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ARCHITECTURAL AND DESIGN FEATURES OF RESIDENTIAL BUILDINGS IN SAINT-PETERSBURG IN THE SECOND HALF OF THE XVIII CENTURY

The paper presents a review of architectural and design techniques which were characteristic for residential development in the second half of the XVIII century in St. Petersburg. During that period, there was formed the urban planning, volumetric spatial and constructional structure of residential buildings, which later, in the XIX – early XX century, became a typical solution for residential development in St. Petersburg. The firewalled residential house was usually built along the perimeter of the possessory plot of land with an inner courtyard formed inside. The residential house consisted of a two-span front building and one-span side buildings located along the perimeter of the site. The constructional system of a residential building in the second half of the XVIII century was a vaulted-beam scheme along the longitudinal walls. The main construction structures are described, such as brick walls with subsequent finishing, strip stone footings based on wooden joists, roofs built on wooden batter rafters in a cold attic with no heating.

Keywords: *historical buildings, historical structures, types of structural solutions, historical building materials.*

В статье рассматриваются архитектурные и конструктивные приемы, характерные для жилой застройки второй половины XVIII века в Санкт-Петербурге. В этот период сложилась градостроительная, объемно-пространственная и конструктивная структура жилых зданий, которая стала типовым решением для жилой застройки Санкт-Петербурга в XIX – начале XX века. Жилой дом брандмауэрного типа строили на владельческом участке по периметру с образованием внутреннего двора, он состоял из лицевого корпуса в два пролета шириной и боковых корпусов в один пролет по периметру участка. Конструктивной системой жилого дома была сводчато-балочная конструктивная схема по продольным стенам. В статье описываются основные строительные конструкции: кирпичные стены с последующей отделкой, фундаменты – ленточные каменные по деревянным лагам, крыша – по деревянным наклонным стропилам с неотапливаемым холодным чердаком.

Ключевые слова: *исторические здания, исторические конструкции, типы конструктивных решений, исторические строительные материалы.*

Introduction. In the mid-to-late 18th century, a type of urban residential house was developed in St. Petersburg, Russia that became the most popular design for residential developments in the centers of the largest cities of the country. The volumetric–spatial structure of the residential buildings in the northern capital was influenced by specific urban planning conditions, design solutions, and style requirements. This period was characterized by an improvement in the quality of basic building materials (e.g., an improvement in the quality and standardization of brick sizes), the introduction of highly efficient masonry systems, the use of hydraulic mortars, and an increase in the number of products such as limestone and other stone rocks. Prussian vaults and those with a cross-shaped pattern were constructed for basement ceilings as well as drempel walls for attics. Moreover, metal and cast iron were used to manufacture individual construction elements, and the first cast-iron cantilevers for balcony structures appeared [1].

Materials and methods. Knowledge of construction techniques and their relationship with architectural solutions at specific historical stages is necessary to understand the patterns of architectural development. Identification of the aspects of a design solution would enable the determination of valuable structural elements and help in the preservation, restoration, and adaptation of historical buildings. The conclusions presented in this article are drawn from an analysis of a large number of surveys of buildings in St. Petersburg conducted via design and restoration workshops and extensive archival and reference materials, including works from the late 18th to early-19th centuries.

Main body. The mid-to-late 18th century marked the reign of Catherine II (1762–1796) and Paul I (1796–1801). During this period, significant changes occurred in the social and economic structures of the state. In 1762, the "Commission on the stone structure of St. Petersburg and Moscow" was implemented; its design was headed by A. Kvasov, I. Starov, and I. Lem at different times. In 1769, a new general layout for the capital was approved. In addition, the Russian Academy of Arts opened in St. Petersburg and a school for architects was started under the Office of Buildings. Meanwhile, international experts such as A. Rinaldi, J. B. Wallen-Delamot, J. Quarenghi, and C. Cameron

were invited to serve at the court. Classicism was the dominant style from 1760 to the 1800s, which is traditionally divided into three periods, namely, early classicism, strict classicism, and Pavlovian classicism [2].

