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HISTORY OF HOLY TRINITY CHURCH IN PYATAYA GORA HOMESTEAD OF TSARSKOSELSKY COUNTY AND CHOICE OF METHOD OF ITS RESTORATION

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Abstract

This research covers the Holy Trinity Church, a monument of church architecture located in Pyataya Gora homestead of the Tsarskoselsky County, today's Volosovsky district of the Leningrad region. The article is devoted to the study of architectural development of the territory of the estate of O. K. Briskorn Pyataya Gora and the history of construction of Holy Trinity Church. The study includes the analysis of the territory of Volosovsky district as local geographic and municipal area in the framework of the subject topic. The history of the area development and construction of the church was examined based on the preserved archival document "Statement of Inventory... prepared by priest Ioannes Shkorbatov", the archives of the Trinity Church in Pyataya Gora homestead and the studied "Inventory of the church property" dated May 1829. We also used the measurement drawings of the SPSUACE students performed in 2015.

The study performed resulted in the development of the design proposal on renovation of the area around the church. The proposal is aimed at promotion of the studied area and inclusion of the Pyataya Gora estate in the architectural background of the district.

Keywords: Pyataya Gora homestead, rotunda church, the Tsarskoselsky County, restoration, classic architecture, column order.

Introduction

Study and restoration of monuments in the Leningrad region is a topic issue of preservation of the architectural heritage. Tsarskoselsky County is one of the most important cultural centers of the Petersburg province, possessing a large number of cultural facilities both of civil and church architecture. Monuments located near St. Petersburg are widely known and under the spotlight of the society that keeps them in good repair. A different situation refers to the monuments located in remote, often sparsely populated regions. Architectural objects located in the relative remoteness are often destroyed and need additional protection. The loss of these objects will be not only the loss of an architecture monument, but also the loss of a historical cultural landscape leaving a gap in cultural memory of people. One of the outstanding monuments of church architecture of the Tsarskoselsky County is Holy Trinity Church in Pyataya Gora homestead of today's Volosovsky district. A centric church constructed on the top of the hill in XIX century is an important landscape spot both for the village and the surrounding areas. It is visible from far away, but nowadays its ruins is a sorrowful centerpiece of the surrounding landscape. Restoration of this monument of architecture is the matter of interest of local and administration authorities of rural settlement Kalitino.

Subject, tasks and methods

The subject of the study is the development of the territory of Pyataya Gora homestead and the history of construction of certain architectural monument, Holy Trinity Church.

Our objective was the selection of the restoration method for the regional architectural monument and development of the design proposal on renovation of the adjacent estate territory.

The tasks of the study are the following:

• Identification of significance of the former Pyataya Gora homestead within the municipal area, as well as in the context of the existing historical and cultural landscape; determination of the ways to renovate the village area.

• Selection of the most appropriate method of the temple restoration.

Study of archival sources on the subject, analysis of functional zoning schemes, analysis of historically valuable sites for the prospects of tourism; study of regional development plan of the Leningrad region, as well as onsite study of the monument allows to deal with the issue of the significance of the village and the Holy Trinity Church in the context of historical environment and to select the most appropriate method of the church restoration.

The aspect research approach in this case involves development of the subject study in three directions: study of historical archival materials, analysis of the surrounding area as per above stated items, and, finally, renovation project for the Holy Trinity Church and adjacent territory.

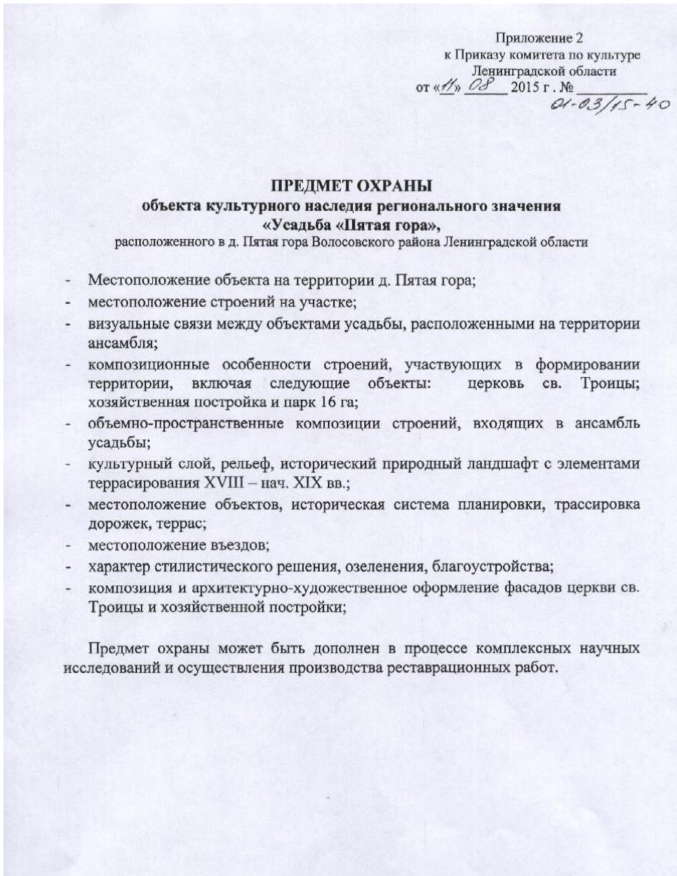
The renovation project for any historical monument implies a detailed study of the history of the monument under reconstruction, which requires determination of its development periods and the analysis of the fact of whole or partial change of layout or planning pattern of the monument.

Research part

Pyataya Gora homestead is located in rural settlement Kalitino of Volosovsky district. According to the conclusion of the state historical and cultural study, "Pyataya Gora Homestead", which includes the park, the church of the Holy Trinity, the household building located in Pyataya

Приложение 1
к Приказу комитета по культуре
Ленинградской области
от «11» 08 2015 г. № 01-03/15-40

Границы территории
объекта культурного наследия регионального значения
«Усадьба «Пятая гора»,
расположенного в д. Пятая гора Волосовского района Ленинградской области



Приложение 2
к Приказу комитета по культуре
Ленинградской области
от «11» 08 2015 г. № 01-03/15-40

ПРЕДМЕТ ОХРАНЫ
объекта культурного наследия регионального значения
«Усадьба «Пятая гора»,
расположенного в д. Пятая гора Волосовского района Ленинградской области

- Местоположение объекта на территории д. Пятая гора;
- местоположение строений на участке;
- визуальные связи между объектами усадьбы, расположенными на территории ансамбля;
- композиционные особенности строений, участвующих в формировании территории, включая следующие объекты: церковь св. Троицы; хозяйственная постройка и парк 16 га;
- объемно-пространственные композиции строений, входящих в ансамбль усадьбы;
- культурный слой, рельеф, исторический природный ландшафт с элементами террасирования XVIII – нач. XIX вв.;
- местоположение объектов, историческая система планировки, трассировка дорожек, террас;
- местоположение въездов;
- характер стилистического решения, озеленения, благоустройства;
- композиция и архитектурно-художественное оформление фасадов церкви св. Троицы и хозяйственной постройки;

Предмет охраны может быть дополнен в процессе комплексных научных исследований и осуществления производства реставрационных работ.

Figure 1. Borders of the territory and the protection object of the cultural heritage object "Pyataya Gora Homestead" of the regional significance[1]

1 Document 1 (translation): Appendix 1 to the Order of the Committee for State Control, Utilization and Protection of Historical and Cultural Landmarks of the Leningrad region No. 01-03/15-40 dd. 11/08/2015. Borders of territory of cultural heritage object "Village Pyataya Gora" of regional significance located in village Pyataya Gora of Volosovsky district of the Leningrad region.

Document 2 (translation): Appendix 2 to the Order of the Committee for State Control, Utilization and Protection of Historical and Cultural Landmarks of the Leningrad region No. 01-03/15-40 dd. 11.08.2015

OBJECT OF PROTECTION of the cultural heritage object "Village Pyataya Gora" of regional significance located in village Pyataya Gora of Volosovsky district of the Leningrad region:

- location of the object at the territory of village Pyataya Gora;
- location of buildings at the site;

Gora village in Volosovsky district of the Leningrad region, was included in the Register of cultural heritage objects of regional significance (Order of the Committee No. 01-03/15-35 dd. 13.07.2015). Order of the Committee No. 01-03/15-40 dd. 11.08.2015 stated the borders of the territory and the object of such cultural heritage protection.

Prior to the beginning of XIX century, the land of the homestead belonged to the Tsarskoselsky County. Such inhabited localities as Elizavetino, Kikerino, Glumitsy, Kurkovitsy, Kalitino, Pyataya Gora, Bolshoe Zarechye are old villages. The first mention of the localities is found in cadastre books of 1499. Surrounding territories of these settlements are full of ancient burial places, while the territory of Volosovsky district, that takes its name from the words “Volos”, “practice magic in the name of Volos” (tell fortune), still remains one of the most mysterious and archaeologically unexplored area.

At the end of XVIII century different noble estates appeared here; they belonged mostly to descendants from Prussia and the Baltic countries (Esthonia, Livonia and Courland). Baltic nobles preferred to settle somewhere in the middle of the way from their native lands to the Russian capital. Among the owners of estates one may meet such names as the Wrangels, the Veimarns, the Stackelbergs, the Frederiks, the Ragulovs, the von Korffs, the Osten-Sackens, the von Dubelts and others.

The Pyataya Gora homestead was mentioned for the first time in 1747. Then, it belonged to German Lieutenant Colonel I. I. Plat. “Short economic notes of the Rozhdestvensky County” compiled in the end of the XVIII century stated that “Pyataya Gora homestead belonged to Lieutenant Colonel Ivan Ivanovich Plat and then came into possession of the Premier Major Kateryna Mikhaylovna Renkevich” (Short economic notes…, 1789). Then, Christiana Mikhaylovna Phocas, sister of Catherine Rankevich, the wife of the Major General, became the owner of the country house in Pyataya Gora. In 1805, Senator Theodore Maksimovich Briskorn bought the estate. After Briskorn’s death, the house passed to his widow Olga Konstantinovna, then to their daughter Elizabeth, her married name Levshina, who owned it until 1844, when the Briskorns ceased their possession of the estate. It was exactly in the time of the Briskorns’ possession of Pyataya Gora estate when the church in the name of the Holy Trinity, that we are discussing, was built. What is so interesting and remarkable about this church? Why is it necessary to preserve and restore it, and how to do this?

Holy Trinity is a centric temple. Its architectural solutions and the layout are identical to another two churches: Pokrovskaya Church in Prilepy homestead of the Kursk province of the Dmitrievsky County (purchased by O.K. Briskorn in 1809) and Church of Exaltation of Holy Cross in village Vyshetarasovsokoe in the Ekaterinoslavskaya province, which also was owned by the Briskorns. Holy Trinity church, Pokrovskaya church and church of Exaltation of the Holy Cross were built according to the same design and are of centric temple type. It should be noted that construction of centric (including rotunda) churches is quite rare in Russia. Such churches were built in the estates of the nobility and representatives of the wealthiest strata of the Russian society, as a rule. Often, great landowners were the customers. The construction period of this type of churches lasted from the end of XVIII century to the first third of XIX century. The authors of engineering designs of these churches were well-known architects of St. Petersburg and Moscow, such as V. I. Bazhenov, M. F. Kazakov, N. A. Lvov, O. I. Bove, I. E. Starov. Churches of centric composition were not widespread in the Russian religious architecture, since they did not comply with the Orthodox ceremonials and the Russian traditions of church construction. These churches are represented by single monuments, most of which were completed with refectories and bell towers damaging the typological feature of such churches. There are several centric churches remained in St. Petersburg: Church of the Holy Prophet Elias (architect F. I. Demertsov, construction period of 1781–1785), Church of the Annunciation in village Staraya (architect I. N. Mochulsky, construction period of 1805–1809), Church “Easter cake and pudding” (architect N. A. Lvov, construction period of 1785–1790). All of them were somewhat distorted by subsequent reconstructions.

Centric composition of churches originated in Europe, having appeared in the end of XV century in Italy (in the form of rotunda-shaped churches) and later spread to Poland and Ukraine. It should be noted that the first one (the Holy Cross Church) of three mentioned churches in estates of the Briskorns was built exactly in the Ukraine; only after that, Church of the Intercession of the same design project was built, and the last was extant church in Pyataya Gora homestead.

The history of the Church may be divided into three periods: the period of 1830–1879 (construction and operation of the church), the period of 1897–1933 (abolition of the township and overhauling), the period of 1930–2016 (destruction and registration as the cultural heritage site).

The period of 1830–1879. O. K. Briskorn wrote in her petition to the Synod, asking for a permission to build a stone church (officially, her daughter already owned the

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- visual connections between villages located on the territory of the ensemble;
- compositional features of buildings involved in formation of the territory, including the following sites: the Church of the Holy Trinity, a household facility and a 16 ha park;
- three-dimensional arrangement of buildings belonging to the village ensemble;
- a cultural layer, relief, historical elements of natural landscape with terracing of XVIII to early XIX centuries;
- location of objects, historical planning system, layout of paths and terraces
- location of access roads;
- aspects of stylistic solutions, landscaping and improvements;
- composition and architectural decoration of front faces of the Holy Trinity Church and the household facility.

The protection object may be enhanced in the course of comprehensive researches and restoration works.

estate): “I have an estate in the Tsarskoselsky county, known known as Pyataya Gora. A half of peasants are of Lutheran Confession, while the others belong to Greek Russian Orthodoxy. The latter have to go to church in village of Dylitsy. However, Dylitsy is five or six versts (eight kilometers) away, and they have to go through marshy paths and snowstorms in winter, that is why the peasants practically do not visit the Church” (Briskorn, 1829a). Location for Holy Trinity Church was chosen based on the requirements of the beauty significance. The place was surveyed and acknowledged as “decorous”, for “it is situated on a decent hill, making a pleasant view of the church and the beauty surrounding from all sides, and is located on a dry ground and a solid soil foundation, at that” (Briskorn, 1829b). By March 5, 1830 construction of the stone church was completed, and it was consecrated in the name of Holy Trinity on February 8, 1831.

Marina Artovna Arbogly, a member of the Society of Russian Estate Study, describes the church during her trip to the Leningrad region at the beginning of XIX century: “... the architect of Holy Trinity Church in Pyataya Gora completed it with rotunda under a squat dome and a small bell tower and designed semicircle apses and porches on the east and the west sides, giving an amazing plasticity and softness to the building. Sophistication of the architectural appearance was enhanced with evenly spaced 24 three-quarter ionic columns, decorating semicircles and porticos. A wide and high entablature unites the building into a single whole surrounding its perimeter and ending with gables on side faces ... Double light windows lit an ornate interior of the church hall, the walls of which are decorated with ionic semi-columns and the altar is separated with free-standing columns. Only the bell tower reminded that this was not a palace hall, but a parish church. The white stone church constructed on elevation, foreseeable from all sides, contrasted with the green background of the estate park ... And if analogue churches in the Kursk province and the Ekaterinoslav province fulfill one of the conditions for church construction of “watching” from a high bank of the river, the church in Pyataya Gora complies with another condition: it is towering above the surrounding spaciousness — Holy Trinity Church “looks” down the road. It seems that the church grows out of the landscape being its natural and integral part...” (Arabogly, 2006).

As per structural features, the columns of the church are made of red brick, all masonry walls consist of bricks and white calcareous sinter mined in village Pudost at Gatchina. The church is finished with light-colored plastering, the color and composition of which can be defined as there are remnants on the outside walls.

Period of 1897–1933. In 1879, Holy Synod released decree of abolishment of the independent parish, as the parishioners stopped supplying the bread to the clergy. The church was attributed to the neighboring Vladimir Church in estate Dylitsy owned by the Trubetskoys. Holy Trinity Church gradually fell into decay. In 1889, it was registered that it was unsafe to perform services, as the foundation was washed out with springs and the dome had through cracks. Church facilities were fit only for demolition. Architect Fidelli examined the church in 1890 and stated that the building required overhaul. Roof was repaired the following year. The parishioners stated that “the obvious negligence of the former clergy, the elder and our ancestors has led the church to a total disrepair. Architect of Gatchina administration G. Dmitriev agreed to supervise the repairs” (Fidelli, 1890). Only in 1902 a major repair was carried out including repair of the foundation and wooden structures, renovation of plaster topping, arrangement of the basement, repair of cracks in the dome, whitewashing of faces.

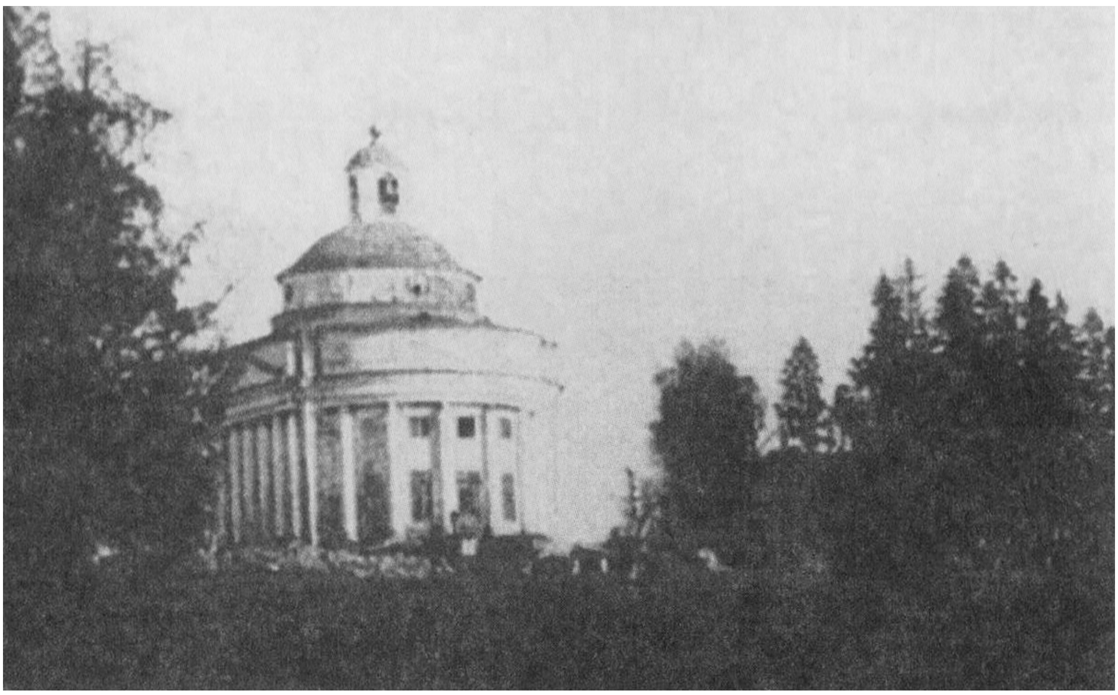

Figure 2. Holy Trinity Church in 1900s

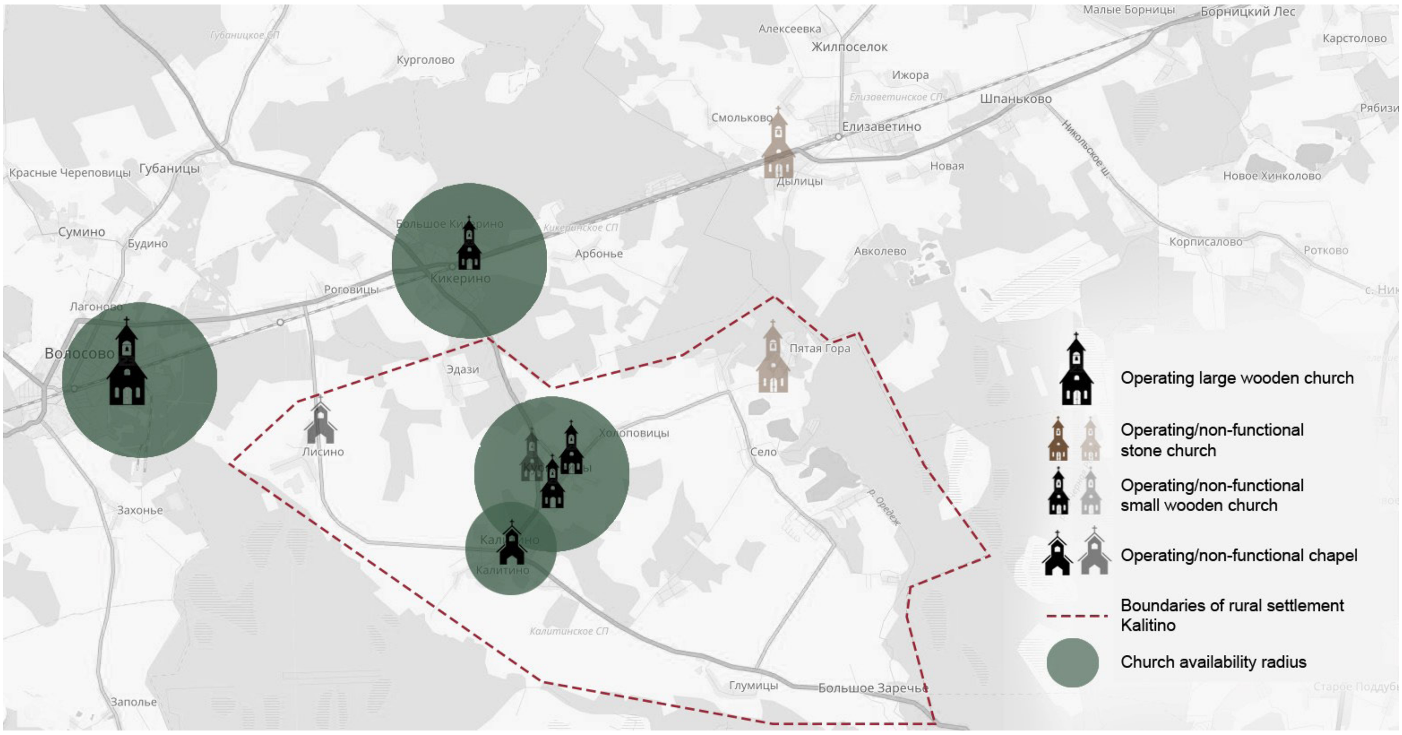

Figure 3. Layout of churches in village Kalitino of Volosovsky region

Period of 1930–2016. At the beginning of World War II, services still continued in the church, and in 1960 the dome was pulled out with tractors. In 1970s, the church partially preserved a wooden dome (Figure 2). On 14.06.1994, the church was registered as an identified object of cultural heritage. In the summer of 2015, "Pyataya Gora" historic estate and park complex in Volosovo district of the Leningrad region was declared as monument and included in the register of cultural objects. It is planned to allocate funds from the regional budget in 2016 to restore the facility. It is planned to include "Pyataya Gora" into the program "Cultural development of the Leningrad region" and to develop construction documents for its restoration.

