Saimaa University of Applied Sciences
Technology, Lappeenranta
Double Degree Programme in Civil and Construction Engineering

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Fire protection of steel structures

Abstract

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Fire protection of steel structures, 29 pages, 1 appendix
Saimaa University of Applied Sciences, Lappeenranta
Technology, Civil and Construction Engineering
Double Degree Programme in Civil and Construction Engineering
Thesis 2014
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The purpose of the work was to make a simple program for constructors to choose and check the different options of fire protection of steel structures and to analyze the results of it. The idea of the program was to include all the factors influencing the result: the fire resistant class of the structure, the load, the geometrical characteristics, the type of work of a structure and the type of steel.

The calculation was made according to the Russian regulations: SP 16.13330.2011. "Steel Constructions", №123-FZ «Technical regulations for fire safety requirements». The materials were chosen due to their real tests. The work was commissioned by the company Ruukki, specialized in steel and steel construction.

As a result of work the program was realised in Microsoft Excel Software. It was simple in use with a small instruction. The program checks the load bearing capacity of steel construction and gives different options to protect it from fire. The analysis of program was made.

Keywords: steel constructions, fire protection, load-bearing capacity, calculation, simple program.

Contents

1 Introduction

The purpose of the work was to make a program for fire protection calculation. The main idea of this program was to be as simple as possible. The program was realised with a table made in Microsoft Excel. The table was separated into two parts: the basic data and the results.

The calculation was made according to the Russian regulations: SP 16.13330.2011. “Steel Construction”, Federal Law of 22 July 2008 N 123-FZ "Technical Regulations on fire safety requirements". The result is presented as different materials that can be used in the current situation.

The table has an attractive interface and can be printed easily. Although it contains links to the Russian regulations.

1.1 The proposition and the actuality of the work

Building constructions, including steel are used widely because of the opportunities that they give to various objectives. Steel is often used in construction due to a wonderful combination of technological and operational properties, exemplified by many unique architectural constructions in the world. However, there is an important problem, with which humanity faced since its inception - fire protection. The main objective in this protection is to achieve security of people in the building. The second most important task is the preservation of wealth that can be lost in a fire. Many studies, standards, numerous tests of materials and structures are devoted to this problem. However, because of the importance of this problem and the development of technology, the relevance of the fire safety and search for new technical solutions in this area are retained.

Due to the numerous technical solutions and requirements for steel structures, it is difficult to expect the same solutions for different constructions. Firstly, the solution of fire protection of steel structures considers a number of factors the importance of which often depends on the function of construction. Therefore, it is important to determine the fundamental criteria that define the ways of fire protection of steel structures.

1.2 Basic criteria of fire resistance in Russian regulations

To ensure the safety of people in case of fire the most rapid removal of people from places of danger must be provided. Therefore, a generally accepted criterion used for the analysis of all solutions in the field of fire safety is the time factor. Time is the basis of all existing standards adopted in the field of fire protection and fire safety designs.

Experience behaviour of unprotected steel structures under fire exposure shows that heating of the steel subjected to direct heat exposure to the critical temperature is not more than 15 minutes. This fact is recorded in Flammability Rating of open steel structures - R15. Instant heating to the critical temperature never occurs. All material objects have a specific heat and thermal conductivity, and they transfer heat to their surrounded material objects, so there exists a finite heating time. The notion of critical temperature of steel means achieving stress equal yield limit value at a certain temperature. It should be understood that the yield point can be achieved even at room temperature under very high loads, and then the critical temperature may be room temperature. Therefore, the task of providing the desired degree of fire resistance of the steel structure is solved by reaching a predetermined time of heating of steel to the critical temperature. In typical constructions, the critical temperature of steel is 450-550°C.

2 Ways of fire protection of constructions

2.1 Classification of buildings and structures according to fire danger

The time of the fire cannot be infinite both because of the limited quantity of combustible material and due to the limited lifetime of constructions under fire exposure. Therefore, in Fire safety regulations for most constructions fire is normalized in the range of 0 to 6 hours.

Constructions separated into bearing and non-bearing have a significant difference in the required fire resistance. Therefore, different technical retardant solutions are used for them, although they can be made of a same steel assortment. For load-bearing elements an important factor is their responsibility for geometric variability of the structure under load during a fire, which can significantly reduce the critical temperature of steel. For non-bearing elements fire protection requirements are less stringent, as their role in ensuring the stability of the frame is negligible.

Table 1. Compliance of fire class and fire-resistance of building constructions

Fire class of building	Fire-resistance	
	load-bearing constructions	non-bearing constructions
I	R120	E30
II	R90	E15
III	R45	E15
IV	R15	E15
V	No regulations	No regulations

Table 1 is a part of Table 21 from №123-FZ «Technical regulations for fire safety requirements» - the main Russian regulation in fire safety. There are five fire classes of building in Russian regulations. In Microsoft Excel program only load-bearing constructions are considered due to their importance in frame of the building.

2.2 Fire safety materials

The choice of materials for fire protection of steel structures is based on an understanding of their behaviour under high temperatures. It is important to know that some of the materials having good thermal properties can mechanically collapse from heat stress and thus not provide thermal protection. Others, however, having a flammability, but maintaining the mechanical stability under load during combustion (for example: wood), do not break down for some time and thus provide a barrier between the fire source and the structure. It is important to remember that the construction of the outer device fireproof cladding can significantly affect the fire resistance of a structure. The presence or appearance of fire-permeable holes can negate all the efforts of fireproofing.

The greatest distribution for fire protection of building structures in Russian Federation received the following solutions:

1. Fireproof plaster on reinforcing mesh

2. Fireproof thermally intumescent paint

3. Facing with fireproof plate materials

Among all the ways of protection one of the most universal ones is the application of special paints. A part of this paint has components that are designed to protect steel by forming a foam- or paint-like structures. At the moment of contact of the composition with fire, non-toxic gases are distinguished, which contribute to the rapid formation of a protective layer. A foamed carbonated layer has a low thermal conductivity, thus protecting the metal against overheating.

