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A DETERMINATION OF THE QUANTITY OF ORNAMENTAL COMPOSITION ELEMENTS DEPENDING ON THE PREASSIGNED PROPORTION

Abstract: *Harmonization of the dimension proportions of the elements of architectural composition in most cases of a creative approach to architectural design is one of the basic tasks. For many thousands years of architecture development, the authors of the projects have tried a large number methods of proportioning elements. The mathematical formalization method of empirical data considered in the article allows to determinenumber of elements in the composition, the accentuation of which allows solving the question of its general harmonization. A particular case of this method is optimal for determining the number of ornamental compositions elements.*
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Introduction

Modern architecture demonstrates many examples of the active use of thematically different ornaments, not only as separate elements or inserts, but also in the sense-forming solutions of surfaces of different configurations that form an array of very interesting material for analysis (B.C.Brolin, 2000; A.U.Mal'chik, 2010; J.H.Gleiter, 2012; S.G.Khmelnitsky, 2013; D.D.Omuraliev, O.V.Wolitschenko, 2013; O.N.Priemetz, K.I.Samoilov, 2013 and other). Among the typical examples of this century, such buildings as: The Restaurant «Zhety Kazyna», Almaty, Kazakhstan, 2002(Arch. S.Usenko, K.Samoilov – «Autotechnika – Architectural workshop»); The Acqualina Sunny Isles Condos., Sunny Isles, Florida, USA, 2006 (Arch. R.M.Swedroe – «Robert M.Swedroe Architects & Planners»); The dwelling house – reconstruction, Almaty, Kazakhstan, 2007 (Arch. «Etnomura»); The «Cardinal Group» headquarters – «The Orange Cube», Lyon, France, 2011(Arch. D.Jakob and B.MacFarlane – «Jakob+MacFarlane Architects»); The Schoolchild Creativity Palace, Astana, Kazakhstan, 2012 (Arch. N.Yavein – «Studio 44 Architects», «Basis-A»); The Republic of Kazakhstan National Museum, Astana, Kazakhstan, 2014 (Arch. V.Laptev – «VL», «Bazis-A»); The «Novotel-Almaty» Hotel, Almaty, Kazakhstan, 2016 (Arch. «AHR»); The National Museum of African American History and Culture, Washington D.C., USA, 2016 (Arch. P.Freelon); The Mall, Addis Ababa, Ethiopia, 2016 (Arch. X.Vilalta – «Vilalta Arquitectura»); The «Astana Ballet» Theatre and the «Kazakhstan National Academy of choreography» Education Center, Astana, Kazakhstan, 2016 (Arch. «Studio 44 Architects», «Bazis-A»); The "AmurE" Triumph Palace, Almaty, Kazakhstan, 2016 (Arch. K.Samoilov – "Europolis") and others.

Materials and methods

As the analised material used complexes of buildings and structures. The sizes of these buildings are analyzed in terms of their ratios. At each position within the complex, these ratios are perceived differently. Graphical analysis method allows you to define groups of harmonious relationships.

Results and discussion

In general, architectural ornament, as an element of a building composition, in the best works of architecture is in a harmonious proportional link with all its parts. However, in most cases this concerns only the overall characteristics of the ornamental component itself. The structuring of groups and individual elements of ornamental components in the context of the general proportional structure of a one-time perceived composition is an interesting creative task that can be translated from a largely intuitive plane into a relatively simple sphere of computing (especially given the modern parameters of computer capabilities), which are included in a set of computational technologies and methods of architectural design, with an interesting history of application (Wolitschenko, O.V., 2011). At the same time, in the field of personal creative interpretation, the main thing remains - the choice of the most proportional system, which the author considers most harmonious for the composition being formed.

Thus, the problem is reduced to determining the sequence of dimensions of all components in the composition in the gap between the known values of the largest and smallest elements (Samoilov, KI 1987). The idea of the possibility of calculating parameters for the identification of harmonious relationships is based on the analysis of the perception of the complex of buildings and structures of Microdistrict No. 1 "on Strelka" in Ust-Kamenogorsk, Kazakhstan (arch. L.Baitanova, A.Dushenin, B.Zakharov, A.Kalinichenko, A.Laptev, S.Khristoforov). The microdistrict occupies the most responsible plot in the town planning aspect at the confluence of the rivers Ulba and Irtysh.