In the mid-1760s, numerous decrees were implemented to increase the "efficiency of using urban territories" and decisions were made to compact buildings, increase the number of stories, and introduce an altitude regulation of 10 sazhens [3]. At the same time, measures were taken to prevent fires, including adherence to the principles of firewall construction, prohibition of timber engineering in the city center and use of attics for housing, and the widespread use of roofing iron [16].

During the early to mid-18th century, the principles for dividing the urban territory into possessory plots were developed, which remained unchanged until 1917. A quarter, bounded by streets along its perimeter, was divided into two parallel rows of identical plots. The size of the plots varied, with the typical sizes being 10, 15, or 20 sazhens (42.6, 31.95, or 21.3 m, respectively) [1]. The noble "elite" strived to preserve the manor-type buildings in the new capital and combined several plots to construct palaces that included parks within the city limits.

General urban planning and architectural solutions. During 1761–1800, the size of land plots for conventional houses remained the same. During this time, firewall-type perimeter buildings with commercial apartment building construction elements were developed (Fig. 1). Typically, the main front building was designed along frontage lines for the entire width of the site and was separated from the adjacent site by a firewall. Access to the courtyard was through an arched opening along the lateral or central axes of the building. Courtyard outbuildings were built close to the plot boundaries—typically adjacent to the main house, thereby forming an inner courtyard. Such buildings were multifunctional, comprising stables, woodsheds, and services on the ground floor. Housing on the upper floors was given to servants or rented out to tenants. Moreover, several courtyards were constructed on the plot. A transverse courtyard building was constructed if the plot was long so that the courtyard was at least 10 × 20 sazhens to 12 × 25 sazhens (21.3 × 42.6 m to 25.6 × 53.3 m) [1]. One-span wide (approximately 4 m) internal outbuildings with one or two stories and single-raftered roofs were built along the perimeter of the plot. The main house typically had two or three stories (rarely four stories), was two spans wide (6–9 m), and had a gable roof.

By the end of the 18th century, continuous firewall-type housing developments were built along streets, first two and three stories then three and four stories. According to J. B. Vallin-Delamot, "rather surprised Petersburg, having built a house with four floors, which, in his opinion, had a great advantage that the stairs could not be seen or their location could not be guessed" [5]. During the early to mid-18th century, stairs leading to chambers on the residential floor above the basement were built in front of the house in the form of a protruding porch. Such porches were decorated in the Russian (open porch) or European style (columned portico) and often protruded beyond the frontage line of the street. However, in the mid-to-late 18th century, such porches were demolished, buildings were rebuilt such that access to the house was directly from the street, and staircases were built inside houses.

House facades were built according to the classic tastes of the era and were typically symmetrical, with an accent in the central section. During this period, the use of classical orders was common, especially "giant orders" with a height of two floors for public buildings and palaces, and large-scale residential buildings were limited to one-story columns or constructed without order columns. A typical technique was highlighting the first or basement floor using rustication but keeping

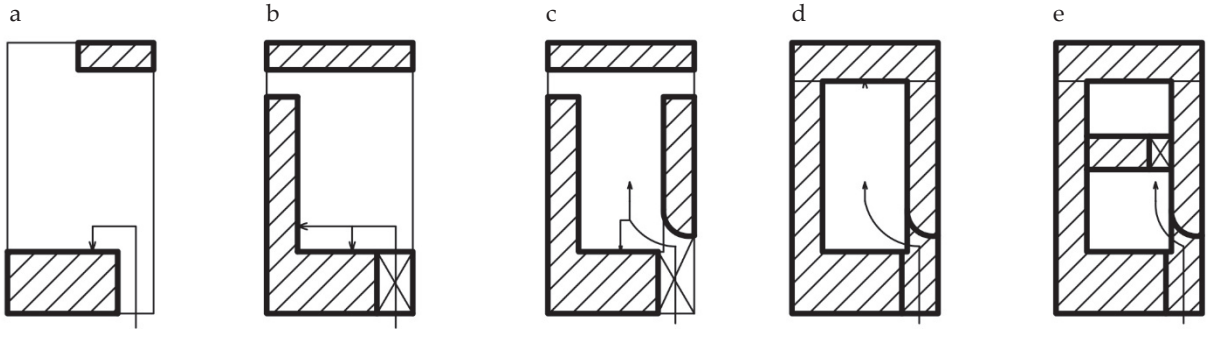

Fig. 1. Development of arrangement of possessory land plots: (a) manorial development according to exemplary projects in the early 18th century; (b) (c) firewall development with the beginning of plot perimeter development; (d) commercial apartment building with one courtyard; (e) commercial apartment building with two courtyards

the walls of upper floors smooth. Regardless of the simplicity of a house, it featured a highlighted basement, crowning cornices, window frames, and other classical architecture elements. Over time, Baroque decor was gradually replaced by Classical decor. Furthermore, the central sections of facades were highlighted by pediments or mezzanines with pediments.