The correct sequence involves the initial processing of steel corrosion-resistant coating, and then the top layer of fire retardant paint applying directly. To achieve the desired results it is recommended to carefully select paint and primer in each case. As the most correct output it is worth noting the use of primers that were designed specifically for use with fire-retardant paint.

Application of plate materials of gypsum-based solutions require a detailed study of the carrier material substructure as the gypsum loses crystallization water during the heating. On the one hand, it improves the efficiency of the fire-retardant with slowing heat. On the other hand, it leads to rapid destruction of the gypsum boards because of increased deformability in the phase transition of crystal water into steam and stripe protection structure. Therefore, gypsum boards must be glued to a metal surface of a continuous layer of adhesive or use pieces of gypsum boards, which require separate fasteners or steel mesh.

Vermiculite slabs and magnesite boards are non-combustible and have been successfully used for fire protection of steel structures, although they have a large thickness. Vermiculite plates are based on vermiculite and binder - liquid glass. They sometimes have a double-sided facing of steel sheet, which increases their stability under fire exposure, as well as provides better technological effectiveness of mounting. In contrast to gypsum, these materials do not contain crystallization water and therefore do not break down in a fire, maintaining containment structure to be protected. However, as a result, they merely serve to heat barrier, but heat faster than gypsum boards. New developments of gypsum-based materials rely on a greater concentration of the reinforcing glass fibers in the material to increase its porosity to prevent rapid heating of the entire thickness of the plate and increase its resistance unexposed.

The fibrous materials based on mineral fibers and quartz are preferred because of the high insulating ability and mechanical resistance to fire.

3 Description of the calculation

3.1 Calculation of the load bearing capacity and stability

Before making calculation of steel structures for fire-retardant treatment, you need to check an element in accordance with SP16.13330.2011. The calculation is made depending on the type of work of a rod. If the tension in a rod operates, it is just necessary to check the load bearing capacity according to the formula:

$$\frac{\mathrm{N}}{A_n R_y \gamma_c} \leq 1 \qquad (1)$$

where:

N - load acting on the rod;

A_n – cross sectional area;

R_y - calculated resistance of steel working on tensile, compression, bending in yield strength;

γ_c - coefficient of working conditions;

If the bending in rod operates, it is necessary to check the load bearing capacity according to the formula:

$$\frac{\mathrm{N}}{R_y \gamma_c}\left(\frac{e}{W}+\frac{1}{A_n}\right) \leq 1 \qquad (2)$$

where:

e - eccentricity;

W – moment of resistance;

If the element is in compression, then in addition to checking for load-bearing capacity it is also necessary to check the stability of the element according to the formula:

$$\frac{\mathrm{N}}{\varphi A_n R_y \gamma_c} \leq 1 \qquad (3)$$

where:

φ - stability factor in the central compression;

If the element is in compression and bending, then in addition to checking for load-bearing capacity it is also necessary to check the stability of element according to the formula:

$$\frac{\mathrm{N}}{\varphi R_y \gamma_c}\left(\frac{e}{W}+\frac{1}{A_n}\right) \leq 1 \qquad (4)$$

The value of the stability factor in the central compression should be determined by the formula:

$$\varphi = 0{,}5(\delta - \sqrt{\delta^2 - 39{,}48\lambda'^2})/\lambda'^2 \qquad (5)$$

where:

δ – coefficient;

λ' - conditional flexibility of the rod;

The coefficient δ should be determined by the formula:

$$\delta = 9{,}87(1 - \alpha + \beta\lambda') + \lambda'^2 \qquad (6)$$

where:

α and β – coefficients;

The conditional flexibility of the rod should be determined by the formula:

$$\lambda' = \lambda\sqrt{\frac{R_y}{E}} \qquad (7)$$

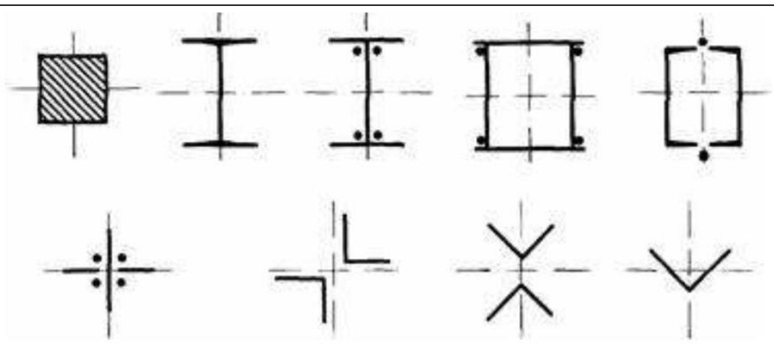
where:

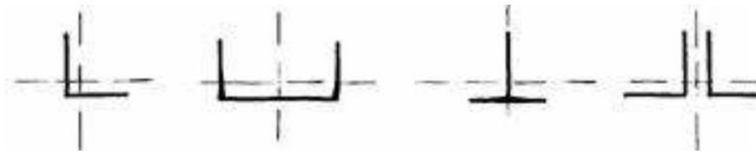
λ – flexibility of the rod;

E - modulus of elasticity of steel;

The coefficients α and β should be determined according to the table 2:

Table 2. Coefficients α and β depending on the types of sections

Section	α	β
	0,03	0,06
	0,04	0,09

	0,04	0,14

The flexibility of the rod should be determined by the formula:

$$\lambda = \frac{l_0}{i_{min}} \qquad (8)$$

where:

l_0 – calculated length of the rod;

i_{min} - minimal radius of gyration;

The minimal radius of gyration should be determined by the formula:

$$i_{min} = \sqrt{\frac{I_{min}}{A_n}} \qquad (9)$$

where:

I_{min} – minimal moment of inertia;

The calculated length of the rod should be determined by the formula:

$$l_0 = \mu \cdot l \qquad (10)$$

where:

l – geometrical length of the rod;

μ - coefficient depending on the rod fixing conditions;

The coefficient μ should be determined according to the table 3:

Table 3. Coefficient μ depending on the rod fixing conditions

Rod fixing conditions	μ

Picture	Description	
	hinged bearing at the ends	1,0
	one end is fixed and the other hinged	0,7
	fixing the ends	0,5

	one end fixed other free	2,0

3.2 Calculation of the fire-retardant treatment

Steel for building structures has a high thermal conductivity, which significantly effects on structural fire protection engineering solutions. On one side elements of the steel structure heat up quickly, and the other - well distribute and dissipate heat. Balance of heat flows in heating and cooling determines the change in temperature of the structure and the time to reach the critical temperature.