At the present moment, there are two small operating wooden churches in the village of Kalitino; their availability radius does not overlap Pyataya Gora village and the surrounding developing cottage settlements (Figure 3). Analysis of program of regional development of St. Pe-

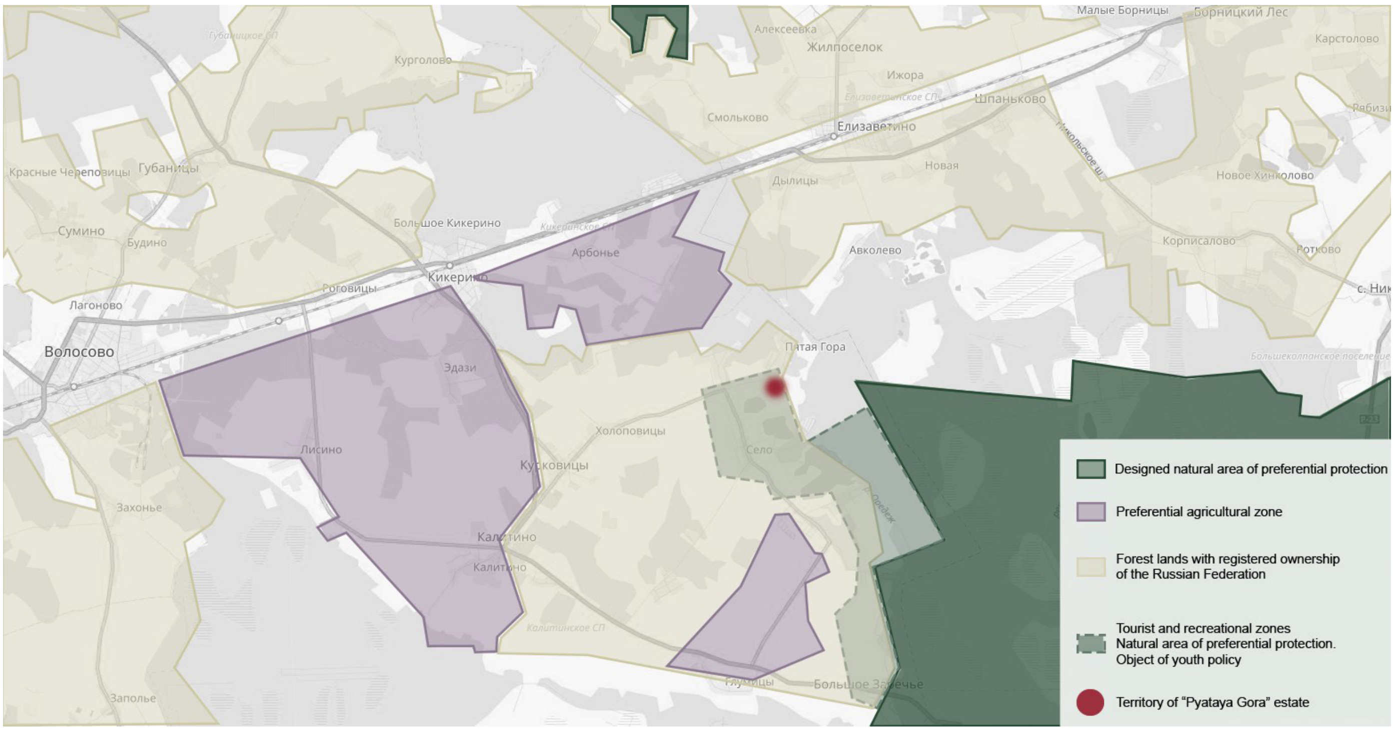

Figure 4. Layout of functional zones of the development program for Saint Petersburg and the Leningrad region

Figure 5. Layout of places of tourist attraction

tersburg and the Leningrad region indicated that the land plot of Pyataya Gora is located within the boundaries of a tourism and recreational zone of the natural area of preferential protection, referred to the objects of the youth policy. According to the scheme, agricultural production lands prevail in this area (Figure 4). Having regard to the above said, we may conclude that integration of these areas and complying with tasks of the urban planning policy of the Leningrad region should be considered while designing of the functional content of these areas in order to promote these places. Thereafter, the project should be partly aimed at young people and have tourism and recreational targets, as well as possible developing of agricultural production of the local level.

In addition, we analyzed the heat maps composed on the basis of map-referenced photos on Panoramio and Flicker sites. The cloud of points allows seeing the most interesting places where picture shooting was carried out. A layout of places for tourist attraction (Figure 5) was drawn up on the basis of the heat map. Layout reveals that “Pyataya Gora” estate is very popular among tourists. Ruins of the church are particularly interesting due to its unique space-planning solutions and the remains of household facilities on the territory of the former estate, especially it concerns the former estate house and sta-

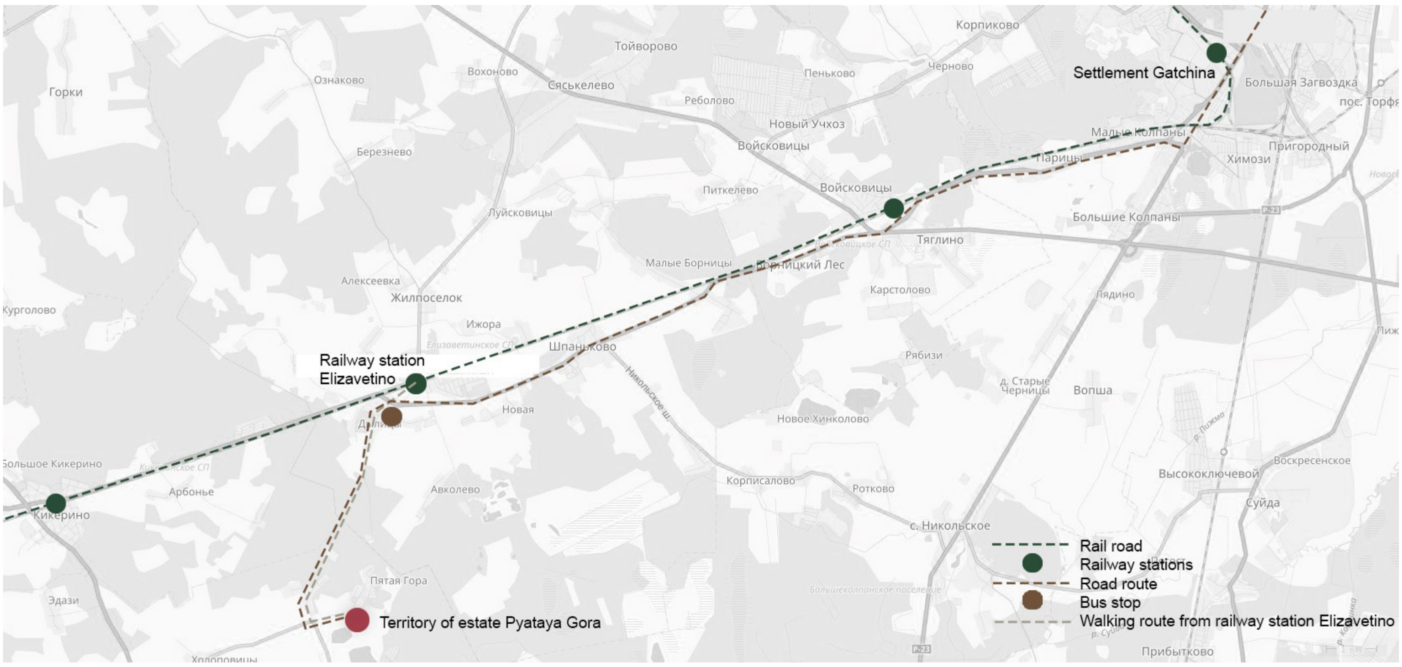

Figure 6. Scheme of transportation availability of the estate

bles preserved at the level of foundations and the remains of a former glacier.

Local Orthodox community has constructed a large wooden cross near the ruins of the church, which proves once again that the local population wants to restore the church, but the question of the restoration type remains unsolved. What form of preservation for the architectural monument would be better: conservation in the preserved form, restoration and reconstruction of historic design or conceptual reconstruction?

According to the Venice Charter: "The process of restoration is a highly specialized operation. Its aim is to preserve and reveal the aesthetic and historic value of the monument and is based on respect for original material and authentic documents. It must stop at the point where conjecture begins, and in this case moreover any extra work which is indispensable must be distinct from the architectural composition and must bear a contemporary stamp...." (Restoration…, 1998)

Concluding the above stated, conservation of the monument in the preserved form will be most correct option with the respect to the monument itself, which meets all criteria of concept of restoration of cultural heritage object; meanwhile, restoration of the church will bring functional and economic viability to the project design proposal. These two aspects are very important for attracting investments for the purpose of current implementation of the project design and the further maintenance of the restored monument. Considering two options of reconstruction – reconstruction and conceptual restoration – reconstruction seems to be functionally, aesthetically and economically more justified. Functional justification implies the fact, that the monument of regional importance – the church of the Holy Trinity – has a complicated transport accessibility (Figure 6), and the interest of the local Orthodox population to the church requires the object to be reconstructed in its original function and be used by the residents of nearby settlements.

Economic justification derives from the functional justification: funds for reconstruction of the church could be raised from three sources: the Orthodox diocese, as it is an Orthodox church, the regional budget, since it is a monument of a regional significance, as well as investments and donations of Orthodox citizens and tourists. As for aesthetic aspects, original location of the church was chosen for the reasons of aesthetic appeal; that is why introduction of modern trends into this "landscape-architectural composition" can ruin a harmonious combination of the spirit of XIX century beginning.

Measurements of the remaining parts were carried out to draw a graphic reconstruction plan of the church. It is clear from measuring diagrams and maps of exterior defects of Holy Trinity Church drafted during period of 2015

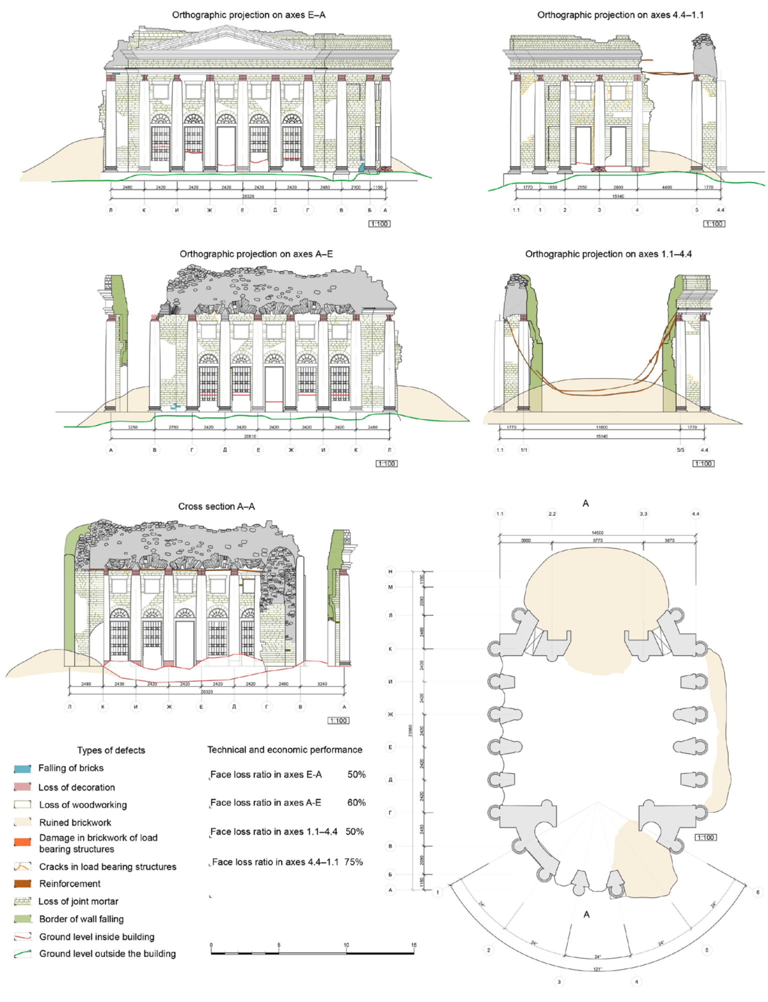

Figure 7. Map of defects

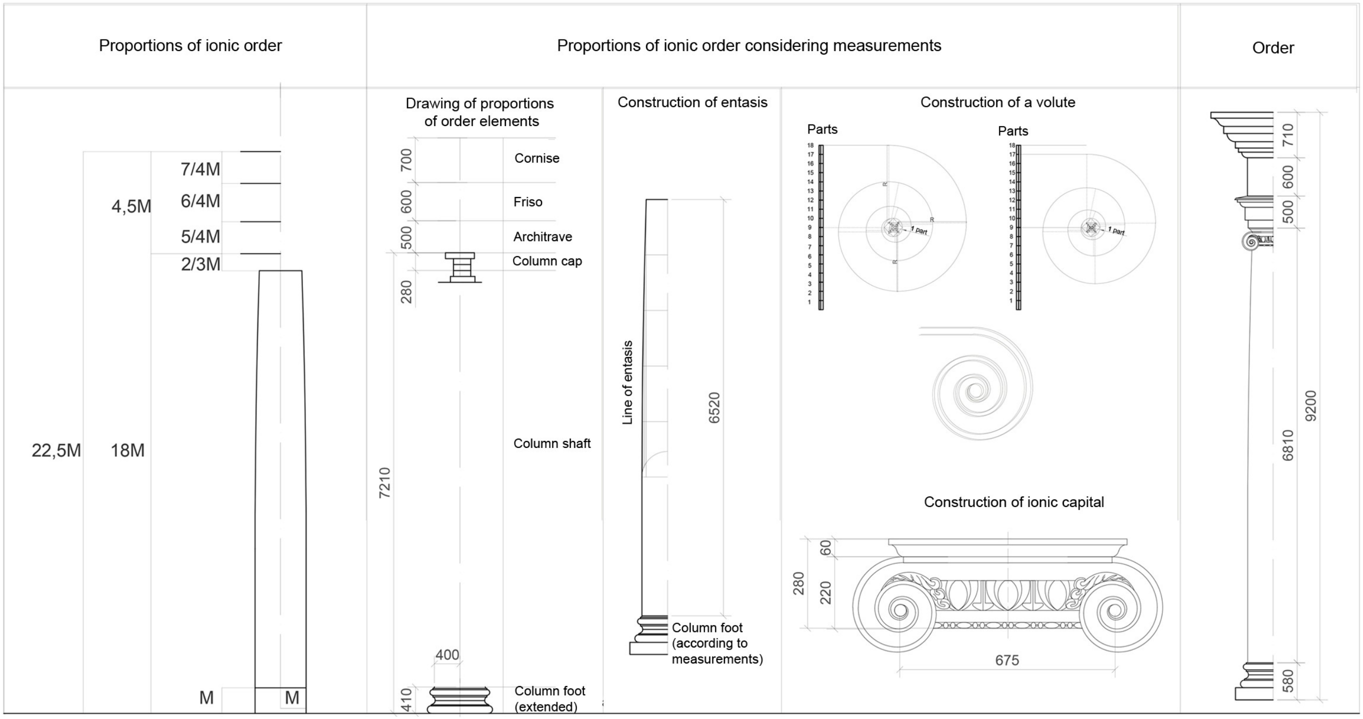

Figure 8. Drawing of proportions of ionic order

that significant collapse of masonry had taken place (Figure 7).

By the present day, there are preserved parts of the walls within Ionic order of the face front. In order to make the most accurate order, a scheme of order systems was applied to this project design (Figure 8). A question of proportions of the dome drum and the dome, as well as church completion work remained unclear, but survived iconographic materials make it possible to identify proportions according to perspective pictures; stated method was described in book "The theory of the perspective" by R. Schmidt in detail (Schmidt, 1983), and was applied in the stated project design.

Architectural solutions of details of Holy Trinity Church can be judged by ruined remains of the church and descriptions of its analogues, as well as surviving Soviet photography and the painting of Church of Exaltation of Holy Cross in village Vyshetarasovka (a direct analogue) written in the 1920s by artist S. S. Orlov. It should be noted that in the 1880s the St. Petersburg Academy of Arts started a campaign aimed at "delivery of information about ancient Orthodox churches, buildings and art objects to the Academy", collected "with the help of diocesan authorities and local statistical committees". In the 1890s, public registers (sheets with printed standard questions) were transferred to the Imperial Archaeological Commission. Nowadays they are stored in archives of the St. Petersburg Institute of Material Culture History. Besides, fourteen pages describing Pokrovskaya Church (direct analogue) in village Prilepy of the Dmitrievsky County of the Kursk province were preserved. Public register specifies the following information: "Present Church in the name of Holy Virgin is cold, the side-chapel in the name of the Nativity is warm ... It was founded in the year of eighteen hundred twenty-one. It is stony. Church was built at the own expense of the general's wife Olga Konstantinovna Briskorn. It was founded on the level ground near the river Nemyody within the boundaries of the land ownership of Baron von Meiendorf in village of Prilepy of the Dmitrievsky County of the Diocese of Kursk. It is round, built in two floors; the first floor houses a vault... Ground floor of the church was built of rough stone; the first floor was built of bricks. Walls are made of ordinary brick, the middle of the walls are filled with rough stones and mortar... Exterior walls are smooth, unadorned, and decorated with round columns attached to the walls and topped with the cornice in the northern and southern sides of the church... Roof of the church is tent-shaped with four iron slopes... Roof has wooden cornice covered with iron sheets. Lantern is blind, hanged on the smooth neck directly above the arches... Dome of the church is semi-circular, covered with iron... Cross on the church is iron, gilded, four-pointed. Windows in the church are arranged in two tiers: the lower are narrow oblong and the top are small round right under the arch ... Windows have iron lattice. There are three iron doors in the church; they are located on the northern, the southern and the western sides... Interior of the church... Vaults of the church are arranged in semi-circular and founded on round pillars and columns. There are sixteen columns in total in the middle of the church; they are all round, smooth, without any cavities and decoration... Near the western wall... there is a stair way to the lofts and the bell tower ... Iconostasis is made of bass-wood, without any decorations or cuttings… there are two tiers ... There is a belfry in the church placed on roof... there are six bells there... There is no bell tower available. Walls of the church are blue painted since its foundation and currently remain the same... Answers were given by priest Peter Bulgakov from Orlovsky Seminary... Time of register completion: the 1st day of February, 1887" (Bulgakov, 1887).

