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THE COMPOSITION OF STRUCTURAL STEEL USED IN THE REPUBLIC OF KAZAKHSTAN AND THE RELATIONSHIP WITH HARDNESS CHARACTERISTICS

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ABSTRACT: The Republic of Kazakhstan possesses significant plant capacities for producing constructional steel sheets for use in the construction industry. Since 2015, a new Eurocode-based regulatory framework in construction has been in effect. One of the primary challenges addressed has been ensuring compliance of local structural steel with the chemical composition requirements of the Eurocode. To address this, chemical composition determinations have been conducted for seven types of steel commonly utilized in construction. The content of the main components was compared with the specifications outlined in EN 10025. It has been determined that the chemical composition of the local structural steel fully aligns with the requirements of EN 10025. For the first time, correlation dependencies between Brinell numbers and components of the steel's chemical composition have been established. A linear correlation between the Brinell hardness factor and the percentages of carbon, manganese, and silicon has been identified. The correlation coefficient in this context ranges from 0.7 to 0.8, indicating a stable correlation relationship. This study provides an example of determining Brinell hardness based on the carbon or manganese content in steel samples. Additionally, utilizing the correlation dependence, the impact strength was determined. The findings of this research are expected to significantly improve the utilization of Kazakh structural steel in design and construction applications.

Keywords: Construction steel, Chemical composition, Correlation, Eurocode, Brinell hardness

1. INTRODUCTION

The analysis of the chemical composition of steel serves as an effective tool for assessing the quality of steel reinforcement and steel sheets. The evolution of the chemical composition of building steels and their processing methods aims to enhance the complex of their mechanical properties, which determine the overall reliability of structures [1]. For instance, society frequently encounters issues such as the destruction of buildings and bridges due to the use of poor-quality materials in steelwork [2].

In [3], the chemical properties of selected grades of steel reinforcement from Nigeria were evaluated. Thirty selected grades of valves manufactured in Russia and Ukraine were obtained from six geopolitical areas in Nigeria, and their chemical composition was analyzed for compliance with five selected standards (SON, BSI, ASTM, AISI, ISO).

The study [4] investigated the correlation between Brinell strength and the strength properties and composition of thermomechanically rolled structural steel S460M. It compared historical (1895-1930) and modern (2000-2015) laboratory tests on hot-rolled steel samples used in building structures. The study examined the tensile limit and yield point characteristics and explored their relationship with the chemical composition of the steel.

Moreover, numerous engineering challenges in construction and industry necessitate an investigation into the material-to-material joining process of duplex stainless steels (DSS). Therefore, it is important to examine the material properties during the welding process to assess the quality of welding. In [5], the chemical composition can be quantitatively measured using predetermined calibration curves.

In the study [6], researchers establish a correlation between steel chemical composition and hardness in circumferential welds. This correlation arises from the frequent observation that the strength of structures is often dictated by the strength of the welded joints.

Another study, documented in [7], conducts comprehensive changes in the chemical composition, microstructure, and hardness of Chinese railway steel rails over a century. The findings reveal the increased carbon content over time, with proper control of phosphorus and sulfur elements. Moreover, Chinese steel rails exhibit an upward trend in manganese content, while foreign steel rails demonstrate the opposite trend. Notably, Chinese steel rails exhibit lower hardness compared to foreign steel rails.

It is important to highlight the significance of Brinell hardness as a key characteristic of structural steel and our focus on studying the correlation between steel's chemical composition and this specific characteristic. Brignell hardness is determined by the diameter of the imprint left by a metal ball pressed into a surface. Hardness is calculated as the ratio of the force applied to the ball to the area of the imprint. This aspect has been investigated by numerous specialists [8].

The primary criterion for assessing the quality of structural materials lies in their mechanical characteristics. Mechanical tests, such as uniaxial tension, are employed to determine these properties. From these tests, fundamental traits like strength and ductility, crucial for structural integrity, are derived. However, these tests are labor-intensive, time-consuming, and expensive, requiring the production of reference materials that comply with ISO standards.

An alternative mechanical testing method for metal products is hardness testing, which offers a non-destructive means of determining mechanical characteristics at a relatively low cost. Hence, it is preferable to establish the correlation between Brinell hardness and the chemical composition of steel. Subsequently, utilizing regression dependencies, we can determine the yield point, tensile limit and strength at break.

