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Engineering and Technical Basics of A. D. Kryachkov's "Sustainable Architecture"

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Abstract. The work of Siberian architect A. D. Kryachkov was focused on the development of buildings resistant to exposure to severe Siberian climate. The article investigates the role of engineering and construction factors in formation of his ideas. The research is based on A. D. Kryachkov's publications and design documents and photos of his buildings constructed in the 1910s–1930s. Comparative analysis of the documents revealed that engineering and technical factors played the key role in his approach. He carefully studied the behavior of structural materials and structural elements in the cold climate conditions. The findings were then used in the design process. The buildings constructed according to his projects between 1920 and 1930 have preserved their original image for many decades. This fact makes the opinion that Siberian climate is incompatible with artistic and expressive architecture controversial.

INTRODUCTION

The term "sustainable architecture" became widely used recently, while the constituting components of this approach always existed. It reflects the desire of architects to design comfortable conditions for people's life while providing cost-efficiency and resistance to unfavorable environmental effects [1–4].

In Siberia, the problems of relationship between architecture and climatic/environmental conditions were first studied in Tomsk, which was the largest center of architectural ideas in the XIX – XX centuries. The researchers considered some aspects of "Siberian architecture" when investigating the so-called "search of Siberian style". In their research V. G. Zalesov and L. S. Romanova showed that Tomsk architects believed that applying local building materials and styling the decoration and architectural image in accordance with the natural motifs, local ornaments and North-European architectural analogs would enable them to efficiently fit the architecture of buildings in Siberian climatic conditions [5, pp. 85–86, 88–90; 6, pp. 20, 23, 36, 45, 48, 185].

One of the brightest representatives of Tomsk architectural school was a renowned Siberian architect Andrey D. Kryachkov (1876 – 1950). S. N. Balandin showed that searching for specificity of "Siberian architecture" was the key issue in A. Kryachkov's research and activity [7, pp. 59–93]. Balandin studied the methods used by A. Kryachkov for adapting buildings to environmental and climatic conditions of Siberia, while used technical and engineering principals still require investigation.

MATERIALS AND METHODS

This paper is aimed at analyzing the role of technical and engineering factors that influenced formation of A. Kryachkov's vision of regional features of Siberian architecture. The research tasks include: 1) identifying the technical and engineering principles found out by A. Kryachkov as the results of his studies; 2) analyzing their application in the buildings of his design. Materials of the period between the 1900s and the 1950s were analyzed. The architect's publications (2 articles and 1 monograph), projects and photos of the buildings constructed (49 projects and buildings that are adapted to the conditions of Siberia), as well as the testimony of his contemporaries

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[8–19] served as the source for this research. Comparative analysis of textual and graphic materials served as a research method.

RESULTS

Kryachkov's publications analysis allowed learning about his initial hypotheses on the reasons of damages of buildings and structures, including their décor that he observed when he arrived in Siberia. He suggested that damages were related to harsh climate conditions and poor quality of construction work, as many others architects concluded too [9, pp. 265–266]. Following examination of the buildings and structures showed that building materials in Siberia corresponded to their properties. So, the conclusion of Kryachkov was that damages were caused by poor quality of design.

Buildings and structures in Siberia were designed and constructed based on experience that specialists learned from the European part of the country. The special climatic conditions of Siberia were not taken into account and different interaction and response of local materials and structural elements with each other.

A. Kryachkov supported his conclusions with the results of his examinations, observations and experiments. The most important of them included the findings of special committees the members of which had studied the so-called "temperature emergencies" in the walls of new buildings in Novosibirsk. Between 1920 and 1931, A. Kryachkov undertook observations on the walls of the buildings exposed to wet conditions (saunas) in Tomsk, Novosibirsk and Kuzbass. In the early 1940s, he conducted experiments on the behavior of basic types of plasterwork recommended by the USSR Academy of Architecture and frequently applied in construction practice in Siberia [10, pp. 4, 12, 19]. The obtained data was taken into account by him when designing and constructing the buildings, thus confirming the soundness of his conclusions.

It is necessary to take into account the fact that A. Kryachkov's interest in the impact of climate on building architecture is not accidental. The architects of the "old school" would not just do plotting work. They used to combine the jobs of a designer, engineer, supplier and builder. They were in charge of not only the project and its implementation, but of conservation of the constructed building image as well.

Intensive development of Siberia in the late XIX – early XX centuries brought "a discovery" of new environment which differed from the ordinary territory of the Russian flatlands. A traditional image of Siberia consists of severe frosts (below – 40°C) and a long sustainable snow cover which sets in at the beginning of November and lasts as long as the end of April. It is a significant but not the main difference from the European territory of Russia, for instance, from Greater Moscow Area which is located in the same latitude. From A. Kryachkov's point of view the most important differences were sharp temperature drops and general weather changes during mid-seasons (spring and autumn): late spring and early autumn frost, spring recurrences of chills and short-term thaws during winter. As he noted, "in the Siberian conditions of sharp temperature changes in autumn and spring" during several days or even during a day there would happen sharp transitions from warmth to cold and vice versa [9, p. 266; 10: pp. 17, 28].

