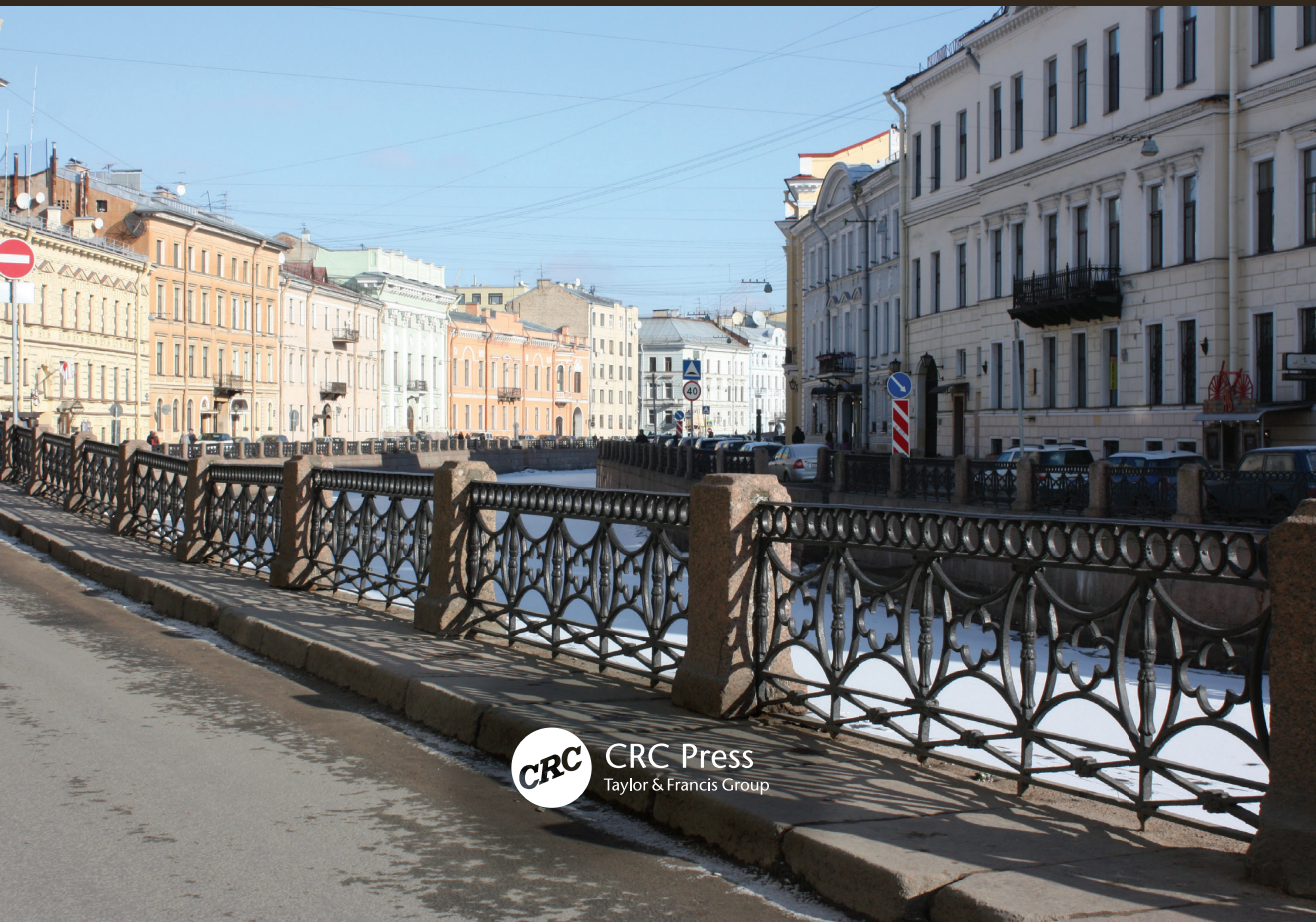


# Reconstruction and Restoration of Architectural Heritage 2021

Edited by  
Sergey Sementsov,  
Alexander Leontyev and  
Santiago Huerta



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RECONSTRUCTION AND RESTORATION OF ARCHITECTURAL  
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# Reconstruction and Restoration of Architectural Heritage 2021

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## Preface

We are pleased to present the new book *Reconstruction and Restoration of Architectural Heritage 2021*, which was prepared at the oldest department of the St. Petersburg State University of Architecture and Civil Engineering (SPbGASU) together with prominent scientist and experts in the field of cultural heritage preservation, conservation, restoration and renovation of monuments.

The book *Reconstruction and Restoration of Architectural Heritage 2021* presents the main directions of the conference of the same name (RRAH 2021, St. Petersburg, Russia, March 24-27, 2021) in key focus:

- the historical formation of buildings, construction and territories;
- the conservation, reconstruction and restoration of buildings and constructions: The transformation of historical spaces and areas;
- parallels and features in the development of urban planning, architecture and construction art in Russia and Spain: The fate and work of Augustine Augustinovich Betancourt.

We are well aware that the preservation of cultural heritage is the most important task of preserving the memory of civilizations. Through the efforts of the international community, UNESCO, ICOMOS, ICOM, and other public organizations were created to fight for the preservation of cultural heritage, including immovable architectural monuments.