According to archive documents “Statement of Inventory... prepared by priest Johannes Shkorbatov” on the construction of the church in village Prilepy, the church looked like as follows as of March 25th, 1823: “Church is stony, single-storey, with two altars. It is dedicated in the name of the Holy Virgin; inside it is round, with columns inside and outside, capitals of the ionic order, columns with front faced cornices and medallions of white stone mined from the Myachkovskian area, with lofts for singers, with iron bars on the windows and three iron doors. Length of the church is 57 arshins and width is 36 arshins; basement is masonry; roof is covered with

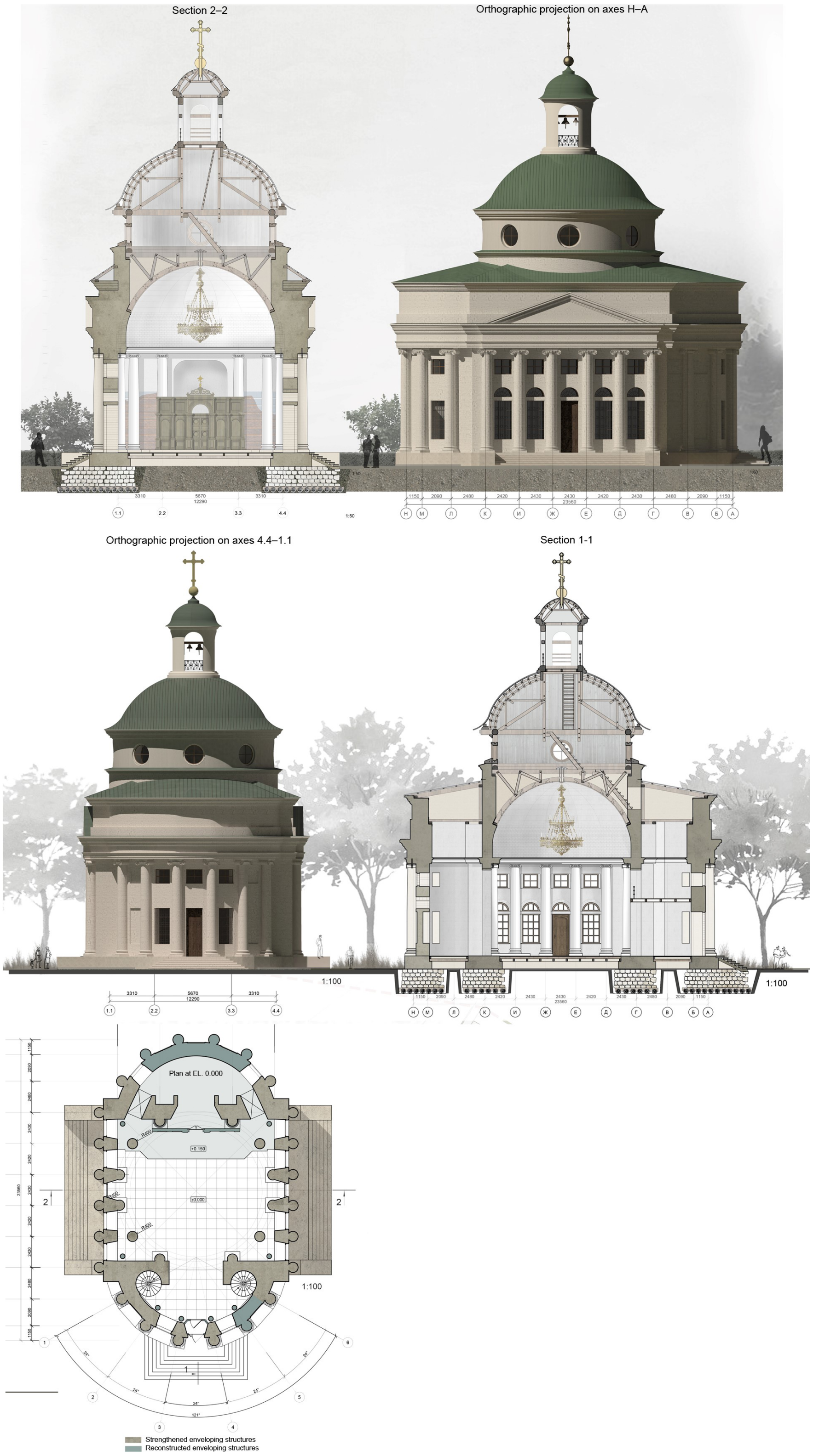

Figure 9. Graphical restoration of Holy Trinity Church in estate Pyataya Gora. student’s work. Archives of the SPSUACE

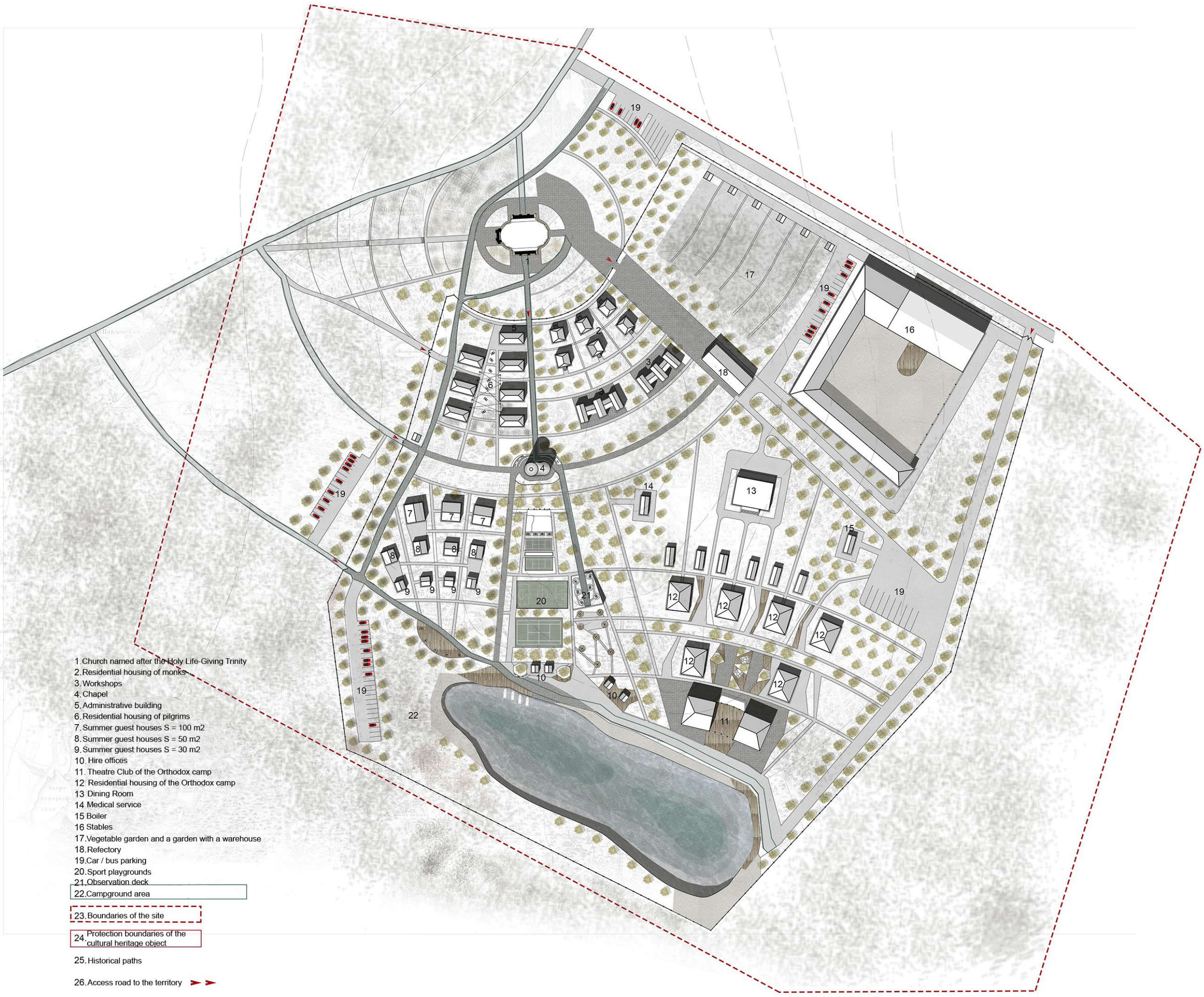

Figure 10. Graphical restoration of Holy Trinity Church in estate Pyataya Gora. Student's work. Archives of the SPSUACE

sheet metal, painted with green paint, with an apple and the cross gilded with fire on the dome; floor in the church and in the altar is cast iron; floor in the warm side-chapel named for the Nativity is wooden, exterior bracings are made of stone; fence is stone with wooden lattice" (Insarsky, 1898).

Archiving of Holy Trinity Church in homestead Pyataya Gora comprises an "Inventory of church property" dated May 1829. An image of soaring Sabaoth cut in wood holding a "chandelier with 18 candleholders, with gilded cherubim and gilded bronze ball inside with a gilded angel and a cross" is pictured on the dome. Iconostasis has "22 images on the right bottom side of the lower tier", among which is the image of the Holy Life-Giving Trinity, a shroud, gilded royal gates with two images of the four evangelists, a baptistery, brocaded anabatas and books, six bells (52 pounds one) of 104 pounds in total" (Inventory…, 1829). Also, a surveying of estate Pyataya Gora and a measurement diagram made by the Restoration Factory of the Association "Rosrestavratsiya" in 1977 are present in the archive.

Thus, taking into account the above stated documents, iconographic materials and available archival resources, descriptions and drawings it is possible to restore the church in its historical proportions, dimensions and architectural decoration. Graphic reconstruction of the church was performed by the students of the SPSUACE (Figure 9). Conceptual design comprises the whole dimensions of the church with a dome and a lantern tower, including all decorations of classical architectural forms on the front face. The church interior is supposed to be restored according to verbal descriptions of the interior taken from archival sources, as well as following the analogues of the church constructed in the late XVIII century to the early XIX century.

It should be noted during the reconstruction of Holy Trinity Church that long-lasting safety of the monument and economical justification are possible only under active use and filling with life of the restored object. This is possible only by creating an Orthodox monastery or a church with their own household facilities on the territory of Pyataya Gora estate that will serve as a certain start point for new development of the abandoned territory, while arrangement of a hotel for pilgrims or a camp for orthodox citizens will ensure its inclusion in tourist routes, that, in its turn, will be the source of investments for the further development of reconstructed facilities and further new construction. This type of restoration meets all the above stated requirements of functional filling of the area according to the program of regional development. Implementation of the project of an Orthodox children's camp will, among other things, comply with the youth recreation needs.

Conclusion

The studied materials allow us to make the following conclusions, according to the stated tasks.

The church in the name of Holy Trinity and the surrounding areas of Pyataya Gora estate is of great significance both for the rural settlement Kalitino and for the historically formed landscape. Besides, Pyataya Gora homestead is quite popular destination among tourists. Analysis of the main characteristics of the territory and the regional development plan of the Leningrad region revealed that the most suitable type for the monument restoration is the reconstruction of the historic proportions and structures of the monument. In addition, we propose to renovate the architectural environment of the church and to develop the complex for creation of a monastery metochion in order to promote the place and active use of the territory of the estate. Moreover, the church itself dominates the area, and taking into account the active construction of cottage villages around it, the territory could serve as a significant nucleus of one of the areas of future functional division of the rural settlement Kalitino.

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AN INDUCTIVE METHOD OF CALCULATION OF THE DEFLECTION OF THE TRUSS REGULAR TYPE

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Abstract

In this paper, the author proposes a regular option of statically determinate flat truss with a lattice of Shukhov's type working under beam scheme. By induction, using Maple computer algebra system, the exact formula for the mid-span deflection under the action of the uniform load is obtained. The deflection of the elastic structure is defined by the formula of Maxwell – Mohr. Forces in the rods are found using cut nodes method with the composition of the management of the matrix of equations in vector form. The analysis of the coefficients in the truss evaluation with a different number of panels revealed the recurrence equation satisfied by these coefficients, and then the determined operators of a specialized package genfunc give a solution of the resulting equation that determines the required general formula. The case of a uniform load on the top horizontal zone is considered. The author obtained a simple asymptotic evaluation of this solution, proving the cubic nature of the growth of deflection for a fixed span length and a given nodal load. The solution found for an even number of panels and rods of the same cross-section, has a polynomial form; the dependence is non-monotonic and detects extremum, which allows optimizing the design.

Keywords: truss, deflection, induction, exact solution, Maple.

Introduction

The number of diagrams of statically determinate trusses of the regular type, which used in mechanical engineering as elements of bearing systems, lifting mechanisms of lightweight truss manipulators is very limited. Based on them more complex (regular or irregular) statically indefinable constructions are created. Solutions for basic systems can be used as a part of the solution for the real system by the method of forces or just as a test, and debug for various kinds of numerical methods or software packages based on them. The problem of finding diagrams of statically determinate trusses is called "hunting", and this "hunting" is keep going (Hutchinson and Fleck, 2005). In this paper, author proposes a new scheme of the regular type, where the cell performs the regular Shukhov' truss. This type of truss doesn't allow the direct computation of forces in the rods (regardless of the current load). In this paper we consider regular truss (Figure 1). Denote *n* is the number of panels (cell periodicity in the form of Shukhov's truss).

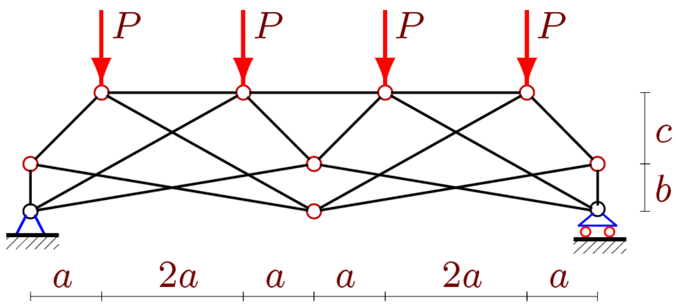

Figure 1. Truss, *k*=1

The method of cutting out of knots in the form in which it is usually applied (calculation from node to node with a consistent definition of the forces of the "chain") are not suitable. There are no such nodes which are attached to only two rods with unknown forces and with which to begin the calculation. The method of sections (Ritter's method) is also not suitable since the respective cross sections for n>1 does not exist. Only the calculation of the complete system of equilibrium equations of all components and definition forces across all terminals, including three rods, simulating the support is possible. This approach will be used below. Moreover, the aim is not just to obtain a formula for a specific truss, but to deduce the General formula for all trusses of this scheme, i.e. to obtain the solution for an arbitrary number of panels. The solution will be obtained by the methods of symbolic mathematics using the method of induction. Previously this method was used for deriving the formulas of deflection in a plane and spatial structures (Kirsanov, 2014, 2015a,b; Tinkov, 2015).

The geometry of the truss and the system of equations of equilibrium

We will create the system of equilibrium equations of all the nodes in the projections on the coordinate axes to compute the forces in the rods using cut nodes. The origin of coordinates we choose the left fixed support. Calculation program is compiled in the Maple language (Monagan et al., 2005). Assume that the truss contains an even number of panels: $n = 2k$. The number of the rod is $n_s = 8n + 4$, including three support rods. The number of nods along with three nods mounted on the base $m = 4n + 5$. We will set coordinates of nodes on which it will be possible to determine the directing cosines of the forces included in the equation of equilibrium:

$$x_i = 4a(i-1), y_i = 0,$$

$$x_{i+n+1} = x_i, \quad y_{i+n+1} = b, \; i = 1,...,n+1,$$

$$x_{i+2n+2} = a + 2a(i-1), \; y_{i+2n+2} = b + c, \; i = 1,...,2n.$$

Coordinates of the supports:

$$x_{m-2} = -2, y_{m-2} = 0,$$

$$x_{m-1} = x_1, y_{m-1} = -1,$$

$$x_m = x_{n+1}, y_m = -1.$$

The order of connection of nodes and cores in the truss we will introduce by special vectors $\bar{V}_i, i = 1,...,n_s$. Here the first component is the number of the joint at the beginning of the corresponding rod, the second is the number of the hinge at the end. Of course, the choice of special direction vectors of the rods is not associated with the sign of force in them. We have the following vectors:

$$\bar{V}_i = [i, 2(i+n+1)], \; \bar{V}_{i+n} = [i, i+n+2], \; \bar{V}_{i+2n} = [i+1, i+n+1],$$

$$\bar{V}_{i+3n} = [i+1, 2(i+n)+1], \; \bar{V}_{i+4n} = [i+n+1, 2(i+n)+1],$$

$$\bar{V}_{i+5n} = [i+n+2, 2(i+n+1)], \quad i = 1,...,n,$$

$$\bar{V}_{i+6n} = [i+2(n+1), i+2n+3], i = 1,...,2n-1.$$

The following vectors present the vertical side rods of the truss:

$$\bar{V}_{8n} = [1, n+2], \; \bar{V}_{8n+1} = [1+n, 2n+2].$$

Three rods of the supports correspond to the following vectors:

$$\bar{V}_{n_s-2} = [1, m-2], \;\; \bar{V}_{n_s-1} = [1, m-1], \;\; \bar{V}_{n_s} = [n+1, m].$$

The length of the rods and the projection of the vector representations of these rods need to calculate the direction cosines:

$$l_i = \sqrt{l_{1,i}^{\;2} + l_{2,i}^{\;2}}, \; l_{1,i} = x_{V_{2,i}} - x_{V_{1,i}}, \; l_{2,i} = y_{V_{2,i}} - y_{V_{1,i}}, \;\; i = 1,...,n_s.$$

The first index in the number $V_{j,i}$ takes on the values 1 or 2 and corresponds to the number of components of the vector V_i ; the second is a number of the rod. The matrix Φ guides of the cosines has the following elements

$$\Phi_{k,i} = -l_{j,i} / l_i, \; k = 2V_{i,2} - 2 + j, \;\; k \le n_s, \; j = 1,2, \; i = 1,...,n_s,$$

$$\Phi_{k,i} = l_{j,i} / l_i, \;\; k = 2V_{i,1} - 2 + j, \;\;\; k \le n_s, \;\; j = 1,2, \; i = 1,...,n_s.$$

The forces can be determined as:

$$\Phi \bar{S} = \bar{B}, \qquad (1)$$

where $S = \{S_1,...,S_{n_s}\}$ is the vector of forces in rods, $B = \{P_{x,1}, P_{y,1},..., P_{x,n_s}, P_{y,n_s}\}$ is the vector of the right parts (external loads applied to nodes). In order to calculate the deflection of the truss by the formula of Maxwell – Mohr: $\Delta = P \sum_{i=1}^{n_s-3} S_i^{(P)} S_i^{(1)} l_i / (EF)$, it is necessary to determine the force $S_i^{(1)}$ from the action of a single force applied at the middle of the lower zone (unit k+1, Figure 2). $S_i^{(P)}$ is the force in the rods from a given load and calculates the length of the rods l_i . The rigidity of the rods *EF* accepts the same.

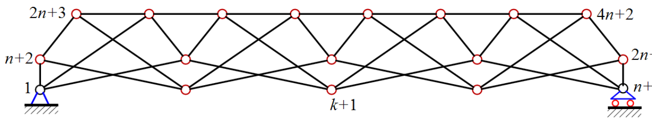

Figure 2. The numbering of the nodes in the truss, n=2k=4

Solution

We consider the case of loading of the upper belt truss when $b = c$. In this case, the non-zero elements of the vector of the right part of the system of equilibrium equations of the nodes will have the following: $B_{2i} = -P, \; i = 2n+3,..., 4n+2$. Solution (1) with such right-hand side gives the vector of forces $\bar{S}^{(P)}$. The vector $\bar{S}^{(1)}$ of forces from a single power at node k+1 selected at $B_{2(k+1)} = 1$ (the other elements are zero). The calculation is produced in the analytical form consistently for a truss with two panels, then four, three, etc. In every solution it is possible to identify specific components and their ratios. The deflection of the truss with k panels in half of the span takes the form

$$EF\Delta_k = P(A_k a^3 + B_k b^3 + G_k g^3 + D_k d^3 + H_k h^3) / (25b^2), (2)$$

where $d = \sqrt{16a^2 + b^2}$, $g = \sqrt{a^2 + b^2}$, $h = \sqrt{9a^2 + b^2}$ is the length of the braces.

