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# METHOD OF CALCULATING SPACE OF MULTISUPPORTS CONSTRUCTION

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*This paper presents a) the method of calculation of the spatial multisupport construction.*

Two-moment bending torsion theory together with the methods of construction mechanics makes it relatively simple to calculate the spatial systems such as a thin-walled one, having in a span an arbitrarily given points intermediate supports. Such systems include, in particular, the design of beam bridges with diagonal supports (Fig. 1), the design covers like ribbed vaults shells with respect to the longitudinal edges of the support rod (Fig. 2). For simplicity sake we shall assume that the system in cross section has a vertical axis of symmetry.

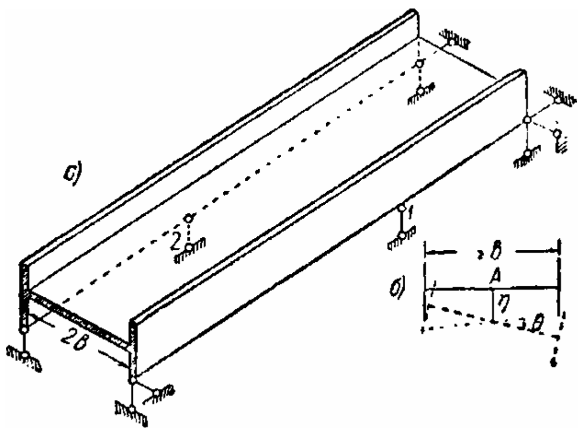

Fig. 1. Design with diagonal supports

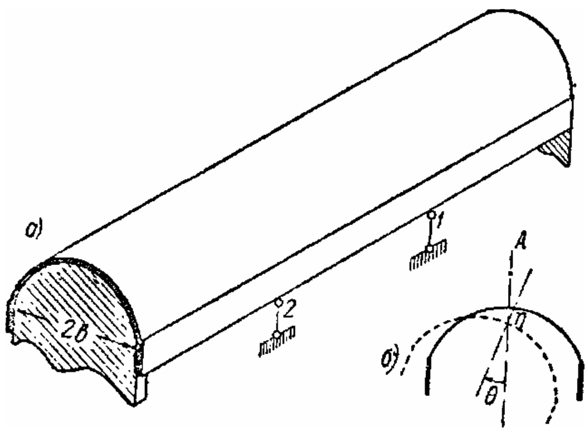

Fig. 2. Strain model

Suppose that such a system is under the influence of the vertical load, for which the resultant transverse strips of unit width in the plane of symmetry of the profile. An example of such a load is the weight of its own design. This load in the absence of asymmetric support connections according to the above theory, cause a bending deformation only. A torsional deformation is absent, since the load will pass through the center line of bending, also lying in the longitudinal plane of symmetry. In the presence of links arranged at a certain distance from the axis of symmetry of the profile design, along with the bend and will experience torsional deformation caused by reactions of reference relationships. To determine these reactions, we can use the methods of structural mechanics, extending and generalizing these methods to be considered here walled spatial system. We will proceed from the force method. We choose as primary thin-walled single-span structure, obtained from the set by dropping the intermediate support connections. Strain state of the system at any complex loading can be determined by applying the elementary conditions of bending and torsion of the bending. Since in our example the external load and the supporting communications vertical, the states of elementary basic system we are interested in the status of the two species, namely, pure bending and bending-torsion (Fig. 1, b, 2, b).

Action reaction of any of the support rod, not passing through the center of curvature, can be reduced to the busy main system concentrated vertical load in the plane of symmetry and causing pure bending deformation, and concentrated torque that causes the bending deformation of the torsion. Vertical deflection γ1 = γ1 (z, t) of the rod in any section z = const of a concentrated vertical load P acting along the axis of symmetry in any other section t = const with hinged support rod ends determined by the formulas:

values for $l \geq z \geq t$

$$\eta\left(z,t\right)=\frac{P(l-z)t}{6EI_x l}\left[l^2-(l-z)^2-t^2\right]; \tag{1.1}$$

for values of $t > z \geq 0$

$$\eta\left(z,t\right)=\frac{P(l-t)z}{6EI_x l}\left[l^2-(l-t)^2-z^2\right]. \tag{1.2}$$

Equations (1.1) and (1.2) can be prepared either by the method of initial parameters for the differential equation in Equation beam bending system, or by applying the general Mors formula for the displacement.

