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Analysis of trends in the development of load codes for building structures

The content of the article is a consistent review of approaches to considering loads on building structures and their reflection in regulatory documents of different years. Attention is focused on the continuity of the method of limit states and the method of permissible stresses in the part of the description of loads. With regard to climatic loads (snow, wind), attention is paid to changes in territorial zoning and calculation coefficients, the assignment of normative and calculation values and the involvement of experimental statistical data. Attention is also paid to the connection between the development of codes of crane loads and the results of experimental studies of these loads.

Keywords: reliability, design codes, limit states, snow loads, wind loads, crane loads

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Introduction

Engineers always face the question of how the builders of the past ensured the reliability of buildings and structures that have been safely preserved to this day. At the same time, issues of substantiation of some calculated parameters and coefficients of the allowable stress method, which later became part of the codes of the limit states method, remain unclear. These and other questions are answered by the study of the development of domestic and foreign design codes, the relevance of which is connected not only with the fact that history provides factual knowledge about past construction experience, but allows predicting trends in the development of building codes.

Review of the latest sources and publications

Separate stages of the development of building mechanics, building structures and building design codes are covered in domestic articles and monographs of different years [1,2]. From foreign publications dedicated to this topic, major reviews stand out [3,4]. The analysis of the evolution of building design codes should begin with the capital Urgent position, which regulated construction activities on the territory of Ukraine from the middle of the 19th century to the beginning of the 20th century [5]. Foreign construction regulation, in particular in Germany, in the same period is represented by the multi-volume HŰTTE handbook, which was quite popular until the 1930s [6]. The period 1930-1955 is characterized by constant development and revision of domestic design codes based on the allowable stress method, which was later replaced by the limit state method, the features of which are analyzed in monographs [7,8]. An important direction in the development t of design codes is the clarification of the calculated values of loads acting on the building and having a complex probabilistic nature [9]. Domestic studies of loads have intensified in recent decades in connection with the implementation of the State Building Codes of Ukraine [10-12].

Definition of unsolved aspects of the problem.

It should be noted that currently there are not enough scientific publications in which the chronological development of the method of allowable stresses, which was the basis of the design of building structures for more than 100 years, until the middle of the 20th century, was analyzed in detail. Therefore, it can be assumed that the long-term positive potential of the allowable stress method, on the basis of which the transition to the modern calculation of building structures according to limit states was made in the 1950s, was generally ignored.

Problem statement

The aim and objectives of the study are a consistent review of approaches to the consideration of loads on building structures and their reflection in regulatory documents of different years. Attention is focused on the continuity of the method of limit states and the method of allowable stresses in the part of the load description. With regard to climatic loads (snow, wind), attention is paid to changes in territorial zoning and calculation coefficients, the assignment of normative and calculation values, and the involvement of experimental statistical data. Attention is also paid to the connection between the development of codes of crane loads and the results of experimental studies of these loads.

Basic material and results

As indicated above, the first normative document that was effective in the territory of Ukraine was "Urgent position: a guide for drawing up and checking estimates, designing and performing works" [5]. This document contained some provisions of the structure calculation methodology. It is interesting to note that its author was Count De Rochefort N.I. (1846 – 1903), civil engineer and architect, builder of railways, highways and palaces. The Urgent position is a unique manual that served as a reference for builders and architects, a textbook for teachers, and a guide for construction contractors. For the first time, it explained the building regulations and rules and contained the necessary reference material related to construction. The Urgent position came into effect for the first time in 1869, it was republished with changes 13 times, the last edition was printed in 1930. The Urgent position had an important state status and was mandatory for use throughout the country.

In the second half of the 19th century and at the beginning of the 20th century, domestic technical literature was practically absent. Therefore, translated technical publications, mainly German, were popular. Such a publication was the Hütte handbook - a multi-volume "Handbook for engineers, technicians and students" [6]. The first German edition of the Handbook was published in Germany in 1857, it included sections: mathematics and mechanics, mechanical engineering and construction. Soon, in 1863, the first Russian translation of the Handbook was published. Before World War II, Hütte was one of the most common technical reference books in our country. The Handbook continued to be published in the post-war years, the last 34th edition was printed in 2012.

