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## THE HISTORY OF ARCHITECTURE FORMS ESTABLISHMENT IN UKRAINE ON THE BASIS OF METROLOGICAL CONCEPTS

*In the article historical aspects of establishment and development of basic forms of architecture are revealed on the basis of metrological concepts on the territory of Ukraine. Using sound material, the authors conduct historiographic analysis of metrological concepts development from the times of Kyiv Rus to the XVII century. The main attention in the article is paid to the analysis of architecture forms development under the influence of metrology and standards' formation. Analysing, the authors come to the conclusion, that industrial crop of Ukraine from the times of Kyiv Rus was at high level, that allowed to attain a progressive advance in building and art.*

**Keywords:** *architecture, metrology, industrial crop of Ukraine.*

The common ways for Ukrainian villagers to measure parcels were areas of a rectangle 30 for 80 fathoms or 40 for 60 fathoms. There were the next common measurements: tithes, “morg”, “den”, “oprug”, “lan”, “half-a-lan”, “obriz”, “klitka”. Some of these measurements marked the amount of time for processing or the amount of gathered harvest from some space. The measures of ground, such as “morg” and “woloka”, appeared in Ukraine from Polish-Lithuanian Commonwealth. Here are some of them [1, p.37]:

- a) tithes – the measure of the area, that was due to 2400<sup>2</sup> fathoms;
- b) portage – the measure of area (30 “morgs”), that was used on the right bank of Dnieper river;
- c) “morg” – the measure of area, that was used mostly on the West of Ukraine, and was due to 0,57 ha.;
- d) “den” – the measure of area, the sector of about 1800 fathoms, that can be cultivated with the help of plow during one day;
- e) “lan” – the measure of area from 10 to 30 tithes;
- f) “gona” – the measure of distance, the length of “lan”.

In Kievan Rus an Ancient Egyptian measurement system was also used. That accordance was demonstrated by M.T.Belajew. He defined, that Old Russian system of measuring the length was based on the Ancient Egyptian system of measuring (III century BC), its basis – “elbow” (Old Russian – 538,5 mm, Ancient Egyptian – 540 mm), the measure of the area – a square with the edge in elbow. For example, an Old Russian fathom was 2154 mm, but an Ancient Egyptian one was 2160 mm; an Old Russian yard was 718 mm, but an Ancient Egyptian one was 720 mm. The versts were used in Kievan Rus. Such measure of the length as fathom was mentioned in chronicles of year 1017. The elbow was used in textile trade. A

span was used as the smaller measure, it is the distance between a big and an index finger. The verst, according to D.I. Prozorskiy [3], originates from the verb “to verst”, that means “to distribute”, “to compare with the help of matching”. So, the verst is something to be compared. The verst was also mentioned in chronicles of year 1097, where it was due to 750 fathoms.

The “elbow” is the measurement of the length from the elbow to the middle finger. The first mention of “the elbow” as the measure of length can be found in “Ruska Pravda” by Jaroslaw the Wise and in “Patericon Kyiv Pechersk” [4; 5]. The Old Russian elbow valued 46-47 cm and was taken by Father Superior Daniil. In agreement with the conclusions of M.V. Ustiygow [6] and L.V. Cherepnin [7], the “elbow” was due to one third of fathom, so that its measure should be 47 cm (when the fathom is 142 cm) or 51 cm (when the fathom is 162 cm). The “elbow” was used widely as a convenient measure. It continued to be used in retail after the appearance of a cubit in XVI century. They considered that ancient architects built without making calculations, but the architects of Rus knew the proportions and Babylon diagrams helped them to make calculations.

B.O. Rybarow represented Old Russian measurements as a wholesome system and proved, that fathoms were geometric lines of architects’ design tables (babylons). Babylons are tables with a depicted scheme of proportional ratio. With its help architects could find all necessary rations of the future building. During the comparison of the found babylons with the measurements of architectural monuments and the system of Russian measures, it was found, that all old Russian measures met the diagram of a Babylon with the side of a measured fathom [9, p. 13]. So, if the qualities of the Babylon are known, it is easy to show several proportional lines and so on.

Neither in the Old World, no in Middle Ages, there were metrological services but it is known that babylons were used and stored in churches and measuring tools were verified. The documents of the X century prove the existence of governmental supervision of measurements. For example, in the Statute of Wolodymyr the Great about the consistories (996) it was emphasized that measurements, that were used in trading, in everyday life, should be followed; the belt of Wolodymyr the Great (108cm) was the standard of the length. The Chamber of measurements and scales functionated in Nowgorod in the church of Iwan Predtecha, where the Statute of Prince Nowgorodskij Wsewolod “About consistories, about people and trading measurements” (1136) was accepted. The etalons, such as the pud of honey, “grivenka rublova”, “elbow yevanskij” [10, p. 63] could be found in that church.

