Quantitative and qualitative assessment criteria of load-bearing structures technical state

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Abstract: In the article are stated the quantitative and qualitative assessment criteria of load-bearing structures technical state that determination is achieved by visible defects and visual and instrumental examinations damages, as well as laboratory tests and testing based on calculations.

Keywords: load-bearing structures, buildings, criteria, technical state.

1. Introduction

The structureal evaluating the technical state depends on the functional purpose of the buildings and construction solutions, the type of building structures and the used construction materials, the working conditions, of structuresand other similar factors.

2. Basic part

According to the Law of Georgia on Civil Safety, a shelter is a building or structure that can be used to protect people from various damaging factors during an emergency or war. The shelter can be a dual-purpose, civil or industrial building and/or a special hermetic protective structure, which is designed taking into account damaging factors;

The maximum allowable values of the criteria for assessing the technical state of buildings are obtained with the following values:

• Design schemes, loads and impacts - from the project documentation, including explanatory notes for calculation of structures;

• Strength and physical-mechanical characteristics of materials and structures - according to projects, technical passports, Eurocodes, technical regulations and resolutions currently in force in the territory of Georgia, etc. according to;

• Geometric dimensions of buildings and structures - working drawings, technical passports, etc. according to;

• Deviations in linear dimensions and height marks - according to executive schemes, Eurocodes, technical regulations and resolutions currently in force on the territory of Georgia for the production and acceptance of the relevant types of construction and installation works;

• Operating characteristics - calculations of project documentation, Eurocodes, technical regulations and resolutions currently in force in the territory of Georgia, etc. according to

The actual values of the criteria for assessing the technical state of load-bearing structures are obtained on the basis of visual and instrumental examinations, as well as laboratory tests and verification calculations.

The criteria for assessing the technical state of load-bearing structures would be divided into two groups:

1. Characteristic criteria of carrying capacity, stability and deformability of construction structures (first and second group of limit states);

2. Characteristic criteria of operational suitability of buildings and their structures.

Normative documents (Eurocodes, technical regulations and decrees currently in force on the territory of Georgia, etc.) establish the marginally permissible values of the criteria for assessing the technical state of construction structures of buildings.

The technical state of the building structures must be determined based on the evaluation of the joint impact of the defects and injuries identified as a result of preliminary and detailed investigations, as well as on the basis of verification calculations of their carrying capacity, stability and operational suitability.

In the event that one of the criteria of the technical state of the buildings does not meet the requirements of the normative documents, the building structures are subject to repair, strengthening or replacement.

On the basis of many observations, we develop the criteria for evaluating the categories of the technical state of individual load-bearing structures of the building.

Structure	Defect	Over stress, %	Relative reliab-ility, $y = \gamma / \gamma_0$	Defect size at down state
1	2	3	4	5
1. reinforced concrete slab	Reducing the protective layer thickness from 3.5 cm to 1.5 cm	38	0,72	3,3 cm
2. reinforced concrete column	Reduction of concrete strength by one class (reduction of strength by 24%)	17	0,85	27%
3. Steel column	Profile thickness up to 20% is metal corrosion	28	0,78	21%
4. Roofing steel beam	Profile thickness up to 20% is metal corrosion Profile thickness up to 20% is metal corrosion	15	0,87	23%
5. Beams support on brickwall	Absence of support pads (support area is reduced by 52%)	110	0,47	32%
6. 5-story frame building's flooring and roof structures	Exceeding the loads by 15% on individual areas of roofing and covering due to the growth of crusts from slabs and beams	15% of slabs and beams	0.87 of slabs and beams	25% of slabs and beams
		35	0,85	30%

Using this criterion, the impact of defects and injuries in structures on reducing their strength and stability can be evaluated on specific examples of calculations taken from practice.

Example 1. During the manufacture of a 100 mm in thickness reinforced concrete roofing slab, the protective layer was reduced from the bottom side of the slab, the protective layer of the working reinforcement of the lower layer of the reinforcing mesh was reduced to 15 mm, instead of 35 mm provided by the project. It is necessary to determine how this will affect the strength of the structure (Figure 1).
The reinforcement of the slab is obtained from 5 rods of diameter Ø10 mm, diameter 20 cm, reinforcement class A500c,

A_S = 3.93 cm², R_S = 375 MPa = 3750 kgf/cm².
Concrete B25 class,
R_{bt} = 10.7 MPa = 107 kgf/cm².
Determine the bearing capacity of the slab taking into account the defect obtained during the pouring of the existing slab (by reducing the protective layer)
The working height of the slab is equal to

$$h_0 = 10 – 1,5 – 0,5 = 8 \text{ cm}.$$

Let's determine the height of the compressed concrete zone

$$x = R_s A_s / R_{bt} b = 3750 \cdot 3,93/107 \cdot 100 = =1,38 \text{ cm}.$$

Let's determine the load-bearing capacity of slab

$$[M]_0 = R_s A_s (h_0 – x/2) = 3750 \cdot 3,93\ (8-1.38/2) = 3750 \cdot 3,93 \cdot 7.31=107\ 731 \text{ kg/sm}.$$

Let’s determine the design load-bearing capacity on bending:

$h0 = 10 – 3{,}5 – 0{,}5 = 6$ cm.