Changes in snow load rationing. Based on these and other sources, let's first consider how the regulation of such an important and dangerous force on buildings as snow load changed over time. The Urgent provision contained some instructions regarding loads on structures, in particular, on rafter trusses. The load from own weight was regulated in the range of 20 – 70 kgf/m^2, variable loads – at 160 kgf/m^2. It can be assumed that this variable load with a margin took into account the snow load in the main territory of the country, and the total calculated load of 180 – 230 kgf/m^2, together with a margin for strength, ensured a certain level of safety of structures made according to competent calculations. It should be noted that the specified recommendations regarding the total loads on the roof corresponded to the German codes of that time for pitched roofs in Germany [6].

In the first post-revolutionary Unified Rules for Building Design (1931), the snow load P_c (kgf/m^2) was determined by a formula that is quite unusual from a modern point of view:

$$P_c = P_c^0\left(1+0.002h\right)\left(45^\circ-\alpha\right), \quad (1)$$

where P_c^0 – an empirical value that depended on the geographical location of the area (latitude and longitude), and was found in the corresponding table with latitude values in the range of 40 – 70° and longitude 20 – 190°; h – height of the area above sea level (in meters); α is the angle of inclination to the horizon (in degrees) of the surface that received the snow load.

To specify the recommendations of the Uniform Rules regarding snow load, we will perform calculations for three geographical points:

- Poltava: latitude 44°35′, longitude 34°34′, h = 146 m, P_c^0 = 1.33, according to formula (1) the estimated snow load on the horizontal surface (α = 0°) was

$$P_c = 1{,}33\left(1+0{,}002\cdot146\right)45^\circ = 77{,}5 \text{ kgf/m}^2;$$

- Kyiv: latitude 50°27′, longitude 30°30′, h = 183 m, P_c^0 = 0.94

$$P_c = 0{,}94\left(1+0{,}002\cdot183\right)45^\circ = 57{,}8 \text{ kgf/m}^2.$$

- Kropyvnytskyi: latitude 48°31′, longitude 32°17′, h = 127 m, P_c^0 =1.10

$$P_c = 1{,}10\left(1+0{,}002\cdot127\right)45^\circ = 62{,}0 \text{ kgf/m}^2.$$

As can be seen, the values of snow load regulated by the Uniform Rules were significantly lower than those previously contained in the Urgent provision.

In the next normative on the height of the snow cover h, and the average document of 1933, the snow load was standardized differently, depending maximum height for the last ten years was taken into account. So, the calculated height of the snow cover had some statistical justification. At the same time, the density of snow was assumed to be ρ = 100 kg/m^3 without sufficient explanation. The calculated value of the snow load was determined as $p = 1{,}6\rho h$. 4 regions were determined with heights of snow cover in the range of 30 sm>h>80 sm and corresponding snow load p = 25 – 120 kgf/m^2 [2].

It is interesting to note that the codes of 1933 (that is, 90 years ago) contained detailed recommendations regarding the possible reduction of snow loads due to melting:

a) for moderately insulated roofs (with a thermal resistance of 0.75...1.10 (m^2·°C)/W) at an internal temperature of 15˚C, 2/3 of which are located above the heated rooms, the snow load was reduced by 50%;

b) for roofs of buildings with large heat emissions (heat flow over 800 cal/h/m^2) with thermal resistance less than 0.75 (m^2·°C)/W – the snow load was reduced by 75%.

In the future, these valid recommendations were omitted, and they are missing from domestic snow codes to this day, although their relevance is obvious, which is confirmed by the presence of similar recommendations in the Eurocode.

In the following codes (1940), when justifying the snow load standard, the snow density was increased with a differentiation of ρ = 200 – 250 kg/m^3 depending on the height of the snow cover. The territory of the country was divided into 5 snow regions with the values of the snow cover height *h* and the calculated snow weight *p* on the ground surface of a slightly higher level compared to the previous codes. At the same time, the territory of Ukraine was attributed to the I region (*h* up to 20 cm, weight p = 50 kgf/m^2) and II region (*h* from 20 to 40 cm, p = 70 kgf/m^2). These unjustified standards ignored the climatic features of Ukraine and were significantly lower than the actual snow loads on its territory. Nevertheless, these standards were left in subsequent editions of the load codes and transferred as normative values to the SNiP, which regulated the calculations of structures for limit states.