$$\eta\left(z,t\right)=\int_0^l \frac{M_z(s)M_t(s)}{EI}ds\,, \tag{1.3}$$

where M(s) and Mt(s) – the bending moments from the individual forces applied at two different points with the beam axis and z abscissae t. Formula (1.1) and (1.2) are a function of influence (Green's function) for the problem of bending of the single beam with hinge supports at the ends. Torsion angle in arising in any section z = const of torque concentrated H = D acting in the plane of any other section *t* = const, is determined by the formulas:

values for $l \geq z \geq t$

$$\theta(z,t)=\frac{H}{GI_d}\left[\frac{t}{l}(l-z)-\frac{l}{k}\cdot\frac{sh\ \frac{k}{l}t}{sh\,k}\cdot sh\ \frac{k}{l}(l-z)\right]; \tag{1.4}$$

for values of $t > z \geq$ about

$$\theta(z,t)=\frac{H}{GI_d}\left[\frac{l-t}{l}z-\frac{l}{k}\cdot\frac{sh\ \frac{k}{l}(l-t)}{sh\,k}\cdot sh\ \frac{k}{l}z\right]. \tag{1.5}$$

These formulas presented the influence function (Green's function) for the problem of single-span flexural torsional thin-walled beams, having the ends of the hinge bearing also.

Formula (1.4) goes into the formula (1.5) by replacing *z-t*, which is in accordance with the symmetry of Green's function, and the reciprocity theorem Betty movements: in (*t*, *z*).

In the case of ribbed vaults shells used in the construction business, as well as in the case of cylindrical and prismatic shells open profile, widely used in aviation and shipbuilding, stiffness GJd Sen-Venan's torsion factor is secondary importance foam values. Assuming that the stiffness and hence the magnitude of k, equal to zero, we can simplify the formula (1.4) and (1.5). To do this, expand the hyperbolic functions included in the formula (1.4) and (1.5) in a row, two terms expansion for each function, and take the limit.

We simplify, for example, formula (1.4):

$$\lim_{k\to 0}(z,t)=\lim_{k\to 0}\frac{H}{GI_d}\cdot\left(\frac{t}{l}(l-z)-\frac{l}{k}\cdot\frac{\frac{k}{l}t\left(1+\frac{k^2}{6l^2}t^2\right)\frac{k}{l}(l-z)\left(1+\frac{k^2}{6l^2}(l-z)^2\right)}{k\left(1+\frac{k^2}{6}\right)}\right)=\lim_{k\to 0}\frac{H}{GI_d}\frac{t(l-z)}{l}\times$$

$$\times\left(1-\left(1+\frac{k^2}{6l^2}t^2\right)\left[1+\frac{k^2}{6l^2}(l-z)^2\right]\left(1+\frac{k^2}{6}\right)\right)=\lim_{k\to 0}\frac{Hk^3}{6GI_d}\frac{t(l-z)}{l^3}\left[l^2-(l-z)^2-t^2\right]= \quad (1.6)$$

$$=\frac{H}{6GI_\omega}\frac{t(l-z)}{l^3}\left[l^2-(l-z)^2-t^2\right]$$

Formula (1.6) is valid for values of $l \geq z \geq t$. For values of $t > z \geq 0$ from (1.5) we obtain

$$\theta(z,t)=\frac{H}{6EI_\omega}\frac{z(l-t)}{l}\left[l^2-(l-t)^2-z^2\right]. \quad (1.7)$$

Formulas (1.6) and (1.7) have a similar structure to the formulas (1.1) and (1.2) and differ from them in quantities related to the displacements, the load and to the generalized geometric characterization. The identity of these formulas is also a consequence of us made up the general provisions relating to the mathematical analogy in the theory of rods in bending and torsional flexural.

We now give a formula for the deflection of the main system outward transverse uniformly distributed load q, acting in the plane of symmetry:

$$\delta_{ij}=\eta_{ij}+b\theta_{ij} \qquad (i,\ j=1,\ 2,\ 3,\ldots,\ n),$$

$$\delta_{iq}=\eta_{iq} \qquad (i=1,\ 2,\ 3,\ldots,\ n),$$

$$\eta(z)=\frac{qz}{24EI_x}\left[l^3-2lz^2+z^3\right]. \quad (1.8)$$

Knowing the strain our basic system considered here its elementary states; we can now easily obtain the equations for the unknown force method reactions vertical piers. These equations when the number n of intermediate supports is of the form:

$$\left.\begin{array}{l}\delta_{11}X_1+\delta_{12}X_2+\ldots+\delta_{1n}X_n+\delta_{1p}=0,\\ \delta_{21}X_1+\delta_{22}X_2+\ldots+\delta_{2n}X_n+\delta_{2p}=0,\\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\\ \delta_{n1}X_1+\delta_{n2}X_2+\ldots+\delta_{nn}X_n+\delta_{np}=0.\end{array}\right\} \quad (1.9)$$

Here, the desired reactions, {$i$ = l, 2, 3, ..., n) with positive considered positive if they comply with the stretchable support links.