Construction materials. In the mid-to-late 18th century, "city bricks" with a uniform size were introduced (6 × 3 × 1.5 vershok [270 × 130 × 67 mm]), and their quality was improved. In addition, iron clay, red bricks, and salmon bricks were produced. Exterior walls were covered with painted lime plaster, and gypsum products with a cast finish were widely used for decoration. Slab panels for openings were represented using brick wedges with flat and arched lintels, and window openings were covered with wood with large divided glazing and improved-quality glass. Glazing large windows on the first floor intended for shops and cafes became possible. Hydraulic mortars were widely used for basements and cornices [16].

Metal and cast iron were used to make decorative foreside parts and occasionally to support structural foreside elements such as balcony corbel carriages. Individual parts were connected by bolts or by forging. Nevertheless, iron was not widely used in construction as iron blooms lacked the desired mechanical properties and band and structural irons were expensive for widespread use. In addition, roofs were covered with sheet roofing iron [16].

Construction techniques. The main types of foundations for residential buildings were girder foundations of limestone and quarry rocks. "When using local building materials, such as quarry rocks and cobblestone, the two lower rows (large stones) were made without mortar in order to avoid the influence of capillary moisture on the wall located above" [1, p. 9]. Foundation beams could be found under the masonry of foundations, which were made from logs with a diameter of approximately 20 cm and placed on a prepared (rammed) surface. These foundation beams had to be placed below the groundwater, and spaces between the bars of the foundation beams had to be filled. For loose soil, a pile stockade was used. At the end of the 18th century, piles with a diameter of 8–17.5 cm were driven in the ground for this purpose at a distance of 2–3 cm from one another.

The basements of buildings were made from embedded fired bricks with natural stone cladding (granite, limestone, and sandstone). Veneer bases made from cut limestone slabs were likewise gradually introduced.

For the masonry of walls, hewn and broken stones, cobblestone, and bricks with lime mortar were used. Moreover, walls became pourable when their two outer contours were laid out with bricks. Meanwhile, inner spaces were filled with cobblestones containing melted lime [6]. The Prioratsky Palace in Gatchina is the only surviving rammed earth architectural structure from the 18th century. Its walls and fence were built with compacted layers of loam mixed with lime. Before the construction of the Priorat in the garden of the Gatchina Palace, under the guidance of N. A. Lvov, the corner of a hut with a foundation was built using rammed earth technology. The ladies of the court tested it by piercing it using umbrellas, and the officers attempted to destroy it using broadswords [7].

Most of the city's buildings were built of bricks. By 1854, the country had 954 brick factories and produced 126 million pieces of bricks annually. In the mid-18th century, the thickness of walls was equivalent to seven bricks, such as those of the Stroganov Palace. However, with the development of commercial apartment building construction, walls on the top of cornices were reduced to a width of two and a half bricks and those of basements were decreased to a width of four bricks. Brickwork decreased in thickness story-by-story; the walls were constructed with ledges from inside of the buildings. Walls were laid in four rows, with a chain and cross placement, and brick walls were periodically plastered and repainted. A specific feature observed in St. Petersburg was the permanent renovation of facades, such as by changing their color, and in the 18th century, changing the style of facade details and replacing Baroque elements with Classical ones.

For the decoration of buildings, natural stone was widely used. The decoration of the Marble Palace using marble and granite slabs was innovative for that time period. "The marble siding was fastened with cramp irons, and the decorative details were fastened with a kind of copper bolts-cramps" [12]. During 1779–1785, Yu. M. Felten used natural stone in the decoration of the Zubovsky building facade of the Catherine Palace in Tsarskoe Selo. The first floor of the building was faced with granite, and the central part of the facade was highlighted with a portico with 12 paired columns of patterned gray Juvenian marble with bronze capitals and bases. The decoration of the facade of the Gatchina Palace was also an innovation. A. Rinaldi was the first to use Pudozh stone as a facing stone as it is easy to process and becomes brick hard when exposed to air. Subsequently, the stone was used in the facing of numerous buildings, such as the Cameron Gallery and Kazan Cathedral.