The collection is devoted to many aspects, stages, and problems of preserving cultural heritage and includes an overview of professional work with monuments.

In 2021, the RRAH 2021 conference, supported by Spain, focused on the development of the historical and architectural destiny of Spain and Russia and devoted the biography and creative activity in the early 19th century in Russia of the outstanding Spanish engineer Augustin Augustinovich Betancourt. Along with this, the collection contains articles by many authors from different countries on various aspects of historical and modern study, restoration of architectural monuments, and reconstruction of major historical objects of urban planning, as well as on many complex and problematic aspects of engineering reconstruction of monuments.

This book is intended for scientists and specialists and combines materials about the history and restoration of many of the largest nature reserves, estates, cities, and monuments.

Doctor of Architectural Sciences, Professor S. V. Sementsov.



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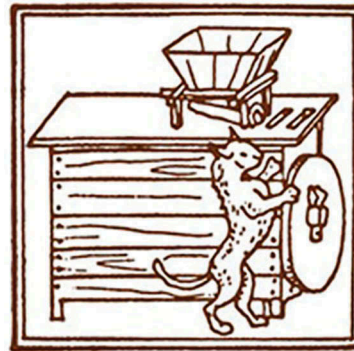
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*The historical formation of buildings, construction and territories*



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# Construction history: Tool to improve maintenance and intervention in built heritage

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**ABSTRACT:** This paper describes intervention in a building that can be considered historic. The objective is to reflect on the role that construction history (CH) has had on the decision-making process in a refurbishment project. At the same time, a series of tasks are proposed to be addressed by the CH. These are activities that are already carried out and are disseminated in congresses and magazines dedicated to the discipline. Systematic works are proposed, with the aim of defining temporal and geographical catalogues of construction procedures and materials.

## 1 INTRODUCTION

The objective is to describe the intervention process in a historic building, highlighting the issues in which construction history (CH) can provide knowledge that helps decision-making during the project and execution of the work. Several study objectives included within the scope of the CH are indicated which, if achieved, would be very useful in the work of technicians on an intervention project in an existing building.

The work in question is made of reinforced concrete and construction was completed in 1935, making it more than eighty years old. It was in uninterrupted service for fifty years dedicated to the use for which it was conceived, followed by thirty years in which it housed different activities. It has imperfections due to multiple causes: careless use, lack of maintenance and repair. Material deterioration is one of the consequences of lack of proper maintenance.

The building in question is Legazpi covered market, in Madrid. This work was completed in 1935 by the architect Francisco Javier Ferrero, and the engineer Alfonso Peña Boeuf collaborated in the design and calculation of its reinforced concrete structure. This building was one of a series of markets built during the second republic to improve public health and distribute food in a hygienic and controlled manner. The Puerta de Toledo fish market was built at the same time.

The building served as a wholesale fruit and vegetable distribution centre for the whole city. It was organized in two levels: the ground floor and the first floor. Goods entered by train on the first floor and were distributed on the ground floor after being taken up to the area corresponding to each distributor. The merchants' warehouses were on the first floor, and an adjacent street allowed direct road access by lorry.

## 2 PROJECT DESCRIPTION

The project is located on a triangle-shaped plot with sides measuring 290 m, 240 m and 200 m. The building is located parallel to the boundaries of the plot and occupies a depth of 37.50 m around the perimeter, leaving a large patio inside. The building is organized in 6 corridors, five of them 6.50 m wide while the external one is 4.00 m wide. The ground floor railway track ran through the 4.00 m wide external corridor. The rest of the floor was open plan. The upper floor was organized around an uncovered central road, corresponding to the fourth corridor from the outside, through which delivery vehicles circulated. The two bays adjacent to the central road functioned as sidewalks with lifts to the lower floor. The merchants' warehouses were on each side. The roof here is the distinctive formal feature of this building. The central bay in which the road was located was open, and the two sidewalks are covered by cantilevered slabs with a span of 6.50 m.

The structure of the building is in ten blocks of reinforced concrete separated by expansion joints. Eight of these blocks have the same arrangement although they are of different lengths. The other two blocks have a similar organization although it is modified to adapt to the corners of the plot.

The flooring consists of a 10 cm thick reinforced concrete slab placed over 15 cm wide concrete beams 1.30 m apart. The beams are supported by other larger section beams. The beams are arranged in lengthwise to the blocks, except in the bay of the carriageway where they are transverse and the joists, which here are thicker, run lengthwise. On the upper floor the layout is similar, and the cantilever that covers the sidewalks that flank the central road is

composed of a solid variable thickness slab with a span of 6.50 m. These slabs vary in depth from 11 cm at the end to 28 cm at the start.

The structure is regular. The sections of the supports are all 50 cm x 50 cm, except for the supports located under the road that are 60 cm wide. The floor joists are 35 cm x 15 cm in the outer bay, 45 cm x 30 cm under the driveway and 45 cm x 15 cm under the rest of the ground floor. On the roof they measure 60 cm x 15 cm.

The ground on which the building rests is sand and the level of the pavement varies from 1.50 m to 3.50 m below the ground floor level. The foundation consists of isolated square 2.50 m to 4.90 m footings depending on the loads, so that contact stress with the ground is less than 0.3 kg/cm<sup>2</sup>.

Intervention in existing buildings is a common activity and systematic procedures for various types of structures have been established. There are instructions for the Inspection of reinforced concrete structures such as the ACI, or inspection manuals for wooden and steel structures.