Thus, according to A. Kryachkov, it was not just winter but mid-seasons as well that strongly affected the buildings in Siberia. This feature was ignored by many designers.

In the meantime, temperature drops kept impacting the building materials. A. Kryachkov carefully analyzed temperature-related failures of bearing structures of recently commissioned buildings and those under construction. He paid attention to cross cracks that tended to appear in the structure conjunction points: brick walls, concrete slabs, steel beams and rafters. The greater the differences were in the linear expansion coefficient and the dimension change "lagging" coefficient (thermal inertia values) of the materials, the earlier the cracks appeared. It was non-heated industrial buildings with a great quantity of conjunctions made of different materials that were mostly affected by temperatures [10, pp. 11–12].

Similar tendencies were found out by A. Kryachkov in filler and bearing structures. His observations and experiments revealed low resistance of cement plasterwork to Siberian frosts and high resistance of stone plastering: lime/sand, lime/compact gypsum and marble plasters [10, pp. 23, 25, 28].

A. Kryachkov noticed that in all cities of Western Siberia "there was not a single building older than 1–2 years with cement plastering that had no temperature cracks or plaster peeling off the walls and their shapes" [10, p. 17], whereas outside stone plasters of "old buildings" in Siberia had served for 20 to 60 years and had no temperature cracks. He concluded that it could be caused by similarity in temperature expansion coefficients of brickwork and stone plasters [10: p. 26].

According to the estimates that A. Kryachkov made in compliance with the norms and specifications for stone structures of that time, additional temperature stress in cement plaster, with a difference between outside and inside temperatures reaching 50 °C, amounted to 21 kg/cm^2. It inevitably led to cracks in plastering even in a favorable situation of its simultaneous deformation with the brickwork [10, pp. 24–25]. Thus, A. Kryachkov managed to prove that cement plaster damage in Siberia primarily occurred because of cement used as a binding material and not because of a failure to comply with the specifications of plasterwork [10, pp 19–28].

A. Kryachkov confirmed his findings on the impact of temperatures by the following data [10, p. 23] (Table 1).

TABLE 1. Temperature expansion coefficients of building materials.

Material	Temperature expansion coefficient
Galvanized steel sheet	$28.35.10^{-6}$
Cast steel	12.10^{-6}
Cement plaster	$8.10^{-6} – 11.10^{-6}$
Concrete	$9.10^{-6} – 10.10^{-6}$
Lime plaster	$8.10^{-6} – 9.10^{-6}$
Limestone/sandstone walling	$8.10^{-6} – 8,5.10^{-6}$
Clay tiles	8.10^{-6}
Wood	6.10^{-6}
Red brickwork	5.10^{-6}

Analysis shows that studying the mechanism of destroying the walls of buildings with excess moisture, such as bath houses in Leninsk mines (1919), Tomsk (1924), Novosibirsk (1926) and Kemerovo (1929) was of great importance for the development of A. Kryachkov's architectural approach. The bath houses withstood only 2–3 years and then the outside plaster would collapse and the walls dilatate through thickness. As a rule, the damages started from the middle of the wall and propagated towards the ceiling [9, p. 266; 10, p. 12]. A. Kryachkov proved that the damage was caused not by poor quality of construction but by steam condensation from the inner premises resulting in wall wetting. As the heat conductivity factor increased in a wet wall, its outside layer would get frozen very frequently. The frozen layer prevented removal of steam from the wall, the steam kept condensing on the frozen area border, got frozen and broke the wall in two layers [10, pp. 12–15; 9, p. 267]. Therefore, A. Kryachkov thought that cement-mortar-based walls are inapplicable for bath houses and bathing establishments because of their considerable expansion coefficient and insufficient porosity [10, p. 16].

In this connection, he paid attention to boiler slag which was available in huge quantities at Kuzbass mines. That material was porous and had a smaller expansion coefficient as compared to brick. The vapor permeability coefficient of boiler slag (the architect sometimes called it "a drying coefficient") exceeded that of brickwork by 30 %. In 1920–1924, A. Kryachkov built a few, as they would put it today, experimental bath houses in Andzhero-Sudzhensk and Kemerovo made of slag concrete with 1:1:12–15 composition and 600 mm wall thickness [9: p. 267]. In 1942, he wrote that the assumption about quick drying of bath house walls fully proved its value. For 20 years of operation these constructions "showed no signs of damage" that were typical for similar buildings with cement-mortar-based brick walls [10, p. 16].