The accurate measurements and calculations made it possible for architects to achieve harmony while creating the architectural monuments. Near the St. Sophia Temple in Kyiv there was another temple – the church of the Tithes, built in 989 – 996. After the investigation of the Tithes church three ovens for burning plinthite (the sort of brick) were found. Not far from one of them the picture of the trinefny temple was found; it was the façade of the church, its scale is 1/75 in comparison with the real size of the central part of the church. It was the first drawing, found on

the place of the building. To be able to build bridges, builders should be masters. In the chronicle “The tale of Bygone Years” (11 century) bridges of old Russian towns such as Owruch and Wasiliev were mentioned. In year 1115 Volodymyr Monomach, according to Ipatiiv chronicle built a bridge across the Dnieper [11, p. 15]. They used different types of the fathom, Old Russian metrologists provided architects with them. And that’s why masters had aesthetic architectural proportions.

The fathom was mentioned in “Kiev-Pechersk patericon” by Nestor the chronicler, where it was mentioned, that in year 1071, the monk Illarion made cave for himself with a size of two fathoms [4]. The stone in Tmutaracan’ river, near the Kerch Strait, helped to define the fathom. There was an inscription; it informed that in year 1068 Glib the Prince had gauged the sea, using fathoms (10000 for 40000 fathoms). The comparison of such dimensions of the width of Kerch strait and the results received by the Russian topographs in the first part of XIX century, using pre-revolutional Russian measurements, were almost the same. M.V. Ustugov found the meaning for an ancient fathom, it was due to 142 cm. It was different from that meaning of the verst; so that B.O. Rybakov [6] compared the results of the measuring of Glib the Prince with that of Byzantine topographs, made in 952. He reached a conclusion that the measurements were almost the same.

The name “pud” according to D.I. Prozovskij means “a weight”. Some time before “the pud” meant not only a weight, but also a device. While weighting metals the pud was used both as the unit of measurement and the unit for calculation, and was preferred even when the results of the weighting were equal to dozens or even hundreds of puds. The word “grivnia” was used to mark both a weight unit and a currency (the measure of value), can be found in “Ruska Prawda” [5]. The “grivnia” was the most common unit for weighting in trade and craft; it was used to weight gold and silver.

In 1949, Rybakow B.O., while analyzing the architectural buildings, reviewed the medieval metrology of Rus. From XI to XVII century there existed seven types of fathom: a big fathom – 1494,6 mm, a fathom without a “chota” – 1972 mm, a fathom for measuring – 1764 mm, an oblique fathom – 2160 mm, a direct fathom – 1527,6 mm, a tubular fathom – 1870,8 mm, a marine fathom – 1830 mm [12, p. 84]. For building of churches in the Post-Mongol period there was used the oblique fathom, for what comfortable antropometric methods were used. In XIV – XV centuries the oblique fathom turned up to be used not only by builders but also in the other branches, instead of a straight fathom. In XVI century an oblique fathom had several types: a tubular fathom and a bridging one, they were straightened up with metal etalons.

It is known that from XI to XVII century several types of fathom existed in Rus; but neither the length of its majority, no its interconnection can be determined as absolutely studied. The apartment of Russian measurements XVI – XVII centuries was explored by Prozorskij D.I., Ustugov M.W., Cherepnin L.W. [3; 6]. While analyzing their views, Rybakow B.O. pointed that, there were some doubts about the suggested gap between measurements of Kyivan Rus and Moskowian Rus; the existence of different measurements in XVI – XVII centuries

was also not explained. Moreover the scientists overestimated the unification of measurements by the state. In XVI-XVII centuries the fathoms of several types were determined. They had different regional and functional signs. The majority of them were fixed with metal etalons. All the types of the fathoms of that period had the size bigger than that of XI – XIV centuries.

The most valuable contribution in the investigation of measurements was made by Rybakow B.O., especially in the appearance of metrological ideas. The results of the measurement made it possible for him to install that the measures of the length and their classification were related. So he made a conclusion that they were complete systems. Rybakow B.O. had the idea about the possibility for architects to establish simple correlation between measures; that provided the functionality of their usage. That concept was made to life as the geometric building involving the system of circles with squares in them. For every system of measurements one and the same coefficient was used – two [12].

The universal character of these geometrical structures should be mentioned. They work with every measure of the length in Old Rus (fathom, half-a-fathom, “elbow”, “span”). The sides of one set of squares, located in one, reproduce the meaning of half-a-fathom, “an elbow” and “a span”, that are partial units against a fathom in 152 cm; and sides of the second set of squares provide the partial units 108, 54, 27 cm for the fathom of 216 cm. With the help of this system the sizes of the bridges and towers were determined. They were very important to watch for enemy. According to this system underground workings (wells, tunnels) were determined. The system was used mainly for building of temples, that’s why it was authorized by church and managed to survive in the whole territory of Rus even in the period of its feudal disunity. More over, these measures were used in construction practice in XI – XVII centuries; that was supported by the existence of three systems of measurement (with fathom 152, 176 and 216 cm). The availability of these, interrelated and easy to reproduce measures, made it possible to avoid using a fraction.