A comparison of the properties of Russian and European steel, including chemical composition, in relation to Eurocodes, was carried out in the study [9]. It was noted that for high-strength steels produced in Russia, the content of harmful impurities, sulfur (S) and phosphorus (P), is higher than for steels that meet Eurocode requirements. The values of yield point, tensile limit and strength at break could be determined from the results of studies [10, 11]. However, this applied only to Russian-made steels.

The task is to determine the chemical composition of structural steel produced in the Republic of Kazakhstan based on the results of experimental studies and establish correlations between elements of chemical composition of structural steel and BH of steel, which then allows for the evaluation of yield strength, tensile strength and relative strain at rupture values. It is also necessary to assess the compliance of structural steel produced in the Republic of Kazakhstan with the requirements of ISO Eurostandards in terms of chemical composition. This would enable using of the Kazakhstani structural steel in the design of metal structures according to Eurocode 1993. This task is highly relevant for the Republic of Kazakhstan.

Thus, the following tasks are further solved:

- Experimental determination of the chemical composition of 7 samples of Kazakh structural steel. Assessment of compliance of the chemical composition with Eurocode requirements.
- Determination of the correlation between the elements of the chemical composition of steel and Brignell hardness (BH).
- Construction of regression dependencies between 7 components of structural steel.
- Examples of determining impact strength using previously obtained regression dependencies.
- Discussion of research results.

Previously, such studies have not been carried out for Kazakh structural steel.

2. RESEARCH SIGNIFICANCE

The primary significance of this research lies in conducting experimental and scientific investigations aimed at facilitating the practical application of the regulatory framework based on Eurocode 1993 in the construction industry of the Republic of Kazakhstan. Over six years of the new regulatory framework's implementation, steel structures were hardly designed. Design organizations lacked information regarding the compliance of Kazakhstan structural steel with the requirements of Eurocode 1993 concerning its chemical composition, physical and mechanical properties, and impact toughness. Such information was simply unavailable.

Using European steel was economically unfeasible due to significant transportation costs.

Therefore, this scientific work enables the use of local structural steel for designing metal structures in both ordinary and seismic regions, as well as in the northern areas of the Republic of Kazakhstan.

The scientific significance of the work lies in determining the correlation between the chemical composition of steel and Brinell hardness (BH), which is easily measurable. This allows for the translation of chemical composition data into the values of the physical and mechanical properties of structural steel.

3. MATERIALS AND METHODS

3.1 Materials

One of the most common types of steel is St3SP5. As previously mentioned, the main chemical elements are iron and carbon. The concentration of iron accounts for 97%, while carbon ranges from 0.14% to 0.22%. Carbon specifically influences the hardness index and other physical and chemical properties of the structure. The structure contains a relatively small amount of alloying elements, primarily chromium and nickel, each with a concentration of 0.3%. Copper is also included at the same concentration. Despite the wide variety of steel grades considered, the concentration of harmful impurities, such as phosphorus and sulfur, as well as gases (oxygen, nitrogen, hydrogen), is strictly controlled.

The main characteristics of St3SP5 (produced by Arcelor-Mittal Iron and Steel Works), such as maintaining material strength despite high loads and a wide range of temperatures it can withstand, make it suitable for use in load-bearing structures. An additional advantage is that there is no requirement to heat the metal before welding, and no heat treatment is needed at the end of welding.

Mill products from the 09G2S steel grade are utilized in building structures of various shapes and sizes. The high mechanical strength of this steel allows for the use of thinner elements compared to other types of steel. 09G2S steel finds applications in constructing building structures and steam boilers (for oil, water, and natural gas). It is practically employed in all areas of construction operations and mechanical engineering. Its high thermal stability enables its use in a temperature range from -70°C to +450°C.

3.2 Methods

Chemical analysis of steel was carried out using “wet chemistry” methods (gravimetric, titrimetric, photometric, coulometric).

In Europe, ordinary and high-strength construction steels are manufactured according to the EN 10025 European standard (Table 1). Generally, these steels closely resemble domestic steels, but they allow for a higher carbon content of up to 0.23%, which exceeds the carbon content of domestic steel. The 2010 version of the specified Euro standard had, on average, higher carbon content. However, in a more recent version of the standard for 2019, the carbon content has been reduced. Currently, the EN 10025 standard comprises six parts.