A number of researchers have identified significant shortcomings of SNiP regarding the standardization of snow loads [2].

1. Underestimation of the calculated values of snow load, which is the result of the imperfection of the methodology for their justification, as a result of which they are exceeded quite often, in some areas every 5...10 years. This is largely due to the fact that methodological approaches to the standardization of snow loads, appropriate for areas with heavy snow winters, have not been sufficiently justified in areas with unstable snow cover (which includes, for example, most of Ukraine). Here, the snow load has significant specifics, in particular, it cannot be described by the normal distribution law, which satisfactorily assesses the snow load in continental areas. As a result, on average across Ukraine, the calculated values of snow load were underestimated by 50...60% compared to the values necessary to ensure a minimum sufficient level of reliability of load-bearing structures. Such a serious discrepancy between snow standards and reality was the cause of a large number of accidents in building structures.

2. Overly generalized zoning of the territory of the former USSR (6 snow regions), which ignored the specifics of individual regions of the country. To a large extent, this situation is attributed to the territory of Ukraine with various physical and geographical features and climatic regions, such as coastal, mountainous, steppe, forest and other areas. As a result, the changeable Ukrainian winters form a territorial distribution of snow cover, which is significantly different from the zoning map of snow load according to SNiP. Here we give the remarks of R.I. Kinash [2], who, as a curiosity, noted that in terms of snow load, Lviv (in which in 1995/96 and 1996/97 the snow lay for almost 6 months) was attributed to the same region as Tashkent and Ashgabat, and Vinnytsia, close to Lviv, to a remote continental high-snowfall region of inland Asia with markedly different climatic characteristics. Obviously, for a vast territory that constituted one sixth of the Earth's landmass, such a generalized zoning with a limited number of snowy areas can be considered forcibly justified, but insufficiently differentiated.

3. The lack of a clear connection between the snow load standard and its recurrence period, which makes it impossible to take into account the service life of buildings, as a result of which they are designed for an indefinite service life, which supports the misconception: "Buildings should stand forever!".

4. Disadvantages in the standardization of the long-term component of the snow load, which is not regulated at all for I and II snow regions. Such an approach is illogical, since whatever the nature of the change in the snow load in low-snow regions (to which I and II regions belong), it will still create rheological phenomena in structures (even if insignificant and have little effect on the operation of the structure). Therefore, long-term components should also be established for I and II regions, at least from a methodological point of view.

5. The fundamental incorrectness of taking into account the differentiated reliability coefficient γ_f = 1.4...1.6 depending on the weight of the roof. Taking into account the necessity of such an approach, it should be emphasized that this coefficient depends only on the probabilistic properties of the snow load and is not related to the design and weight of the roof.

With the collapse of the USSR, the new independent states had the opportunity to move away from the crude Soviet snow standardization and develop their own, more differentiated snow zoning. Further development of snow standards in the CIS was implemented in the form of national standards of individual states. The codes of Ukraine DBN V.1.2-2:2006 “Loads and loadings” finally (after 70 years!) introduced statistically justified increased values of snow load. Compiled on the basis of research by domestic scientists [9], these codes regulate the characteristic values of snow load, in particular, for Poltava and Kyiv 1600 Pa (160 kgf/m^2 – 5th region), for Kropyvnytskyi 1400 Pa (140 kgf/m^2 – 4 region). A more detailed description of the evolution of snow load standardization is given in the publication [10].

Evolution of normalization of wind loads. The beginning of this was laid in 1931 with the publication of "Uniform codes of construction design". There was already a certain scientific basis for substantiating the codes in that period: long-term meteorological wind observations (3 times a day) with the measurement of wind speed by a Wild weathervane with two-minute averaging; aerodynamic studies that have been carried out since pre-revolutionary times in laboratories and institutes. In the Uniform codes, the wind load was determined by the formula, which also had a rather unusual appearance from a modern point of view:

$$p_в = k\left(p_в^0 + k_1 h\right) \tag{2}$$

where $p_в$ – the wind pressure in kgf/m^2; k – coefficient of flow, which depended on the shape and position of the object exposed to the wind; $p_в^0$ – the highest pressure in kgf/m^2 when the air flow is directed normally to the surface; h is the total height of the building (m) above the edge of the foundation; k_1 – calculation coefficient, which was taken depending on the nature of the wind flow around the buildings.