The regularity in the sequence of coefficients can be found by the methods of Maple computer algebra system. With the command *rgf_findrecur* of package *genfunc* for next sequence 225, 4400, 21925, 69600, 169325, ... 17753600 of *Ak* of length 16 we obtain the recurrence equation as follows:

$$A_k = 2A_{k-1} + 2A_{k-2} - 6A_{k-3} + 6A_{k-5} - 2A_{k-6} - 2A_{k-7} + A_{k-8}$$

The operator *rsolve* gives the solution of this equation. The following general member of the sequence has the form:

$$A_k = 25(65k^4/6 + (3(-1)^k + 5)k^2/12 + (-1)^k - 1).$$

In a similar way the next coefficients are obtained:

$$B_k = (25/2)k(1-(-1)^k),$$
$$G_k = (10/3)k^4 + ((-1)^k + 23/3)k^2 + 3(1-(-1)^k),$$
$$D_k = (10/3)k^4 + ((-1)^k + 1/6)k^2 - 3(1-(-1)^k)/4,$$
$$H_k = (5/6)k^4 + (3(-1)^k + 53)k^2/12 - 3(1-(-1)^k).$$

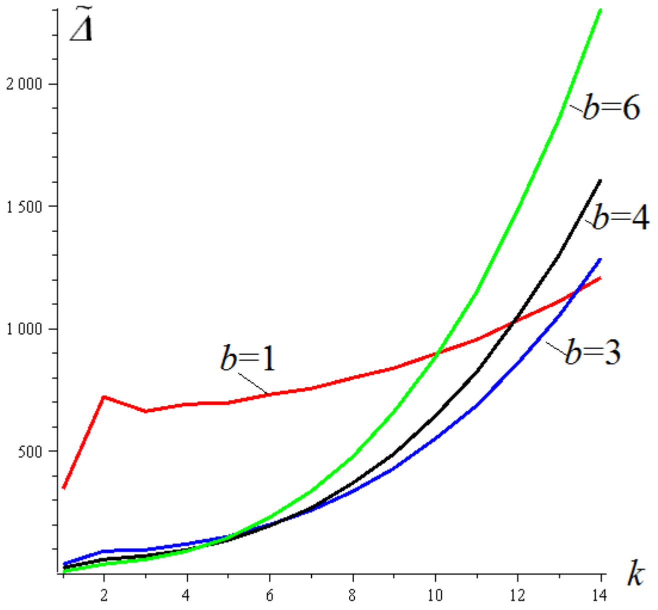

Figure 3. The dependence of the deflection on the number of panels

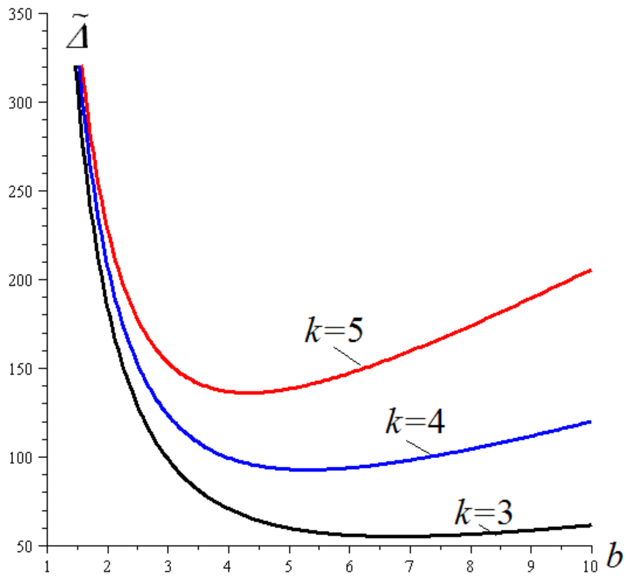

Figure 4. The dependence of deflection from the height

Analysis

Graph of (2) deflection $\Delta = \Delta EF/P_{sum}$ from the number of panels with constant span length $L = 4an = 40$ m and a given total magnitude of the vertical load $P_{sum} = 2nP$ (Figure 3, the dimensions in meters) shows that this dependence is non-monotonic for small heights of the truss. The kinks of the curves appear for small k and define “flashing” terms $(-1)^k$ in the coefficients. Of course, the initial part of the curve with $b = 1$ m has no practical value, because the corresponding panel length is too big for this altitude truss $a = 40/8 = 5$ m, but the fact of crossing curves can be used in a practical sense in case of choosing the optimal size of a truss. The dependence of the deflection height (Figure 4) shows a clear minimum, which can also be used to optimize the structures. For a larger number of panels, extremum is stronger. It is interesting to perform the marginal analysis of the obtained formula. In the Maple system, using the limit operator (*Delta/k^3,k=infinity*) we find that the increase of deflection is cubic $\lim_{k\to\infty} \tilde{\Delta}/k^3 = 2b/15$ and it is determined only by the height of the truss.

Conclusions

We proposed and calculated analytically statically determinate trusses in Maple regular scheme. Although the machines and mechanisms, in which the use of such schemes is assumed, undergo mainly dynamic loads, the static solution makes sense as a base, or estimated for more complex tasks, loads and types of supports. The solution has a polynomial form; the dependence is non-monotonic and detects extremum, which allows optimizing the design. The author provided the plots of deflection against a number of panels and height of the truss, showing the link between the deflection number of panels and height of the truss. Calculation and analysis are performed for a particular case when $b = c$. Based on the proposed algorithm, this solution can be easily generalized to any instance. However, the final formula, in this case, will be more complex. Marginal analysis revealed the cubic nature of the change of the deflection depending on the number of panels fixed on the length of the passage. Without any changes, the whole calculation can be performed in other symbolic mathematics packages. Similar design with precise formulas can be embedded in building structures to give them architectural expression and optimum rigidity. The analysis and optimization of beam structures was examined in a number of related researches (Farshi and Alinia-ziazi, 2010; Heyman, 2010; Kaveh and Talataharib, 2009).

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HISTORICAL PECULIARITIES OF FORMATION OF SMALL TOWN OF SHEBEKINO STRUCTURE

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Abstract

Article is dedicated to study of historical peculiarities which influenced the social and economic development and formation of the functional and planning structure of the small town of Shebekino of the Belgorod Region. Time scheme of land owners based on historical documentary data and scheme of territorial development during period from the 19th till 21st centuries were developed. Development of the town-forming base under rule of the town of Shebekino by the Rehbenders is considered and logical interrelation of husbandries located within their possessions is made. Main historical and extant architectural monuments of that time, their placement in the town structure were analyzed to preserve historical and cultural development and steady continuity and harmony in development of the territories.

Keywords: Small town, historical peculiarities, territorial development, historical and cultural heritage.

Introduction

Each of the small towns existing today has its historical value and uniqueness. The process of development of territory of historical inhabited places has to possess steady continuity and harmony (Bondarenko, 2016). The necessity of preservation of historical heritage and value of building of cities is caused by creation of the identical environment. This research reveals factors, which had the greatest impact on development of the town-forming base and functional and planning structure of the town of Shebekino.

The year of 1713 is considered to be the date of appearance of Shebekino when it was marked on Russian maps for the first time. However, it is likely that there was some small settlement on this place earlier which arose in 17th century during colonization of these territories by Russians (Gorbacheva and Krivtsova, 2011). Moreover, the Belgorod defensive line passed just a short distance away from this place and one of its watchboxes was situated there. In 1654–1658, the third construction period of the Belgorod fencing line was completed and Nezhegolsk fortress was built, which territorially was placed in direct proximity to modern Shebekino (Figure 1) (Nikitin, 1955). However, having lost its defensive value, the settlement did not gain further development, and at the beginning of 18th century a village with wooden and brick constructions, in which ara-

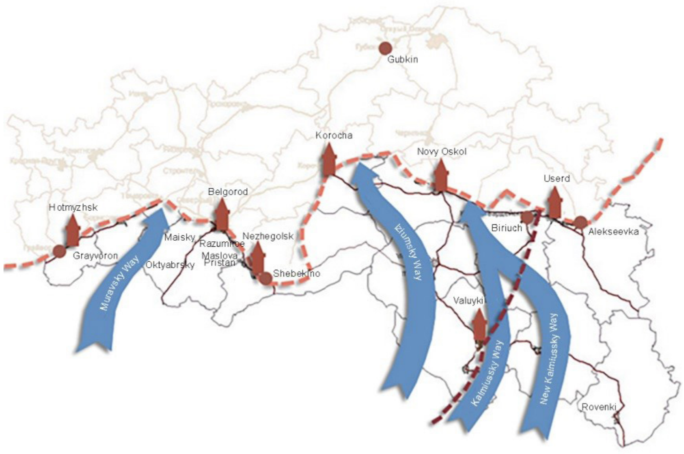

Figure 1. Belgorod fencing line within the territory of the Belgorod Region

ble farming and handicraft trade were being developed not far from the former fortress (Per'kova et al., 2015).

Inhabited area got its name by surname of the first landowner who, having settled his serfs here, founded the settlement. Lieutenant colonel Ivan Dmitriyevich Shibeko, one of the participants of the Battle of Poltava, bought 160 quarters of land from a nobleman N.R. Maslov. In 1785, village of Shebekino came into possession of Princess Yekaterina Petrovna Bariatinskaya. In 19th century, the village became a volost center of Belgorod uyezd of the Kursk province. The territory gained active social and economic development when in 1836 village of Shebekino was bought by the lieutenant general Aleksei Maksimovich Rehbinder (1795 – 1869) (Ovchinnikova, 2007, Pozdnjakov, 1988).

Subject, tasks and methods

Subject of the research is historical peculiarities of development of the functional and planning structure of small town of Shebekino of the Belgorod Region situated in half-hour transport accessibility to the regional center of the Belgorod Region — city of Belgorod.

The following tasks were set in the research: to reveal the main factors influencing the territorial development of town of Shebekino; to retrace development of the town-forming base and functional and planning structure under rule by the Rehbenders; to analyze the main historical and cultural monuments of that time in order to preserve historical and cultural heritage.

The historical and genetic as well as analytical methods were used for the investigation.

Results and discussion

Shebekinsky district is located in the central part of the Russian Plain, on the southern slopes of the Central Russian Upland, in the basin of two large rivers, Dnieper and Don, with the largest area of wooded lands in the region. Small town of Shebekino populated with about 43 thousand people is a large industrial center of Shebekinsky district according to regional measures for more than a century, which has concentrated chemical, machinery, construction and food production in its territory (Borodin, 1988, Shebekino Town Administration, 2008).

From the date of foundation in 1713 and before transfer of power to the Councils of working and peasant deputies (1917), a great number of famous historical figures were owners of the town: I.D. Shibeko, A.V. Makarov, Ye. P. Bariatinskaya, I.I. Bariatinsky, A.M. Rehbinder, A.A. Rehbinder, N.A. Rehbinder, A.A. Rehbinder (A.A. Rehbinder's son), M.A. Rehbinder as well as interim owners after A.V. Makarov's death (Figure 2) (Kosenko, 2011).

After passing into possession of the Rehbinders, active development of the town-forming base of inhabited area had begun in the village. In 1839, a primitive sugar plant was constructed on Nezhegol river bank, which was reconstructed and expanded in 1848. The beet sugar mill of the Rehbinders became one of the largest in the Kursk province by 1850. In 1888, it was reconstructed, the main and two side buildings were completed. Water-pump station was supplied for water delivery. In 1847, brickworks intended for providing the enterprise with construction materials was built.

Expansion of production required additional servicing enterprises and son of Aleksei Maksimovich, Aleksandr, built mechanical workshops for repair of agricultural implements in 1867. In 1875, he built a distillery and a two-storeyed mill with a butter churn. Due to a large production volume of sugar plants, in 1890 a decision about construction of a railway line from Belgorod to Kupiansk was made. Approach lines were laid from Nezhegol station to Botkino goods station in Novo-Tavolzhanka and to Rehbinderovo

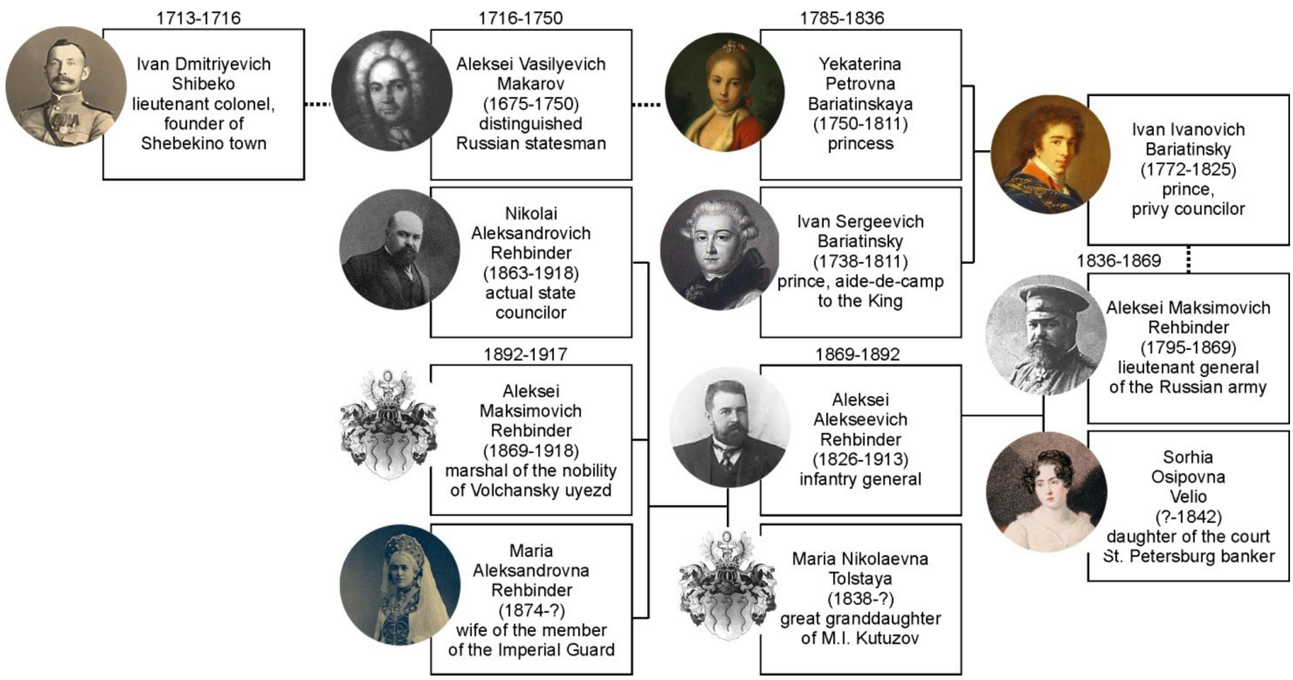

Figure 2. Historical scheme of lands possession of Shebekinskaya volost from 1713 till 1917.
Prepared by A.S. Zaikina according to (Kosenko, 2011)

goods station in village of Shebekino. Development of the space frame of the town was being proceeded.

In 1905, A. A. Rehbinder built at the sugar plant a power plant, which provided with electric power not only industrial enterprises but also dwelling houses. So, a comfortable environment of population activity was created. At the beginning of 20th century, Alekseevsky plant became the largest in Russia, and daily sugar production was amounted to 15 carloads by 900 poods in each that yielded revenue to 3 million roubles per year. Application of the up-to-date machinery at the sugar plant as well as use of new methods of field husbandry and agrotechnology during cultivation of sugar beet caused the need for educated and skilled workers. Farm workshops were organized. In this regard, Aleksandr Alekseevich together with his brother Nikolai founded an agricultural school for workers for 120 people in Shebekino in 1875. So, human potential in territory of Shebekino gained traction.

Construction production was presented by the chalk and brick works at that time. Rich deposits of minerals presented by high-quality chalk, a sedimentary layer – clays, marls and sandstones with silicon inclusions, fields of phosphorites and quartz, located at a small depth, allowed to turn out construction materials for local needs providing the construction branch. At the beginning of 20th century (1914), A. Rehbinder built a tannery and a slaughterhouse at which 1385 laborers worked (Kohanovskaja, 2009, Krupenkova, 2000).

All possession of the Rehbenders represented 12 husbandries, each of which was a specialized farm and united with others into a single economic complex. By the early 19th century, sugar plant, distillery and brickworks as well as mechanical workshops and mill constructed by the founder had worked in the territory of Shebekino. All processes in husbandries were interconnected among themselves and presented a closed chain for processing of secondary and production of fresh raw materials (Figure 3), presenting practically closed production cycle.

Initially the settlement could be divided into right and left banks of Nezhegol River visually and functionally. Areas of industrial and agricultural purposes were situated on one bank, and the baron's estate, gardens, parks, school, college and other household buildings were placed on the second one. Only since the 20th century, territorial borders of the settlement extended due to accession of near-

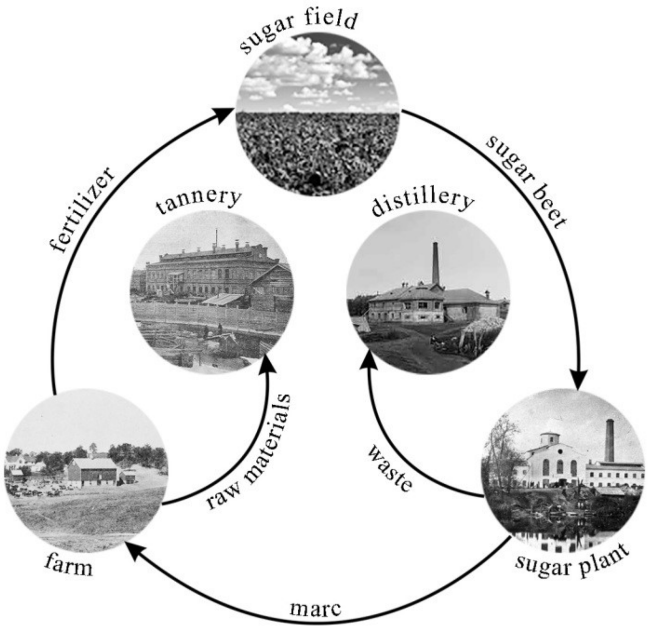

Figure 3. Interconnection of husbandries in Shebekino. Prepared by A.S. Zaikina

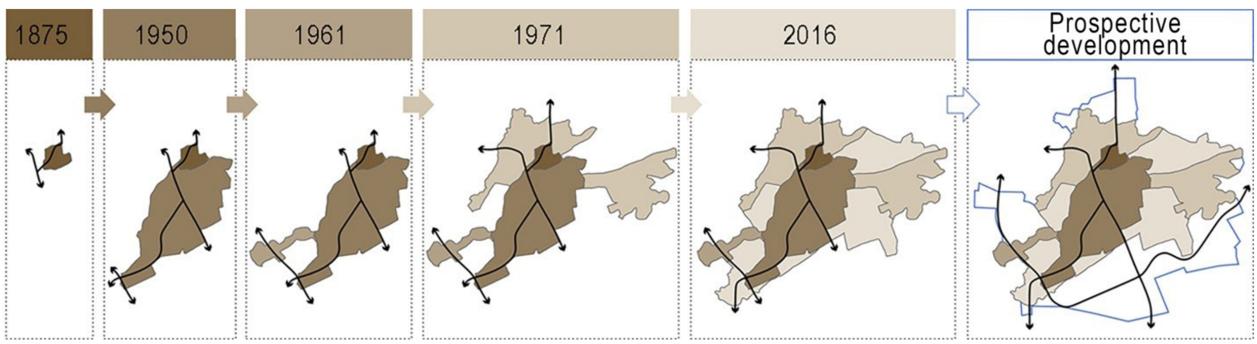

Figure 4. Scheme of development of territory of Shebekino in historical dynamics. Prepared by A.S. Zaikina (using the materials (Shebekino Town Administration, 2008, Per'kova et al., 2015))

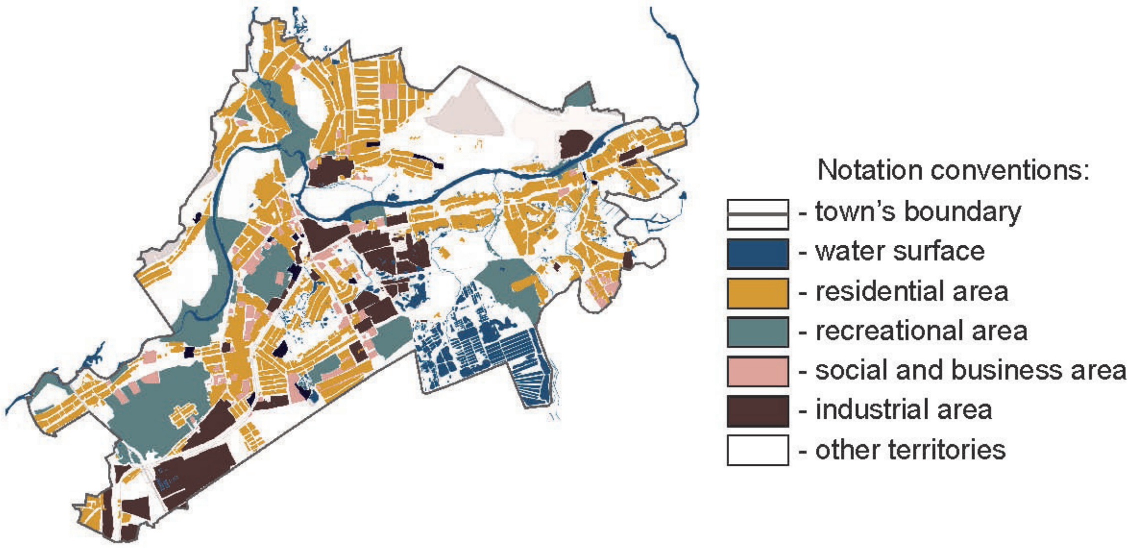

Figure 5. Scheme of functional zoning of Shebekino. Prepared by A.S. Zaikina according to (Shebekino Town Administration, 2008)

by villages – Titovka (1961), Ustinka and Logovoe (1971) (Figure 4) (Web page of Shebekino Town, 2016).

Historical spatial axes have preserved continuity, developing along the annexed territories. Historical center is situated in the northern part of the modern town today. Industrial areas are concentrated all over the town. Taking into account complex production processes and lack of minimally necessary sanitary protection zones, a complex environmental situation was expressed in neighborhood of industrial, storehouse, and public utilities areas with recreational, residential, social, and business territories of the town by the end of the previous century (Figure 5). However, at the beginning of the 21st century the production facilities were reduced greatly enough, partial production modernization was carried out. As a result, the industry-related load decreased, but degraded industrial areas needing land recultivation and refunctionalization of the urban environment, arose in the town center (Per'kova and Zaikina, 2016a).

Monuments of historical and cultural heritage of that time are located in the territory of the historic development today. Social infrastructure facilities, recreational areas and sometimes residential areas of town of Shebekino are designed around historically significant places forming separate micro-districts with a unique (at the regional level) structure (Perkova and Zaikina, 2016b). Majority of the historical and architectural monuments remaining today were erected under the Rehbinders. They include office of the sugar plant (1839), outpatient department of the hospital (1902), house of merchant Zolotarev, non-classical secondary school (1913) and other (Figure 6).

