THE BENDING CALCULATION OF A METAL FRAME BUILT OF RESISTANT MATERIALS WITH DIFFERENT SECTIONS

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Abstract. *The subject proposed was developed based on a real situation. This paper aims at developing an evaluation method, the calculation of frame-strength steel structures, used in industrial and reinforcing possibilities of these structures.*

Keywords: *calculation of resistance, metal frame, reinforcing*

1. CALCULATION OF STRUCTURE RESISTANCE

1.1. General aspects

In industry, there are numerous cases where frame-made metal constructions, or beam, where necessary, the design phase under conditions of design.

Organisms ability in the field, impose conditions for the design, construction and operation by national rules and international rules. While with the passing years, a new problem arose if all these constructions are safe to work.

Requests to tensions, normal ranges while tangential (σ , τ), periodically between a lower limit and one upper varying loads are called. With these varying tensions, pieces break off and break at much lower tensions than in the case of static requests. The phenomenon of decreasing resistance characteristics under the effect of varying loads, is called (improperly) material fatigue [1].

The reality is that tearing at a piece varying loads (construction) constitutes a process of occurrence and development of cracks, which decreases continuously active section of the piece. When the section is insufficient to activate the stress effectively, breakage occurs. The maximum value of the tension at which the rupture does not occur to varying loads is called fatigue resistance

Clarification breaking mechanism varying loads and fatigue resistance setting is a very complex phenomenon, influenced by many factors.

The total tension values σ or τ , in a certain period of time, form a cycle. Depending periodic variation in tension σ , τ they were established following cycles:

- undulating pulsating; $\sigma_{\max}$ or $\sigma_{\min}$
- alternating symmetrically. $\sigma_{\max} = -\sigma_{\min}$.

Fatigue resistance is noted at symmetrical alternating cycle with σ_{-1} and the pulsating cycle σ_0 . The values of these tensions are determined experimentally in the laboratory.

For various materials commonly used spreadsheet literature offers this information. External loads applied to the bodies, up to a certain limit, determine their elastic deformations.

If this limit is exceeded, plastic deformations occur, accompanied by shear (changes right angle) irreversible destruction they cause atomic structure links the material.

These microscopic cracks forming atomic destruction. The extension of these cracks leads to cracks and to reduce the active section. Micro cracks, as a result of efforts sometimes lower the yield of the material can be damaged domestic factors related to the material structure (very small inclusions, voids), either due to external factors – layer defects on the surface of the work piece, particularities shape of the piece (goals, fittings), - how topical application of concentrated loads. When required variables, nano-leakage is a specific phenomenon so frangible material and the tenacious.

Top of cracks is the site of important concentrations of tensions, which occur due to crack propagation and to reduce the active section. Repeated opening and closing of cracks smoothes surfaces in contact, what distinguishes the rift with the glossy (smooth) before breaking the corresponding area and a rough area, breaking the corresponding time.

The maximum amount of stress that does not develop cracks, no matter how great the number of stress cycles is called fatigue resistance. It depends on the material properties, such as cycle and many other factors constructive, technological and operational.

Resistances admissible σ_a and τ_a, tension that occur in the material are required and must not be exceeded bodies of the actual, those occurring under load. They are determined by the mechanical characteristics of the part material that can be σ_r, τ_r (frangible materials) and σ_c, τ_c (tenacious materials),[2].

$$\sigma_a = \frac{\sigma_{r(c)}}{c} ; \tau_a = \frac{\tau_{r(c)}}{c} \qquad (1)$$

Choosing coefficient of safety „c" the possibility of determining the allowable tension lead. In practice two methods of choice admissible resistance, coefficient of safety. In paper [2] it gives some indication of choice σ_a and τ_a, the three cases (load static- case I, load through pulsed cycle - case II, call by alternating cycle symmetrically - case III).

The method of safety coefficients representing a global estimate coefficient thereby achieving safety and admissible values for resistances σ_a and τ_a. The global safety coefficient is determined as follows:

$$c = c_1 \cdot c_2 \cdot c_3 \cdot ......c_n \qquad (2)$$

where: $c_1, c_2, c_3, ..., c_n$ - are factors that lead to an approximation of the global coefficient of safety;

$c_1 -$ the accuracy calculation formulas; - $c_2 -$_material quality;- $c_3 -$ important piece calculated,[2].