Territorial zoning in the first wind codes was practically absent, since the same maximum wind pressure
$p_в^0$ = 50 kgf/m^2 was assumed for the entire country, except for the coasts of seas and the mouths of large rivers
75 – 100 kgf/m^2.

Standardization of wind load was developed in the codes introduced in 1933 [2]. In them, the wind load was determined by a different formula:

$$P_a = k \cdot q \tag{3}$$

where k is the flow coefficient; q – wind pressure, similar to $p_в^0$ in the formula (2).

The wind division was maintained for the above-mentioned three geographical areas, and for the entire territory the pressure was reduced to 45 kgf/m^2.

Evaluating the described wind codes, it should be noted that the first wind zoning was not differentiated enough and regulated only one basic value of wind pressure of $q = 45$ kgf/m^2 for the entire territory of the country (with few exceptions). It was not sufficiently statistically substantiated. As subsequent studies have shown, this value turned out to be underestimated and was subsequently increased. Perhaps the authors of the codes took this into account, so they recommended the designers to use the additionally known Beaufort wind force scale, supplemented with wind pressure values [11]. According to this scale, the normalized value of 45 kgf/m^2 corresponds to 8 points and "very strong wind" with a speed of 18 – 20 m/s. At the same time, judging by the Beaufort scale, during storms and hurricanes (9 – 12 points), the wind speed and the corresponding wind pressure can be much higher. It should be noted that the first codes already took into account the increase in wind load with height, the impact of the protection of buildings and the nature of the flow around buildings of different configurations.

Over the next ninety years, the design codes of building structures regarding the standardization of wind loads have undergone significant changes and expanded their statistical bases. Territorial wind zoning has been developed, the number of wind regions has increased. In particular, according to the current DBN V.1.2-2:2006 "Loads and loadings", the characteristic value of wind pressure W_0 is equal to the average (static) component of wind pressure at a height of 10 m above the ground surface, which can be exceeded, unlike SNiP, on average once in 50 years (similar to Eurocode standards). The characteristic value of wind pressure W_0 is determined depending on the wind region according to a map or tabular appendix. It should be noted that the wind zoning of the territory of Ukraine according to the DBN takes into account significant territorial variability of wind load, which is noticeably different from its overly generalized standardization of SNiP, according to which almost the entire territory of Ukraine was classified as II (normative load W_0 = 0.3 kPa, design load 0.42 kPa) and III (W_0 = 0.38 kPa, design load 0.53 kPa) wind regions. A more detailed territorial zoning of Ukraine by characteristic values of wind load includes five territorial regions with characteristic values from 0.4 to 0.6 kPa. The lowest values of wind load are observed in the central and northwestern regions of Ukraine, as well as in Transcarpathia. Large wind loads are realized in the Carpathians, Precarpathian and coastal regions. Territorial zoning of Ukraine by characteristic values of wind pressure was performed according to the method developed by V.A. Pashinsky [9]. A probabilistic model of a non-stationary normal random field was used, the ordinates of which were the values of the loads of individual weather stations located at distances of 30…60 km. The smoothing procedure made it possible to obtain a smooth surface of the mathematical expectation of the wind load, free from random fluctuations of the data of individual weather stations. Region values of the design wind load were set so that the excess reserves of the territorial zoning were minimal.

Comparison of wind zoning according to DBN with SNiP reveals a relatively small difference in the calculated velocity pressures. In the central regions, Crimea, Lviv, Odessa, Kherson and Luhansk, the wind load is lower than in the SNiP. In the Azov region, on the contrary, the wind load is much higher. On average in Ukraine, zoning according to the DBN underestimates the wind load by 4%. At the same time, for 34% of observation points, wind load is underestimated by 15…25%, and for 12% of points, it is increased by 25…65%.

Stages of crane loads normalization. The beginning of domestic standardization of crane loads was laid in 1931 with the introduction of the "Uniform codes of construction design" [2]. Due to the fact that at that time the relevant experimental works were not carried out, the basis of the adopted standards were foreign codes, works of crane operators and reference publications, for example [6].

The horizontal loads transmitted from the cranes to the crane tracks and directed along the building were determined as

$$H = 0{,}1Pn \tag{4}$$

where P is the calculated vertical pressure on the crane wheel; n is the number of brake crane wheels located on the crane beam.