The percentage content of each chemical element in structural steel was determined using specific methods. The silicon and nickel content was determined by the gravimetric method, which involves combustion of the precipitate followed by weighing. The manganese and chromium content was determined using a titrimetric method, based on color change in the presence of an indicator. The phosphorus content was determined using a photometric method, based on the optical density of the solution. The carbon and sulfur content was measured using a Combustion Master CS device (Germany) with an error margin of 0.1-0.5 ppm.

The chemical composition of the specified steel types is analyzed below, followed by an assessment of their conformity with the requirements of Eurostandards.

The research techniques involve experimental methods followed by processing using a mathematical package such as MATLAB and Mathcad PRIME 7.0.0.0.0. Regression and correlation analysis are being performed.

When processing the measurement results, subroutines for constructing pairwise empirical relationships were used, employing the least squares method. Correlation coefficients were also calculated.

The MATLAB software package was used to verify the accuracy of the calculations. The calculations for individual pairwise empirical relationships were repeated

4. RESULTS AND DISCUSSION

4.1 The Results of Experimental Studies

The experimental research methods described in the previous section were used. The accuracy of measuring the chemical composition of structural steel is to three decimal places.

Tables 2-5 provide a summary of the results of experimental tests on the chemical composition of steel and chemical composition indices from certificates of conformity. of the Euro standard. Figures 1-3 illustrate the experimental findings The analysis suggests that, overall, the steels used comply with the requirements corresponding to Tables 2-7, obtained using the utilities of the Mathcad PRIME 7.0.0.0.0 software package. PTC Mathcad – is a general-purpose mathematical program designed for conducting and documenting engineering calculations. Manufacturer: PTC from the USA.

The results from Tables 2-3 are, on average, consistent with the data presented in the tables. For 0.09G2S steel of 10 mm thickness in Table 2, the mass fraction of silicon is 0.63, which exceeds the requirement of 0.55. Hence, it may be necessary to increase the number of samples with this type of steel to ensure thorough examination.

The chemical composition of structural steel has a decisive influence on the strength and deformability characteristics of structural steel. Carbon primarily affects tensile limit, yield point and tensile strain at break. Manganese, like carbon, affects the strength of steel, but to a lesser extent.

The copper content affects the strength of steel and the impact strength values.

Let us give examples of the application of the obtained correlation dependencies.

Tables 6-7 show the linear approximation coefficients of the experimental evidence and certification data:

$$x_i = a_0 + a_1 BH \quad (1)$$

where xi – % content of a specific metal type, BH – Brinell hardness. The hardness test results for 7 types of steel are derived from previously completed work [12]. In Figures 1-3, approximating curves are constructed for carbon, silicon, and manganese, as these elements have the most significant influence on the strength and deformation characteristics of structural steel, with correlation coefficients ranging from 0.806 to 0.647.

Table 1 Chemical composition of steel up to 40 mm thick according to EN 10025

Designation		Deoxidation method	C in % max for nominal product thickness, in mm			Si	Mn	P	S	N	Cu	Other
According to EN 10027–1 and CR 10260	According to EN 10027–2		≤ 16	< 16 ≤ 40	> 40	% max						
S235JR	1,0038	FN	0,17	0,17	0,20	–	1,40	0,035	0,035	0,012	0,55	–
S235J0	1,0114	FN	0,17	0,17	0,17	–	1,40	0,030	0,030	0,012	0,55	–
S235J2	1,0117	FF	0,17	0,17	0,17	–	1,40	0,025	0,025	–	0,55	–
S275JR	1,0044	FN	0,21	0,21	0,22	–	1,50	0,035	0,035	0,012	0,55	–
S275J0	1,0143	FN	0,18	0,18	**0,18**[h]	–	1,50	0,030	0,030	0,012	0,55	–
S275J2	1,0145	FF	0,18	0,18	**0,18**[h]	–	1,50	0,025	0,025	–	0,55	–
S355JR	1,0045	FN	0,24	0,24	0,24	0,55	1,60	0,035	0,035	0,012	0,55	–
S355J0	1,0553	FN	0,20	**0,20**[i]	0,22	0,55	1,60	0,030	0,030	0,012	0,55	–
S355J2	1,0577	FF	0,20	**0,20**[i]	0,22	0,55	1,60	0,025	0,025	–	0,55	–
S355K2	1,0596	FF	0,20	**0,20**[i]	0,22	0,55	1,60	0,025	0,025	–	0,55	–
S460JR[j]	1,0507	FF	0,20	**0,20**[i]	0,22	0,55	1,70	0,030	0,030	0,025	0,55	k
S460J0[j]	1,0538	FF										
S460J2[j]	1,0552	FF										
S460K2[j]	1,0581	FF										
S500J0[j]	1,0502	FF	0,20	0,20	0,22	0,55	1,70	0,030	0,030	0,025	0,55	k