Recommendations generally include the need to perform several tasks: a) a study of the procedures and materials used at the time of construction as preliminary work, b) inspection visits to the building, with various degrees of detail, c) tests of the materials with which the building is constructed, d) verification that stability, resistance and rigidity requirements meet current codes, e) drafting of reports on the state of the structure, the needs for repair or reinforcement and, finally, f) the project containing necessary actions.

### 3 TASKS REQUIRED IN THE INTERVENTION

Knowledge of construction history is relevant for each of these activities, and each aspect will be discussed below. Actions in the building under study will be described, pointing out what the construction history has contributed and tasks that should be addressed in the future.

#### 3.1 *Construction procedure and materials*

The market building structure consists of concrete reinforced with smooth steel bars. A series of tests determined the quality of these materials.

The qualities of the materials used and the way in which the reinforcement is arranged and the anchorages differ from current practice. There were no obligatory minimum amounts and the arrangement of the bars tried to adapt to the trajectory of the forces, using curved bars in the beams and slabs. Likewise, the solution of the joints between beams and supports or between slab and beams differs from contemporary practice.

One of the objectives of CH was to describe the patented reinforced concrete systems that were used to a greater or lesser extent until the end of the

1920s, as well as the works carried out by the first technicians who used them independently of the registered trademarks. There are numerous works in which buildings using patented methods and others by independent technicians are studied, as well as others on works by companies in different periods. Likewise, there are studies that focus on the quality of the materials used.

However, there is no systematic compilation in which practices used in different geographical areas and times are described. Works should include the different construction systems and materials characteristics. There are a large number of sources from which such data can be obtained. On the one hand, there are the buildings themselves, in which different types of works have been carried out and in which the construction procedures used and the quality of the materials have been investigated. Although there are many examples distributed in conferences and magazines, they have not been systematically compiled.

Sources of information include works' technicians' files, files of companies that carried out construction work and those of the laboratories that tested the materials used. This type of information is available in Spain for at least the last 130 years. For instance, ACI instructions include tables with minimum strength values for concrete and steel that can be assumed, grouped by date.

On the other hand, within the historical study of construction and material systems it is necessary to include intervention, repair and reinforcement techniques that have historically been used. In all of the buildings that we can call historical, at some point works will have been carried out to modify, repair or reinforce parts of them.

The study of each procedure must be accompanied by what is known about its history, including the consequences of the deterioration of interventions and the results of these in the original building. This will make it possible to forecast expected damage.

#### 3.2 *Building inspection*

Alfonso Peña Bouef was in charge of designing this reinforced concrete structure, and he left a publication in which he briefly described it. Although no project documents were located, those corresponding to other similar projects from the same time and in nearby locations are available, as well as contemporary technical texts describing similar works. These give an idea of how the slabs, joists, beams, supports and footings were organized. Inspection visits were planned using these data. Prospecions were made at various points based on information, which made it possible to confirm the arrangement of the reinforcement in the different elements.

Previous information about the building in which construction period, type of building and the structure used are specified, together with CH data, make

it possible to gain an idea of what one can find in a building and thereby to plan the first inspection. The CH will provide information on the type of structure to be expected, the way in which it will be arranged and, in each case, the relevant aspects on which attention must be focused.

But it should also warn of the different types of damage to be expected, the way they manifest and the procedures and materials used in each period of time to carry out repair and reinforcement work.

To discover the state of the building it will be necessary to carry out several visits, each with a different scope each, so that what is identified in each inspection makes it possible to specify the objectives to be investigated in the following ones. In any case, the objective is to conclude with a detailed survey of the building and structure. The layout and dimensions of the building, its parts and in particular the structural elements must be specified. In addition, the type of damage observed, its location and magnitude must be precisely detailed in structural elements, floors, beams, supports or walls, as well as in other construction elements.

The information that the CH can provide for building inspection is based on studies of buildings published in different journals or congresses. One of the objectives of CH is the description of buildings and the different techniques used in their construction. In addition, CH must include the techniques and materials used in their maintenance, conservation, repair or reinforcement throughout their existence.

### 3.3 *Materials testing*

To complete inspection information a series of tests and inspections were planned to confirm the arrangement of the reinforcement and the strength of the concrete and steel. These inspections made it possible to discover the distribution of the reinforcement in the elements and different joints. With this it was possible to draw the distribution of the reinforcement throughout the structure. The tests showed not only the strength of the steel and concrete, as they also indicated the degree of homogeneity of their quality.

One CH objective is to study of the materials used in different works. Existing monographic works should be completed with a systematic study of the temporal and geographical distribution of the materials used, their strengths, expected causes of deterioration in each case, and techniques used historically for their repair or reinforcement.

Tests should not be limited to those intended to quantify the strength of the materials, but should include tests on the building itself and past load tests. Although it is a relatively modern technique, all model testing carried out prior to construction should also be included, as this technique was used for some buildings.

### 3.4 *Verification of structural requirements*

The objective of the project in Legazpi Market was to modify it for use as offices. The forces specified in the current code for this use are less than those foreseen in the original project. On the other hand, inspection revealed the existence of some major additions of material that created a load greater than the structure's own weight. The choice of light flooring together with modification of its use meant that the weight of the new building, including the expected forces, will be less than it had been throughout its history.