At the same time, the values of forces of normal intensity were taken to be equal to 0.5 of the values obtained by formula (4) (obviously, this was the first attempt to take into account the mode of operation of bridge cranes).

The transverse crane load was taken as that created by braking of cart with a cargo, and was determined by the formula

$$T = \frac{0{,}1(Q+q)n}{n_0} \tag{5}$$

where Q is the weight of the cargo; q – cart weight; n_0 – the number of all wheels of the crane; n is the number of brake wheels of the crane.

This effort was distributed between the crane beams in proportion to their lateral stiffnesses.

Formulas (4) and (5) take into account that the friction force F is equal to the normal pressure N multiplied by the coefficient of friction between the rails and the wheels of the crane or cart f , which is equal to 0.1.

For especially fast or slow working cranes, it was allowed to determine horizontal forces using the formula:

$$H = \frac{\sum Q}{10} \cdot \frac{v}{t} \qquad (6)$$

where $\sum Q/10$ is the mass of moving goods (the number 10 in the denominator approximately takes into account $g = 9{,}8$ m/s^2); v – the maximum speed of the crane (cart); t – braking time.

Formula (6) was obtained from the condition of equality of the kinetic energy of motion and the work of the force H. For increasing speed according to the law of the triangle, this formula determines the average value of the force, which is equal to half of the maximum instantaneous force H_{max}, which is detected during braking. In subsequent editions of the codes, formula (6) was deleted.

In subsequent years, the crane load codes were gradually changed [12], but only in 2006, in the national standards DBN V.1.2-2:2006 “Loads and loadings”, the erroneous braking force formula (5) was replaced by the formulas for lateral forces caused by skewing of bridge cranes and non-parallelism of crane tracks. Lateral forces are regulated separately for four-wheeled cranes of small lifting capacity, prone to skewing during movement. For these bridge cranes, the lateral force formula has the following form:

$$H_{\kappa} = 0{,}1F_{\max} + \alpha(F_{\max} - F_{\min})\frac{L_{cr}}{B} \qquad (7)$$

where $F_{\max}$ and $F_{\min}$ are the wheel pressures of greater and less loaded side of the crane; L_{cr}, B are the span and base of the crane; α is a coefficient equal to 0.01 for cranes with a separate drive of the movement mechanism and 0.03 for cranes with a central drive.

In the above formula, the first term gives the transverse force from the wheel skew, the second term gives the horizontal component on the wheel flange, which limits the skew of the bridge. This formula provides a fairly close match with the experimental values [12].

The lateral forces H_k, calculated by formula (7), can be applied:

• to the wheels of one side of the crane and directed in different directions (inside or outside the span of the building under consideration), which corresponds to the limitation of the crane skew by the wheels of one side;

• to the wheels along the diagonal of the crane and also directed in different directions (inside or outside the span of the building under consideration), which corresponds to the case of limiting the crane skew by the wheels located along the diagonal of the crane.

In this case, forces equal to $0{,}1F^n_{\max}(0{,}1F^n_{\min})$, directed in the most unfavorable direction (inside or outside the span under consideration), are applied to the other wheels.

For multi-wheel cranes with a large load capacity, not prone to skewing during movement, a new lateral force standard has been introduced based on the results of many years of testing of such cranes. The characteristic value of the lateral force on the wheel of multi-wheel cranes with flexible load suspension is taken as 0.1 of the vertical load on the wheel, calculated under the condition that the trolley with a load equal to the crane's rated load capacity is located in the middle of the bridge. The following formula can be used in this case:

$$H^n_k = 0{,}1\left(G_M + G_B + Q\right)/2n_0 \qquad (8)$$

where G_M is the weight of the crane bridge; G_B is the weight of the trolley; Q is the lifting capacity of the bridge crane; n_0 is the number of wheels on one side of the crane.

For multi-wheel cranes with rigid suspension of the load, a characteristic lateral force H^n_k is taken equal to 0.1 of the maximum vertical load on the wheel. When determining the characteristic values H^n_k, it is taken into account that the lateral forces from two multi-wheel cranes are transmitted to both sides of the crane track. On each side of the crane, the lateral forces have one direction – outward or inward, on different tracks they are directed in opposite directions (both inward or both outward). On one of the tracks, the full lateral force is taken, on the other track, half of the lateral force is applied.