To make decisions on fire protection of steel structures two criteria were introduced: the given thickness of the metal and the critical temperature. The given thickness of metal allows to consider the cross section of the steel profile and the nature of the heat supply in case of fire. Like every criterion the given thickness of metal involves some simplification, but for many practical solutions it is very useful.

The given metal thickness is calculated by the formula:

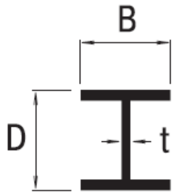
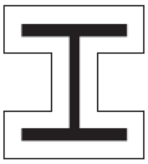
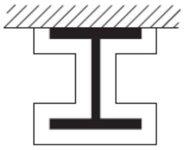
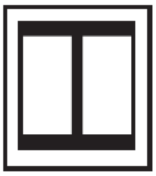
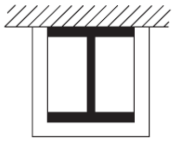
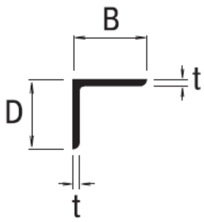
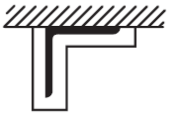
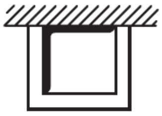
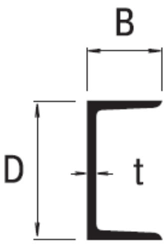
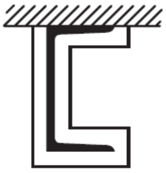
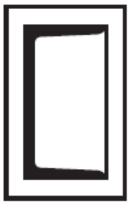
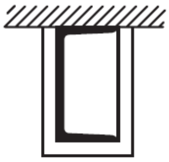
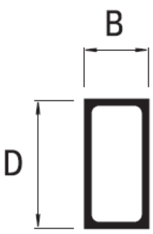
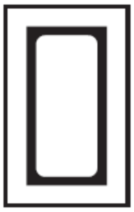
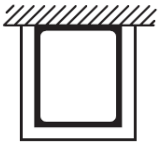
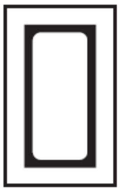
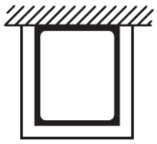
$$\delta = \frac{A_n}{P} \qquad (11)$$

where:

P - heated perimeter;

The heated perimeter value depends on the geometry of the cross section and is calculated according to the formulas in table 4:

Table 4. Heated perimeter at various kinds of facings and heating conditions

Profile	Facing along the contour		Facing a box-shaped	
	with 4 sides	with 3 sides	with 4 sides	with 3 sides
	 P=4B+2D-2t	 P=3B+2D-2t	 P=2B+2D	 P=B+2D
	 P=2B+2D	 P=B+2D	 P=2B+2D	 P=B+2D
	 P=4B+2D-2t	 P=3B+2D-2t	 P=2B+2D	 P=B+2D
	 P=2B+2D	 P=B+2D	 P=2B+2D	 P=B+2D

	 P=πD	-	 P=πD	-

This criterion shows how effective heat removal is in relation to heating depending on the shape of the cross section under the conditions of heating.

Another important criterion is the critical temperature. The fire resistance of steel structures occurs as a result of warming up their sections or parts of it to the critical temperature. The critical temperature of steel structures under a load depends on the type of design scheme of its bearing, the metal stamp and the value of the load.

The critical temperature is defined as the lowest value of the two found in Table 5, depending on the values of the coefficients γ_t and γ_e. Values of the coefficients γ_t and γ_e, take into account changes in regulatory resistance and modulus of elasticity of steel.

Table 5. Values of the coefficients γ_t and γ_e depending on the temperature

T_{cr}, °C	γ_t	γ_e
20	1,00	1,00
100	0,99	0,96
150	0,93	0,95
200	0,85	0,94
250	0,81	0,92
300	0,77	0,90
350	0,74	0,88

400	0,70	0,86
450	0,65	0,84
500	0,58	0,80
550	0,45	0,77
600	0,34	0,72
650	0,22	0,68
700	0,11	0,59

Coefficient γ_t is calculated by the formula:

$$\gamma_t = \frac{N}{R_y}\left(\frac{e}{W} + \frac{1}{A_n}\right) \qquad (12)$$

Coefficient γ_e is calculated by the formula:

$$\gamma_e = \frac{Nl_0^2}{\pi^2 EI_{min}} \qquad (13)$$

4 Description of the program

4.1 Introduction

The program is carried out in accordance with the requirements of the regulatory documents:

1. Federal Law of 22 July 2008 N 123-FZ "Technical Regulations on fire safety requirements";

2. SP 20.13330.2011 "Steel Constructions";

3. Instructions for calculation of the actual limits of fire resistance of steel structures, consistent with EMERCOM Russia;

4. GOST 8239-89 "Hot-rolled steel I beams. Assortment";

5. STO ASCHM 20-93 "Rolled steel profiled shaped profile";

6. GOST 8240-89 "Hot-rolled steel channel bars. Assortment";

7. GOST 2590-88 "Hot rolled round steel. Assortment";

8. GOST 8509-93 "Hot-rolled steel equal corners. Assortment";

9. GOST 8732-78 "Hot-rolled seamless steel pipes. Assortment";

10. GOST 10704-91 "Electrically welded steel pipes. Assortment";

11. GOST 8639-82* "Steel square pipes. Assortment";

12. GOST 8645-68* "Steel rectangular pipes. Assortment";

13. GOST 30245-2003 "Bent steel profiles closed welded square and rectangular for building. Specifications";

14. GOST 30245-94 "Bent steel profiles closed welded square and rectangular for building. Specifications".

All recommended in the program materials meet the requirements of the documents:

1. GOST 30247-94 "Building structures. Methods of Fire Test. General requirements";

2. NPB 236-97 "Fire-proof materials for steel structures. General requirements. Method for determination of fire resistance rating".