Because in reality and structures are requesting a zone requests for calculating variables recommend a check of the structure that take account of material fatigue.

1.2. Establishing calculation model

To illustrate, justify the choice of this topic, I considered a simplified model of metal frame as in the figure below (Figure 1).

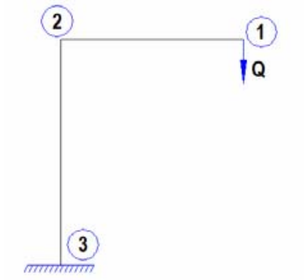
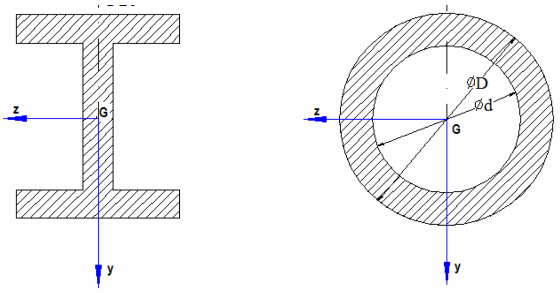


Fig. 1. Metal frame

The metal frame is constructed of crane type bar type elements, the different sections, requested bending a concentrated load Q.

For the study, consider the structure consists of two elements bar type sections having presented as in Figure 2, distributed as follows, on the portion 1-2 section is type I (Figure 2 a), and the portion of 2-3 is tubular section (Figure 2 b).



a). b).

Fig. 2. Sections of the metal frame

1.3. Drawing diagram effort $M_{i\max}$. Identification of dangerous area

Based on a calculation of minimum resistance, calculating the reactions of links, diagram effort, bending moment is shown in the following figure (Figure. 3).

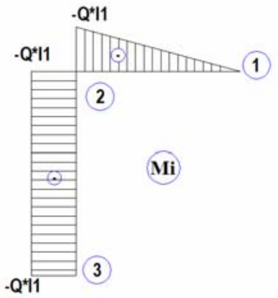


Fig. 3. Bending moment diagram effort

From the bending moment diagram is observed risk areas, the danger zone is the portion 1-2 in Section 2 where we have maximum time and the 2-3 section we can see that the entire length of the maximum bending moment. Calculation verification will be done in section 2 and at any point between section 2-3. It is the maximum bending moment $M_{i\max} = -Q \cdot l1$.

1.4. Calculation of axial moment of inertia I_z and resistance module W_z for each type of section

For the profile section I (Figure 2 a).) provide specialty literature tabulated values regardless of the size selected profile. Such a profile for I 20 values, axial moment of inertia and modulus are:

Profile section	$I_z\left[mm^4\right]$	$w_z\left[mm^3\right]$
I 20	21400000	214000

For the section tubular profile (Figure. 2 b), the axial moment of inertia is calculated from the relationship;

$$I_z[\,mm^4\,] = \frac{\pi}{64} D^4 \left(1 - \left(\frac{d}{D} \right)^4 \right) \qquad (3)$$

and resistance module is calculated with

$$W_z[\,mm^3\,] = \frac{\pi}{32} D^3 \left(1 - \left(\frac{d}{D} \right)^4 \right) \qquad (4)$$

In calculating the mechanical strength required of the material structure determination. For this specialty literature provides the desired spreadsheet [2].

2. CALCULATION OF THE EFFECTIVE TENSION

Check calculation involves determining the actual tension comparison section considered dangerous and allowable tension (σ_a), established taking into account the calculation of the structure and not only fatigue

$* \sigma_{ef} = \frac{M_{i\max}}{W_z} \le \sigma_a \left[\frac{N}{mm^2} \right]$ - allowable tension static [2];

* $\sigma_a = \frac{\sigma_{-1}}{c}\left[\frac{N}{mm^2}\right]$ - allowable tension that takes into consideration various factors material fatigue and what goes into coefficient. global safety c.

* $\sigma_{-1}\left[\frac{N}{mm^2}\right]$ determined by laboratory tests, experimental[2].

2.1. The influence of material fatigue strength calculation. Establishing safety coefficient

Experimental material was found as a breaking resistance σ_r, subject to a number of requests variable values break $\sigma_{\max}$ lower tension σ_r. This phenomenon is known in the art as the fatigue of the material [3].