The observations made in inspections made it possible allowed to draw the arrangement of the reinforcement in the different elements. With this, it was possible to obtain the strength of the various structural elements and, finally, the total permissible load. Verifying that the expected forces are less than the maximum obtained shows that the strength requirement is met for the new use.

To verify the structural requirements for strength and stiffness, the need for structural analysis is commonly mentioned. It is often said that the resistance required at each point should be compared with that of the structure. Thus, if the capacity is greater at each point, than the stresses obtained by analysis, it can be concluded that the building structure meets the strength requirement. However, analysis of the structure should only be approached with the precise knowledge of the way in which the connections between elements are made: how they connect slabs and floors with the beams and these with the supports, the supports with each other and with the foundation.

In hyperstatic systems, although comparison of the stresses obtained after analysing the structure with what the different sections support makes it possible to validate a structure, this cannot invalidate it. It is a sufficient condition, but not a necessary one. In order for the results of analysis to confirm the capacity of a structure, it is necessary to identify the arrangement of the reinforcement at each point and thus know the capacity of each section. This analysis should be approached by taking into account the actual capacity of each section.

The data provided by CH will make it possible to create a correct hypothesis regarding the arrangement of the elements and their resistance capacity, which must be confirmed by inspection. It should provide information on the geographical and temporal distribution of the technical solutions used, but it should also include a systematic study of the codes used. In the same way that there are numerous monographs on standards, stonework, carpentry or construction in general, a systematic study of the codes used in different countries should be carried out. Studying codes parallel to the study of the technique used will make it possible to discover to what extent the aspects that are codified are conditioned by the uses and technical capacity available in each era.

This study will show that there were no codes to regulate forces in buildings until a few years ago, when this need began to be considered. On the other hand, another current shortcoming is the lack of procedures to quantify the safety of an existing structure and how close it is to collapse. Obtaining tools that quantify the safety of an existing structure and covering all types of buildings and their foundations will make it possible to adjust the budgets necessary to carry out interventions in buildings with the necessary safety.

### 3.5 Reports and projects

Several documents were available to prepare a detailed report on the market building. A survey of the building made it possible to have detailed plans in which the shape and sections of the different structural elements were specified. In addition, a report on the state of the building described the state of the structure, the situation of the reinforcements in the different elements in terms of their position and diameter, and provides details on the resistance of the materials. A geotechnical report prepared in 2008 at the same time as the previous one describes the position, size and depth of the foundations, as well as the type of terrain found up to a depth of 30 m from the base level.

With this initial information a work plan was prepared simultaneously with the project to precisely show the extent of the damage. To complete the report on the condition of the building, so that it could serve to assess the scope of the intervention, a comprehensive inspection of the condition of the structure was carried out. The types of damage found were classified and detailed, identifying their origin, indicating their location and size on the plans. With this it was possible to know the precise amount of repairs to be carried out.

Preparing the building status report coincides with one of the tasks that are carried out when investigating construction history. This task includes those mentioned in the previous sections, summarising them. One of the objectives of CH will be to help systematize the writing of these reports.

As sources of information, in addition to monographic works in different CH magazines and congresses, or technical journals in any field related to construction, there are others that should be used. Files of the technicians, architects and engineers involved in construction and intervention projects, files of the different administrative bodies, files of laboratories and companies involved in the control and construction of new and repair works, as well as files of materials companies and construction systems.

## 4 DISCUSSION

Construction history is not an auxiliary discipline about intervention in buildings, as it is an

autonomous discipline. But we propose here that the results of research in construction history may be useful in decision-making when intervening in an existing building. An objective is proposed for construction history that consists of ordering the information on built heritage in such a way that the following objectives can be achieved:

- A detailed timeline of the systems and materials used in different types of buildings in different geographic areas.
- A catalogue of expected damage associated with each system used and material, adapted to each geographical area with similar characteristics.
- A catalogue of the repair and reinforcement techniques and materials used in each period of time and geographical area, and the effects that these interventions have had on the buildings in which they were used. A description of the damage that they may cause and the evidence of their appearance.
- Study of the different building codes. Among the aspects to be investigated is the evolution of the methods used to analyse structures and calculate the sections used, as well as how to check safety.
- Help define codes of good practice in the study and verification of existing structures, in the verification of safety and in the drafting of intervention projects.
- Definition of inspection procedures and dissemination of research results in existing buildings.
- Include the above objectives in the curricula of the disciplines involved in building together with the study of CH.

## 5 CONCLUSIONS

Investigating CH has given rise to better knowledge about existing buildings. Although it is not a purpose of the discipline, thanks to the information it provides, the technicians in charge of carrying out intervention projects can correctly interpret the real situation of constructions and propose actions that, while respecting the qualities of a building, are more economical and durable.

The text proposes seven CH objectives which would be of great help for the interpretation of the situation of built heritage, as well as a working basis for planning preventive maintenance actions. The useful life of buildings would thereby be lengthened and the costs associated with rehabilitation, repair and reinforcement would be reduced.

## 6 FUTURE WORK

One of the fundamental tasks involved in achieving the objectives set out in this work is to synchronize the efforts of scholars from different geographical

areas to organize their work and initiate synthetic work on existing and new research.