Coefficients and the free terms of the equations (1.9) are calculated by the general formulas: where $i$ and $j$ – the serial numbers of equations and unknowns; – Deflection of the $i$-th section of the support unit concentrated force corresponding to the desired reaction $j$-th support; – Torsion angle in the $i$-th section of support from the local, single torque $Hj = b$, acting in a plane passing through the $j$-th support.

The $b$ value represents the half width of the structure (torque shoulder). In accordance with the rule of signs, this value will be positive for poles located on Fig. 1 and 2 to the right of the axis of symmetry and to the negative poles to the left of the axis.

Free term b, $i$-th equation is calculated by the formula (1.8) as deflection for a given load in the section passing through the $i$-th prop. Determined from the equation (1.9) support reactions, we can then use the above formulas for elementary states the basic system by the method of superposition to get deflections $m$ angles of twist given spatial multisupporting system. Normal and tangential stresses in the cross-sections of the system, in the case considered here should be calculated on the binomial formula:

$$\sigma(z,s)=-E\left[\eta''(z)y(s)+\theta''(z)\omega(s)\right]$$

$$\tau(z,s)=E\left[\eta'''(z)\frac{S_x(s)}{\delta(s)}+\theta'''(z)\frac{S_\omega(s)}{\delta(s)}\right].$$

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## STRENGTHENING OF FOUNDATION BY BUILDING-UP WITH RIGID REINFORCING

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*This article treats methods of strengthening of strip foundations by increasing the base of foundation. Structural concepts providing joint work of elements of existing foundations and concrete building-up are analyzed. It's shown that reinforcement of gripper-arm interface by rolled profiles allows more stringent and more reliable interfacing of new and old elements of foundation. Construction diagrams of installation of metal-rolling profiles in reinforced foundation are shown. Technology of strengthening of foundation by building-up with the use of rigid rebars is described.*

When reconstruction of buildings and constructions takes place there is often necessity to strengthen the foundations. Mostly this problem should be solved when superstructure of additional floors, increasing the span between the supporting structures, changing of scheme of support of overlapping elements etc. Strengthening of the foundations is also made during the stabilization of ground foundation deformations of a building that is in an emergency condition.

As it is shown by building practice, works of foundations strengthening are labor-consuming and quite expensive. Cost of foundations strengthening works can compose more than half of cost of all works during buildings reconstruction. In many instances, reconstruction, connected to strengthening of the foundation, becomes economically impractical.

Working-out of new structural concepts of the foundation strengthening that satisfy requirements of manufacturability, security, minimal consumption of materials and labor intensity will allow to reduce considerably the cost of such works and to make projects of reconstruction of buildings more attractive for investors.

The most widespread method of strengthening of strip foundations is increasing the base of foundation by building-up the reinforced concrete mantle both from one side, and from the other side of reinforced foundation. At present, there are some methods of broadening the strip foundation base by building-up protrusions: with the use of anchors (fig.1,a); with the installation of reinforced construction under the base of existing foundation (fig. 1, *b*); with the use of perforating anchors (fig. 1, *c*); with a simultaneous injection of foundation (fig. 1, *d*).

Joint work of reinforcement elements with existing foundation in abovementioned methods is provided by:

– arrangement of concrete dowels, projections in recesses of existing foundation or supporting structures of building;
– arrangement of anchors embedded into body of existing foundation;
– arrangement of perforating armature;
– welding of armature of elements of broadening with bared fittings of reinforced foundation;
– with the use of special support elements: struts, unloading metal or reinforced concrete beams.

In this work the method of strengthening of strip foundations by building-up with use of rigid reinforcement. As rigid armature can be used rolled profiles in the form of channel sections, T-beams or I-beams, installed into drilled by diamond crowns holes. Scheme of strengthening is shown on fig. 2

In proposed method, metal-rolling profile will allow creation of rigid connection between existing foundation and construction of reinforcement that cannot be provided fully with the use of anchors. Besides, there is no need in installation of longitudinal dowels or metal beams over the entire length of reinforced foundation, thus, the step of installation of rigid reinforcing element is determined by the condition of providing the strength of concrete extrusion of the existing foundation.