The decorative elements of facades were laid out with hewn bricks, and the final shape was formed using plaster mortar with special templates, which were stretched over the wet plaster. Cast

plaster decor was also used, which was attached to the brickwork with metal embedded details.

Crowning cornices were integral parts of facades. For the cornice overhang, a coping stone slab was laid on the brick wall such that a part of it hung like a cantilever. The remaining part of the stone on the wall was heavy (with a ratio of 2:3). Coping slabs were fastened to the masonry using horizontal iron anchors. Vertical iron trusses were installed in case of insufficient stability (Fig. 2). Cornices were made on a coping slab for the facades of main buildings, and outbuildings and brick cornices were made for courtyard facades.

In classicism, balconies on corbel carriages were treated with caution and rarely used. However, a balcony with corbel carriages can be found on the facade of the Marble Palace on the side of the Neva River. During this period, balconies were supported by stone and cast-iron cantilevers.

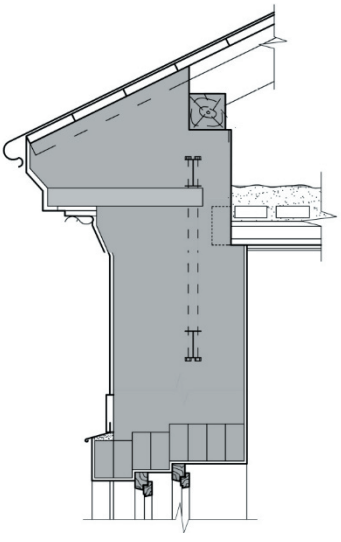

Fig. 2. Cornice with coping stone with anchoring

The lintels of window and door openings were made from bricks in their centering. Bow-shaped lintels were structurally easier to make than straight ones, but during this period, bow-structured lintels on facades were straightened.

In the 18th century, basement ceilings were vaulted (Fig. 3). From the 1720s to the 1780s, Anninsky cellars were replaced by operated cellars. "In the Baroque period, the most widespread were cylindrical and cross vaults, then in the late 18th to early 19th centuries, the cross vaults and Prussian vaults were introduced" [1, p. 12]. Driveways to the courtyards of possessory plots were also covered by brick vaults. Vaulted structures were widely used in residential construction in St. Petersburg until the 1860s. Moreover, vaulted ceilings were fire resistant, stable, and covered large spaces. The disadvantage of vaulted ceilings included the rate and high cost of labor.

Slabs in residential floors were either vaulted or had wooden beams. Lightweight and durable wooden beams were widely used in slabs in the upper floors of buildings. Beams were hewn from round logs, with recesses for the placement of the counter subfloor. The pitch of the beam (105–140 cm) was not intended or built for leaning on window and door headers. To prevent rotting, the ends of the beams were wrapped in felt, birch bark, or tar paper; coated with resin or tar; and placed in mortises left in the brickwork. To prevent the masonry from coming in contact with the beam, a 2.5 cm gap was left. The height of wooden beams in residential premises under normal loads was equal to 1/24 their span [1]. For spans measuring over 8 m, composite beams were used.