4.2 General description of the program's features

This program calculates the core element’s fire protection, working at central or eccentric compression or tension. Fire resistance characteristics, geometrical properties, loading design and information about the steel used are set in the input data. The input data is checked to ensure the necessary strength and stability requirements of the element. The calculation displays the recommendations for the use of different materials for the given data and automatically generates a report for printing.

4.3 Instruction for using the program

1. Data Input.
    a. Select from the drop-down list the degree of fire resistance of the building (I, II, III, IV);
    b. Choose from drop-down lists the type and the number of cross-sectional view of the rod;
    c. Choose from a drop-down list the type of rod work (tension, compression);
    d. Select from the drop-down list the type of rod fixing;
    e. Select from the drop-down list the type of cladding and heating conditions;
        - Note. Round sectional contour is not faced with three sides. If you select such a combination on the screen in red letters will indicate "This type of cladding is not possible for this section"
    f. Enter into the appropriate cell the longitudinal force acting on the rod in kilograms;
    g. Enter into the appropriate cell the eccentricity in inches;
        - Note. Eccentricity must be entered a positive. In the absence of eccentricity the number "0" must be enter in the corresponding cell.
    h. Enter into the appropriate cell the value of geometrical length of the rod;
    i. Select from the drop-down list the steel grade;
    j. Enter into the appropriate cell the value of the initial modulus of elasticity of steel in kilograms per square inch.
2. Results of calculation.
    - A result of calculation program displays a message about fulfillment of strength and stability of the element according to regulatory documents. Also displays the recommended plate and spray materials for fire protection. If contrast material is "-" it means that this material is not applicable in this situation.
3. Printing of the report.

- Report is automatically generated. To print it out it is necessary to select in the bottom panel the tab "Calculation report" and send a report to print. The protocol takes three A4 pages.

4.4 Materials used in calculation

4.4.1 Plate materials

There are four different plate materials used in calculation:

1. Conlit 150
2. Glasroc F
3. Paroc FPS-17
4. KNAUF-Fireboard

The basic principle of the plate materials is that there is no direct contact between facing boards and the steel material, and a protective frame in the absence of mechanical destructive impacts, remains unchanged for a very long time.

The main advantages of plate materials are low thermal conductivity (0,036-0,075 W/m·K), low weight (the density is approximately 165 kg per cubic meter), beautiful appearance and long service life (at least 30 years).

The main drawback is the difficulty of mounting plates to the inclined rod members. Therefore, these plates do not apply to trusses. In general, these plate materials are used for vertical columns and horizontal beams.

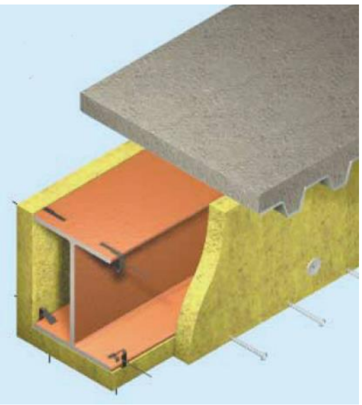


Figure 1. The application of plate material.

4.4.2 Spray materials

There are three different spray materials used in calculation:

1. Siloterm
2. Newspray
3. Devispray

Composite intumescent paints are materials that are based on polymer binders filled with the number of flame retardants, blowing agents, stabilizers and heat-resistant materials. They operate on the principle of decomposition when heated and absorption occurs when a fire heats - thus there is a chemical process of vapor and inert gases displace oxygen in the ambient atmosphere. As a result of this chemical reaction is blocked by penetration of the hot air flow to the structures. Open flame is suppressed and hence the combustion process stops. Foaming, paint components are isolated in the formation of the carbon bed, which turns the absence of oxygen in the solid. With low thermal conductivity, educated and hard foam layer is nothing but a heat shield, causing that the critical temperature does not reach the metal.

The benefits of fire protection with paint compared to other means is considered that the coating of fireproof paints easily restores after a crash or after the expiration of the protective properties. Also important is the fine quality of the coatings, as they can be used indoors without additional finishing.

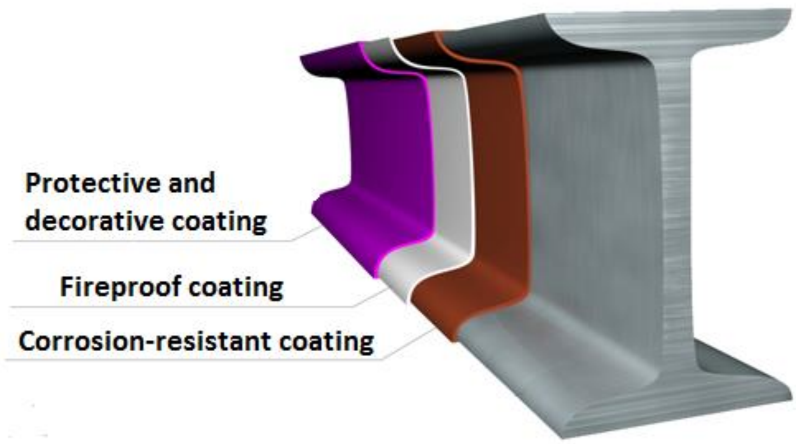


Figure 2. The application of spray material.