The compositional solution of this microdistrict is based on the combination of 5-, 7-, 9-, 12-, 14-, 16-storey houses with 1-, 2-, 3-storey public buildings. The peculiarity of the perception of the microdistrict due to its location is the absence of an average perception plan, since the whole complex is visible either from the opposite embankments of the Ulba River and the Irtysh River, or from the side of the boat traveling along the Irtysh River. The remaining points of perception are inside, in the "interior" of the microdistrict. This is facilitated by the compositional solution. On the Ulba side, along the perimeter, there are 5, 7 and 9-storey houses, curved in plan, alternating with 9-storey towers. Number of buildings storeys increases in the direction of the arrow of the rivers confluence. By Ulbinskaya embankment, from where the whole microdistrict is visible, the traffic is pedestrian, and the roadway is hidden by rows of trees. The range of perception and speed of movement cause a slight change in perspective. Therefore, from this side, a dynamic spatial composition is formed with an increase in volumes. The more distant points of perception on this side are characterized by short-term perception (when passing through a bridge across the Ulba river), which justifies the dynamism of one-time perception composition. And as the microdistrict adjoins here a 3-5-storey building, a smooth scale transition to 14-16-storey tower houses on the arrow is created.

There are only 9-storey houses on the Irtysh side. But after all, perception from this side is possible only from the side of the high-speed hydrofoil vessel, the speed of which ensures a constant change in the perceptions of the building bent wall. That is, static diversity is replaced by a dynamic one. In addition, the building adjacent to the neighborhood on this side consists mainly of 12-storey houses. On this border is the final stop of several bus routes and the movement of the bulk of the inhabitants to their homes begins.

The longitudinal axis of the microdistrict composition (which is also the axis of pedestrian traffic, since the entrance to the houses is organized from the embankments) coincides with the underground pass-through communication channel, which "shows up" on the surface with a clear rhythm of ventilation devices and observation wells. They serve as the first large-scale units located in close proximity to the main pedestrian flow. The next step is the transformer and pumping stations located somewhat in depth and comparable to 2-3-storey public buildings, providing a visual transition directly to residential development.

Visually legible subordination is confirmed, albeit approximately, by mathematical analysis. So, if we express the values of the vertical components of the architectural and spatial environment of the microdistrict in terms of the rows number of brickwork (as the main applied building material), then a sequence almost coincides with the proportion of the "Golden Section" in the form of the Fibonacci series: benches and elements of improvement - 6; forms of children's playgrounds - 9; ventilating devices - 15/16; people - 18/24; manholes - 39/42; substations - 63/64; two-story buildings - 98/102; the main trees are 165; five-story houses - 210/267; nine-storey houses - 364.

The composition of the building is such that at least 75% of possible directions of view from any point inside the microdistrict have a restriction in the form of a nine-storey wall of perimeter houses, and all other elements are perceived against its background or in combination with it. Therefore, we calculate the possible values of the vertical components of the microdistrict, taking for the constant final values the height of the nine-story house (364 rows of brickwork) and the average human perception horizon (18 rows of masonry). The pronounced clarity of the rows of brickwork in the walls of buildings and structures makes it possible to judge quite clearly the magnitude of the element, even taking into account visual prospective cuts. Therefore, let us consider the totality of rhythmic series, uniformly increasing according to the law of geometric progression.