The harmony of building was reached by architects while using not only one system of measures, but two or even three of them. These systems were used in certain proportions. The existence of such measures simplified calculations. The finding of Nowgorod expedition (1972) turned out to be a confirmation of the hypothesis by Rybakow B.O. During that expedition the fragments of a measuring mace (measure) with three different scales were found in the central part of Nowgorod. That fact certified the simultaneous usage of three different fathoms. However the intersections on the mace, placed about 6, 7 or 8 cm, didn’t coincide with the known division of fathoms (span, inch). The comparison of the Westeuropean and Byzantine measures didn’t produce results. But the examination of ratio proportionality of these intersections demonstrated, that it coincided exactly with the proportional ratio of well-known fathoms – straight, measuring and big ones. So it was important to get to know what part of fathom was placed by those intersections on the mace. They were equal to 1/21 of the straight fathom, 1/21 of

the measuring fathom and  $1/21$  of the half of the big fathom. That coincidence could not be random, so Rybakow B.O. assumed, that those intersections were related with the ratio of the circumference and a diameter of a circle. If we take the meaning of the diameter of the circle as the meaning of the fathom, built with 21 intersections of the mace, the circle will be equal to 66 intersections. So, this ratio is equal to  $66/21=3,14285$ . We'll get the sum close to the meaning of  $\pi=3,1416$ . This fact enabled the architects to make the wheels for arches, churches and temples surfaces and other buildings.

The geometric measures partially became the measures of area, such as a square, the side of it was equal to the unit of length: square mile, square ("round") acres and square fathom. Instead of the word "square", not-known at that time, the word "quadrangular" was used and so on. Simultaneously the results of small area measures, only the measures of the length (fathoms) were given. The value and the importance of the basic measures of the land in mid XVI, can be found in the enactment of the year 1556. In XVII the main source of the information about the extent of land area was "The book of the "soshne" writing of the 7137"(1629) [2], which was very important for Russian architects. The meaning of the both types of rectangular acres was given there.

After the XVII century rope books were common. The sizes of steeds of the ménages were written there. The measuring was made with the help of a special rope. That's why these books were called "rope" ones. The ropes for measuring were stored in churches. The people, who measured with the help of ropes were called "ropers". As the result of the division, purchase, transferring, the land should be measured again. One of the tasks of recording the results in a special book was to check and to fix the changes while using the land. The results of such measurements were recorded in such books. According to that book, the system of the area unit was the next: 1 rope = 8 "osmino"; 1 "osmino" = 8 "kruhlyts"; 1 "kruhlytsia" = 100 square fathoms. According to the roped and hewed books, published by Dovnad-Zapolskij M.W., we can set that the units of the length were the next: 1 rope = 10 arches; 1 arch = 8 fathoms; 1 fathom = 4 elbows. As the units of the square, they had the next interrelation: 1 rope = 100 versts; 1 verst = 64 square fathom; 1 square fathom = 16 square elbows; 1 square fathom = 4 quarters; 1 quarter = 4 square "elbows". That was also confirmed with the next fact: 1 rope = 8 "osmin" = 64 "kruhlyts" = 6400 square fathoms. So 1 rope = 100 versts = 6400 square fathoms [3].

The long history of metrology is useful for social development, though its origin and formation were covered only in disparate data. The applied metrology explores the practical application of theoretical knowledge in various fields. Using the material, the authors made the historioraphical analysis of the metrological ideas' development from Kievan Rus to the XVII century.

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**ІСТОРІЯ СТАНОВЛЕННЯ ФОРМ ЗОДЧЕСТВА В УКРАЇНІ  
НА ОСНОВІ МЕТРОЛОГІЧНИХ УЯВЛЕНЬ**

*У статті розкриваються історичні аспекти становлення і розвитку основних форм зодчества на основі метрологічних уявлень на території України. Використовуючи ґрунтовний матеріал, автори проводять історіографічний аналіз розвитку метрологічних уявлень з часів Київської Русі до XVII ст. Основну увагу в статті звернено на аналіз розвитку форм архітектури під впливом становлення метрології та стандартів. Аналізуючи, автори доходять висновку, що технічна культура України з часів Київської*

*Русі була на високому рівні, що дозволило досягти послідовного розвитку в будівництві та мистецтві.*

**Ключові слова:** *зодчество, метрологія, технічна культура України.*

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## **ИСТОРИЯ СТАНОВЛЕНИЯ ФОРМ ЗОДЧЕСТВА В УКРАИНЕ НА ОСНОВЕ МЕТРОЛОГИЧЕСКИХ ПРЕДСТАВЛЕНИЙ**

*В статье раскрываются исторические аспекты становления и развития основных форм зодчества на основе метрологических представлений на территории Украины. Используя материал, авторы проводят историографический анализ развития метрологических представлений со времен Киевской Руси до XVII в. Основное внимание в статье обращено на анализ развития форм архитектуры под воздействием становления метрологии и стандартов. Анализируя, авторы приходят к выводу, что техническая культура Украины со времен Киевской Руси была на высоком уровне, что позволило достичь последовательного развития в строительстве и искусстве.*

**Ключевые слова:** *зодчество, метрология, техническая культура Украины.*