5 Calculation example

5.1 Input data

Degree of fire resistance of the building: I;

Cross-sectional view: Hot-rolled steel I-profile (GOST 8239-89) number 20;

Type of rod work: compression;

Type of fixing: fixing the ends;

Type of cladding and heating conditions: facing a box-shaped with 4 sides;

Longitudinal force: 30000 kg;

Eccentricity: 0,8 cm;

Geometrical length of the rod: 300 cm;

Grade of steel: C235;

The initial modulus of elasticity of steel: 2100000 kg/sq.cm.

5.2 The task of calculation

The task is to calculate the necessary thickness of the plate material Conlit 150 in the current input data.

5.3 Reference data

5.3.1 Characteristic of construction

Degree of fire resistance of the building: I.

In accordance with the Federal Law of 22 July 2008 N 123-FZ "Technical Regulations on fire safety requirements":

The fire resistance of structure: 120 min.

5.3.2 Characteristic of section

Cross-sectional view: Hot-rolled steel I-profile (GOST 8239-89) number 20.

In accordance with the assortment of metal, used in GOST 8239-89:

Geometrical characteristics of the section:

h=200 mm;

b=100 mm;

t=5,2 mm;

A_n=2680,0 mm^2;

I_{min}=115,0 cm^4;

W=184,0 cm^3.

5.3.3 Characteristic of steel

Grade of steel: C235.

R_y=2250 kg/cm^2.

5.4 Strength and stability

As the eccentricity e≠0 then the bending in rod operates, so it is necessary to check the load bearing capacity according to the formula (2):

$$\frac{\mathrm{N}}{R_y\gamma_c}\left(\frac{e}{W}+\frac{1}{A_n}\right)\leq 1;$$

$$\frac{30000}{2250\cdot 1}\left(\frac{0{,}8}{184}+\frac{100}{2680}\right)\leq 1;$$

$$0{,}56\leq 1;$$

So the strength is provided.

The calculated length of the rod should be determined by the formula (10):

$$l_0 = \mu \cdot l;$$

The type of fixing: fixing the ends. In accordance with table 3 μ=0,5.

$$l_0 = 0{,}5 \cdot 300;$$

$$l_0 = 150 \text{ cm};$$

The minimal radius of gyration should be determined by the formula (9):

$$i_{min} = \sqrt{\frac{I_{min}}{A_n}};$$

$$i_{min} = \sqrt{\frac{115}{26{,}80}};$$

$$i_{min} = 2{,}07 \text{ cm};$$

The flexibility of the rod should be determined by the formula (8):

$$\lambda = \frac{l_0}{i_{min}};$$

$$\lambda = \frac{150}{2{,}07};$$

$$\lambda = 72{,}41;$$

The conditional flexibility of the rod should be determined by the formula (7):

$$\lambda' = \lambda\sqrt{\frac{R_y}{E}};$$

$$\lambda' = 72{,}41\sqrt{\frac{2250}{2100000}};$$

$$\lambda' = 2{,}37;$$

The coefficient δ should be determined by the formula (6):

$$\delta = 9{,}87(1 - \alpha + \beta\lambda') + \lambda'^2;$$

Cross-sectional view: Hot-rolled steel I-profile. In accordance with table 2 α=0,04; β=0,09.

$$\delta = 9{,}87(1 - 0{,}04 + 0{,}09 \cdot 2{,}37) + 2{,}37^2;$$

$$\delta = 17{,}20;$$

The value of the stability factor in the central compression should be determined by the formula (5):

$$\varphi = \frac{0{,}5\left(\delta - \sqrt{\delta^2 - 39{,}48\lambda'^2}\right)}{\lambda'^2};$$

$$\varphi = \frac{0{,}5\left(17{,}20 - \sqrt{17{,}20^2 - 39{,}48 \cdot 2{,}37^2}\right)}{2{,}37^2};$$

$$\varphi = 0{,}77;$$

The element is in compression and bending, then in addition to checking for load-bearing capacity, it is also necessary to check the stability of element according to the formula (4):

$$\frac{\mathrm{N}}{\varphi R_y \gamma_c}\left(\frac{e}{W} + \frac{1}{A_n}\right) \leq 1;$$

$$\frac{30000}{0{,}77 \cdot 2250 \cdot 1}\left(\frac{0{,}8}{184} + \frac{100}{2680}\right) \leq 1;$$

$$0{,}73 \leq 1;$$

So the stability is provided.

5.5 Fire-retardant treatment

Type of cladding and heating conditions: facing a box-shaped with 4 sides. In accordance with table 4 heated perimeter should be determined by the formula:

$$\mathrm{P} = 2 \cdot \mathrm{B} + 2 \cdot \mathrm{H};$$

$$P = 2 \cdot 100 + 2 \cdot 200;$$

$$P = 600 \text{ cm};$$

Given metal thickness is calculated by the formula (11):

$$\delta = \frac{A_n}{P};$$

$$\delta = \frac{2680}{600};$$

$$\delta = 4{,}47 \text{ cm};$$

Coefficient γ_t is calculated by the formula (12):

$$\gamma_t = \frac{N}{R_y}\left(\frac{e}{W} + \frac{1}{A_n}\right);$$

$$\gamma_t = \frac{30000}{2250}\left(\frac{0{,}8}{184} + \frac{100}{2680}\right);$$

$$\gamma_t = 0{,}56;$$

In accordance with table 5 critical temperature:

$$T_{cr} = 501{,}61\ ^\circ\text{C};$$

Coefficient γ_e is calculated by the formula (13):

$$\gamma_e = \frac{N l_0^2}{\pi^2 E I_{min}};$$

$$\gamma_e = \frac{30000 \cdot 150^2}{3{,}14^2 \cdot 2100000 \cdot 115};$$

$$\gamma_e = 0{,}28;$$

In accordance with table 5 critical temperature:

$$T_{cr} = 1033{,}32\ ^\circ\text{C};$$

So the minimal critical temperature:

$$T_{cr} = 501{,}61\ °C;$$

In accordance with the Instruction for calculation of the actual limits of fire resistance of steel structures, consistent with EMERCOM Russia:

The minimum allowable thickness of Conlit 150 in these conditions is 50 mm.