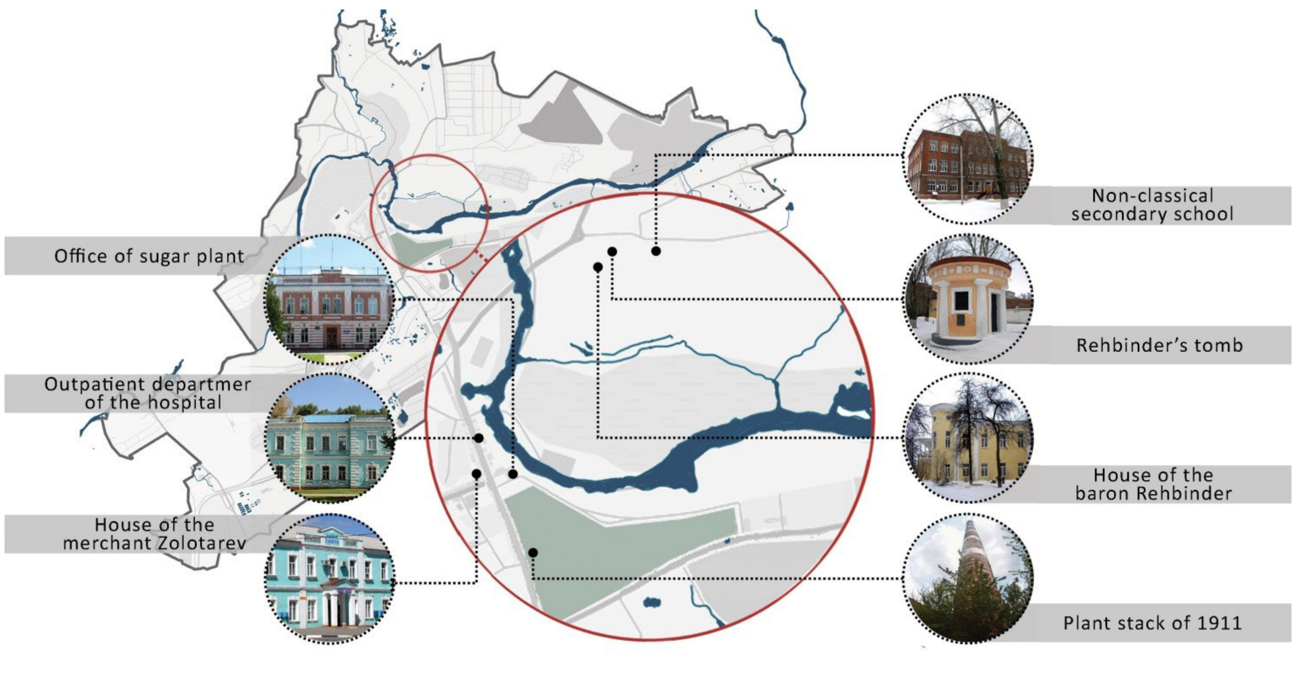

Figure 6. Placement of remaining monuments of historical and cultural heritage in Shebekino. Prepared by A.S. Zaikina

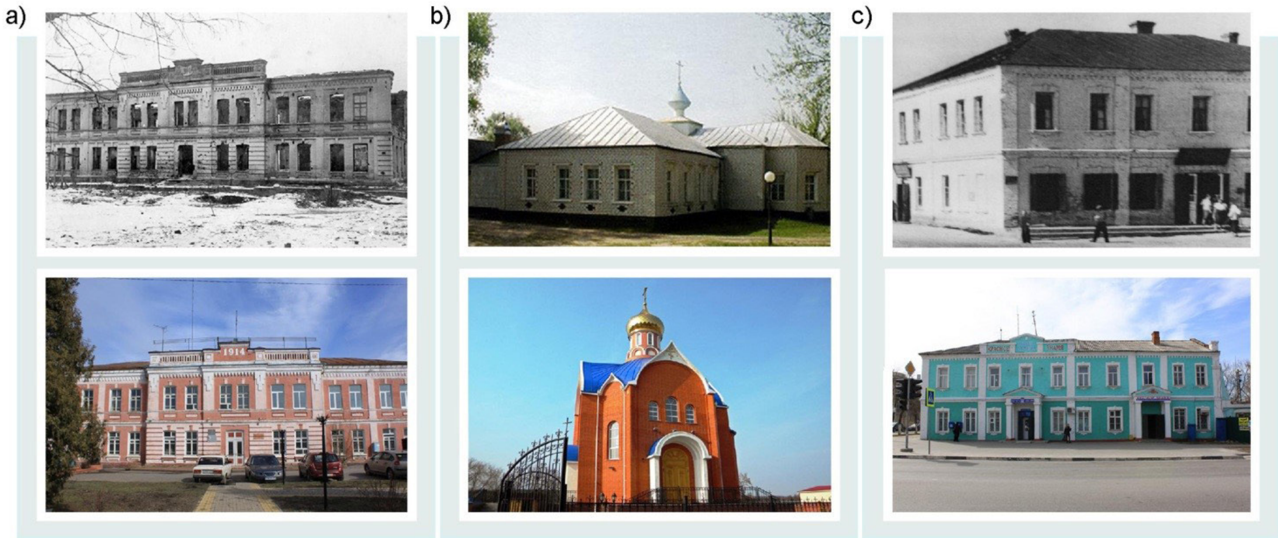

Figure 7. Historical and architectural monuments in Shebekino (Shebekino, 2009, Shebekino, 1995): a – office of the sugar plant; b – Tikhvin Temple of Icon of the God's Mother; c – house of the merchant Zolotarev (historical photographs and the current state)

At the beginning of 20th century Shebekino center was a square, near which the Tikhvin Temple, office of sugar plant, house of merchant Zolotarev and village school were situated (Figure 7) (Pozdnjakov, 2001).

Considering these sights in more detail, it should be noted that each of them was partially or completely destroyed during the World War II. As a result, part of buildings and constructions were reconstructed and restored and some were constructed anew. The first Tikhvin Temple of Icon of the God's Mother in Shebekino was constructed in 1792 at the expense of donations and presented a single-storey wooden construction. In the late 18th century, new stone temple was erected near it with financial support of the Rehbinders. Today the temple-chapel is situated in Titovka micro-district. Office of the sugar plant was restored in post-war years and recognized as a historical and architectural monument protected by the state. Now the building is not operated because of the critical condition. House of merchant Zolotarev has been reconstructed and is used now as a dwelling house and a vending facility, it also has a status of the monument (Kohanovskaja, 2009, Krupenkova, 2000).

Conclusions

So, an integrated approach to social and economic development of the territory by the Rehbenders was the main factor of the town development. The use of methods of production organization, which were progressive at that time, and timely modernization of technological processes, development of the space frame of the territory, human development by means of construction of educational institutions and introduction of advanced technologies in the housing stock have allowed to form rather qualitative environment of the population activity of the period under review.

Steady continuity in the spatial development of the town in 20th century, which preserved spatial axes and historical and cultural heritage of the Rehbinders contributed to harmony in development of the territories and creation of identical environment of the small town. The necessity of preservation of historical and architectural monuments of the past centuries is not only conditioned by their historical value, but also contributes to manifestation of social activity, act as material and spiritual values demonstrating results of activity of the past generations (Sementsov, 2007). Preservation, reconstruction, and restoration of monuments and historical and cultural heritage sites are an important task of the modern society, enabling to emphasize uniqueness of the territory and to render spirit of the past times.

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ASSESSMENT OF ACTUAL POWER AND ELECTRIC POWER AT CONSTRUCTION SITES

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Abstract
The article deals with issues connected with power supply of buildings and structures under construction. Due to nonlinear nature of electric power consumption at building industry enterprises, current and feeding voltage are distorted. This causes additional losses of actual power and energy, as well as inaccuracy and ambiguity in readings of power control devices and electric power metering. The article generalizes results of research on harmonic composition of electric power parameters of static converters and states recommendations on improvement of assessment and accounting of actual power and electric energy in electrical networks of building organizations.

Keywords: actual power, electric power, unsinusoidality, higher-order harmonic, idle-current wattmeter, electric power meter.

Introduction
Due to continuous increase in the number of electric equipment for construction industry which can be applied for non-linear loads, the problem of studying effects of such loads on losses of power and energy in electric power networks, as well as on accuracy and unambiguity of control and accounting of actual power and energy, increases constantly. Therefore, the problem of investigating the influence of non-linear loads on electric power networks, as well as development of methods and tools for assessment of power and energy, is becoming increasingly important.

Methods of study
Studying of scientific books, idealization, analysis, formal characterization, research and generalization of experience, forecasting.

Results of studies
Proper and timely solving of issues of construction power supply, i.e. supply of enough high quality electric power within the given timeframes, influences the terms of construction and installation works, effective operation of construction machines and mechanisms, and, finally, successful fulfillment of the development schedule to a large extent (Kononenko, 2008). The main objectives of electric power supply of construction can be expressed as follows:

- reduction of all types of power losses in electric power supply and at electric facilities of construction sites;
- implementation of energy-efficient construction technologies and introduction of combined electrical engineering processes;
- improvement of existing electric power facilities, engineering and implementation of new, more energy efficient electric power equipment, construction machinery and electric drive mechanisms;
- increasing organizational level of construction; establishing strict monitoring and accounting of power consumption at construction sites, including application of computer technologies; developing and improving science-based activities on metering of electricity consumption during construction and installation works;

- introducing automated and automatic control of processes, building machines and mechanisms, and common use of microprocessor engineering.

Solving the majority of these tasks of quality electrical power supply to construction sites is closely connected with the need of reliable estimation of actual power and energy.

The peculiarity of electric power supply of construction sites is as follows (Kononenko, 2014; Chukayev, 1981):

1. A significant part of electric power networks (overhead and cable) is temporary and is designed, as a rule, without careful calculations. Partly for that reason, the quality of electricity on construction sites is often unsatisfactory.
2. Capacity of supply mains is often relatively small (medium-sized construction site requires 700–1500 kW/A electrical power).
3. The main electricity consuming units at construction sites are engines (asynchronous mainly); their capacity often equals the power of supply transformers.
4. A significant number of other power consumers at construction sites can be referred to power distorting units. These are personal computers, arc and resistance welding devices, gas-discharge lamps, etc.

Powerful static frequency converters are widely used for power supply of engines. The basis of the main circuits of static frequency converters is semiconductor devices, which are nonlinear elements. The work of static converters is based on wiring of groups of semiconductor rectifiers (diodes, silicon controlled rectifiers, transistors, IGBT modules). All wiring circuits of static frequency converters generate consumption of unsinusoidal current from power networks causing distortion of sine waves of electric line voltage (Vershinin, 2000). In general, the curves of current and voltage in electrical networks can be regarded as amplitude-modulated oscillations governed with a random law of changes in amplitude and the initial phase; the voltage can be expressed as follows

$$u(t) = U_m(t)\sin(\omega t + \psi(t)), \quad (1)$$

where $u(t)$ and $U_m(t)$ are instantaneous and amplitude values of voltage for a given time moment t; $\psi(t)$ is the initial phase.

The general equation for current $i(t)$ is similar by the structure. If nonlinear loads operate in steady state, then the equation for the current $i(t)$, supplied from the mains by the converter, is expressed with the Fourier series (Zhezhelenko, 2000):

$$i(t) = \sum\nolimits_{v=1}^{n} I_{vm}\sin(v\omega t + \psi_v) \quad (2)$$

where $I_{vm}\sin(v\omega t + \psi_v)$ are harmonics or harmonic compounds of the order v with the amplitude I_{vm} and the initial phase ψv; n is the order (number) of the last accounted higher harmonic.

The output current of the inverter (2) may consist of different types of harmonics, so it should be presented as follows (Zhezhelenko, 2000; Arrillaga, Bradley and Bodger, 1985; Mayevsky, 1965; Khanzelka and Bien, 2005):

$$i(t) = I_0 + I_{1m}\sin(\omega t + \psi_1) + \sum I_{SH} + \sum I_{CH} + \sum I_{NH} + \sum I_{IH} \quad (3)$$

where I_0 is a DC component; $I_{1m}\sin(\omega t + \psi_1)$ is the current of the main component; $\sum I_{SH}$ is the total of subharmonic frequencies; $\sum I_{CH}$ is the total of higher characteristic harmonics; $\sum I_{NH}$ is the total of higher non-characteristic harmonics; $\sum I_{IH}$ is the total current of interharmonics.

In general, the major possible components of the output current of the frequency converter can be represented in a tabular form (see Table 1):

Table 1. Components of the output current of the frequency converter

Components of output current of the converter	*Frequency, 1/s*
Steady component	ω=0
Main component	ω=ωn=2πfn, where fn=50 Hz — network frequency
Higher characteristic harmonics	ω=(2p+3)ωn, where p=0,1,2,…; f>fn
Higher non-characteristic harmonics (abnormal)	ω=2gωn, where g=2n, where n=1,2,3,…; f>fn
Subharmonics	ω=ωn/k, where k=2,3,4,…; f<fn
Abnormal (non-characteristic) harmonics (interharmonics)	ω≠hωn, where h≠2,3,4,…; f>fn

Depending on the type of converter, the output current is different, which means that the expression (3) may or may not include certain components.

For example, harmonic frequencies are not generated under continuous cyclic control based on half cycles of alternating current, though interharmonics and subharmonics appear (Arrillaga, Bradley and Bodger, 1985).

It should be noted that the present classification of output current of the static frequency converter is conventional. Impulsive and fluctuating distortions appear under non-linear loads. They generate components of continuous spectrum, its energy regarded insignificant for power supply issues in comparison with the power of harmonic components (Zhezhelenko, 2000). However, it is believed that this issue is not yet sufficiently investigated.

Unsinusoidality and unbalance of voltage and current influence losses of power and energy in electrical networks.

Additional technical losses in the electric network are inconsistent if voltage unsinusoidality is less than 5%; total power losses increase significantly if unsinusoidality coefficient KU increases up to 10–15%. The greatest losses of higher harmonics in elements of the electric power system occur under resonant modes (Sharov, 2006).

Methods for calculating losses in electric equipment developed by various authors are approximate due to various reasons. Thus, frequency characteristics of actual and reactive electric resistance are average, specific to the type of equipment (motors, transformers, capacitors, etc.). Nonlinearities of these characteristics are determined with coefficients which are usually different for various frequencies. Impact of skin effect and proximity effect is described with the coefficient that depends on the number of harmonics. Impact of conductor resistance temperature is not considered. Attempts to evaluate the default level of estimation of additional losses were made. To this end, they performed calculations according to well-known methods for specific cases. It was found that calculation errors are positive for higher harmonic frequencies up to 13th harmonic order inclusive, not exceeding 7% and totaling up to 5% for 95% of cases (Shidlovsky, 1985). This applies to calculations of frequencies of characteristic harmonics. Errors of calculation of losses in frequencies of interharmonics have not been sufficiently studied, as "standardization in the field of interharmonics is in the process of accumulation of knowledge" (Zhezhelenko, 2012). According to recommendations of the International Electrotechnical Commission (IEC), voltage interharmonics are limited to 0.2% in the frequency range up to 2 kHz.

Additional harmonics also cause additional inaccuracies in power accounting.

All existing electric power metering devices can be roughly classified in accordance with the base of elements they are made of and measurement principles allowing recording and can be inductive, electronic and microprocessor devices (Sharov, 2006). The quality of electric power affects the work of metering devices in different ways.

Two electrical counterstreams circulate during measurement of actual power of nonlinear loads P_{NL} power supplied from the network P_1 (power of the main component) and power of additionally generated harmonics of different frequencies (depending on the type of static frequency converter) $\sum_2^n P_n$.

Nonlinear loads PNL are a source of additional harmonics, that is why:

$$P_{NL} = P_1 - \sum_2^n P_n \tag{4}$$

Linear loads under unsinusoidality voltage can be determined as follows:

$$P_L = P_1 + \sum_2^n P_n \tag{5}$$

The frequency response of the accuracy of an induction watthourmeter at the frequency of the harmonic n is approximated by the following equation (Ponomarenko, 2003):

$$\gamma = \alpha(\exp(-\beta \cdot n) - 1), \text{ where } \alpha = 1.28 \text{ and } \beta = 1.19. \tag{6}$$

In accordance with this feature and the equation (4), overestimation of electricity is registered during calculation of electric power consumed by non-linear loads, and underestimation is identified for linear loads (5) under unsinusoidality voltage. Thus, the consumer pays for deterioration of the electric power quality due to distorting loads in the electric network, if an induction watthourmeter is installed at a fiscal metering point. However, total balances of overestimation (underestimation) are not registered for the power supply system (Zhelezko, 2009; Shildovsky, 1985; Zhezhelenko, 2012).

Electronic and microprocessor metering devices may identify direction of voltage of higher harmonics at the point of registration, in contrast to induction watthourmeters. As a result, the consumer pays less for the electricity with the source of distortion, while the consumer receiving electricity of higher harmonics pays more than if it receives electric power with sinusoidal voltage.

Based on the aforesaid, it is evidently impossible to produce sufficiently accurate calculation of actual power and energy losses that are present in electric networks. It is also impossible to assess actual power consumption. The possible way out is measurement of actual power and the power consumed from the mains. Comparison of the actual power and energy with designed values can help to determine "standard" losses of power and energy.

Measurement of electric power wattage is one of the main types of measurements in many fields of human activities, and in the power sector in particular. Accuracy of wattage measurement means (WMM) determine the accuracy of measurement and metering of electric power, wattage coefficient, performance of machines and devices. Improving of WMM accuracy can create significant economic benefits. Until recently, the electricity needs were mostly satisfied with industrial frequency WMM with the basic error of less than 0.5%, while high-end devices were used as calibration devices (Bezikovich, 1980).

A few works on power measurement issues, published at the beginning of the second half of the 20th century, were devoted to such WMM. Development of modern automated systems of metering and distribution of electricity taking into account current features of electricity consumers demanded designing of working WMM with the basic error of less than 0.1% on the industrial rate, significant improvement of accuracy of broadpassband and low power-factor WMM, as well as development of high-speed digital WMM. Solving of these issues is associated with development of new methods and means of metrological support.

Development of digital wattmeters is aimed at solving two problems, as a rule: engineering of high-speed high-precision broadpassband instruments (class of 0.01–0.05) for research and metrological works, and designing of general precision instruments (class of 0.1–0.5) with a narrow frequency range of 50–1000 Hz, characterized with high reliability, adaptability, small size and cost for mass use in power systems and electronic power meters (Bezikovich, 1980). However, such devices do not cover the entire frequency range, as the measured signal may contain sub-harmonics (oscillations with the frequency less than 50 Hz) and harmonics with the frequency above 1000Hz (Schneider Electric specialists believe that the harmonics of up to 13th order should be corrected obligatory, meanwhile effective correction is possible under consideration of harmonics up to the 25th order (1250 Hz). It can be assumed that it would be necessary to account higher harmonics in the future, since the same specialists of Schneider Electric believe that harmonic currents above the 50th order are insignificant and can be neglected; that means that lower order harmonics should still be taken into account (Sazhenkov, 2009).

Specific features of AC power metering are that WMM is affected with three physical quantities (traditional approach): voltage, current and wattage factor. In this case, the very measured value, the wattage, does not affect directly the measuring transmitter. Accuracy of wattage measurement in this case is determined with the accuracy of three measurement errors of these quantities, which are characterized by different factors, including the properties of the load.

Measurement of feed-through power is usually performed by determining on-load voltage and current feeding through. In accordance with the accepted terminology (GOST 16263-70), measurements of wattage can be attributed to direct measurements, when the result of conversion is proportional to the product of initial values, none of which is defined at any conversion stages (wattmeter method), or to indirect measurements, when original values are defined and their product is calculated (method of ammeter and voltmeter). In this sense, conventional electricity meters and wattmeters are devices with direct measurement of power and energy. Currently there are metering devices, which comply with today's requirements for such devices. Most CIS manufacturers use an element base and technologies of the leading companies in the world. Thus, the EPQS device metering actual, reactive and full energy is a multifunctional measuring instrument complying with the requirements of the international standard IEC 60687 (Zhezhelenko 2012). The considered EPQS measuring device is similar to SL7000 Smart applying the principle of conversion of measured values and having the same characteristics, but the former is available in the CIS. The high engineering level of Western European metering devices is based on unique technologies. Thus, the company Siemens Metering Ltd (Switzerland) produces electricity meters based on such measuring elements, as Hall transducers. Hall transducers make direct measurements of actual power of individual phases (in the above stated sense) and generate pulses pro rata the power with high precision (Zhezhelenko, 2012). It should be taken into account that these new transducers of metering devices are still affected not by power itself, but its components. Considering specific models of metering devices, it can be stated, that measuring accuracy increase significantly when changing measurements from DC current into AC current.

An alternative to traditional methods of low-frequency power measurement is thermal methods, implying conversion of the measured power (energy) directly into an output signal or comparison of the measured power with a stated DC wattage. The calorimetric method is widely used to measure high frequency and ultra-high frequency power (Spektor, 1987; Remez, 1956).

In principle, the colorimetric method can be applied for power metering of the whole spectrum of frequencies of electromagnetic oscillations (Bilko, 1976).

