having no resistance, and the tensional stresses being distributed almost uniformly (Fig. 3 , b). The main advantage of corrugated beams is the ability to maintain the local resistance of the wall without rib stiffeners, which increases with the increased amplitude of the corrugated wall wave.

Sin-corrugation can be described as a parameter

$$S = \frac{D}{A} \ ,$$

where D is the length of the full period of the corrugation wave, m;
A is the amplitude of corrugated wave, m.

The flexibility λ_2 of the corrugated wall is proposed to be calculated by the flexibility of its base element, that is, one corrugated wave, based on conditions

$$\lambda_2 = \frac{h_c}{i_x} \leq 80,$$

where h_c is the height of the wall given, m;
i_x is the radius of corrugated wave inertia, m.

For this case

$$i_x \geq \frac{h_c}{80} = \sqrt{\frac{J}{F}},$$

thus $J \geq \left(\frac{h_c}{80}\right)^2 \cdot F = k_j \cdot \pi \cdot A \cdot \delta \cdot \left(A^2 + \frac{\delta^2}{4}\right),$

where k_j is the coefficient which depends on the corrugation wave parameter $S = \frac{D}{A}$;
D is the length (step) of corrugated wave, m;
A is the amplitude of corrugated wave, m;
δ is the thickness of the corrugated sheet, m.

The department "Machine parts and Mechanical handling equipment" of ZNTU carried out theoretical studies of static stresses and beam deflections caused by concentrated load for the comparative evaluation of the resistance inertia moment of common and corrugated beams, that is their load characteristics. Also the possible losses of local stability of flat and corrugated walls by finite element method were compared. The diagrams of corrugated and flat beams stress and movement were obtained.

Static analysis demonstrates the advantage of a common beam with a flat wall, which is shown in a lower deflection of 33.6% and, accordingly, in lower flange strains.

Under the same conditions the maximum stress of the corrugated wall is 10.43 times larger than the maximum stress of the flat wall, and the displacement, respectively, is 31.7 times larger. The tension in the corrugated wall is focused on the bends. The local resistance of the corrugated wall to the action of the pressure of the trolley wheels is substantially larger than the flat wall. Consequently, the sufficient local wall firmness makes it impossible to apply rib stiffeners, which significantly increases the machinability of the manufacturing and reduces the metal strength of the beam.

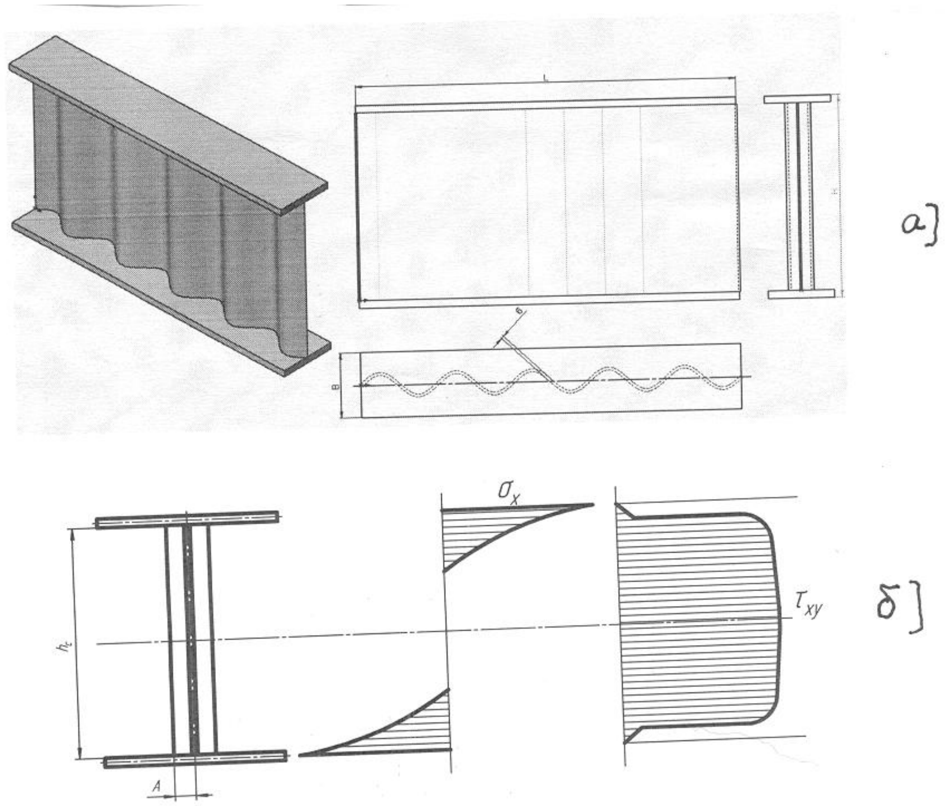

Figure 3 - Potential crane beam with a corrugated wall

The main disadvantage of the corrugated wall is a very small resistance and inertia moment of the transverse section on the effect of the stretching and beam compressing axial forces, thus the loaded beam has a larger deflection due to bending stresses. This disadvantage can be offset by increased height of the beam, or by increased cross-sectional area of the flange, which may be rational in certain cases.

4. Conclusions

By placing the transverse diaphragms in the box-shaped crane beams with variable pitch and inclination to the horizontal, according to the orientation of the wall resistance local loss waves, the number of weld operations decreases, the amount of the diaphragms and ribs decreases with walls stability.

The corrugated walls of the main beams will completely eliminate diaphragm from the design. And this, in turn, reduces the amount of material and increases the machinability of manufacturing retaining the bearing capacity. The lack of diaphragms results in fewer welds, which increases the operational reliability of the structure and reduces costs.

5. Literature

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