To obtain the corresponding formulas, we transfer the known geometric constructions of the method of finding the sequence on the basis of the side and the diagonal of the square in the first quadrant of the coordinate plane (Fig. 1). Then the required quantities (ordinates "Y") of the terms of the series obtained are determined from the points that fix the intersections for each of the two straight lines:

№1 $(X_1, Y_1) \sim (Y = AX + C;\ Y = X)$;
$(Y_1 = AX_1 + C;\ Y_1 = X_1)$.
№2 $(X_2, Y_2) \sim (Y = AX + C;\ Y = X - X_1)$;
$(Y_2 = AX_2 + C;\ Y_2 = X_2 - X_1)$.
№3 $(X_3, Y_3) \sim (Y = AX + C;\ Y = X - X_2)$;
$(Y_3 = AX_3 + C;\ Y_3 = X_3 - X_2)$.
№m $(X_m, Y_m) \sim (Y = AX + C;\ Y = X - X_{m-1})$;
$(Y_m = AX_m + C;\ Y_m = X_m - X_{m-1})$,

where:

A – coefficient of slope of the line, that is, the denominator of the geometric progression (in general: $0 \le A < 1$);

C –ordinate of the initial term of the series.

Therefore, it is necessary to first determine the abscissa "X".

1). $Y_1 = AX_1 + C$; $Y_1 = X_1$, that is $X_1 = AX_1 + C$; $C = X_1(1 - A)$,
respectively $X_1 = C / (1 - A)$. To shorten the recording, we accept
$(1 - A) = F$, then $\mathbf{X_1 = C / F}$.

2). $Y_2 = AX_2 + C$; $Y_2 = X_2 - X_1$, that is
$X_2 - X_1 = AX_2 + C$;
$X_2 - C / F = AX_2 + C$;
$X_2 - AX_2 = C + C / F$;
$X_2F = C(1 + 1 / F)$;
$X_2 = (C / F)(1 + 1 / F)$,
respectively $\mathbf{X_2 = C\,[(F + 1) / F^2]}$,

3). $Y_3 = AX_3 + C$; $Y_3 = X_3 - X_2$, that is
$X_2 - C[(F + 1) / F^2] = AX_3 + C$;
$X_3F = C + C[(F + 1) / F^2]$;
$X_3 = C / F + C[(F + 1) / F^3]$;
$X_3 = C\,[1/ F + (F + 1) / F^3]$;
respectively $\mathbf{X_3 = C\,[(F^2 + F + 1) / F^3]}$.

Using the method of mathematical induction, we assume that for the term of the series with the serial number "m" the following expression is valid: $X_m = C\,[(F^{m-1} + F^{m-2} + \ldots + F^{m-m}) / F^m]$, or $\mathbf{X_m = C\,(1 / F + 1 / F^2 + \ldots + 1 / F^m)}$.

If the total number of members in the series is "n", then:
$Y_n = AX_n + C$; $Y_n = X_n - X_{n-1}$.

Assuming this value of the extreme term as "D" ($Y_n = D$), as a constant value (in the case under consideration - the overall size), we get:
$D = AX_n + C$;
$D = X_n - X_{n-1}$.
$D - C = AX_n$;
$A = (D - C) / X_n$;
$-A = (C - D) / X_n$;
$1 - 1 - A = (C - D) / X_n$;
$(1 - A) - 1 = (C - D) / X_n$.

Taking into account the previously accepted $(1 - A) = F$, we obtain: $F - 1 = (C - D) / X_n$;
$F - 1 = (C - D) / C(F^{n-1} + F^{n-2} + \ldots + F^{n-n}) / F^n$;
$C\,(F - 1)\,[(F^{n-1} + F^{n-2} + \ldots + F^{n-n}) / F^n] = C - D$.
$(C / F^n)\,(F - 1)(F^{n-1} + F^{n-2} + \ldots + F^{n-n}) =$
$= (C / F^n)\,[(F - 1)F^{n-1} + (F - 1)F^{n-2} + \ldots + (F - 1)F^{n-n}] =$
$= (C / F^n)\,(F^n - F^{n-1} + F^{n-1} - F^{n-2} + \ldots + F - F^0) =$
$=(C / F^n)\,(F^n - 1)$.
$C\,(F^n - 1) / F^n = C - D$;
$(F^n - 1) / F^n = 1 - D / C$; $1 - 1 / F^n = 1 - D / C$;
$1 / F^n = D / C$; $F = (C / D)^{1/n}$,
returning the replacement: $1 - A = (C / D)^{1/n}$, $\mathbf{A = 1 - (C / D)^{1/n}}$.