## ACKNOWLEDGEMENTS

Legazpi Fruit and Vegetable Market is owned by Madrid City Council. In 2007 a competition was held to undertake its reform to convert it into municipal offices. The architects Jesús Ulargui and Eduardo Pesquera won this competition and prepared a project that was delivered in 2008. Although it was not implemented, in 2016, the city council promoted another project which modified the previous one. In 2017, repair works were carried out on the structure. In order to carry out the projects several technical reports had to be consulted. We would

like to thank the architects involved for their help in consulting these reports as well as the different projects.

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# Architectural and historical studies of the Exalted Church over the Holy Gate of the Bishop’s Court in Vologda

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**ABSTRACT:** The history of the construction of the Church of the Exaltation of the Exalted over the Holy Gate, which is part of the cultural heritage object “Vologda Kremlin Ensemble” and is accompanied by an architectural and artistic analysis of the building: “Bishop’s House and other buildings, XVI-XIX centuries.” is considered in chronological order. The methodology of the work is based on the study of archival and bibliographic sources, field surveys of the building, comparison of historical and modern photographs, analysis of the environmental environment in the historical context, identification of the characteristic features of the monument of ancient Russian architecture. The purpose of the study is the architectural and artistic analysis and systematization of information about the object of research. The Gate Church of the Exaltation is located above the main Holy Gate of the complex of residential, economic, buildings, and defensive fortifications, which, together with the grandiose St. Sophia Cathedral located nearby, is a single ensemble representing the compositional and ideological core of the historical center of Vologda.

## 1 INTRODUCTION

The gate of the Exaltation of the Holy Cross Church with the Holy Gate was built in the early XVIII century in 1671 and is located on the territory of the Bishop’s Court and is an integral part of the complex of buildings and structures, religious, civil and fortification purposes, forming an ensemble of the monument of ancient Russian architecture and Russian ensemble architecture. (Beloyarskaya 2018). The unique architectural ensemble is located in the central part of the historical core of Vologda on the right bank of the Vologda River. Currently, it is used by the Vologda State Historical, Architectural, and Art Museum-Reserve (Figure 1).

## 2 MATERIALS AND METHODS

The earliest information about the construction of the Holy Gate and the construction of the Exalted Church over it was found in the lists and inventories of the Bishop’s House, the parish-expense books of the Bishop’s Court, which are located in the Vologda State Archive. And the earliest publications about the construction of a complex of buildings and structures of the Episcopal metochion on the territory of the new detinets-the Kremlin of the city of Vologda, the construction of which began by Ivan the Terrible in 1566, appeared at the end of the XIX century. Describing the entire complex of the Episcopal

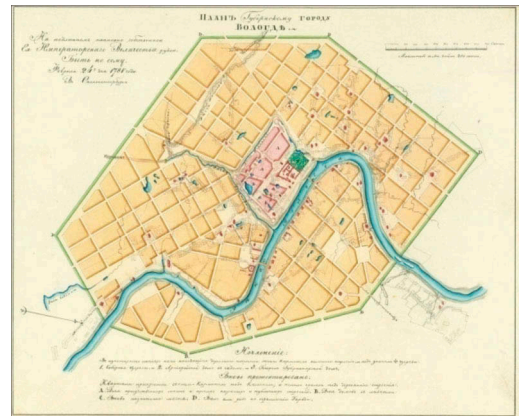


Figure 1. A copy of the first confirmed plan of the city of Vologda in 1781, which is placed in the “Atlas of Cities of the Vologda Viceroyalty” (Russian State Military Historical Archive, f. 846. inv. 16. cas. 21544 sh. 2).

Metochion, each author gave a detailed description of its individual buildings, in particular the gate church of the Exaltation over the Holy Gate. These were books by researchers-local historians A. A. Zasetky, I. K. Stepanovsky, N. I. Suvorov, N. P. Brusilov, B. I. Dunaev, etc. In their books, they published historical information, sometimes contradictory. Later, in the 60s and 70s, the works of art historians and architects M. V. Fechner, V. Banige, and A. K. Vedrov

appeared, which were also mostly descriptive in nature. In these works, there was no analysis of historical sources, materials about the urban history of the environment of the object of study.

The research aims to analyze the architectural and artistic aspects and systematize the information about the main stages of the construction of the Holy Gate and the subsequent construction of the Gate Church of the Exaltation of the Holy Life-Giving Cross, located in the eastern wall of the Bishop's Courtyard.

### 3 RESULTS AND DISCUSSION

The yard of the Archbishop of the Vologda Diocese was moved down the river from the ancient concession stand, which was on the "Lazy Site", to a new location, in connection with the grandiose construction of a powerful fortress - Kremlin in the city of Vologda, conceived by Tsar Ivan the Terrible as a stronghold of the Oprichnina and the placement of the northern royal residence here. Immediately after the construction of the fortress walls began in 1568, the foundation of the cathedral church in the name of the Assumption of the Mother of God was laid, in the likeness of the Assumption Cathedral in Moscow, later consecrated in honor of St. Sophia of the Wisdom of God. At the same time, the wooden buildings of the bishop's residence began to be erected directly behind the cathedral.

The residences of the bishops were built in the central part of the Old Russian city near the main city cathedral. The planning composition and spatial structure were usually formed according to the type of the Orthodox monastery ensemble: the central core, which included the bishop's chambers, the refectory, and the house church (in the monasteries it was the main cathedral, the refectory, and the abbot's chambers), and the placement of residential and out-buildings around the perimeter. The entire complex was surrounded by a fortress wall (Figure 2).