Let’s determine the height of the compressed concrete zone

$x = R_S A_S / R_{bt} b = 3750 \cdot 3{,}93/107 \cdot 100 = {=}1{,}38$cm

Let’s determine the load-bearing capacity of slab

$[M] = R_s A_s (h_0 – x/2) = 3750 \cdot 3{,}93 (6-1.38/2) = 3750 \cdot 3{,}93 \cdot 5.31=77\,659$ kg/sm.

The overstress of the structure is equal to (107 731 – 77 659) 100/77 659 = 38.7%.

Relative reliability of the structure compared to the design one

$y=\gamma/ \gamma_0 =[M] / [M]_0$ = 77 659 / 107 731 = 0,72 < 1, or the technical state is unworkable, or the load-bearing capacity is reduced (up to 38.7%).

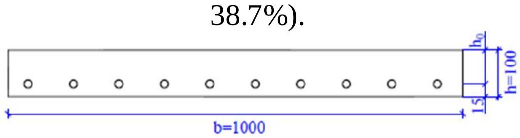

Fig. 1. Cross-section of monolithic concrete slab

Example 2. During the manufacture of a centrally compressed reinforced concrete column of a multi-storey building, the strength of concrete was reduced by one class compared to the design one, i.e. concrete of class B25 with calculated compressive strength R_b = 14.5 MPa = 145 kgf/cm² was obtained instead of concrete of class B20 R_b = 11.5 MPa = 115 kgf/cm² (the strength was reduced by 22%). It is necessary to determine how this affects the technical state of the structure (Figure 2).

Floor height (desugn length of the column) l0l= 4.8 m. Column section A = 40x40 = 1600 cm2. Working longitudinal reinforcement 4 Ø25 mm in diameter, A500c class, A_S = 19.63 cm², R_{SC} = 3750 kgf/cm².

Determine the flexibility of the column

$l0/ h = 480/40 =12, \varphi = 0{,}96$.

Design load-bearing capacity of the column

$[N]0 = \varphi (Rb\ A + R_{SC} A_S) = 0{,}96(145 \cdot 1600 + 3750 \cdot 19{,}63) = 293\,388$ kgf.

Actual load-bearing capacity of the column taking into account the defect

$[N] = 0{,}96(115 \cdot 1600 + 3750 \cdot 19{,}63) = 247\,308$ kgf.

The structure has been overstressed

(293 388 – 247 308) 100/247 308 = 18.6%

Relative reliability of the column

$y=\gamma/ \gamma0 =[N] / [N]0 = 247\,308 / 293\,388 = 0{,}84< 1$, or the technical state is limited operable.

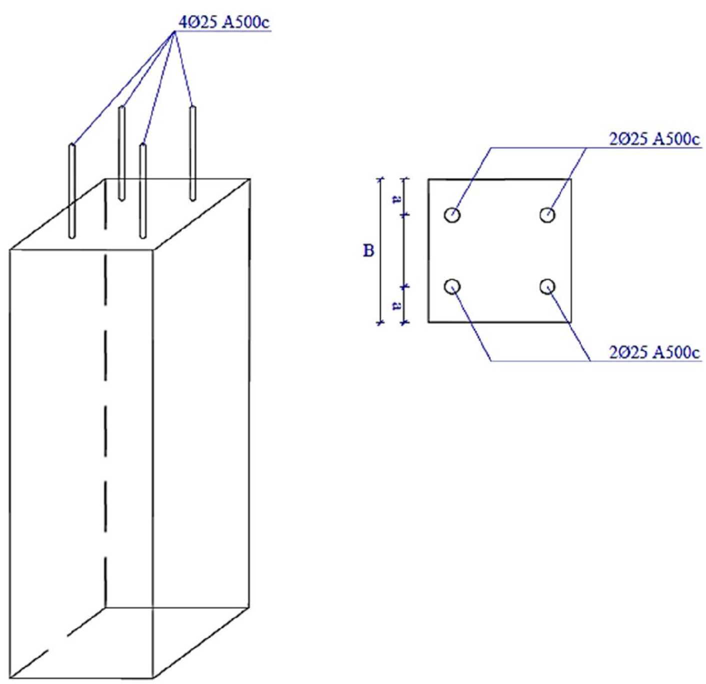

Fig. 2. Section of a monolithic reinforced concrete column

Example 3. A steel column that represents I beam 26K2, with a wall thickness of *d*=7 mm, flange thickness of *t* =11 mm, received corrosion at 1 mm, which is 19.5% of the full thickness. Determine the reduction of the carrying capacity of the column as a result of corrosion (Fig. 3).