That is, the slope (denominator of the progression) "A" for a series with "n" members is determined by the formula:

$\mathbf{A_n = 1 - (C / D)^{1/n}}$.

The value of the abscissa "X" for a member of this series with the serial number "m": $X_m = [(C / D)^{(m-1)/n} + (C / D)^{(m-2)/n} + \ldots + (C / D)^{(m-m)/n}] / (C / D)^{m/n}$,
where: $m = 1, 2, \ldots, n$
($\lim A_1 = 1$, at $D < \infty$; $\lim A_n = 0$, at $n < \infty$).

Thence:
$Y_m = X_m - X_{m-1}$; $X_m = C\,(F^{m-1} + F^{m-2} + \ldots + F^{m-m}) / F^m$;
$X_{m-1} = C\,(F^{(m-1)-1} + F^{(m-1)-2} + \ldots + F^{(m-1)-(m-1)}) / F^{m-1}$;
$X_m - X_{m-1} = C\{[(F^{m-1} + F^{m-2} + \ldots + F^{m-m}) / F^m] -$
$- [(F^{(m-1)-1} + F^{(m-1)-2} + \ldots + F^{(m-1)-(m-1)}) / F^{m-1}]\}$;
$X_m - X_{m-1} = (C / F^m)\,(F^{m-1} + F^{m-2} + \ldots + F^{m-m} - F^{(m-1)-1+1} - F^{(m-1)-2+1} - \ldots - F^{(m-1)-(m-1)+1})$;
$X_m - X_{m-1} = (C / F^m)\,(F^{m-1} + F^{m-2} + \ldots + F + 1 - F^{(m-1)} - F^{(m-2)} - \ldots - F)$;
$X_m - X_{m-1} = (C / F^m)\,1$; $X_m - X_{m-1} = C / F^m$; $\mathbf{Y_m = C / F^m}$.

Given the previous,
$F = (C / D)^{1/n}$; $Y_m = C / (C / D)^{m/n}$; $Y_m = C / (C^{m/n} / D^{m/n})$;
$Y_m = (C / C^{m/n})\,D^{m/n}$.

Accordingly, the ordinate "Y" for a member of the series with the serial number "m" with the number of members in the "n" row is determined by the formula:

$\mathbf{Y_m = C^{1-m/n} D^{m/n}}$,

where:

C, D – are the known ordinates of the extreme terms of the series;

m –is the ordinal number of the desired term of the series (m = 1, 2, ..., n);

n – is the number of members of the given series (n = 1, 2, ..., k);

k – is the total number of rows.

Thus, for closed spaces of urban complexes (as in the example of a microdistrict), a constant presence of a visual frame of the limiting building is characteristic, while other elements disappear or appear as the motion moves (an analogous situation occurs in other types of spaces in unidirectional motion - this allows us to apply calculation and for the stationary perception of individual compositions with harmonically linked components, as a special case of the general methodology).