At present, deviations of the curve of the measured voltage or current from an ideal sine wave lead to incorrect results of current metering in modern power networks by voltage or current meters with average readings. In this regard, they developed instruments that measure the so-called actual rms values of AC voltage and current of any form, which are determined with heating of an ohmic resistor fed from the measuring voltage (Dyakonov, 2011). Modern multimeters which measure true RMS of AC voltage and current (not necessarily sinusoidal) are marked as True RMS, as a rule. In fact, these devices involve thermal methods.

Therefore, power measurement of unsinusoidality processes with a wide harmonic composition requires the use of thermal methods.

Thermal power measurement methods are suitable for all frequencies, but actually applied only for very high frequencies.

Besides thermal methods, there are other methods that have not been traditionally used for engineering of commercial power (energy) measurement devices, described in detail in the scientific literature (Bezikovich, 1980). There were unique measuring devices even in the Soviet Union; their characteristics are not inferior, and sometimes even superior to that of modern instruments developed abroad (Dyakonov, 2011). Such experience of engineering these devices could be used to develop instruments of power control and energy measurement, which would comply with modern requirements. It is required to design such devices, that would allow reliable monitoring and metering of power and energy, as well as to develop calibration devices of high accuracy.

Although modern measuring devices present at the Russian market are called electronic, microprocessor and intelligent, they are not intended for reliable control and metering (according to the information available, mainly advertising), but are aimed at meeting increasing requirements of power supply companies. The following characteristics of “smart” metering devices are focused in the available works (Osika, 2011):

- protection against unauthorized actions;
- automatic readings;
- imposition of penalties on defaulters;
- secure data storage, etc.

Results of study

- Results of harmonic analysis of static frequency converters of various types are summarized.
- Recommendations on improvement of power and energy estimation at construction sites are given.

Conclusions

1. Currently available devices for control and metering of actual power and electricity do not provide reliable information on quantitative values of these parameters due to characteristics of modern electric power consumers.
2. It is necessary to use power and energy metering devices with reliable readings in order to assess accuracy of power and energy values. The most appropriate devices for measuring are those ones applying thermal methods.

3. Since there are no calorimetric instruments for metering power and energy in electricity networks at present time, it is necessary to develop and introduce such devices.
4. At present day, existing devices can measure actual power and energy allowing for harmonic voltage or spectral analysis in the electric network and the load current.
5. Sensitive measuring instruments designed for measuring audio-frequency range can be used as a reference for calibration of existing power control and metering devices.

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ANALYSIS OF APPLICABILITY OF COMPOSITE MATERIALS IN SUPPORTING CONSTRUCTIONS OF BRIDGES

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Abstract

In this paper we substantiated the necessity for application of composite materials in bridge supporting constructions. We listed the disadvantages of traditional materials and advantages of innovative ones. We also considered basic loads and effects on bridge supporting constructions which are to be sustained by structures made from the applied materials. We described the structure of composite materials, methods of manufacturing them as well as the factors influencing the characteristics of constructions made of them. We selected the type of bridge supporting constructions suitable for application of the new materials. We provided the results of experiments under poles made of polymer materials conducted by our foreign colleagues. We presented the information about testing of screw piles made of composite materials.

Keywords: bridgework, supporting constructions, composite materials, advantages and disadvantages of composite materials, experimental studies.

Introduction

Due to the successful use of composite materials in various industries, such as aerospace and defense industries, engineers' wish to use materials with beneficial properties is quite reasonable. New progressive materials are used in construction as well. They are used, for example in works at the facade of buildings for heat insulation, in laying utilities, and generally in non structural elements. However, it is obvious that the potential for development of composite materials allows applying them in load-carrying structures as well. The perspective direction for their use is manufacturing of bridge pile piers. Composite materials have low weight, they are lighter than steel by several times. They are factory fabricated and can be easily framed in the shortest possible time. The cost of mass-produced budget-priced composite materials, for example, made of fiberglass is close to the cost of metal.

Steel parts have been employed in bridge engineering for a long time and significantly excel reinforced concrete in some quality characteristics, but they are much more expensive; this is the main reason that steel is not generally adopted to replace reinforced concrete structures. That is why engineers search for an alternative, which will not be much more expensive than traditional reinforced concrete and will not demand high cost for maintenance as steel construction. New materials should have the characteristics which are as good as those of reinforced concrete and steel when they are traditionally applied for erection of bridge piers. Composite materials cannot completely replace reinforced concrete, but the units made from them should be capable of withstanding exactly those types of load, which affect the piers of a bridge. The characteristics of various composite materials can significantly differ depending on the way of their manufacturing and of the employed materials. Manufacturers should aim at the necessary characteristics knowing beforehand their final use. If a change is introduced even in one of the manufacturing parameters in the technology, this will result in a different material. Thus, it is possible to produce with such changes from a composite material which has already been manufactured before a new one with the characteristics necessary for a particular case. Structural elements made of these materials may be used in the construction of mid-piers of bridges. Further, in this article experimental studies conducted by different authors are presented. From our point of view, it is quite possible to use composite materials in the constructions of mid-piers of small-size bridges supported by piles.

The aim of this study is to examine the reliability of bridge supporting constructions made of composite materials. Structurally this study includes experimental investigation of models in order to examine loads and effects, working out of recommendations for testing of supporting constructions made of composite materials. The characteristics obtained in these experiments will allow deciding whether to adapt the existing method of calculation, such as that of reinforced concrete envelope, for composite materials or to work out a new method of calculation. Since there are no prototype bridges with composite piers, this is a scientifically novel study. We expect that, as a result of this study, a useful model patent will be worked out and this model will be used in designing a prototype application.

Composites can be more economically viable than traditional materials, because during their production several substances are used and the final product has all the advantages of each composing substance (Solntsev, 2007). The components of composites vary greatly from each other by their characteristics.

Structurally, the mid-pier consists of a foundation, a pier body and a cap with bed blocks on which bearings are mounted. In pile pier construction the piles act as both a foundation and a body joined together by cap at the top. These piles as well as other parts can be made of composite materials (Figure 1), which is the objective of the present study.

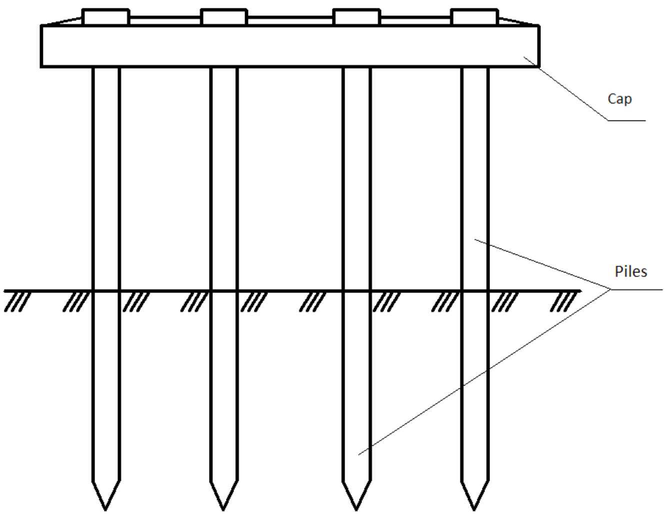

Figure 1. Drawing of pile-type pier

Such piles for piers without grillage are relevant to bridgeworks built upon dry valleys as well as for the elevated roads and viaducts. These structures are very simple to erect. Their peculiarity to offset corrosive environments will be very useful here. Although, inevitable difficulties must be overcome when combining reinforced concrete cap and piles made of composite material. Then there is a possibility for structural support of the span by means of cap plates of pile or pole supporting structures. It will be an economically viable solution to use composite materials for such supporting structures (Salamakhin, 2014). Pole piers have been constructed in our country since late 1960s; the reinforced concrete hollow shell piles with diameter of 0.8 m to 1.0 m made of circular sections up to 8 m in length with a wall thickness of 10 cm to 12 cm were traditionally used. At a later stage, piles with a hollow section having a diameter of 1.6 m and with 12 m in length were also used. These hollow section piles were joined by means of flanges connected by bolts. The lower part of these hollow shells was filled with concrete up to 3 m to ensure their bearing capacity, while the upper inner part of the hollow shells was filled with soil and water-repellent sand to the height of the supposed fluctuation of water horizon in order to eliminate the possibility of pressure break by the freezing water. The advantage of this solution is avoiding the necessity for erection of grillages as well as the reduction of materials consumption (Ivanchev, 2008). However, vertical cracks often appeared before the expiration of the expected working life of piers. It is necessary to thoroughly study the cause for this phenomenon. Making such supporting constructions from composite materials is rational due to their lower weight than reinforced concrete piles and their economical viability. However, prior to using such composite material piers in actual construction they must be theoretically and experimentally checked.

Certain aspects of this issue have been studied by our foreign colleagues. M.A. ElGawady and H.M. Dawood (2012) conducted theoretical computations along with experiment; they studied a finite element three-dimensional numerical model using *ABAQUS Standard* software, and their results of testing such piers to lateral loads are briefly presented in the next section.

Pile specimens subjected to lateral loading

According to the initial data, the tests were performed for the piers constructed out of segmental precast concrete filled polymer tubes. Reinforcing steel bars were also placed through channels prepared in advance. Subsequent tests showed that an increase in the pre-stressing force led to an increase in the strength rating. In addition, such parameters as the dimension of the sides, the length of the piers and their cross sectional diameter significantly influence their characteristics.

Lateral load was applied exactly in the middle of 254 mm cap by a special gear. Thus, the lever arm from foundation to the loading point was equal to 1651 mm. Sample 1 consisted of 1 solid segment of tube, while sample 2 consisted of 4 segments of composite tubes of 381 m in height filled with concrete (Figure 2).

After such numerical simulations were performed, an actual experiment was also conducted.

A series of tubes with wall thickness of 19 mm, “L” diameter of 1,220 mm and “S” diameter of 610 mm were manufactured. Each series included three samples with heights of 3,660 mm, 5,490 mm and 9,150 mm. The tubes were made

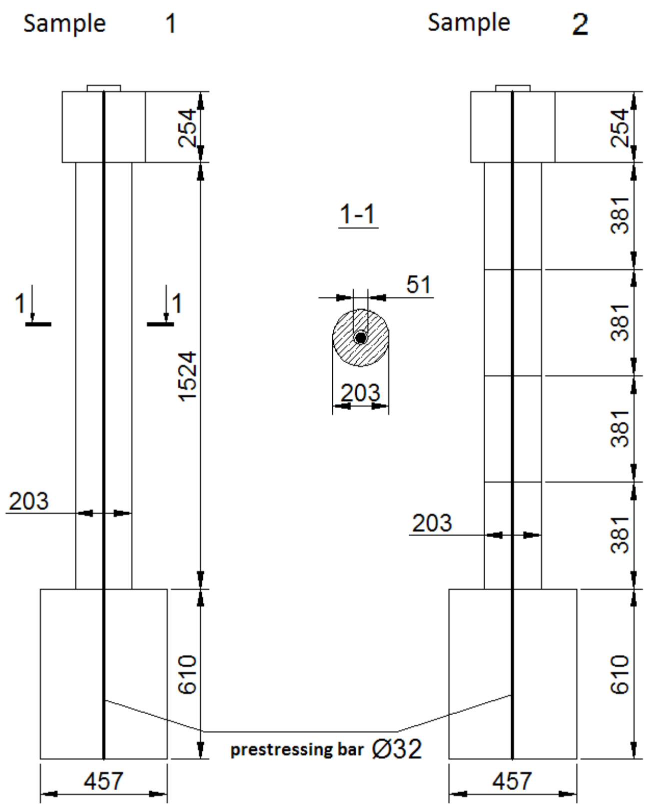

Figure 2. Sample sizes of three-dimensional model (Reproduced with minor modifications by permission of M.A. ElGawady and H.M. Dawood)

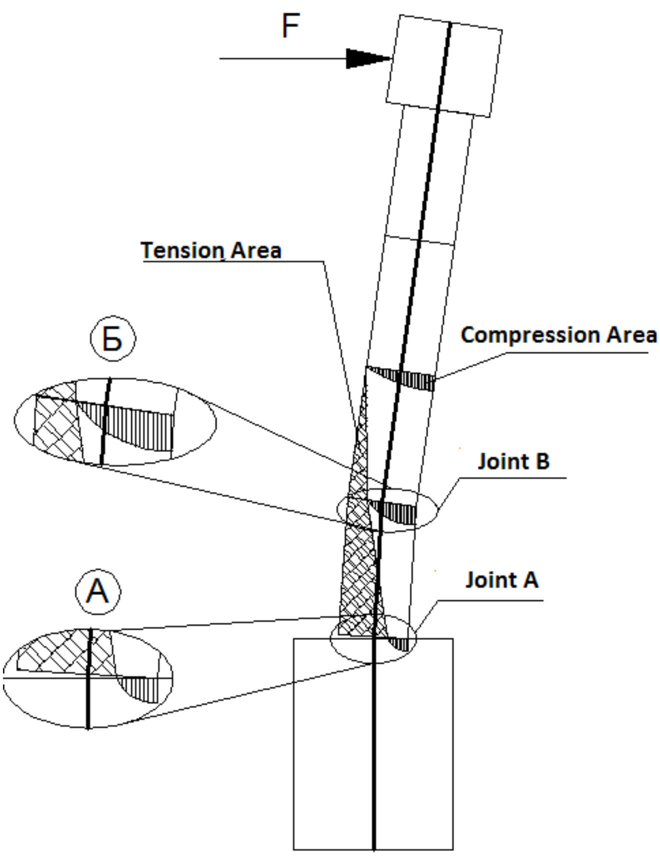

Figure 4. Deformation of pile affected by lateral load (Reproduced with minor modifications by permission of M.A. ElGawady and H.M. Dawood)

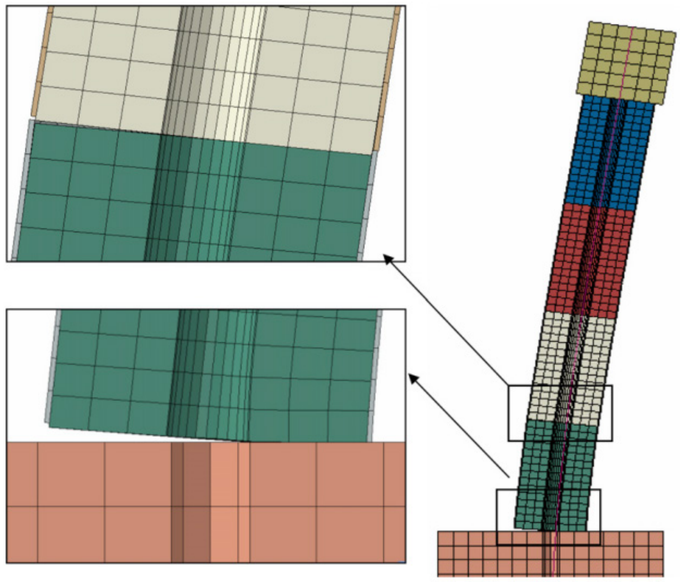

Figure 3. Deformation of sample 2 three-dimensional model (Reproduced by permission of M.A. ElGawady and H.M. Dawood)

by filament-winding technique with 55° glass fiber orientation with respect to the longitudinal axis of the tube. Each sample was reinforced by 32 mm post-tensioning bar placed along the whole length of the tube through PVC-channel inside the pier. Two strain gauges were mounted on the bar and were used to monitor the strains in the bar during the posttensioning and tests. The effective strain in the bar after post-tensioning was approximately 165 kN or 30% of the ultimate strength of the post-tensioning bar (Figure 4). The material properties for the bar were provided by the bar manufacturer (ElGawady and Dawood, 2012).

The bar was rigidly fixed to the foundation embedded in the floor. A U-shaped frame made from three steel H-beams welded to each other was fixed above the bar. 2 horizontal metal cores were positioned between the foundation and the vertical beams of the frame. The bar was slightly shifted from the symmetry axis of the U-shaped frame, and the mechanism for providing load effect on the bar was attached to one of the H-beam (see the test setup in ElGawady and Dawood, 2012). During this experiment, when the applied load was increased, the interface joint at the bottom of the pier opened. This loading sequence stopped once the actuator reached its displacement capacity, when the specimen reached a lateral drift angle of 15% and showed the lateral strength of 17 kN. The tested tubes showed maximum tensile stress of 275.79 MPa and modulus of elasticity of 24,821 MPa.

Pile specimens subjected to vertical loads

By studying this effort of the foreign researchers, the behavior of such pile piers made of composite materials was clarified. Fellow workers of the Department of Roads, Bridges and Tunnels at the Saint Petersburg State University of Architecture and Civil Engineering carried out tests of the piles made from fiberglass. These piles are manufactured by the method of dual helical winding. The angle between fibers equals to 55°. Four piles with welded metal screw caps were screwed in ground by drilling machine with maximal torque of 5200 kgf/m^2.

Figure 5. Composite screw pile

Figure 6. Overall view of the test setup

For the testing of composite screw piles we used dismountable setup consisting of metal H-beam No. 30 welded to metal screw piles. In order to increase the weight, H-beam was additionally loaded with 1.0 t load (Figure 6). Such test setup was mounted over each composite screw pile.

After the preparatory phase, when the physical and mechanical characteristics of soil at testing ground were examined (to ensure the accurateness of the readings) and the test setup mounted, we proceeded to the first phase of tests and conducted two series of experiments. We examined bearing load of each composite screw pile and value of soil sagging under static load. At first series we increased the load stepwise by 1000 kg. Each step was maintained at least 5 minutes. Maximal load on one composite screw pile was 11000 kg, when the pulling out of the metal screw piles of the test setup was observed. Displacement limits for the composite piles comprised 52 mm and 44 mm.

At the second series of tests, each pile was loaded with 10500 kg at once and then fully unloaded in order to examine the character of residual deformation. We examined bearing load of composite screw pile and value of soil sagging under cyclic load. Loading and unloading was performed in fast pace. Each cycle of loading/unloading took 2…3 minutes. At last cycles of loading sagging increase was less than 0.1 mm, additional sagging under cyclic loading of piles for the first and the second series of tests was 18 mm and 15 mm correspondingly (or 34% of the maximum sagging value obtained during the first phase of tests).

Upon completion of the on-site tests the piles were dug out and examined in order to find possible deformations. Metal caps and joints between pultruded fiberglass tube and metal caps have not deformed.

Conclusions

The results of this experiment led to the conclusion: composite screw piles worked well when tested on static and cyclic compressive load. Bearing of 11 tons loading by a 100 mm diameter pile with screw cap having 400 mm diameter blade is well enough to recommend the use of such piles in the construction, including the construction of transport facilities. This type of structures may in principle be applied as structural components of pile piers of small bridges. In order to identify the properties of the structures, we will continue experiments examining bearing horizontal loads and pull-out behavior. Introduction of composite structures to the Russian bridge engineering is not just possible, but inevitable due to certain advantages of composites over traditional materials.

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MANIFESTATION OF "INDOCHINESE STYLE" IN HANOI'S ARCHITECTURE IN 1920–1950s

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Abstract

In parallel to the avant-garde development of Western architecture in the 1920s, the architecture in Vietnam developed into the "Indochinese style", and it became eclectic at its genesis and synthesized specific forms of the architecture of the West and Southeast Asia. In Vietnam, this style combined elements and principles of the national and, to a great extent, the French architecture. The purpose of this article is to identify development patterns, the essence and manifestation of this style in the area of Hanoi from the 1920s till the 1950s. The goal is to be achieved through examining the architecture of specific public, residential and cult and sacred objects.

Keywords: "Indochinese style", architecture of Hanoi, public buildings, residential buildings, cult and sacred buildings, Ernest Hebrard, Arthur Kruze.

Introduction

In the 1920s, Neoclassicism brought to Vietnam by French colonizers began to give way to eclectic trends. One of the reasons of mass spread of such trend was inconsistency between neoclassical buildings and hot and humid climatic conditions, and that was proven by construction practice. The other reason was a wave of search of new architectural styles, which had already gripped the whole Europe at that time and reached Vietnam. Moreover, the interests of the colonial economy at the certain stage of its development began to require more organic coexistence of cultural and social forms intrinsic to the metropolis and to national consciousness of the aboriginal population. In these conditions, the task was to elaborate a new architectural style, which would combine eclectically the features of the French architecture with elements and principles of composition of the Vietnamese architecture. Finally, the "Indochinese style" became the outcome of these targeted creative endeavors, spreading all over the French colonies in the Indochinese Peninsula.

The pioneer of the new style was Ernest Hebrard. He was then followed by Arthur Kruze, R. Gaston, C. Batteur, Louis Georger, Leo Craste (Ho Hai Nam, 2007) and other Vietnamese architects. Partial changes started to take place in the national architecture under the influence of new trends. Thus, for example, the facades of rowhouse residential buildings (in Vietnam, they were called "tubular houses") started to adopt some elements of the European architecture. Changes were introduced into the layouts of buildings in the French quarters. Some cult and sacred buildings were built from new construction materials incorporating new methods of construction, etc.

The central city of Vietnam, Hanoi, could not remain on the sidelines of new trends in architecture, and, thus, beginning from the mid-1920s, the "Indochinese style" started to express itself actively in the look of residential and public buildings constructed in Hanoi, as well as in the look of cult and sacred buildings.