5.6 Calculating verification in the program

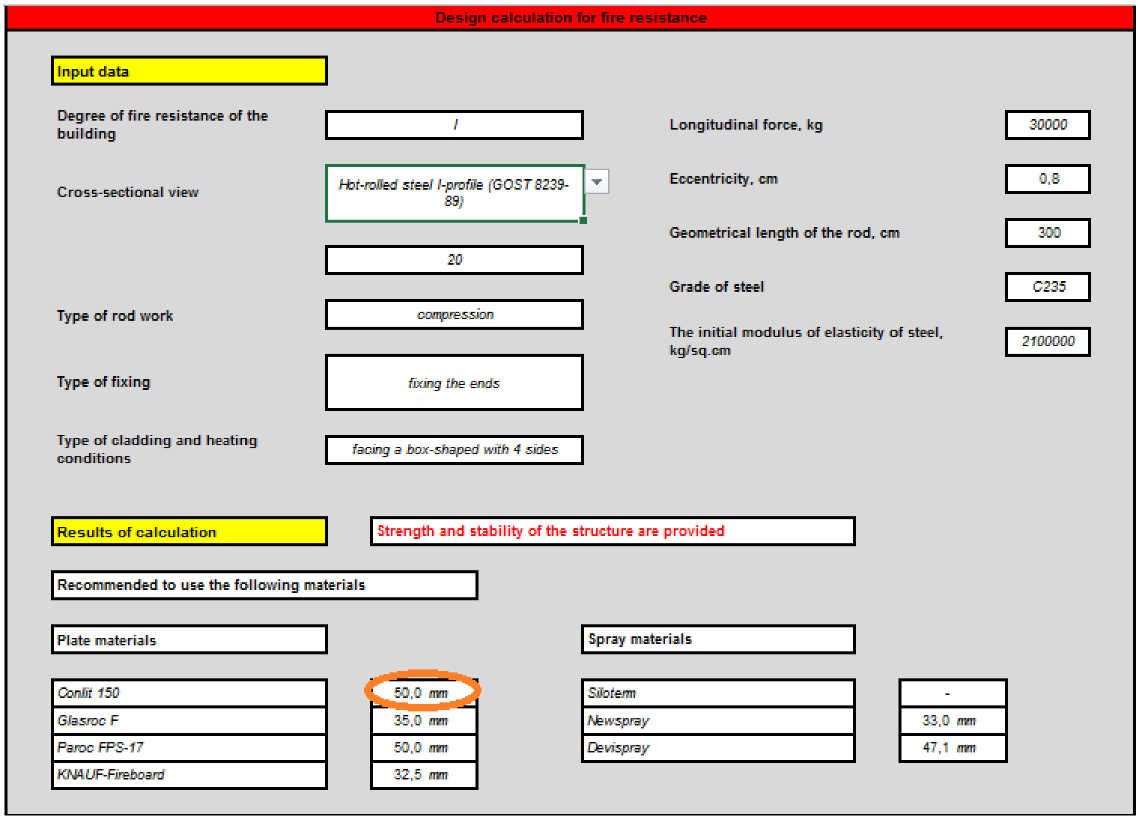
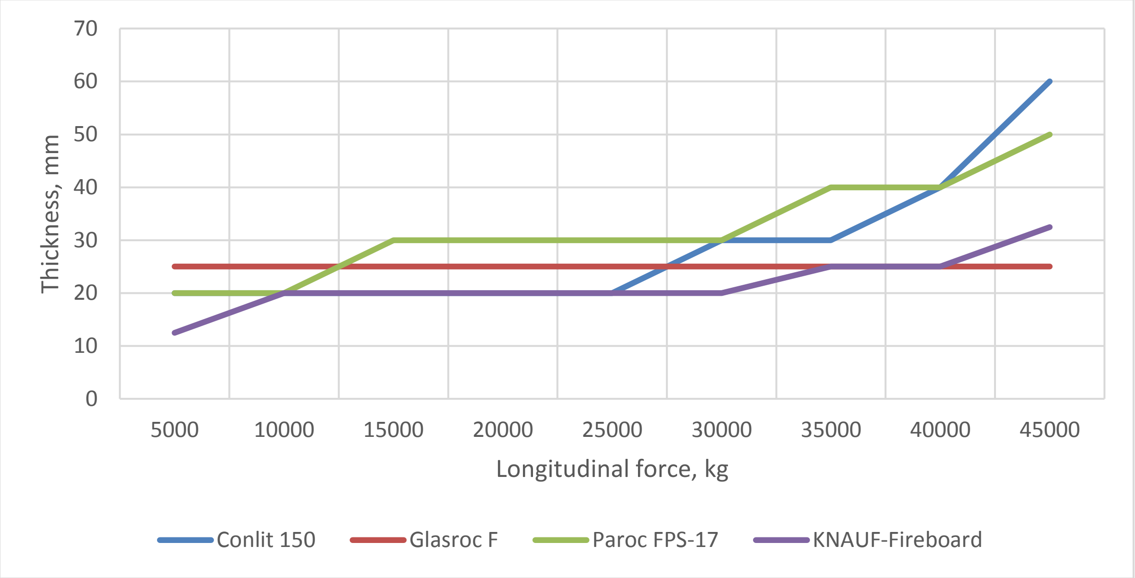


Figure 3. The calculating verification in the program.

The calculation in program has the same result as manual calculation: the minimum allowable thickness of Conlit 150 in these conditions is 50 mm.