Table 2 Chemical composition of construction steel according to experimental data

№	Steel	Mass fraction of carbon, C, %	Mass fraction of silicon, Si, %	Mass fraction of manganese, Mn, %	Mass fraction of chromium, Cr, %
1	St3SP5, 8	0,21	0,12	0,51	0,10
2	St3SP5, 10	0,17	0,14	0,53	0,11
3	09G2S, 8 mm	0,09	0,59	1,43	0,12
4	09G2S, 10	0,09	0,63	1,44	0,09
5	St3SP5, 20	0,22	0,13	0,42	0,07
6	09G2S, 20	0,08	0,50	1,45	0,08
7	St3SP5, 10	0,20	0,14	0,52	0,14
	Average	0,15	0,32	0,9	0.10

Table 3 Chemical composition of construction steel according to experimental data

№	Steel	Mass fraction of nickel, Ni, %	Mass fraction of sulfur, S, %	Mass fraction of phosphorus, P, %	Mass fraction of copper, Cu, %
1	St3SP5, 8 mm	0,14	0,012	0,010	0,11
2	St3SP5, 10 mm	0,19	0,015	0,011	0,06
3	09G2S, 8 mm	0,18	0,019	0,012	0,09
4	09G2S, 10 mm	0,14	0,017	0,021	0,08
5	St3SP5, 20 mm	0,10	0,011	0,014	0,08
6	09G2S, 20 mm	0,17	0,015	0,012	0,09
7	St3SP5, 10 mm	0,17	0,019	0,021	0,08
	Average	0.16	0.015	0.014	0.08

Table 4 Chemical composition of construction steel according to conformity certificates

№	Steel	Mass fraction of carbon, C, %	Mass fraction of silicon, Si, %	Mass fraction of manganese, Mn, %	Mass fraction of chromium, Cr, %
1	St3SP5 8 mm	0,197	0,217	0,505	0,18
2	St3SP5 10 mm	0,19	0,218	0,450	0,022
3	09G2S, 8 mm	0,074	0,658	1,334	0,026
4	09G2S, 10 mm	0,074	0,658	1,334	0,026
5	St3SP5, 20 mm	0,18	0,21	0,42	0,08
6	09G2S, 20 mm	0,11	0,56	1,44	0,09
7	St3SP5, 10 mm	0,16	0,20	0,34	0,05
	Average	0.14	0.39	0.83	0.07

Table 5 Chemical composition of construction steel according to conformity certificates

№	Steel	Mass fraction of nickel, Ni, %	Mass fraction of sulfur, S, %	Mass fraction of phosphorus, P, %	Mass fraction of copper, Cu, %
1	St3SP5, 8 mm	0,017	0,015	0,018	0,037
2	St3SP5, 10 mm	0,017	0,009	0,017	0,035
3	09G2S, 8 mm	0,022	0,014	0,016	0,048
4	09G2S, 10 mm	0,022	0,014	0,016	0,048
5	St3SP5, 20 mm	0,14	0,011	0,009	0,19
6	09G2S, 20 mm	0,17	0,010	0,018	0,17
7	St3SP5, 10 mm	0,01	0,005	0,010	0,01
	Average	0.06	0.01	0.015	0.08