Materials and methods

The materials used for this article consist of relevant literature sources (see References), archival sources, cartographic materials, proprietary photos and photos from the Internet, as well as materials representing on-site surveys of the Hanoi development.

The basic methods for solving the key problem are related to the typology group of comparative analysis and summary of outputs.

Results and discussion

Public buildings

The majority of the "Indochinese" style public buildings featured strictly symmetrical and classical layouts and were built two- or three-storey with the basement that was designed to protect them from moisture and prevented the upper floors from getting wet to remain dry in conditions of high humidity in Hanoi (Tran Quoc Bao, 2011). Horizontal decomposition of facades were formed by a row of windows with stripe cornices over them. The central axis of facades was usually accented with vertical co-articulations and a large decorated roof, which out-topped the side flanks covered with similar roofs of smaller size. The uniqueness of public buildings was emphasized with two- or three-tier Chong Diem roofs (one tier overlaps another) that were common in Southeast Asia. In structures like that, light embrasures and air vents were located between the upper and the lower roofs. Moldings were placed on roof corners and ridges using so-called "printed letter" technique, which also corresponded to the principles of the architecture of Southeast Asia.

Except for the "stripe" cornice that joined rows of windows, each window was equipped with the straight step-shaped console sandric that served not only as a decorative element, but also as a structural element which supported the gutter and the roof. The composition of windows also included air vents located above or below the window frame, as well as wooden shutters protecting rooms from the sun heat.

Specific examples of "Indochinese" style manifestation in the look of public buildings in Hanoi is presented below.

- *Main building of the Indochinese University* (1927, architect Ernest Hebrard). The building was the first example of the "Indochinese" style. It is characteristic that the initial project was consistent with stylistics of Neoclassicism. However, during the construction, Ernest Hebrard resolutely changed the facades using numerous elements

Figure 1. Public buildings: (a) main building of the Indochinese University; (b) building of Louis Finot Museum; (c) building of the Department of Finance

of the architectural style of Southeast Asia (Ngo Huy Quynh, 2008).

The facade's key accent is its two-tier hipped roof located along the central axis. Between the tiers, there are rectangular windows intermixed with concrete "Chinese" consoles, whichimitate wooden structures. The facades are decorated with moldings following the Vietnamese traditions. Above the main entrance, there is an "open book" type cartouche, an octagon from the "Book of Changes" and the iron grid in the shape of coins, symbolizing wealth and prosperity. Above the yard entrance, there is a large balcony of the second floor. The balcony's balustrade is formed with molded elements replicating the motive of elements on the roof. The entrance is flanked by two false "lamp post" type columns corresponding to the Vietnamese traditions, which are often found in Tam Quan (triple-arch gate) (Figure 1a).

The main hall is decorated with a large Vietnamese fresco made by V. Tardieu. It depicts the life of the Hanoi society in the beginning of the 20th century. In the background one can see a traditional Tam Kuan.

- *Building of Louis Finot Museum* (1926–1931, architects: Ernest Hebrard and C. Batteur). The cross-shaped layout of the building is naturally organized around the central display area (Tran Quoc Bao, 2011). An essential supplement is the large octagon-shaped lobby with a corresponding dome-shaped roof. This "European" composition features shapes that typical to traditional architecture of Southeast Asia. Thus, the octagonal dome of the lobby overtops the structure of three-tier roofs, whereas the upper roof is supported by Chinese consoles. In general, the shape of the roof resembles the bell tower of Keo pagoda in Thai Binh Province.

The roofs of the display area resemble roofs of Khmer pagoda in South Vietnam. However, roofs of Khmer pagoda have no air vents or light embrasures, as opposed to the Vietnamese Chong Diem style. The lower roof has a wide extension in order to cover large windows from the sun and the rain. The canopy is supported by paired columns with consoles, styled on elements of the traditional wooden frame. Together with contours of the balustrades, they create an image of the traditional architecture of Southeast Asia. The end facades are enriched with decorative chong giuong frame made from wooden bars. Only absence of stucco wall decor (because of the wall colonnade) distinguishes the facades of the museum building from other buildings.

Natural lighting and air ventilation are provided through traditional combination of window frames, where smaller frames overtop the larger ones. Together with air ventilation embrasures located on the roofs, they allow for horizontal and vertical air circulation inside the building (Figure 1b).

- *Building of the Department of Finance* (1925–1928, architect Ernest Hebrard) (Ngo Huy Quynh, 2008). The building, having the shape of the "gong" letter (工), consists of four-storey and three-storey buildings joined together by the covered way.

The facade of the main building is classically symmetrical and structured with three projections, the one in the

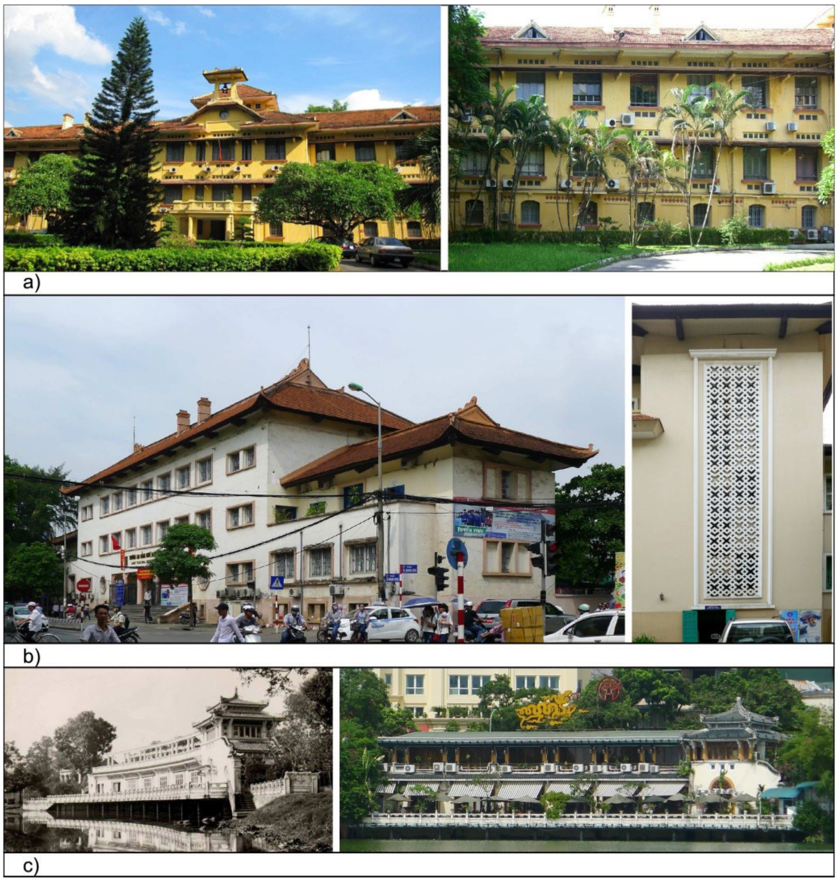

Figure 2. Public buildings: (a) building of the Institut Pasteur; (b) building of Indochina Guest House; (c) building of Thuy-Ta Restaurant

center and two from the sides. Above the central projection, there is a tower, the roof of which with wide extension is supported by columns. The stripe of windows of the third floor is accented with cornices located above and below the window frames. Two watch towers are topped by eightfold sloping roof. Other features of the Indochinese style are represented by the “open book” cartouche on the fronton, the roof with plain Vietnamese Vai Ka or Mui Hai tile, two single Chinese consoles supporting the balcony and consoles of upper buildings, as well as stucco on the fence in the shape of lotus buds which might be often found in pagodas (Figure 1c).

- *Building of the Institut Pasteur* (1928, architect R. Gaston) (Ngo Huy Quynh, 2008). The central axis of the three-storey building with the gallery along the south facade is featured by a small bell tower topped by the roof in Asian style. Below it, there is a complex roof with various slopes. Deep inside the building, a two-tier Chong Diem roof can be seen. On the wall between the roofs, there is an ornament made of glazed bricks in the shape of a lemon flower (Figure 2a).

In front of the main facade, there is a large garden with trees planted to protect the building from the sun.

- *Building of the Indochinese Guest House* (1938–1942) consists of the three-storey central building and two two-storey side blocks. The corresponding roofing system is associated with the ancient Vietnamese Tam Quan system. All roofs feature traditional Vietnamese curved (using Dau Dao elements) corners and ridges decorated in line with the Vietnamese traditional decor pattern, but only in simplified version. The main roof is covered with ridge tile. In contrast to others, the building of the guest house has no common stripe canopies and over-the-window sandrics on its facades. The main entrance is similar to the portico of Louis Finot Museum (Figure 2b).

- *Building of Thuy-Ta Restaurant* (1937, architect Vo Duc Dien) (Hoi KTS, 2008) was built using reinforced concrete structures. Its curved shape repeats the bend of the shore of Hoan Kiem Lake and creates an image of a ship with a tower topped by two-tier eightfold sloping Chong Diem roof. The tower looks similar to Tran Ba Dinh tower of Ngoc Son Temple located across the lake on the island. Big “European” windows with simple patterns are coupled with “Chinese” stripe canopy and the oriental landscape art (Figure 2c).

Residential buildings

- *Hau Lau Palace* (1821) was intended as a residential place for imperial concubines. In 1883, French colonizers renovated this three-storey rectangular building. Its central part and two side parts are crowned with three-

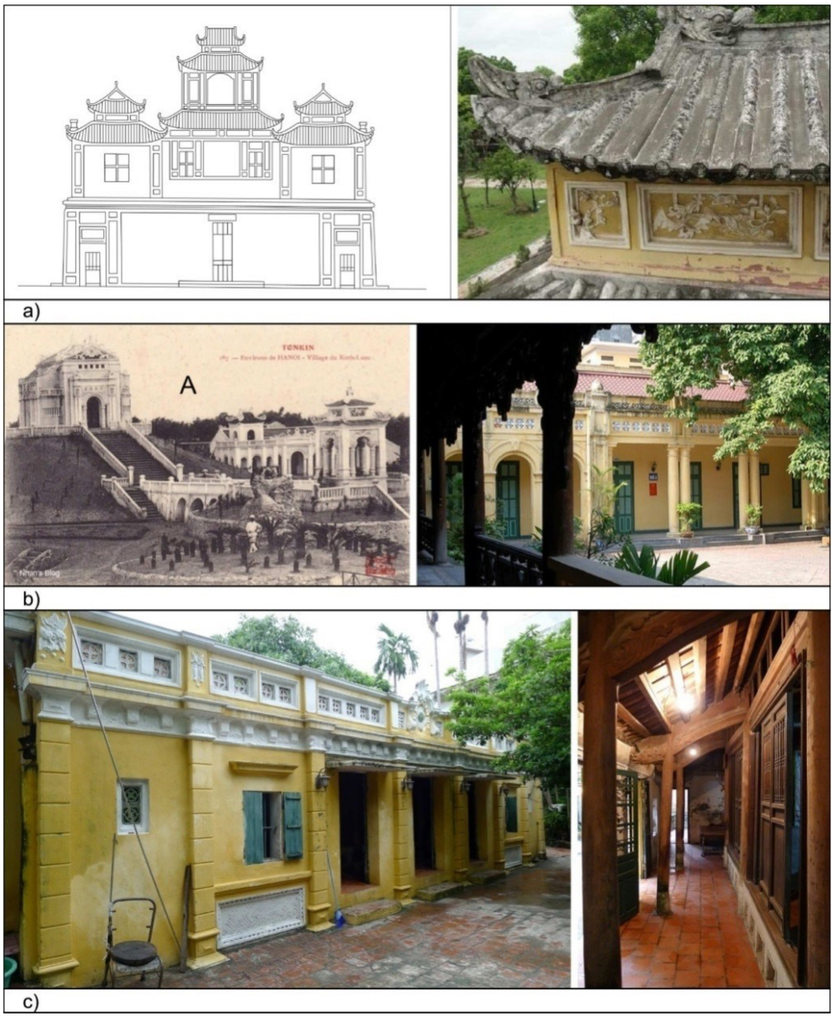

Figure 3. Residential buildings: (a) Hau Lau Palace; (b) Thai Ha Ensemble;(c) traditional residential house in neoclassical style

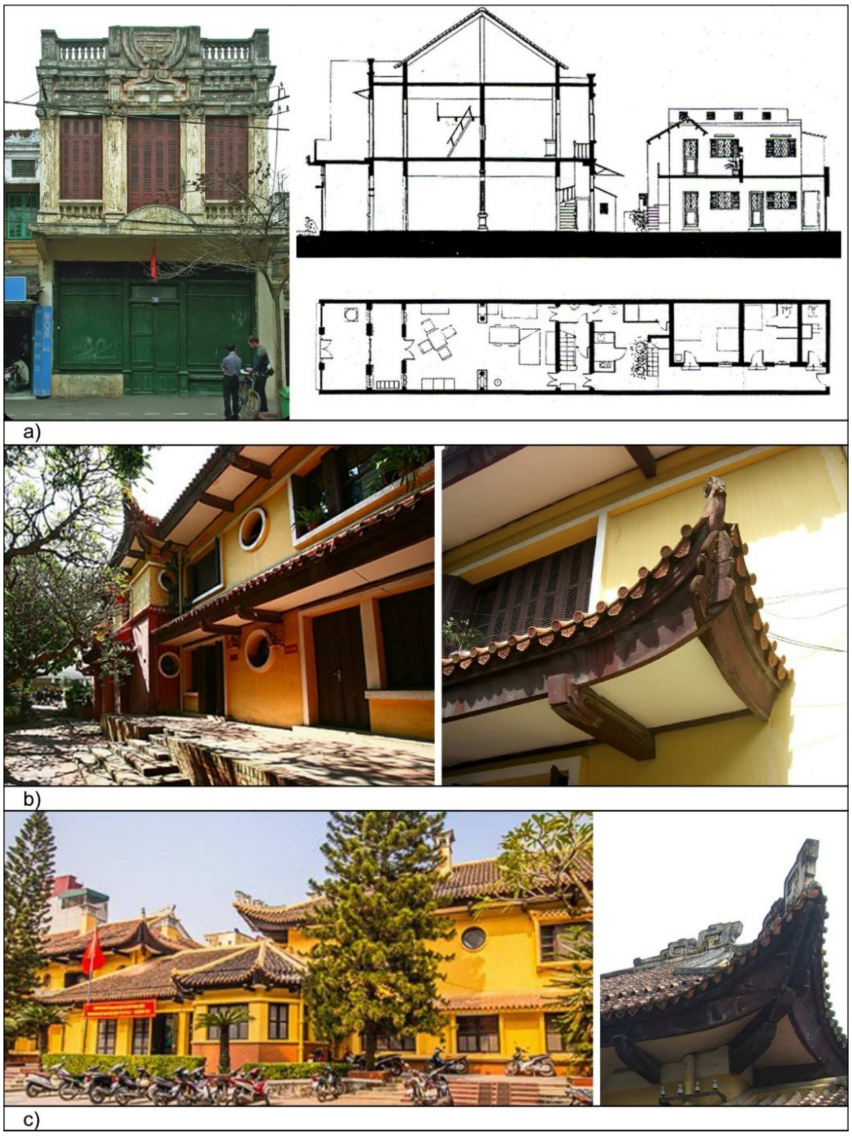

Figure 4. Residential buildings: (a) “tubular” house; (b), (c) French Officers Villa and Naval Club Villa

and two-tier roofs. These outwardly traditional roofs were nevertheless made of reinforced concrete, including “tile”. Traditional but simplified reliefs are made of stucco (Cong thong tin dien tu Chinh phu, 2010) (Fig 3a).

This restored building is the first example of non-conceptual “Indochinese style”.

- *Thai Ha Ensemble* was built at the end of the 19th century to the south of Hanoi and consisted of residencies, mausoleums, pagodas, temples, etc. The large plot had a rectangular layout (the owner was a nobleman under Nguyen dynasty). All structures of the ensemble were made of new construction materials using new technique featuring the Asian and European eclectic style. The combination of classical and Vietnamese forms and techniques paved the way to a brand new architectural style of that time. For example, the big crowning fronton on the facade is complemented with two “lamp post” type Vietnamese columns that framed the arch. The family temple was topped by two traditional towers built of concrete and brick. The temple was divided into seven sections. Three central sections had classical columns supporting the large eaves on the terrace, and on the sides there were symmetrically standing arches with “lamp post” style columns. The pavement of the terrace depicted red dragons (Tap chi dien tu Van Hien Viet Nam, 2014) (Figure 3b).

Terraced residential houses (so-called “tubular” houses), which essentially are the traditional Chong Diem dwellings transformed under influence of the French architecture, represent a large group of “Indochinese style” architecture. Their “adjoint” facade (usually only one) overtops the roof and is designed in line with neoclassical style. However, the gable roof and the interior space of the house remained traditional (Figure 3c).

The facades of “tubular” houses in French quarters strictly followed Western architectural style, but their layout was influenced by traditional style houses of old quarters. Some Indochinese architectural features often appeared in the course of construction (“open book”, “lotus buds” cartouches, “lamp post” columns, etc.) (Figure 4a). This type of houses was popular in the 1920s through the 1940s (Dang Thai Hoang, 1999).

Figure 5. Residential buildings: (a), (b), (c) residential buildings and villas with Southeast Asian decor

The interior of "tubular" houses of that time was peculiar. The space between rooms was provisionally divided by two Corinthian columns instead of traditional wooden columns that divided the internal space of the house into three sections. Sometimes two Corinthian columns were linked with a round arch.

Traditional construction materials were gradually replaced by new ones; brick, steel and even reinforced concrete were used instead of wood.

At the end of the 1930s, villas featuring eclectic facades started to appear. The pioneer was architect Arthur Kruze. The most significant pieces of art created by him in this architectural style were the French Officers Villa and the Naval Club Villa.

- *French Officers Villa* (1939) features a rectangular layout and volumetric solution using traditional motives (Hoi KTS, 2015). Thus, the terrace in front of the entrance is topped by the "Vietnamese" roof supported by two red columns. The wall above the roof is actively decorated using "printed letter" technique. The whole building is covered with a set of curved roofs. Except for the main roof, there is a canopy stripe above the front terrace and canopies above windows of the rear facade. All roofs have large eaves supported by wooden consoles. The decorated roof elements are made in the same way as in previous buildings. Roof corners feature curves using Dau Dao. Bedrooms are located symmetrically to the main axis of the building. All windows are framed with volumetric cover plates (Figure 4b).

- *Naval Club Villa* (1939–1940) (Hoi KTS, 2015) consists of the central public and two side bedroom blocks. There is a large terrace in front of the building. Decorative elements on the balustrade, windows and console surface feature the architectural style of Southeast Asia. The system of roofs with varying elevation on the main facade is divided into three uniform parts. Two bedroom blocks are topped by jerkin-head roof, and the main section of the common block is covered with eightfold sloping roof (Figure 4c).

The architect of these two buildings Arthur Kruze found an unusual solution by locating the gutter at the intersection of the walls and the roof. The area of roof projections is small, therefore, the volume of rain water is not significant and it freely streams down to the yard.

Vietnamese architects also made their contribution to the development of "Indochinese style". Residential houses and villas built by them were mainly located near Thien Quang Lake, where Vietnamese intellectuals were settling, who, as a rule, took interest in modern interpretations of traditional architectural forms. Small two-storey

Figure 6. Cult and sacred buildings: (a) Hung Ky Pagoda; (b) Quan Su Pagoda

villas that were built for them, with bedrooms on the second floor were mainly built from brick and reinforced concrete. Only doors were made of wood featuring traditional decor. Even so, the system of roofs remained traditional. Hipped roofs were still embellished with bas-reliefs typical for Southeast Asia (Figure 5 a, b, c).

Cult and sacred buildings

The eclectic style of cult and sacred buildings was formed under the influence of new construction materials and technologies, as mechanical combination of Western architectural forms with traditional forms in such extremely sustainable typological group of buildings was impossible.

- *Hung Ky Pagoda* (1932) was constructed from reinforced concrete and faced with porcelain tile. Its facades were enriched with "open book" style cartouches, mosaics and reliefs made from porcelain (TT Cong nghe thong tin — BVH, TT & DL, 2010). The architectural composition and bearing construction of the building were also traditional. Reinforced concrete elements of the main block of Chinh Dien were covered with light rose-colored stucco with fine-grained chips. Together with the mosaics, they contributed to formation of the multi-colored image. On the central axis of the pagoda, there is a temple built in strictly traditional manner, and nearby there are some other buildings of colonial architecture that were built for bonzes (Figure 6a).

The combination of architectural objects of different times, constructed using various materials and embellished with rich decor is rare and is a great value for pagodas. Skillful use of concrete for the construction of cult and sacred objects is as well considered as valuable.

- Quan Su Pagoda was built in the 15th century. In 1942, it was reconstructed by architect Nguyen Ngoc Ngoan. This is the first pagoda countrywide that had two storeys. 30 years later two other similar pagodas would be built in Saigon. All of them were constructed from brick, using reinforced concrete structures, though using slight-

Figure 7. Cult and sacred buildings: (a) Cua Bac Catholic Cathedral; (b) two other cathedrals

ly bended traditional two-tier roofs, as Dau Dao element was renovated in order to meet the characteristics of concrete. Concrete consoles, imitating the wooden ones, did not support the roofs anymore. To create the traditional image, the ridges were embellished with mythological images and stripes of glazed brick. Walls, doors and window frames were decorated as well (Figure 6b).