The consequences of implementing the recommendations of DBN V.1.2-2:2006 “Loads and loadings” in terms of bridge crane loads [2] were analysed. It was found that the horizontal loads on the wheel of four-wheel bridge cranes determined according to DBN were 1.3…9.6 times higher than the loads calculated according to SNiP. When determining the force effects of four-wheel bridge cranes according to DBN, the bending moments in the columns of the transverse frames of one-story industrial buildings (OIB) from lateral forces increase by 1.9…6.9 times, compared with the efforts from braking forces according to SNiP, and the bending moments in the structures of crane beams increase by 1.2…7.8 times. As a result, there is a slight increase in the material consumption of crane beams, which is on average 1.1%, as well as a detected increase of up to 24% in the material consumption of crane parts of columns of buildings equipped with four-wheel cranes.

Under the conditions of action on the structures of multi-wheel overhead cranes, the loads on the wheel of multi-wheel cranes according to DBN exceed the loads according to SNiP by 1.3…1.7 times. It was found that the bending moments in the transverse frames increase by 1.1…1.2 times and up to 1.6 times in the crane beams. Based on the tests of the bearing capacity of the structures of the OIB, it was established that in the case of equipping buildings with multi-wheel overhead cranes, the transition to determining the loads according to DBN does not lead to an increase in the material consumption of the structures of the crane beams and columns.

To neutralize the consequences of the introduction of load standards into the practice of design, it is recommended to use such a reserve of steel frames of the OIB as the spatial work of the frames. It has been established that taking into account the effect of spatial work of frames in the calculation of transverse frames of the OIB for combinations of loads allows to approximate the results of calculations of frames for loads according to SNiP 2.01.07-85 and avoid additional material consumption.

Conclusions.

It is shown how, during the last ninety years, the design codes of building structures regarding the normalization of loads have significant changes and expanded their statistical bases. Territorial snow and wind zoning has been developed, the number of regions on the territory of Ukraine has increased. The normalization of crane loads has been significantly changed, especially in the part of lateral forces of bridge cranes. The substantiation of normative (characteristic) and calculated values of climatic and crane loads based on an increased recurrence period has been modified. The high scientific level of codes DBN B.1.2-2006 "Loads and loadings" was noted, which have a modern statistical basis, are associated with Eurocode codes and ensure the required level of reliability of building structures

References

1. Баженов В.А., Ворона Ю.В., Перельмутер А.В. (2016). Будівельна механіка і теорія споруд. Нариси з історії. К.: Каравела. ISBN 978-966-222-968-8/
2. Пічугін С.Ф. (2024). Етапи розвитку загальної методики розрахунку будівельних конструкцій. Полтава: ТОВ «АСМІ». ISBN 978-966-182-699-0
3. Elishakoff I. (1999). Probabilistic Theory of Structures. New York: Dover Publications
4. Truesdell C.A. (1968). Essays in the History of Mechanics. Berlin: Springer Verlag
5. Де-Рошефор Н.І. (1916). Урочне положення. Шосте виправлене видання. Петроград: Видання К.Л. Раккера.
6. HŰTTE. (1935). Довідник для інженерів, техніків і студентів. Том другий. П'ятнадцяте видання (переклад з 26-го німецького видання). М.: Держмашметвидав.
7. Перельмутер А.В., Пічугін С.Ф. (2024). Метод граничних станів. Загальні положення та застосування в нормах проєктування. К.: «Софія-А». ISBN 978-617-8382-12-4
8. Пічугін СФ. (2016). Розрахунок надійності будівельних конструкцій. Полтава: ТОВ «АСМІ», ISBN 978-966-182-418-8
9. Пашинський В.А. (1999). Атмосферні навантаження на будівельні конструкції для території України. К.: УкрНДІПСК,
10. Pichugin Sergii. (2020). Probabilistic basis development of standartization of snow loads on building structures. Industrial Machine Building, Civil Engineering, 2(55). 5-14. https://doi.org/10.26906/znp.2020.55.2335
11. Pichugin Sergii. (2021). Many years of experience of standarding the medium component of wind load on building structures. Industrial Machine Building, Civil Engineering. 2 (57). 5-13. https://doi.org/10.26906/znp.2021.57.2579
12. Pichugin Sergii. (2021). Development of crane load codes on the basis of experimental research. Industrial Machine Building, Civil Engineering. 1 (56). 18-29. https://doi.org/10.26906/znp.2021.56.2493