Table 6 Linear approximation factor from experimental data

№	Type,	a_0	a_1	Correlation factor
1	Carbon, C	0,461	-0,002	-0,73
2	Silicon, Si	-0,934	0,008	0,776
3	Manganese, Mn	-1,558	0,016	0,717
4	Chromium, Cr	0,034	4,352*10^{-4}	0,411
5	Sulfur, S	-0,001	1,090*10^{-4}	0,785
6	Phosphorus, P	0,008	4,417*10^{-5}	0,216
7	Copper, Cu	0,093	-5,803*10^{-5}	-0,087

Table 7 Linear approximation factor (certification)

№	Type,	a_0	a_1	Correlation factor
1	Carbon, C	0,434	-0,002	-0,806
2	Silicon, Si	-0,786	0,008	0,775
3	Manganese, Mn	-1,386	0,014	0,647
4	Chromium, Cr	0,302	-0,002	-0,613
5	Sulfur, S	0,003	5,061*10^{-5}	0,326
6	Phosphorus, P	0,006	5,867*10^{-5}	0,355
7	Copper, Cu	0,317	-0,002	-0,494

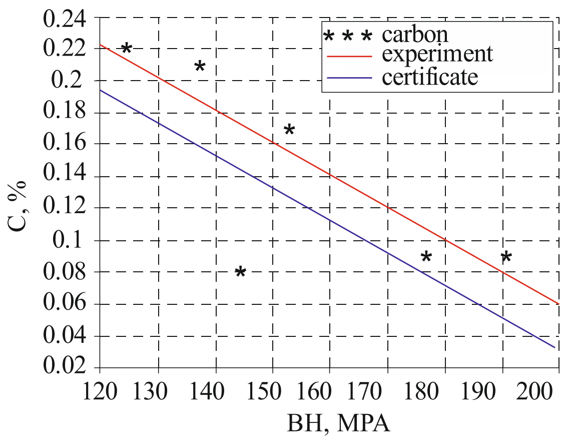

Fig.1 Correlation dependence between the carbon content and BH

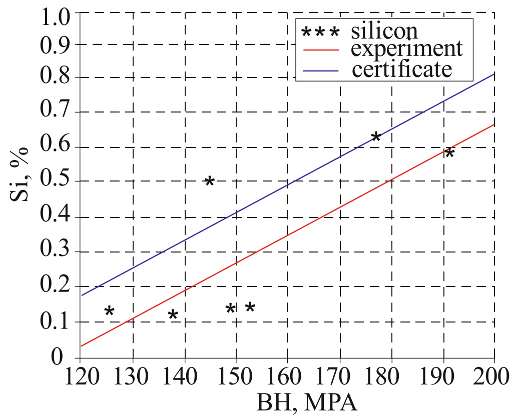

Fig.2 Correlation dependence between the silicon content and BH

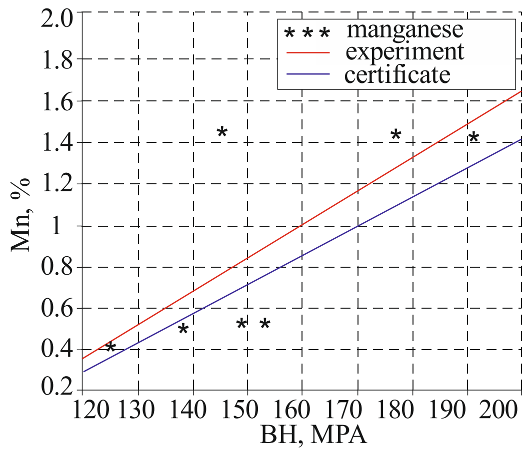

Fig.3 Correlation dependence between the manganese content and BH

The Chaddock scale is utilized to assess the strength of the coupling force of correlation coefficients. When the coefficient value falls within the range of 0.7 to 0.9, the correlation degree is considered high. Hence, such functional relations should be duly considered.

For example, there is a correlation for carbon C

$$\mathbf{C = 0.461 - 0.002BH} \quad (2)$$

Or solving the equation

$$\mathbf{BH = -500C + 230.5} \quad (3)$$

According to BH values, it is possible to determine the tensile limit, yield point and tensile strain at break [12,13].

In [14], correlations between impact strength and BH at a temperature of -20 degrees were obtained for Kazakh steel

$$\mathbf{KCU = -1.1494BH + 256.7701} \quad (4)$$

$$\mathbf{KCV = -0.4694BH + 136.1878} \quad (5)$$

where KCU is the toughness of the sample with a U notch, KCV is the toughness of the sample with a V notch. In Fig. 4, the graphs of relationships (4) and (5) are shown.