Thus we can say that the value of the upper limit $\sigma_{\max}$ the resist material to a large number of cycles (10^7 cycles) without breaking is called fatigue resistance.

A material has an infinite fatigue resistant to breaking, depending on a number of factors.

It is known that, in calculating fatigue, after a number of operating cycles material tension reached breaking of fatigue, and there was breaking from then increasing the number of cycles, the material no longer fails.

It is important that allowable tension (σ_a)to be as close to real value, but can be considered elusive goal in terms of the designer. Such literature provides values (σ_a)for various materials, representing recommendations on the calculation of allowable tension depending on the type of request (tensile, compression, shear, bending, torsion) but also how to apply [2].

In [2], page 147, Table. 6.1 allowable stress values are presented in bending cycles depending on application (static, pulsating and alternating symmetrical). The order presented showing downward trend allowable voltage sag. In case of a request alternating symmetrical, planners are considering an allowable tension value less than with a request pulsed (Table 1).

Table 1. Admissible Tension bending

Material	Breaking tension $\sigma_r\left[\frac{N}{mm^2}\right]$	Allowable bending resistance $\sigma_{ai}\left[\frac{N}{mm^2}\right]$		
		σ_{ai_I}	$\sigma_{ai_{II}}$	$\sigma_{ai_{III}}$
Carbon steels	400(OL37)	13	70	40
	500	17	75	45
	600	20	95	55
	700	23	11	65
Alloy steels	800	27	13	75
	1000	33	15	90
Cast steel	400	10	50	30
	500	12	70	40

Consider the case of periodic varying loads, continuously oscillating between a maximum value $\sigma_{\max}$ and a minimum $\sigma_{\min}$ - positive value. The fact that tensions $\sigma_{\max}$ and $\sigma_{\min}$ are both of the same sign, it is called oscillatory cycle. So the system is subjected to an oscillating pulse request.

After a while, a number of cycles, it is found that all demountable assemblies (ex. Assembly with screws, etc.) and non-removable (assembly by welding), metal building components are entering the appropriate (ballot verification, non-destructive inspections proves this), it is considered in the calculation to take into account verification of material fatigue and other operational factors so we can write:

$$\sigma_{ef} = \frac{M_{i\max}}{W_z} \leq \sigma_a \text{ where } \sigma_{ef} = \frac{\sigma_{-1}(\sigma_0)}{c}$$

From [2], table 4.1, 4.2 – page. 84, extract allowable tension bending values - alternating cycle symmetrically -σ_{-1} and pulse cycle σ_0.

It should be noted that all these values were determined in the laboratory, the car tried so need to use to take into account a factor of uncertainty, a factor of safety [4] the page. 168, provides guidance on choosing global safety coefficients using (Table 2.).

Table 2. Safety coefficients

Features of the starting resistance in computing	Safety coefficient
Breaking strength (σ_r)	$1.8 \div 2.5$
Limit of flow (σ_c)	$1.1 \div 1.8$
Fatigue resistance (σ_{-1})	$1.2 \div 2.0$

In the calculation is required following algorithm verification:

a). it sets a recommended safety coefficient of literature $c = 1.2 \div 2.0$, and thus adopt Admissible tension σ_{-1} and σ_0;

b). verification consists in checking account inequality:

$$\sigma_{ef} \leq \frac{(\sigma_{-1})\sigma_0}{c_{ales}} \tag{5}$$

If inequality is satisfied that a compromise is necessary to limit the maximum load value Q that does not exceed, get relationship;

$$M_{i\max} \leq \frac{\sigma_0 \cdot W_z}{c_{ales}} \rightarrow Q \leq \frac{\sigma_0 \cdot W_z}{c_{ales} \cdot l_1}[kN] \tag{6}$$

Another way to increase endurance strength is 1-2 bar which is a stiffening of it (Figure. 6). The model in this case is complicated, the system is statically indeterminate and how to check the strength of resistance requires knowledge rich.