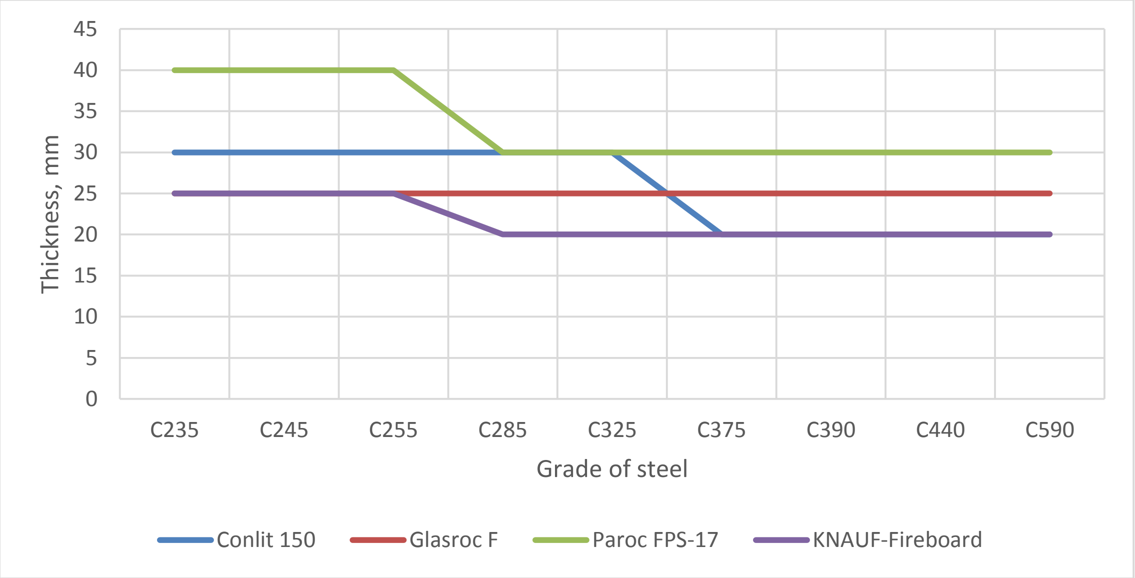
6 Analysis of the calculation results

6.1 Material thickness dependence on the load



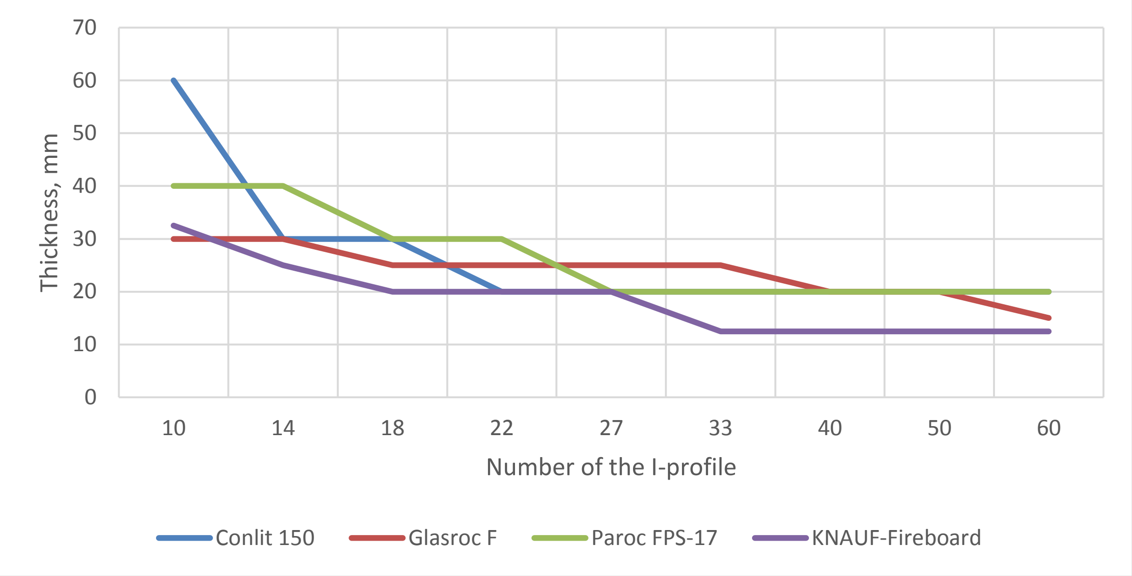
The graph shows that the larger load, the larger material thickness is required.

6.2 Material thickness dependence on the grade of steel



The graph shows that the higher the grade of steel, the less the thickness of material required. However, the influence of the steel grade is not too much.

6.3 Material thickness dependence on the number of the I-profile



The graph shows that the higher the number of the I-profile, the smaller thickness of material is required.

7 Conclusion

The purpose of the work was to make a small simple program for constructors to choose and check the different options of fire protection of steel structures.

The program was realised in Microsoft Excel Software. It includes a lot of factors: the fire resistant class of the structure, the load, the geometrical characteristics, the type of work of a structure and the type of steel.

It is simple in use with a small instruction and attractive interface. The program checks the load bearing capacity of steel construction and gives different options to protect it from fire.

The program was realised according to Russian regulations and provides recommendations on the use of seven different materials: plate and spray.

The program should help designers to quickly provide customers various options for the protection of steel structures against fire.

As a result the analyse shows that the load and the cross-sectional view have the biggest influence on the fire protection. However the grade of steel I not so important as it does not have such a big graduation.

REFERENCES

1. Federal Law of 22 July 2008 N 123-FZ "Technical Regulations on fire safety requirements";
2. SP 20.13330.2011 "Steel Constructions";
3. Instructions for calculation of the actual limits of fire resistance of steel structures, consistent with EMERCOM Russia;
4. GOST 8239-89 "Hot-rolled steel I beams. Assortment";
5. STO ASCHM 20-93 "Rolled steel profiled shaped profile";
6. GOST 8240-89 "Hot-rolled steel channel bars. Assortment";
7. GOST 2590-88 "Hot rolled round steel. Assortment";
8. GOST 8509-93 "Hot-rolled steel equal corners. Assortment";
9. GOST 8732-78 "Hot-rolled seamless steel pipes. Assortment";
10. GOST 10704-91 "Electrically welded steel pipes. Assortment";
11. GOST 8639-82* "Steel square pipes. Assortment";
12. GOST 8645-68* "Steel rectangular pipes. Assortment";
13. GOST 30245-2003 "Bent steel profiles closed welded square and rectangular for building. Specifications";
14. GOST 30245-94 "Bent steel profiles closed welded square and rectangular for building. Specifications".
15. GOST 30247-94 "Building structures. Methods of Fire Test. General requirements";
16. NPB 236-97 "Fire-proof materials for steel structures. General requirements. Method for determination of fire resistance rating".