It was mandatory, as well as in monasteries, to set up the main front gates - the Holy Gate and the Watergate, the household gate, through which water and firewood were transported. The Watergate always went to the source of water - a river or lake. The Holy Gate had two entrance arches. One was smaller for people on foot, and the other was wider and taller for travel.

The main Holy Gate was located opposite the front porch of St. Sophia Cathedral. The path from the Joseph's Building through the Holy Gate to the main entrance to the cathedral was paved with bridges. It was not just a road from the Bishop's chambers to the main cathedral of the city. It was a road connecting the world of the "Mountain" and the world of the "Valley", as well as connecting the people with their shepherd.

The first complex of the Bishop's Court was built opposite the main city cathedral in 1585-1587. At first, all the buildings of the complex were wooden,

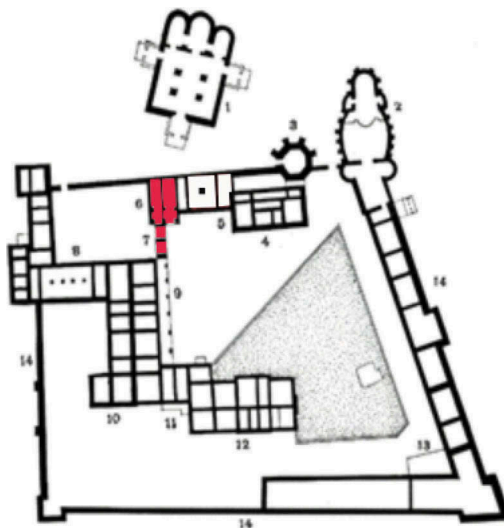


Figure 2. Plan bishop's monastery and churches of the city of Vologda (Bange 1970).

1 - Cathedral of St. Sophia; 2 - resurrection Cathedral; 3 - a bell tower; 4 - public order; 5 - ring housing; 6 - the gate Church of the exaltation; 7 - go to gallery Phillips chamber; 8 - Consistorial housing; 9 - cross chamber with the Church of the Nativity; 10 - Ianevski body; 11 - Gabriel's Palace housing; 12 - Josifovski housing; 13 - service of the body; 14 - wall and towers of the Bishop's house their accessories.

and the fence was wooden. The fence of the Bishop's court had several gates. In the eastern wall between the bell tower and the south-eastern tower of the fence, there was a "Watergate", which was intended for the supply of water from the river and other household needs. In the northwest tower, there was another gate, the "Passing Gate". In the middle of the eastern wall of the fence, which separated the complex of the Bishop's Court from the St. Sophia Cathedral, opposite the western entrance to the cathedral was the Holy Gate. In 1650-1653, a church was built over the Holy Gate in the name of the three Perm Saints Gerasim, Pitirim, and Joseph. The church was completed in the form of three tents (Suvorov 1898).

In 1654, the production of bricks began in connection with the construction of the stone cathedral bell tower, which was built into the wall fence of the Bishop's house. In 1658, the first stone building of the "State Order" was built in the Bishop's yard, later called the Economics building. (Beloyarskaya 2018). After the completion of the construction of the Economics building and the tent bell tower in 1673, in July, the laying of the stone wall of the fence begins, and more specifically its eastern spin from the bell tower to the Holy Gate (Trekhsvyatsky Gate), and then the foundation of the stone Holy Gate, "under the Trekhsvyatsky Gate, ditches were dug... and piled with stones and wooden beams ..." (Archive Service of the Voronezh region f. 883. op. 1. cas. 3).

The construction of the Three Holy Gates and the eastern wall-fence was completed in 1674 in the month of July. The stone gate in the name of the three Permian Saints Gerasim, Pitirim, and Joseph had a three-tent completion. In 1687, the construction of the stone church of the Exaltation over the Holy Gate began (Figure 3). Before the construction of the church, it was necessary to increase the volume of the Holy Gate in the western direction. The construction was completed in 1692 (Perfilieva 2000).

By the beginning of the XVIII century, small volumes of the L-shaped porch were added to the western and northern sides of the church (Figure 4).

The Church of the Exaltation is a slender chetverik covered with a vault, completed with one small chapter, which appeared at the end of the XVIII century, instead of three decorative tents, repeating the shape of the previous ones, crowning the wooden gate (Brusilov 1883). Currently, the Church of the Exaltation is



Figure 3. The Holy Gate with the Exalted Church of the Bishop's House of Vologda. Photo by author.

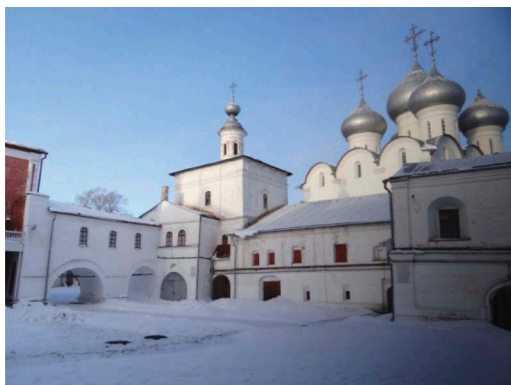


Figure 4. The Church of the Exaltation over the Holy Gate from the inner courtyard of the Bishop's House. Photo by author.

located on the base, which is the volume of the Holy Gate.