As an example of long life of the walls, A. Kryachkov recalled the bath houses in Tomsk (Zaistochye). The walls were 2.5-3.0-brick thick and joint with fat lime grout and had no outside plastering. For more than 25 years (1894 – 1919) "no temperature-related damage had been observed" [10, pp. 16–17].

When studying the structures working in wet conditions, A. Kryachkov addressed the issue of watering the structures with both precipitation and condensate in Siberian conditions. According to his observations, the building components fell into decay much faster when they were exposed to south-western winds prevailing in Siberia. Because of moisture, heat conductivity of filler structures and décor components increased, the temperature difference between them and bearing structures increased even more, with no ventilation, as well as with their windward (western and south-western) or northern orientation [9, p. 266; 10, p. 17].

It became obvious that mitigating an uneven impact of Siberian climate on buildings and their components by means of architectural/planning tools is one of the key tasks for a designer. Kryachkov thought that designing the jointly working structures of a building must be done with due regard to temperature expansion coefficients of the materials, with the difference between them being at a minimum [10, p. 25]. One more Kryachkov's recommendation was to enlarge the structures, as the latter would be less exposed to deformation with a decreased number of separate elements and junctions [8, pp. 4, 6–7].

Since “temperature is deleterious to the upper part of a building and its effect decreases downward to the bottom, i.e. the foundation”, it is the upper part of a building that should be effectively protected against poor weather conditions. A building should have simple plans and perimeters, a wide bulk, basements and ventilated attics [10, p. 11; 7, p. 149].

Kryachkov’s plastic solution also played a great role in building protection. He believed that architecture of Siberian buildings should retain the properties typical for Siberian clothes, i.e. keep warmth and remain dry during quick changes of weather. Interestingly, but it is this last recommendation and not the weather that A. Kryachkov put emphasis on. In Siberian conditions the upper parts of walls must be definitely protected against precipitation by means of cornices with a large overhang. In addition, the face plastic itself should be restrained and simple clean, without coble tables, like balcony slabs. Refusing from active horizontal articulation allowed for avoiding accumulation of precipitation (water, snow and ice) which was of paramount importance during autumn/spring frost. Owing to all these measures, the structures, elements and décor details were protected against abundant watering with rain and melted snow and, consequently, against inevitable freezing [10, pp. 17, 26, 28].

According to A. Kryachkov’s approach, the inner structures of a building should also remain dry. When some structures of a number of buildings built in accordance with A. Kryachkov’s projects were investigated in 1980 – 2000, it turned out that their ledger strips were provided with a special system of ventilation channels brought out through the chimneys outside. The channels enabled a free flow of air in the structures, therefore, the larch beams were preserved in an excellent condition during almost 100 years of service. Incompetent new owners of the buildings walled up the channels and the wooden structures decayed during one year [20, pp. 55–57].

A. Kryachkov’s findings were used in a number of designed buildings constructed between 1925 and 1931. Below are given just a few of them:

- Siberian Revolutionary Committee (Sibrevkom) in Novosibirsk, 1925 [19, sh. 1] (Fig. 1).
- House of Siberian Region Unions (Sibkraisoyuz) in Novosibirsk, 1926 [12, sh. 43a, photo 6, sh. 56, photo 1].
- Palace of Labor in Shcheglovsk (now Kemerovo), 1927 [11, sh. 50, photos 1–2, sh. 58, photos 1–2, sh. 65, photo 2, sh. 79, photo 1–2; 14, shs 5–8] (Fig. 2–3).
- State Bank (Gosbank) in Novosibirsk, 1929 [12, sh. 39, photo 2, sh. 73, photos 2–3; 15, sh. 15].
- Regional Executive Committee (Kraiispolkom) in Novosibirsk, 1931 (co-authored by B.A. Gordeyev and S.P. Turgenev) [12, sh. 43, photo 1; 13, sh. 139, photo 3; 16, shs 35–37].

FIGURE 1. Sibrevkom building in Novosibirsk, Photo of 1930s [19, sh. 1]