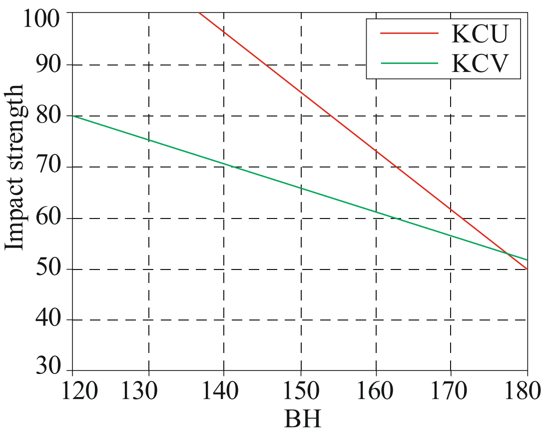

Fig. 4 Relationship between hardness and impact toughness at a temperature of -20 degrees.

With a carbon content of C=0.15%, hardness BH=155.5, impact strength KCU=78.03, KCV=63.19.

For manganese (Mn) the following dependence was obtained (Table 6):

$$Mn=-1.558+0.016BH \quad (6)$$

Solving equation (6) we get

$$BH=62.5Mn+97.375 \quad (7)$$

With a manganese content of Mn=0.9% (average value from Table 2), the hardness value BH=153.63, and impact strength values of KCU=80.19 and KCV=64.08 were obtained. The differences in the impact strength values at -20 degrees Celsius range from 1.5% to 3%. These results are deemed acceptable and affirm the presence of stable correlations. Similarly, impact strength values can be determined at temperatures of +20º and -40º [14]. It's important to note that impact strength tests are quite costly and require special sample preparation. Therefore, utilizing dependencies such as those in equations (4) and (5) enables accurate determination of these values.

Hence, by utilizing the data presented in Table 6 and the linear dependence expressed in equation (1), it becomes feasible to swiftly determine BH values corresponding to the content of, for instance, carbon. It has been established [15] that such indirect methods of determining yield strength and other steel characteristics are sufficiently reliable and theoretically supported.

It's noteworthy that for carbon and silicon, which are among the most significant components of structural steel, the slope of the straight lines is identical (as depicted in Fig. 1-2). Here, the certification and experimental data exhibit statistical closeness.

4.2 Discussion

In study [16], a 'regression model' was proposed to examine the influence of the chemical composition of structural steel on impact strength values. The model was developed using old data from 1989, which utilized steel types no longer in production. It was observed that impact strength values were solely affected by the presence of carbon. However, as demonstrated earlier, impact strength is significantly influenced by the presence of manganese. Our study utilizes experimental data from testing modern types of steel, rendering it more relevant.

In study [17], it was demonstrated how the purity of structural steel regarding harmful impurities (chemical composition) affects the results of fracture toughness tests. The necessity of testing the fracture toughness of steel samples with a fatigue crack as a concentrator is substantiated. This work essentially confirms the results of our research. It is shown that the relationship between the chemical composition of the steel and the values of fracture toughness is exclusively due to the microstructure of the structural steel as a building material.

In article [4], empirical dependencies between Brinell hardness (BH), strength characteristics, and chemical composition of structural steel were determined.

Researchers established empirical relationships between Brinell hardness (BH) and the strength characteristics of structural steel. They observed that measurements of Brinell hardness in structural steels, along with analysis of chemical composition, provide a reliable means to estimate the strength parameters of steel structural elements using non-destructive methods. Notably, the study focused solely on one type of steel.

Furthermore, our research reveals a correlation between the chemical composition of structural steel and Brinell hardness, suggesting the need for new approaches to determine mechanical properties without traditional testing methods. Study [18] proposed a semi-analytical model describing the relationship between strain energy, displacement, and a novel hardness testing method. This method enables more accurate determination of hardness, tensile strain at break, and elastic modulus, akin to deformation curves obtained from tensile tests. Exploring correlations between chemical composition and results using this semi-analytical method would be of interest.

Another semi-analytical method for determining Brinell hardness was introduced in study [19], based on plasticity theory methods.