3. CALCULATION OF BUCKLING VERIFICATION

But for this case, we suggest checking for calculation of the resistance bar 1-2, covering the verification calculation, ie a calculation of buckling verification of the profile longitudinal stiffeners

Thus we believe that the construction becomes unstable when entering stiffening strut buckling and so all this calculation is limited to a checking account buckling of the strut *BD*. This calculation is based on reductionist assumptions. We believe that 1-2, while officials acting on the strut with external load *Q*. We aim to determine if the maximum load *Q* this brace enter buckling. The dimensions are known and are respectfully considered in Figure. 5.

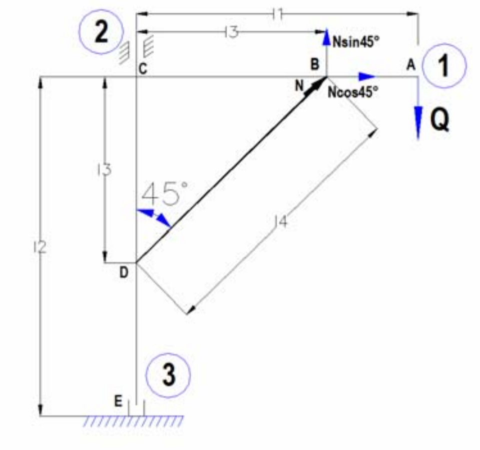


Fig. 5. Reinforced metal frame

The effort N from *BD* bar moments result from the equation of the point C so.

$$\sum M_C = 0 \Rightarrow Q \cdot l_1 - l3 \cdot N \cdot \sin 45^\circ N = 0 \qquad (7)$$
$$N_{ef} = ...[N]$$

Metal constructions (structures of industrial, buildings, cranes) buckling safety factor is provided as a linear value $c_f = 1.6 + 0.0066\lambda$ elastic buckling case $\lambda \in (0, \lambda_0)$ and $c_f = 2.3$ for $\lambda > \lambda_0$ [1], page. 475.

In determining the buckling length is adopted $c_f = 0.5 \cdot l1$ [5], BD bar is considered encapsulated at both ends. It is considered the reference slenderness ratio λ_0, the material from which the bar is made *BD* thus obtained: $\lambda_0 = \pi \sqrt{\dfrac{E}{\sigma_p}}$,

where: E - modulus of elasticity, Young's modulus;

σ_p - proportional limit of the material, tension to the material behaves elastically.

Coefficient of slenderness for *BD* bar is obtained using:

$\lambda_{calc.} = \dfrac{l_f}{i_{\min}}$, where: - $i_{\min} = \sqrt{\dfrac{I}{A}}$ - radius of inertia;- I – axial moment of inertia;- A - sectional area.

Depending on the value of this ratio, we set the buckling:

- $\lambda_{calc.} < \lambda_0$ - the plastic buckling (which means that material flow occurs before buckling);
- $\lambda_{calc.} > \lambda_0$ - the elastic buckling-field computing Euler.

It calculates buckling safety factor according to the above: $c_f = 1.6 + 0.0066\lambda$ for $\lambda_{calc.} < \lambda_0$ or $c_f = 2.3$ for $\lambda_{calc.} > \lambda_0$.

Establishing admissible tension buckling σ_{af}, is made considering σ_{cr} buckling. In specialized books, for example, the material OL37 material widely used in steel construction has included slenderness coefficient value $20 < \lambda_{calc.} < \lambda_0$, critical tension is achieved with such a relationship [1];

$$\sigma_{cr} = 1778 + 7.178 \cdot \sqrt{7515 - (\lambda - 20)^2} \qquad (8)$$

Establishing buckling is made Admissible tension relationship;

$\sigma_{af} = \dfrac{\sigma_{cr}}{c_f}$, and buckling allowable effort is determined by the relationship; $N_{af} \le \sigma_{af} A_{ef} \Rightarrow N_{af} \le ....[N]$

4. CONCLUSIONS

The element of structure checked, *BD* bar buckling enter a value $N_{af} = ...[N]$ and in the structure of the relationship (7), determined $N_{ef} = ...[N]$ so we can say that the structure, load bar 1-2 resists exterior deemed satisfied when inequality $N_{ef} < N_{af}$.

From my point of view, this way of calculating, the calculations to verify the strength of a steel structure is easily applied in this paper are put together simple notions of resistance. The results are easy to obtain.

In subsequent papers will present solutions for the verification of the resistance calculation of such structures, static structure indeterminate method used based on linear elastic calculation.

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