The cross-sectional area of the column is A0 =75.5 cm², the thickness of the corroded metal on both sides of the profile thickness - $\delta = 2 \cdot 1 = 2$ mm = 0.2 cm, the reference resistance of steel

R_y = 245 MPa = 2450 kgf/cm².

Let's determine the attenuation coefficient

$k_{sa} = \delta / 0,5(t + d) = 0,2/0,5(1,1 + 0,7) = 0,22.$

Reduced cross-sectional area

$A = A_0 (1 - ksa) = 75,5(1-0,22) = 59$ cm².

The load-bearing capacity by project

$[N]0 = Ry\ A0 = 2450 \cdot 75,5 = 184\ 975$ kgf.

The load-bearing capacity with taking into account the defect

$[N] = Ry\ A = 2450 \cdot 59 = 144\ 550$ kgf.

Overloading of the column from the design loads

$(184\ 795 – 144\ 550)\ 100\% / 144\ 550 = 27,9\%.$

Relative reliability

$y = \gamma/\gamma_0 = [N] / [N]0 = 144\ 550/184\ 795 = 0,78 < 1.$

The technical state is inoperable.

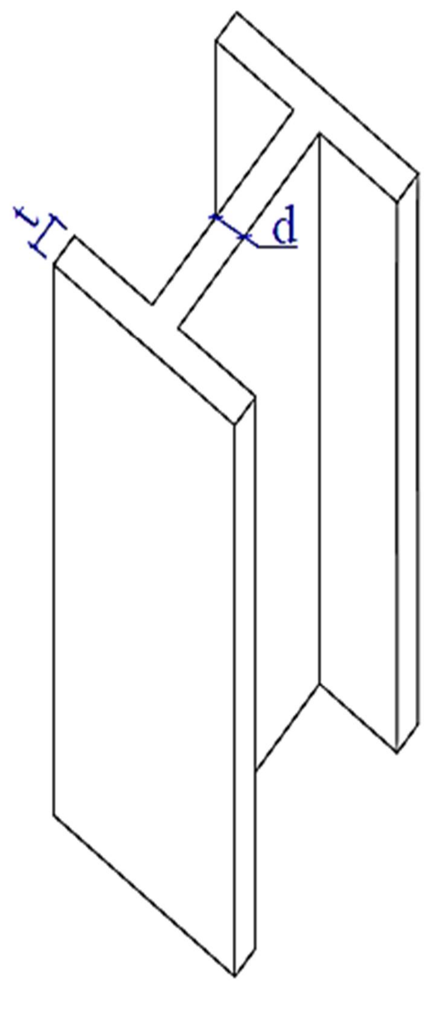

Fig. 3. Cross section of metal beam 26K2

Conclusion

The actual values of the criteria for assessing the technical state of load-bearing structures are obtained on the basis of visual and instrumental examinations, as well as laboratory tests and verification calculations. The criteria for assessing the technical state of load-bearing structures can be divided into two groups: criteria for load-bearing capacity, stability and deformability of building structures (the first and second group of limit states); Characteristic criteria of operational suitability of buildings and their structures. In the event that one of the criteria of the technical state of the buildings does not meet the requirements of the normative documents, the building structures are subject to repair, strengthening or replacement.

References

1. Tsikarishvili M., Imedadze R. Investigation of buildings snd restoration of damages. Tbilisi, 2012. - 281 p. (In Georgian).
2. Tsakadze A, Tsikarishvili M. Survey of limired state and remained resourses of being under operation buildings with taking into account damages. Tbilisi, 2017. -208p. (In Georgian).
3. Tsikarishvili M., Vardiashvili M. System monitoring and diagnostics of historical-cultural monuments. Monograph. . Tbilisi 2012. -148 p. (In Georgian).
4. Esadze A. Berdzenishvili A. Jijieshvili D. Survey and restoration-reinfoecement of buildings. Tbilisi 2020. -125 p. (In Georgian).
5. Rekvava P. Multi-factor estimation and rehabilitation of buildings seismic resistance. Tbilisi, 2022. -169 p. (In Georgian).