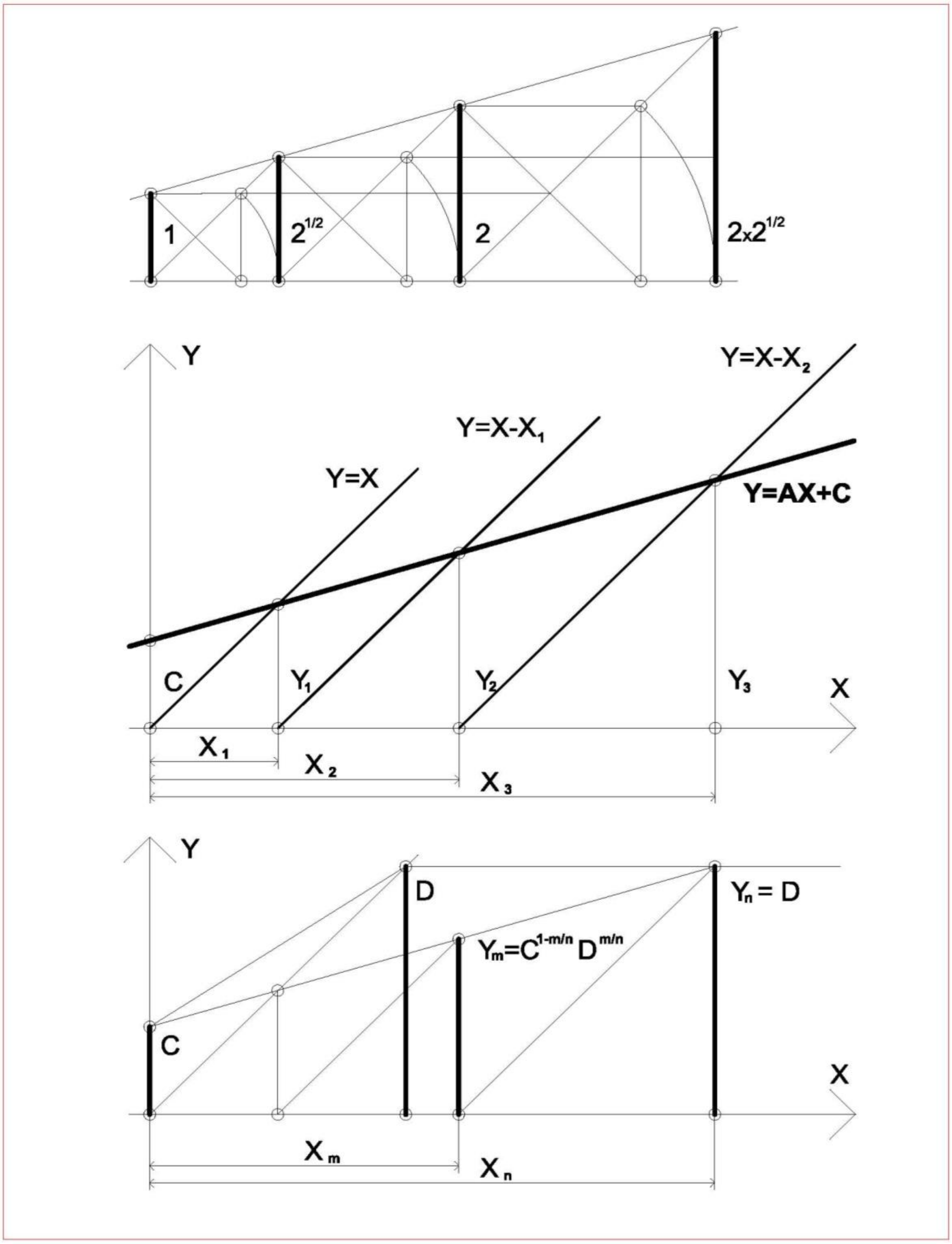

Figure 1 - Geometric construction of the method of finding the sequence on the basis of the side and the diagonal of the square.

Consequently, we obtain a system of verticals with constant extreme terms (the horizon of perception and height of building), the values of which, depending on the number of them in the visual frame, are determined by the indicated formula. Moreover, in the particular case, if the number of terms in the series is factorized, then elements of the same value appear in adjacent rows,

for example: a row of 6 terms (m / n = 1/6, 2/6, 3/6, 4/6, 5/6, 6/6) has common terms in the 2-, 3- and 4-membered series - 2/6 = 1/3, 4/6 = 2/3 (1/3, 2/3, 3/3 3/6 = 1/2 (1/2, 2/2) Since "m / n" is a power exponent, numbers that are very close in value can occur for a given degree of accuracy, for example: $C^{1-5/8} D^{5/8}$и $C^{1-3/5} D^{3/5}$; $C^{1-5/11} D^{5/11}$и $C^{1-9/20} D^{9/20}$.