Hence, the method for determining Brinell hardness, established at the beginning of the last century, continues to evolve through novel approaches and techniques. Hardness emerges as a crucial concept, strongly correlating with the chemical composition and physical and mechanical characteristics of structural steel.

In summary, the results obtained in this study are in line with previous findings and offer significant supplementary insights.

It should be noted that this article continues the series of studies devoted to the issues of application of structural steels produced in the Republic of Kazakhstan in the design of steel structures according to the requirements of the Eurocode.

4.3 Consideration

A significant increase in earthquake-resistant construction volume is anticipated in the Republic of Kazakhstan through the utilization of locally manufactured steel structures. Buildings featuring steel frames demonstrate satisfactory resistance to strong seismic impacts during long-period earthquakes [20]. Moreover, simple damping systems can be installed on such buildings [21].

New types of steel frames, characterized by prefabricated systems with specialized bolted connections, have been experimentally shown to possess enhanced dissipative properties and high resistance to seismic impacts [22]. Future plans include studying these systems in relation to Kazakh structural steel.

Additionally, exploring the hardness and chemical composition of new types of cold-rolled steel holds promise for their application in the design of building structures [23].

The main results of this work will also contribute to the widespread use of Kazakhstani structural steel in earthquake-resistant construction in the Republic of Kazakhstan. It should be noted that in the seismic areas of the Republic of Kazakhstan (the city of Almaty with a population of 2.5 million people, seismicity of 9 points), buildings with a steel frame are quite widely used in earthquake-resistant construction practice. As experience shows, such buildings are quite earthquake-resistant [24]. In an eleven-story building with a steel frame in the city of Almaty, there is an engineering seismometric station that has been recording earthquakes of various intensities in real time for 30 years [25].

The structural steel 09G2S studied in Tables 2-4 is used in high-rise construction [26]. At the same time, the thickness of structural steel should be increased to 80 mm.

Another possible application of the obtained results is the determination of impact toughness characteristics when inspecting the metal structures of buildings during the reconstruction of construction projects. When performing such work, it is quite simple to cut a sample of structural steel measuring 10x10 cm. Then, the chemical composition of this steel is studied, the hardness characteristics BH are determined based on correlation dependencies, and then the impact toughness values are calculated using relationships (4) and (5).

Further development of research in this area should be aimed at determining the correlation between the components of the chemical composition and the hardness values according to Vickers HV and Rockwell HRC. In this case, the correlation between the components of the chemical composition, the hardness parameters HV or HRC, and the impact toughness characteristics KCU and KCV may be described more accurately.

Promising studies also include the impact toughness KCT with a crack-like notch. Such tests are more complex. Therefore, determining the relationship between the components of the chemical composition of structural steel and the impact toughness KCT has theoretical and practical significance.

5. CONCLUSIONS

-The experimental findings of the chemical composition of 7 types of structural steel indicate that, on average, the composition of domestic structural steel meets the requirements of the 2019 European Standard EN 10025. However, for steel 09G2S with a thickness of 10 mm in Table 2, the

mass fraction of silicon is 0.63, which exceeds the specified value of 0.55 (referenced in Table 1). Nevertheless, the average silicon content for all samples fully complies with the Eurocode requirements. It appears that increasing the number of samples with this type of steel or improving the accuracy of measurements may be necessary here.
- A statistical analysis of batch certificates indicating the percentage content of structural steel components leads to the conclusion that the data in these documents, in general, align with Eurostandards requirements.
- For carbon and silicon contents, a linear function serves as an acceptable approximation of the statistical relationship between component content and BH. The correlation magnitude between the chemical components of structural steel and BH is considered sufficient for practical applications. It's worth noting that such correlations for Kazakh structural steel were obtained for the first time.
- Utilizing the correlations between BH and yield point, tensile limit, and tensile strain at break allows for the immediate determination of these parameters based on content values, such as carbon or manganese. Furthermore, employing previously derived regression dependencies facilitates the determination of impact strength of structural steel based on the chemical composition.

The results obtained will significantly contribute to the utilization of Kazakh structural steel in design according to Eurocode 1993, both within the Republic of Kazakhstan and in foreign countries.

6. ACKNOWLEDGMENTS

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