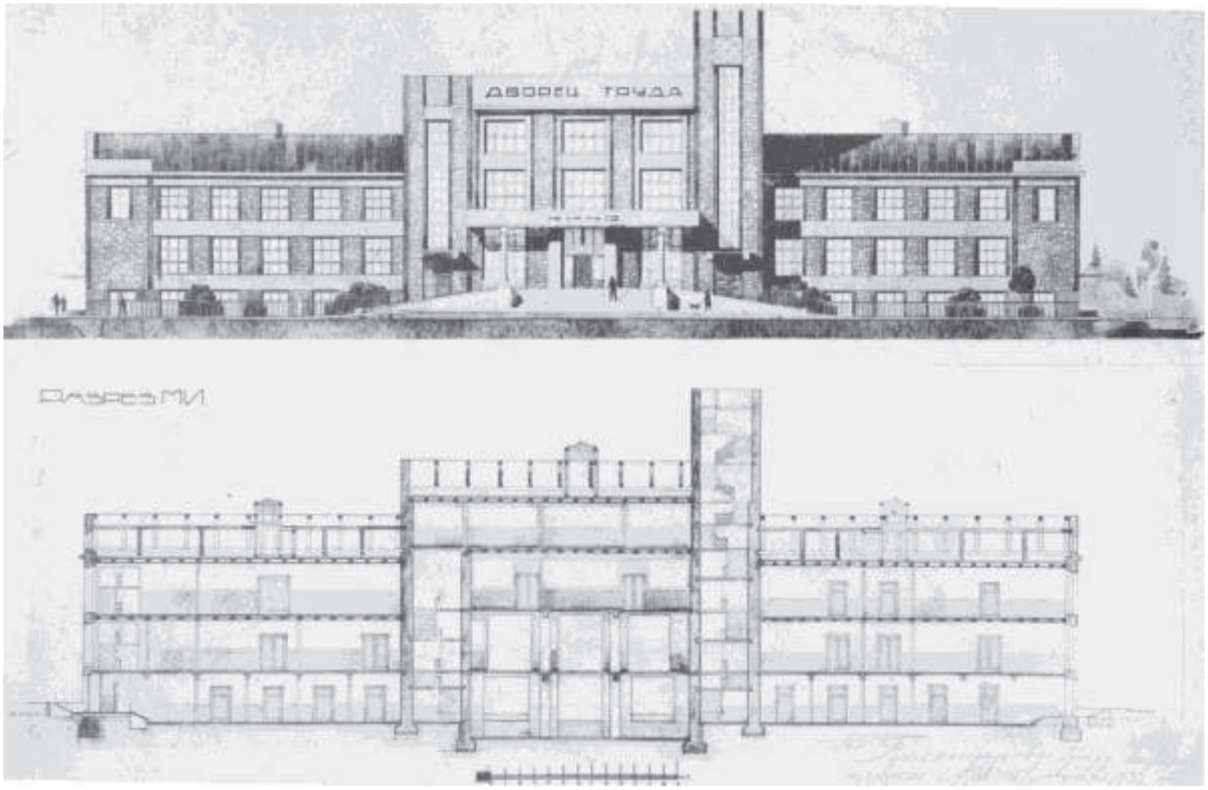

FIGURE 2. Palace of Labor in Shcheglovsk (main face, section drawing), 1927 [11, sh. 58, photo 2]

FIGURE 3. Palace of Labor in Kemerovo. Photo of 1930s [11, sh. 65, photo 2]

The results of comparative analysis of buildings are as follows. The buildings are designed in a different style, however, they have a number of common architectural and engineering features. Their faces are made of a special, somewhat flattened plastic with dominating vertical structural elements. Balconies (not many), as say in the Kraiispolkom building, had a minimal overhang. Flat pilasters and belt courses, horizontal and vertical structural elements, shaped as dumb window sills and frames of windows and pillars, served as the main means of plastic expressiveness for the designer. The Sibkraisoyuz building had multi-storey bow windows. Because of stone plasters the buildings, as a rule, were monochromatic. This approach was based on a combination of "strips" of different overtones (sand or grey ones) confined with belt courses and larger "spots". In the Palace of Labor in Shcheglovsk and Kuznetsk Metal Works Main Office building project (1929) the sections of walls made of local stone harmonized with plastered and painted fragments. A full terra-cotta red color was used in the Gosbank building, which could be easily repainted afterwards. The buildings had inclined roofing, ventilated attics and were devoid of blind ramparts.

Many engineers and architects paid attention to the fact that A. Kryachkov's buildings have preserved their original appearance up to modern days [17, sh. 34]. Some of his contemporaries connected a high degree of building preservation with high construction quality only [18, shs 2 recto – 2 verso, 3 verso]. However, the above evidence proves that the main reason is a high quality of design.

CONCLUSIONS

A. Kryachkov has made a great contribution to the development of "sustainable architecture" in Siberia. Of special significance is his reliance on engineering basics. He has identified important laws of joint work of building structures and components in Siberian conditions. He has proved that buildings got damaged not because of harsh climate but because of a failure to correlate design solutions with this climate. A. Kryachkov has revealed that it is mid-season with sharp negative and positive temperature changes rather than winter that present a critical period for building existence in Siberia. Since watering in such conditions leads to structure freezing, architects should consider protection of a building from accumulation of precipitants on its structures and elements. A. Kryachkov's buildings demonstrate that architectural/planning solutions has direct impact on a building's environmental resistance, thus disproving the assumption that Siberian climate is supposed to hinder creation of artistically meaningful works of architecture.

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