Before the construction of the Gate Church, it was necessary to increase the volume of the Holy Gate in the western direction. The Church of the Exaltation is built on the base, which is a slightly elongated rectangle in the plan from west to east and is the lower (first) tier of the entire structure. The first tier is divided in width into three parts. The first narrowest part was the passageway in the Holy Gate for pedestrians, the middle part served as a passage and the third part was a room, probably it was the gatekeeper's lodge. With the increase in the volume of the Holy Gate, the part of the northern wall of the building of the Storeroom of the Chamber on the cabbage cellars, which was not adjacent to the wall of the gate, became part of the wall of the pedestrian passage, which is confirmed by the preserved details of the decoration of the outer wall of the Cabbage cellar in this passage. Two windows located on the northern wall of the cabbage cellar, located on the first floor of the Storeroom building, were also laid in the interior of the cabbage cellar and turned into niches-stoves. The builders also arrived with three windows on the north wall of the chamber's Storeroom, located on the second floor above the cabbage cellar. In the interior of the Storeroom of the chamber, niches appeared, repeating the size and configuration of the laid windows (Figure 5).

Two and a half meters from the entrance in the pedestrian passage is an arch with a gap for the gers grating, and two and a half meters later another arched opening. It is obvious that the territory of the complex of the Bishop's House was well guarded. Between these two arches on the south wall of the passage is a small niche. The outer entrance arch (from the side of St. Sophia Cathedral) is laid, but the fastenings for the gate hinges are preserved and a small window is left, which is covered with



Figure 5. Diagram of the periods of construction of the Church of the Exaltation. a) First floor, b) Second floor. The author's drawing.

a metal grating. On the side of the courtyard, there is a door that appeared no later than the beginning of the XX century. Minor repairs were carried out in the room, there are fragments of fresh brickwork in the lower part of the walls.

The arched opening for the passage, which is also an elongated room, but larger in width, is located in the center of the first tier. The arched opening of the outer entrance is covered with plywood panels, but it has completely preserved its original dimensions. The arch also has a slot for the gers grating, but it is "sewn" with a wooden board. A short distance away is another arch. Also, a small arch is located at a short distance from the entrance to the room from the courtyard of the complex, which has a door that also appeared no later than the beginning of the XX century. In the room, there are traces of repair work-grout cracks on the walls and ceiling. In the part of the northern wall, which is located closer to the entrance from the courtyard, there is a rectangular opening with the remains of the door jamb to the third room. However, it is clear that the ceilings are wooden, there are no window openings in the room. Outside, almost from the wall fence, there is a huge arch in the wall of this room, with the gates sealed tightly.

Finding out the meaning of the arch is possible with more in-depth research with disclosures.

The second tier, the completion of the Holy Gates – the Gate of the Exalted Church. The main quadrangle of the church is a two-light cubic volume covered by a vault, which is crowned by a small baroque-shaped dome. At the end of the arch, there is a round hole, the presence of which can be assumed that the original drum of the dome was light.

On the west side, a small porch adjoins the quadrangle, shifted to the north so that there is room for a small window opening on the western wall of the first "light" (tier) of the main quadrangle. Also, on the west wall are two arched openings for the entrance to the church from the porch. The narrow northern opening is open, the wide one located on the axis of the western wall is laid on top and there is a double-leaf door.

On the north wall, also at the level of the first "light" in the center, there are two large windows, with wrought-iron bars, authentic fittings, wooden window frames, these windows overlook the gallery porch, which adjoins the western wall of the quadrangle. The second light of the quadrangle is illuminated by three small windows located on the axes of the north, west, and south walls. Obviously, the same window was on the eastern wall, but in the interior of the temple it is missing, and only on the eastern facade is visible a fragment of a niche, almost completely covered by the ridge of the roof of the altar apse. Above the windows of the second light in the vault, there are spandrels. With the altar part, the chetverik is connected by three arched openings: the central one, located on the axis wide, two side ones lower and narrower.

The altar apse is adjacent to the quadrangle on the east side, traditionally for gate temples of rectangular shape and in the plan is a continuation of the main volume-The altar apse is adjacent to the quadrangle on the east side, traditionally for gate temples of rectangular shape and in the plan is a continuation of the main volume – quadrangular frame. The altar is separated from the main volume by a wall with three arches – the central one is wide and the two side arches are narrower. The altar apse is illuminated by two windows in arched openings located on the eastern wall. The altar is separated from the main volume by a wall with three arches – the central one is wide and the two side arches are narrower. The altar apse is illuminated by two windows in arched openings located on the eastern wall. The windows are slightly smaller in size than the openings, resulting in semicircular gables above the windows. On the inner side, the eastern wall of the apse along the axis, between the two windows, has a niche, also arched, protruding from the wall. On the southern and northern sides of the apse, in the walls, there are two doorways opposite each other, forming a space that is a continuation of the passage along the eastern wall-the fence of the entire complex of the bishop's house and this kind of corridor was used for this purpose. This path could be accessed by exiting through the main western entrance of St. Sophia Cathedral through the Holy Gate to the bell tower. The passage along the back wall of the altar, almost through the altar space, is a rare phenomenon, but it is found in Orthodox churches. Especially since the passage was used by a narrow circle of people. Perhaps the altar was separated from the passage by a partition. The altar apse is covered with a box vault with decking over the windows.