APPENDIX A

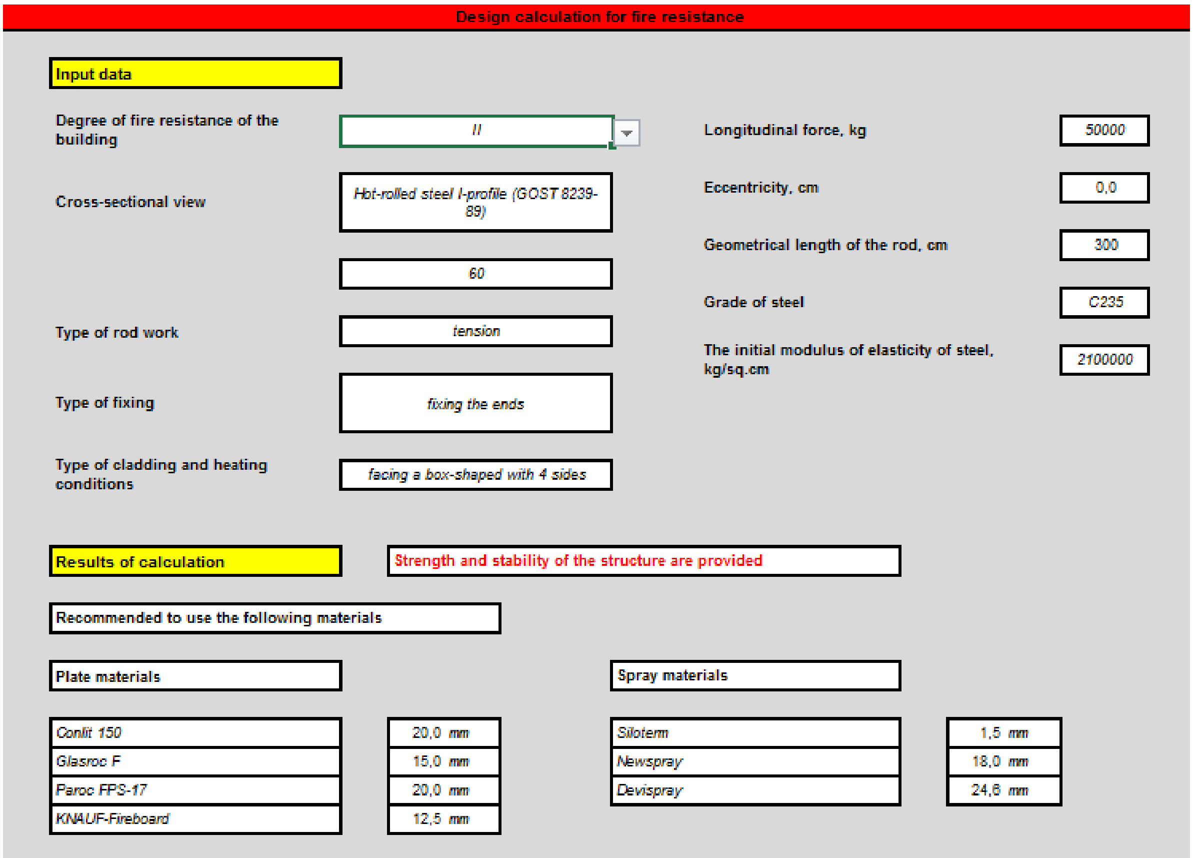


Figure 4. The interface of the program.

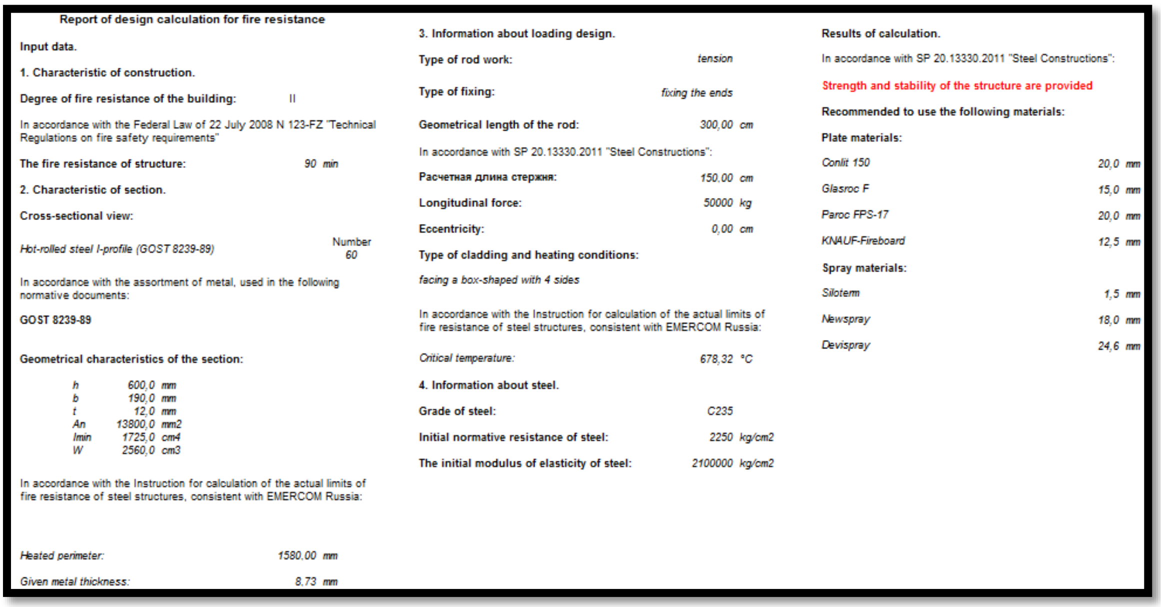


Figure 5. The calculation report.