Thus, it will be justified to assume the existence of such spatial combinations of elements in which, as they are sequentially perceived, compositions with harmonious rhythmic regularity, a ratio of the heights of the elements will appear at certain points. You can specify two simple cases, where 4 or 6 elements are combined: a composition of 4 elements can be represented for dynamic perception in this order (the exponents giving the equality are given) - 1: 4; 3: 4; 1: 2; 1, when elements of the two- and four-member series are used; composition of 6 elements - 1: 6; 5: 6; 1: 2; 1: 3; 2: 3; 1, when elements of two-, three- and six-membered rows are used.

The main thing is the trace of the survey route, that is, the programming of perception. The zone of transition from one position with a harmonious perception of the elements to the other is divided by areas where the panoramic perception is "switched off" by changing the nature of the paving of the track, the presence of a ladder or ramp, bridge, fountain or cascade, trees or bright flower beds, pergolas or tunnels and other distractions attention receptions.

For an example of applying the calculation, take the following values (the number of rows of brickwork): C = 18; 20; 22; 24 (horizon of human perception with growth of 150, 165, 180, 195 cm); D = 364 (the height of a nine-storey perimeter building); k = 25 (the number of considered series is the total number of elements of perception). Then the resulting set of numbers makes it possible to identify series in which the ratios of members are close to those that have become classical proportions (the values are rounded to integers):

- a series of 25 members: "Zholtovsky's function" is $2:5^{1/2}$ or 17:19, that is: 18, 20, 23, 26, 29, 33, 37, 42, 47, 53, 60, 68, 76, 86, 97, 109, 123, 139, 157, 177, 200, 225, 254, 286, 323, "364";

- series of 22 and 21 members: "The Divine Proportion" of Luke Paccioli di Borga - $2:3^{1/2}$ (D.Petrovich (1979) in the book "Theoretical proportions" shows that the often found identification of this name with the "Golden Section" is erroneous, since it proceeds from the incorrect, from his point of view, interpretation of the illustrations of the work of L. Pachcholi di Borg (1508) "On the Divine Proportion"), that is: 18, 21, 24, 27, 31, 36, 41, 47, 54, 62, 71, 81, 93, 106, 122, 140, 160, 184, 211, 242, 277, 318, «364» и 18, 21, 24, 28, 32, 37, 43, 49, 57, 65, 75, 87, 100, 116, 134, 154, 178, 205, 237, 273, 315, «364»;

- a row of 8 members: $1:2^{1/2}$, that is: 18, 26, 38, 56, 81,118, 172, 250, "364";

- a row of 6 members: "Golden Section" is $(1 + 5^{1/2}):2$ that is: 18, 30, 49, 81, 134, 221, "364";

- a number of 4 members: $1:5^{1/2}$, that is: 18, 38, 81, 171, "364".

Comparison of the obtained data with the actual values of the elements of the microdistrict under consideration revealed a certain closeness of the values. And the analysis of various points of perception in the microdistrict showed the presence of individual points, the perception from which confirms the possibility of mathematically predicted compositions with a harmonious ratio of magnitudes. Only approximate coincidence of the values with the calculated and the rarity of the points of perception of the indicated compositions is explained by the absence of the stated mathematical apparatus in the authors of the project of the microdistrict. And on the other hand, it testifies to the legitimacy of its application, since the dimensions determined by the authors of the project, taking into account the internally sensed empirical sense of harmony, are confirmed by mathematical calculations.

As for the harmonization of ornamental compositions on the basis of this technique, it, as was noted, is a particular case of the method considered. In it, as the fixed values, the general dimensions and the smallest element, for example, of an ornamental panel, can be adopted. Then all the intermediate values of the individual sets are determined on the basis of the calculation. It is possible to choose rows with a harmonious ratio of numbers. This will determine the total number of elements in the panel composition that are in one or another harmonious dimensional ratio.

Conclusion

Accordingly, when differentiating different-sized on the basis of color, texture and height of the relief, it is possible to form a combination of different proportional relationships in one composition. Thus, it becomes possible to harmonize the ornamental composition, varying the number and size of its components, depending on the author's design.

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