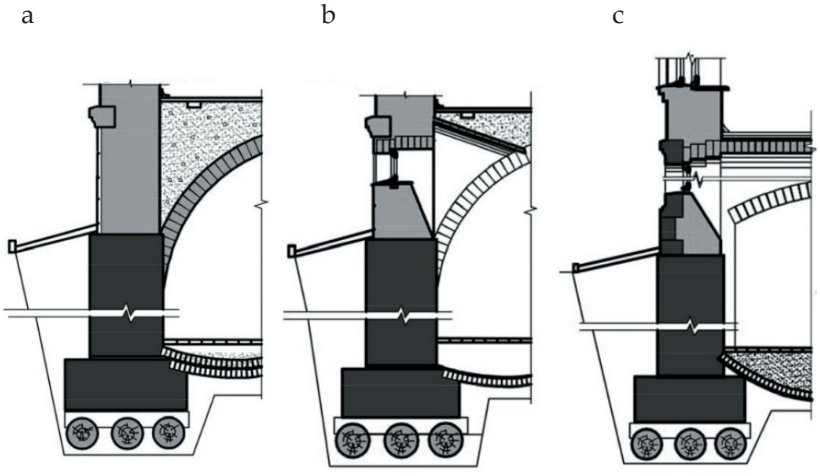

Fig. 3. Basement ceilings with (a) a cylindrical vault;
(b) a cylindrical vault with spandrels; (c) Prussian vaults

Stairs were typically made of bricks and vaulted with support on walls and pillars. Slab stone (Pudossky, Shaldinsky, or Borovitsky) was used for facing the platforms and steps. I. Lem stated that the main staircase should be well lit and wide. Metal, stone, or wooden railings were installed on stone stairs. Every seven steps, high stair flights were divided with platforms no less than three steps wide. The size of steps varied; however, they had a uniform width of 14–18 in (40–45 cm) and height of not less than a foot (30 cm) and 5–6 in (12.7–15 cm) [6].

Early classicism is characterized by stairs placed on the sides of main entrances. Such stairs can be seen in the Gatchina Palace and the project of the Chernyshev Palace on the embankment of the Moika River. In strict classicism structures, architects placed ceremonial staircases at the center of buildings opposite the front entrance, with a wide platform that made it possible to walk around the entire building along its perimeter.

The most widespread types of roofs for residential large-scale construction in the historical center of St. Petersburg were and still are metal roofs over wooden rafters with intermediate support inside cold, unheated attics [16]. "When Catherine II prohibited using the attic for own needs, the rafters with intermediate support were started to be constructed. The tilt angle decreased to 18–20 degrees" [1, p. 16]. A gable roof was built over the main building facing the street, and a single-raftered roof was built over the courtyard outbuildings located along the perimeter at the back of the possessory plot. The span of the rafters ranged from 6 to 9 m. A. Krasovsky wrote that "… it was a method of covering small-width residential buildings. On the main walls, separate pillars with a thickness of 2 or 2.5 bricks are built on each side, and at a mutual distance of 2 to 4 sazhens. On these pillars, horizontal girders are laid, supported by struts. The rafter spars are located on the girders, which can be propped up with the struts, if necessary" [9].

Before the fire of 1837, the attic space of the Winter Palace represented a dense single network of wooden structures comprising rafters and beams. The roof void was not divided by firewalls but rather only rare partitions with openings [10, p. 21]. In the absence of fire-prevention measures, the fire of 1837 destroyed almost the entire building. Since the end of the 18th century, drempel walls—represented by brick walls separating the attics into fire compartments—were constructed inside buildings to prevent fires.

Principal rafters with central posts and struts were used to cover the large halls of palaces and luxurious mansions. Principal rafters did not provide horizontal thrust on walls but allowed large spans to be covered. Truss structure prototypes can be seen in principal rafters from the late 18th century.

During this period, roofs were covered with sheet roofing iron (e.g., tinned sheets and copper). For example, the roof of the Marble Palace was covered with red copper, which resembled gold in the sun.

Conclusions

1. By the end of the 18th century, the traditional housing development in St. Petersburg (the firewall type) had been formed. Buildings were arranged along the perimeter of a possessory plot, resulting in the formation of a courtyard. Streets were formed from the continuous development of the facades of residential buildings located along the red line.

2. During this period, the St. Petersburg residential house design was established, which comprised a front building two spans wide and side buildings one span wide along the perimeter of the possessory plot. Roofs were single-raftered hipped with a slope of approximately 20 degrees and a drain inside the land plot.

3. The structural system for residential buildings in the mid-to-late 18th century included a vaulted-beam structural scheme along the longitudinal walls. The structures of main buildings were made of brick walls with subsequent plastering and a stone base. They also included girder stone foundations on boarding joists; a roof arranged on wooden rafters for intermediate support; and a cold, unheated attic. The main house typically had two or three stories (rarely four stories), was two spans wide (6–9 m), and had a gable roof.

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