- *Cua Bac Catholic Cathedral* (1930–1932, architect Ernest Hebrard) was built near the northern gates of Hanoi's citadel. The cathedral is almost the only sacred building in Hanoi, where volumetric Neo-Renaissance composition is combined with Asian style.

The temple is topped by the system of roofs in Southeast Asian style. The main roofs feature Chong Diem" type forms, others feature Khmer pagoda roofs. However, all of them are built of reinforced concrete structures. There are also small decorative roofs. Windows are always left open providing constant lighting for interior spaces (Figure 7a).

In Hanoi, there are two other sacred buildings that were built before Cua Bac Cathedral. Their common feature is in application of traditional Vietnamese roofs for the whole building, and the use of new construction materials along with wooden roof construction (Figure 7b).

Conclusion

The formation of the "Indochinese style" in the capital of Vietnam was a logical consequence of socio-cultural and socio-economic processes that took place in the first half of the 20th century, both in Europe and in the Asian colonies of France. Providing certain wholeness to the development of the European economy in the Asian country required blurring out the sharp distinctions in the nature of production and culture between France and Vietnam. The same was required for peaceful coexistence between local population and colonizers. As to the architecture, the task involving creation of the synthesized style was facilitated by extensive experience in eclectic architecture in Europe of the 19th century. But there was also "counter flow" of reasons for the formation of the "Indochinese style" in Vietnamese architecture, i.e. the desire of educated population of the Vietnamese society to assimilate attractive forms of the European culture.

Specific manifestations of the "Indochinese style" in buildings for various typological groups had similar optional features, the key among which were the following:

- use of elements of Western architecture in building facades and in course of volumetric construction of buildings, while maintaining the traditional principles of interior arrangement;
- application of of the Vietnamese system of natural air conditioning of rooms in western buildings, which is vital for humid and hot climate;
- embellishment of the European-style buildings with elements typical for the architecture of the countries of Southeast Asia. The most common was the use of tiered roofs with curved edges;
- masking concrete structures and elements under traditional wooden forms.

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ON THE ISSUE OF REGULATION OF ARCHITECTURAL AND CONSTRUCTION PROCESS IN CITY MANAGEMENT STRUCTURE (SECOND HALF OF THE XIX – EARLY XX CENTURIES)

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Abstract
The article examines the city management reforms in the field of architectural and construction process regulation in the course of the second half of the XIX – early XX centuries. Over the general course of those reforms, legislative materials, which had become the basis for formation of new principles of territorial, sectoral and local management, were the governing factor. During that period city became the concentration of social, sanitary and hygienic, housing, transportation and other problems which required urgent solution. For prompt response to the situation in cities, central authorities delegated their powers in that field to the local level.

Key words: city, Saint Petersburg, city management, architectural and construction process.

Introduction

The objective of the study is to identify the basic principles and results of activity of city management authorities in the field of architecture and construction process.

The objective of the study can be achieved by solution of the following tasks:

- identification and research of city management authorities' activity during the period of the second half of the XIX – early XX century;
- determination of the main legal documents governing the cooperation of city management authorities, government authorities, and private persons;
- determination of the degree of influence of state and imperial authority on activities of city management authorities;
- determination of the boundaries of actual practical activity of city management authorities in the domain of architecture and construction.

Activities of the city public management in the field of regulation of architectural and construction process.

The period of the second half of the XIX century was a time of social-economic and political-legal changes, which resulted in fundamental reforms of state institutions and social relations.

Concurrently fundamental changes in the field of architectural creation took place. The heyday of classical architecture, which resulted in significant ensembles of Saint Petersburg (Shvidkovsky, 2005), Moscow and other Russian cities (Shvidkovsky, 2007), was replaced by a process of its re-thinking, generation of new values (Craft, 2004). It was resulted in a new perception of the city as a territory whereon various users of rights acted (Kurbatov, Gorunov, 2013). These processes required a revision of the legislative system in the area of construction and urban land improvement.

One of the results of the city government reforms in the second half of the XIX century was state provision of more rights in organization of economic life to municipal communities. Since that time, great powers with respect to issues of urban development regulation, municipal services, construction, urban land improvement, and prosperity of cities were passed to the city public management. This became possible primarily due to the growth of city prosperity that gave a stimulus for passing to municipal societies the right to freely dispose of their property, which by that time had increased significantly. In addition to that, the right to dispose of not only the city real estate in the form of buildings and structures, but also the land, was granted.

The law dated October 29, 1864 determined the following: "The responsibility for better development... of urban settlements shall rest with the corresponding department... of city public management administrations". The Provincial Court for City Affairs was a state supervisory authority for law enforcement in activities of city management authorities. Since the mid 1860-ies, the law regulated relations between municipal authorities, police, provincial construction departments and the highest instance, i.e. the Technical and Construction Committee of the Ministry of Internal Affairs (Zolotareva, 2008).

The Building Bylaw was the main legal document in force in the construction industry. Its Provisions in respect of construction in cities established the fundamental rules for legal regulation of this activity. They concerned civil, fire protection and sanitary requirements (Code of Laws of the Russian Empire, 1832). The bylaw sections were dedicated to private construction in the urban territory, construction of state-owned and public buildings, churches, industrial buildings, improvement of streets, squares, sidewalks, bridges, etc. This document also specified dimensions of new-laid streets and alleys, creation of inner courts. The bylaw was a legislative act, violation of which gave the city management administration and police the right to initiate legal prosecution of guilty participants of the construction process: architects, builders, customers (house and land owners).

To effectively conduct economic activity in accordance with Art. 73 of the Municipal Statutes, executive committees under the jurisdiction of City Administrative Boards were organized, which supervised various activity areas of public management. For example, the following executive committees were attached to the Saint Petersburg City Administrative Board: sanitary, hospital, water utility, school committees and others. Technical and construction supervision was carried out by the City Administrative Board through its Construction Department which was organized in 1872 (1872).

The scope of activities of the City Administrative Board included agreement of construction work execution for all buildings and structures in the city territory, except for those that belonged to state and departmental institutions.

Nature of works passing agreement was also regulated: this was the case of works that were executed on the basis of certificates issued by City Administrative Board technicians and works that were permitted only after approval by the City Administrative Board. Works which did not require agreement and could be carried out by owners at their sole discretion, were registered separately. For example, the latter group included the following:

- outside of buildings — only small improvements, but not capital repairs (facade painting, re-covering of iron roofings and installation of hoods over entrances, fitting of glasses, window casements, replacement of door panels);
- inside of buildings: all improvements that are not related to changes in the external appearance of a building, except for demolition of stone walls, arches and stairways;
- laying and alteration of gas and water pipes inside of buildings, if these works are not connected with laying of underground pipes.

Solid re-laying and partial correction of pavements on streets was permitted without prior agreement. It was the responsibility of persons, departments and institutions that owned houses in the city. However, "since negligent performance of these works often happened", the Order of the Saint Petersburg Chief of the City Administration was released on March 22, 1883 about the necessity to supervise these works by police.

Let us consider the rules for obtaining permits for construction works in the Construction Department of the City Administrative Board and other institutions of the capital.

Technicians of the City Administrative Board issued certificates which authorized minor construction works, namely:

- repair of wooden roofs, beam replacement, removal of wall sheeting and their calking;
- installation of metal hoods on brackets or columns above entrance doors;
- reworking of windows in doors on facades and vice versa without changes in the nature of a facade;
- construction of slop and garbage pits;
- introduction of changes in construction of entrance areas in buildings, if there are open stairways, to release pavements from them;
- laying of underground pipes;
- arrangement of temporary fences and sheds to store construction materials.

The City Administrative Board issued permits for execution of construction works related to private buildings and structures, as well as their capital repairs. Nature of record management for this process was specifically stipulated. It was required to submit petitions for construction and renovation of buildings on a plain (not headed) paper. Presented design materials, according to the rules, should have contained the following documentation. A "project worked out in every detail" included: plans, facades, sections, as well as cost estimates for work production. Cost estimate documentation contained description of all works that were necessary for construction; price breakdown of work units (Zolotareva, 2008), compiled according to existing rates and types of work; cost of works in detail according to their nature (Zhitkov, Gersevanov, 1910).

Following consultations with the Chief of City Administration, the City Administrative Board approved city arrangement of quays for ship mooring and unloading of goods; public bath-houses; theaters and other sights; factories and plants; gas lighting in buildings.

On the basis of Highest Decree dated July 3, 1867, upon issue of the approved plan, the City Administrative Board charged for each paper format of a plan with appendices: for stone buildings — 3 rubles, for wooden buildings — 1 ruble, certificates for minor restructuring of temporary fences and sheds — 0.75 rubles.

In the capital the following projects were submitted for Emperor's kind consideration:

- facades of private buildings, facing the Field of Mars, squares: Mikhailovskaya, Alexandrinsky and Bolshoi Theaters; prospects: Admiralteiskiy, Nevskiy, Liteinyi, Vladimirskiy, Zagorodniy, and Voznesenskiy; streets: Gogolevskaya, Morskaya, Millionnaya, Mikhailovskaya, Italyanskaya, Sadovaya (between Nevskiy prospect and the Field of Mars), Ekaterininskaya, Karavannaya, and Gorokhovaya; embankment of Bolshaya Neva from Tavricheskiy Garden to New Admiralty and on Vasilyevskiy Island from Birzha to 23rd line;
- facades of churches and houses of worship of various confessions of faith;
- facades of all buildings and structures for public use.

In the late XIX – early XX century, the system of architecture and construction control of public management administration proceeded as follows. The Construction Department of the City Administrative Board considered and approved projects, as well as issued certificates for construction works that were in their competence. Other projects after consideration by the City Administrative Board were either approved by the Administrative Department of the Chief of the City Administration or a construction department of provincial boards of administration, or passed to the Ministry of Internal Affairs with subsequent submission for Imperial consolidation. After all agreements, the permit and project were presented to police superiors. Construction works were carried out under supervision of a district architect and police. Permission for works execution was valid for stone buildings within 5 years, and for wooden buildings — within 3 years.

If during building process a deviation from the agreed project or a violation of the Building Bylaw regulations, as well as of government or City Council decrees was discovered, police drew up the report which was referred to the court. According to Art. 103, 110, and 114 of the Municipal Statutes of 1870, the City Administrative Board also had the powers to initiate legal prosecution through its representative and appear for the prosecution in court in all cases of Building Bylaw violations. In particular, one of the official duties of the city architect was the right to draw up statements from his own name on initiation of legal prosecution of private persons for violation of the Building Bylaw (Code of Laws of the Russian Empire, 1900). Upon dissatisfaction of parties with a decision of the Magistrates Court, the appeal was filed, which was considered by a Magistrates session.

If the issue was quite complicated or violations during the construction process had criminal nature (loss of life in the collapse of a building under construction), representatives of the Prosecutor's Office of a District Court appointed expert examination. In one of Prosecutor's circulars of the Saint Petersburg District Court there was ordered that such expert examinations should have had "scientific nature which would serve as the best guarantee of impartiality and scientific solution of the proposed issue". It should be noted that this provision got vivid response in the Saint Petersburg Society of Architects which expressed willingness to participate professionally in these expert examinations.

To improve works in the field of municipal economy and urban land improvement, the post of municipal architects under the jurisdiction of City Administrative Boards in accordance with Note 2 of Art. 114 of the Municipal Statutes was established. Besides, in the Draft of the Statute "On the structure of municipal economy" dated December 31, 1866, it was recommended to city societies to have the position of the architect among employees of the City Public Administration. The following was noted in the Draft: "to fulfill the duties on city public management and for the benefit of local residents in the event of real need, the city assembly should appoint, at its discretion, in the position of architects,... persons having appropriate certificates, without the right of public service, by voluntary agreement with him" (Sementsov, 2002). According to the rules of the Municipal Statutes of 1870, the rights of public service and technical supervision were stipulated for Municipal Architects.

Official position of city architects at public administrations was as follows: the Municipal Architect and engineer were invited for the service in the city administration and received a salary; these specialists were appointed and dismissed from service by the Ministry of Internal Affairs. as advised by City Administrative Boards. In seeking to resolve technical issues by the municipal administration, the municipal architect had consultative capacity (Zolotareva, 2008). Persons applying for the position of the municipal architect at the City Administrative Board were to submit certificates confirming the corresponding specialty, specify their employment history, provide references from previous employers or references of constructed buildings, as well as provide a certificate stating that such person was permitted to develop projects, prepare estimates and fulfill construction of buildings and structures of various nature (Zolotareva, 1992).

With issue of the next Municipal Statutes in 1892, the rights of Municipal Architects for public service were not confirmed, and that created a crisis situation and aroused concerns of the architectural community. The main problem of the official position of the architect at the city administrative board according to the Municipal Statutes of 1892 was lack of social protection, as this position did not fall under the category of public service. The post of the Chief Architect was considered elective, therefore, with expiry of the elected term, such person no longer acted as a public employee. Besides, there was no capital from which pension accounting for this category of public employees would be produced. And only at the end of 1890 the Imperial Assent followed for "those Municipal Architects and engineers, who have been designated to the places occupied by them prior to introduction of the Municipal Statutes of 1892, to be recognized, acknowledged as being on public service and exercising the corresponding right specified in the Municipal Statutes of 1870" (Shmeling, 1894).

Another result of the reforms of the second half of the XIX century was provision to city authorities, in accordance with Article 55 of the Municipal Statutes of 1870, the possibility (in agreement with the authorities) to develop regulatory standards in various branches of city economy, including those in the field of architectural and construction activity and urban land improvement (which came into force after the Imperial consolidation).

Subjects of these regulations were listed in Art. 103 (Collection of mandatory regulations for urban residents issued by the Saint Petersburg City Council on the basis of Article 103 and subsequent articles of the Municipal Statute by Imperial consolidation as of June 16, 1870). Thus, the Building Bylaws determined the general policy of the state in the field of architectural and construction activity and urban land improvement, and regulations on construction of cities took into account the settlement status and features of a region in which certain cities were located. In some cases, the empire gave recommendations to the public administration on compilation of certain regulations.

Here are some examples of activity areas of the city administration, under which it was allowed to issue "compulsory regulations for urban residents" in accordance with Article 103 of the Municipal Statutes of 1870:

a) on the order of upkeep and cleanliness of streets, squares, pavements, sidewalks, bridges and log-roads, as well as sewers, canals, ponds, wells, ditches, and natural canals, including those located on lands owned by private persons, institutions, and departments;

b) on measures to ensure integrity and cleanliness, as well as damage protection of city-owned public structures and monuments, gardens, boulevards and other public places;

c) on the arrangement of quays, temporary bridges and ferries, as well as horse-drawn railways and other advanced routes, on the order of their maintenance and use, on production of carrier's trade, on city omnibuses and other public cabs;

d) on yard cleaning, on the arrangement and cleaning of slop pits and latrines;

e) on the arrangement and order of upkeep of slaughter-houses and their use;

e) on measures taken to keep cleanliness in rooms for sale of provisions and drinks, and ensure their safety;

f) on precautions against water damage;

g) on the internal routine at fairs, markets and bazaars;

h) on the arrangement of roofings, on the arrangement, cleanliness and inspection of house pipes and furnaces, and generally on precautions against fire;

i) on places where storage of firewood, hay, straw, oil, alcohol, and other flammable substances is not permitted and on the order of storage of these substances;

j) on the procedures of prevention and cessation of contagious, epidemic and local diseases, and also loss of cattle;

k) on acceptance of measures, connected with expenses or restrictions in execution of trade and crafts, for keeping decency and order in public places.

In 1881, the Compulsory Regulations on building were approved in Saint Petersburg. Planning characteristics of the city structure and volumetric-spatial parameters of privately owned buildings, as well as the process of design documentation agreement were captured in this document. This document presented in detail the regulations on construction of individual buildings, their parts, as well as bridge and temporary structures (for the period of construction works).

The Compulsory Regulations and Rules for construction of various types of buildings, structures and premises were issued separately. For example, in 1886, the "Compulsory Regulations on the arrangement and upkeep of theaters, circuses and halls for public meetings" were issued; in 1883 — the "Rules of the arrangement and maintenance of pavements in Saint Petersburg"; in 1903 — "On the arrangement of public baths and order of bath trade in Saint Petersburg"; in 1908 — "On the arrangement and upkeep of premises for cinema"; in 1909 — "On the arrangement of trades with sales of spirits in Saint Petersburg and its suburbs". In 1885, the Compulsory Regulations of the Saint Petersburg City Council "On navigation in Saint Petersburg waters and maintenance of surface structures" were supplemented with new articles. In one of its sections the rules for the arrangement of quays and other surface structures (bathrooms, laundries, shopping places, cages, etc.) were presented. During 1880–1890, the Compulsory Regulations concerning fire safety and sanitary condition of the city were repeatedly issued in Saint Petersburg.

Similar regulations were issued in other cities in accordance with their needs and specific character. In 1912, city societies and territorial establishments (zemstvos) were ordered to develop the Compulsory Regulations on measures for sanitary protection of air, water, and soil in connection with adverse situation in respect of sanitary conditions.

One of the major regulatory documents that determined development of urban settlements from the second half of XVIII century was the city plan by Imperial consolidation. It should be noted that the provision, which became a part of the Building Bylaw article stating that "cities are built just in accordance with plans approved in the prescribed order", remained unchanged since its proclamation in the XIX century.

In the early XX century Saint Petersburg got in a number of crisis situations (housing, sanitary, transport ones), which were interlinked and required not a separate solution of every problem, but comprehensive approach based on accurate statistical calculations and the newest achievements of city-planning art of that time.

Active participants of creative unions of the city — architects, engineers and technicians — put forward proposals and projects of reconstruction of Saint Petersburg, Petrograd. Among the authors of these proposals and projects were F. Ye. Yenakiev, L. N. Benois, P. O. Salmanovich, Yu. P. Suzor. The main principles for reformation of the capital for elected city authorities were to be: solution of tasks of public hygiene, supply of the city with drinking water, sewerage arrangement, building of hospitals and low-cost housing for poor people, creation of free green areas (parks and gardens), reconstruction of old residential blocks, conservation of architectural monuments, transfer of industrial enterprises outside the city, easy and cheap transport connection between the center and suburbs.

Thus, the main way to prevent the crisis that emerged in Saint Petersburg, should have been urban planning modernization of the city structure which entailed the changes not only in object-spatial environment, but also in relations between the state, city authorities and citizens. There appeared the urgent need to develop a new city reconstruction plan. The commission that was established for this purpose in 1916 did not have enough time to push the matter through.

The Municipal Statutes, issued in the second half of the XIX century, ordered to City Councils to submit to the Minister of Internal Affairs for approval newly created plans and changes introduced in existing approved plans of principal towns of provinces. The rest of the cities and suburbs were considered by local provincial authorities and approved by Provincial governors.

In 1880, the new plan for settlement of Saint Petersburg was approved, which became the legal instrument for development of the city nearly for forty years (Zolotareva, 2014). Works on development of the detailed plan of Moscow, which had the aim of settlement of urban thoroughfares, were launched in 1886.

According to the Saint Petersburg plan of 1880, some transformations were made in the city, that were mainly connected with extension of existing and laying of new streets which connected individual parts of the city. This document, that was intended to manage the elements of mass construction, was realized with great difficulties. The reason was that funding of urban works was in fact under the jurisdiction of city authorities. Implementation of large-scale events laid a heavy burden on the city budget, therefore, only priority and urgent urban planning problems were resolved. Therefore, this period is often characterized as the time when urban planning initiatives lost their former large-scale and ensemble focus.

Summary

1. As a result of political and economic reforms in the second half of the XIX – early XX century, formation of the new city regulation system became possible, in which the citizen, the owner of real estate, became a full-fledged participant of the city-planning process. His tastes, preferences, and interests formed the city environment, his mutual relations with urban planning and city regulation authorities became one of the bases of the city planning policy of the late XIX – beginning of the XX century. The result was building development that became almost dominant in the territory of Saint Petersburg's historical center. At this particular time new types of buildings in terms of their functionality, as well as spacial-planning and design characteristics appeared.

2. City management authorities, as well as territorial establishments (zemstvos) largely depended on state bureaucratic and police authorities. At the same time, creation of new management authorities contributed to establishment of social-political and cultural life, helped trade and industrial development of Russian cities.

3. City planning reorganization of Saint Petersburg in the second half of the XIX – early XX century had features that were typical for the city representing a large developing industrial center. This was accompanied by population growth and, as a result, urban densification in the center and its further growth in the suburbs. The following factors had great city-forming significance: expansion of the railway network, establishment of large industrial enterprises which, in fact, created the "industrial zone" around Saint Petersburg, development of the public transport network that connected the center with city outskirts.

Conclusion

Development of urban planning regulation in the late XIX – early XX century provides an invaluable lesson on compromise between priorities of the urban society as a whole and other participants of the architectural and construction process. And this is even more important at the present time when new socio-economic conditions offer challenges of transformation of the Saint Petersburg historical environment, ownership of private persons and third-party departments of the areas that were assigned to them according to building plans.

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