1. Bazhenov V.A. Vorona Y.V., Perelmuter A.V. (2016). *Construction mechanics and theory of buildings. Essays on history*. K.:Caravela. ISBN 978-966-222-968-8
2. Pichugin S.F. (2024). *Development stages of general methodology for building structure calculation.* Poltava: TOV "ASMI". ISBN 978-966-182-699-0
3. Elishakoff I. (1999). *Probabilistic Theory of Structures*. New York: Dover Publications
4. Truesdell C.A. (1968). *Essays in the History of Mechanics*. Berlin: Springer Verlag
5. De Rochefort N.I. (1916). *Urgent position.* Sixth revised edition. Petrograd: K. L. Rakker Edition.
6. HŰTTE. (1935). *Handbook for engineers, technicians and students*. Volume 2. Fifteenth edition (translated from the 26th German edition). M.: Gosmashmetizdat
7. Perelmuter A.V., Pichugin S.F. (2024). *Method of limit states. General provisions and application in design codes*. K.: "Sofia-A" ISBN 978-617-8382-12-4
8. Pichugin S.F. (2016). *Reliability calculation of building structures*. Poltava: TOV "ASMI" ISBN 978-966-182-418-8
9. Pashynskyi V.A. (1999). *Atmospheric loads on building structures for the territory of Ukraine*. K.: UkrNDIPSK
10. Pichugin Sergii. (2020). Probabilistic basis development of standartization of snow loads on building structures. *Industrial Machine Building, Civil Engineering,* 2(55). 5-14. https://doi.org/10.26906/znp.2020.55.2335
11. Pichugin Sergii. (2021). Many years of experience of standarding the medium component of wind load on building structures. *Industrial Machine Building, Civil Engineering.* 2 (57). 5-13. https://doi.org/10.26906/znp.2021.57.2579
12. Pichugin Sergii. (2021). Development of crane load codes on the basis of experimental research. *Industrial Machine Building, Civil Engineering.* 1 (56). 18-29. https://doi.org/10.26906/znp.2021.56.2493

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Аналіз тенденцій розвитку норм навантажень на будівельні конструкції

У статті послідовно розглянуті підходи до врахування навантажень на будівельні конструкцій та їхнє відображення у нормативних документах різних років. Зосереджено увагу на спадкоємність методу граничних станів і методу допустимих напружень у частині опису навантажень. Показано, як протягом останніх дев'яноста років норми проектування будівельних конструкцій щодо нормування навантажень зазнали значних змін і розширили свої статистичні основи. Перші рекомендації, що містилися в Урочному положенні, із запасом враховували снігове навантаження на основній території країни. Початкове нормування вітрового навантаження регламентувало однаковий вітровий тиск для всіх місцевостей. З роками стосовно кліматичних навантажень (снігових, вітрових) приділялась увага змінам територіального районування (кількість районів на території України було збільшено) та розрахункових коефіцієнтів, призначенню нормативних і розрахункових значень та залученню до цього дослідних статистичних даних. Приділено також увагу зв'язку розвитку норм кранових навантажень з результатами експериментальних досліджень цих навантажень. Норми кранових навантажень поступово змінювали, але тільки у 2006 р в національних нормах ДБН В.1.2-2:2006 «Навантаження і впливи» помилкову формулу гальмівних сил було замінено на формулу бічних сил, що спричиняються перекосами мостових кранів і непаралельністю кранових колій. Модифіковано обґрунтування нормативних (характеристичних) та розрахункових значень кліматичних і кранових навантажень на основі збільшеного періоду повторюваності. Вітчизняні дослідження навантажень активізувалися останні десятиліття у зв'язку із впровадженням Державних будівельних норм України. Відзначено високий науковий рівень вітчизняних норм ДБН В.1.2-2006 «Навантаження та впливи», які мають сучасний статистичний базис, асоціюються з нормами Єврокод та забезпечують необхідний рівень надійності будівельних конструкцій.

Ключові слова: надійність, норми проєктування, граничні стани, снігове навантаження, вітрове навантаження, кранове навантаження

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