On the west side, a small porch adjoins the quadrangle, shifted to the north along the western facade. Two arches lead from the porch to the church – a large and a small one. There is also a door in the north wall that connects the porch to the gallery porch. On the west side, two windows well illuminate the small space of the porch.

Another room, strongly elongated, which is adjacent to the main volume of the church – the quadrangle on the north side, is a passage gallery-porch. On the west side, it has a wide entrance door, through which at an early stage one got from the courtyard space to the church on a high porch. On the opposite eastern side of the wall, there is an arched niche, which is repeated on the eastern facade. This suggests that there was a window here first, laid later. On the north wall, there are two large windows, but on the facade, there are two niches on the sides of the windows. The gallery porch is covered with a cylindrical vault with decking over the windows. Above the entrance door to the gallery porch, two pewter doors are visible, and a chimney has been preserved on the outside above this entrance.

The last room on the second floor is a covered passage from the house church of the Nativity of

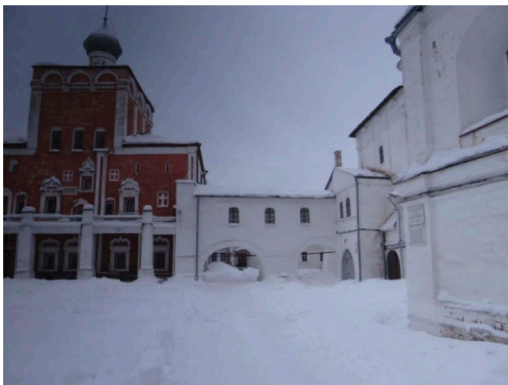


Figure 6. Covered passages from the House Church of the Nativity of Christ to the Vozdvizhenskaya Gate. Photo by author.

Christ to the Gate Church of the Exaltation. But in fact, this is one passage from the building of “Joseph the Golden” through the open gallery to the Church of the Nativity of Christ, and then through the covered passages to the Gate Church (Figure 6).

The covered walkways are supported by two powerful arches that rest on a pillar located in the center. The arches still have iron links. Through the arches, you can get into a small cozy space, a kind of complex of buildings, which is called the Consistory courtyard. The passages appeared at the same time with the appearance of the first one-story building of this separate complex in the early XVIII century (Bocharov 1982). Later, the building was added to the second floor.

The entrance to the passages, and in fact, the main entrance to the complex of premises of the gate Church of the Exaltation, located above the Holy Gate, is located in the western wall of the covered passages under the open gallery of the Church of the Nativity of Christ. A steep staircase leads directly up to the second level and into a long space of passages. On the second level, next to the main entrance stairs leading from the first floor, there is a wide opening to the open gallery of the Church of the Nativity. This corridor is lit from two sides by windows: three windows on the south wall and three windows on the north wall. The central window is blocked.

There is no decor in the interiors of all the rooms of the complex of the Gate Church of the Exaltation.

The facade decor is modest. Only on the southern facade, the two-tiered passages have decoration in the form of a simple belt, repeating the pattern of the arched openings. The facades of the chetverik are decorated along the perimeter with a narrow belt of a simple profile with three false zakomars, which are loosened on the blades located at the corners and there are two blades on the eastern and western facades. Small windows of the second light of the

quadrangle, located on the axis of the facades, have a keel-shaped frame (Figure 5).

The first floor of the southern facade of the church is almost completely covered by the adjacent building of the Storeroom Chamber. The second floor, on the south facade of the quadrangular frame, completely repeats the decor of the north facade of the quadrangle and a small part of the decor, which is a continuation of the frieze of the west facade.

The western facade is a multi-volume composition—the volume of the porch shifted to the north, located on the second floor, above a wide arch, closed door to the room, which is the passage arch of the Holy Gate. The porch is illuminated by two closely spaced windows in a double keel-shaped frame, completed by a triangular pediment. Directly above the windows is a wide cornice of two shelves and a lower belt with a curb. The lower part of the windows is also marked by a protruding belt. Between the wall of the Storeroom of the chamber on the cabbage cellar and the protruding volume of the refectory is a small volume consisting of an arch, a pedestrian passage of the Holy Gate, a closed-door, above which a roof is equipped, and above the roof a window through which the lower light of the church’s quadrangle is illuminated. The window is located in a small niche, which is completed on top with a pediment of a bow shape. At the level of the overhang of the roof of the adjacent volume of the porch, a frieze runs along the wall, repeating both the pattern and the dimensions of the upper part of the cornice without a belt with a curb. The west facade on the first floor has two arches - a small and a large one. On the ground floor, there are two arches, a large one for driving and a small one for pedestrians. Above the small arch is a simple frieze, which is a continuation of the frieze of the Storeroom of the chamber on the cabbage cellar.

On the northern facade of the quadrangle, there are no middle blades and a frieze. Along the level of the bottom of the axial window of the chetverik passes the ridge of the roof of the gallery porch. On the ground floor, in the very corner, almost adjacent to the wall fence, there is an arch, commensurate with the passage arch of the Holy Gate with a wooden gate.

The most elegant and decorated is the eastern facade of the complex of the Holy Gate with the Church of the Exaltation, which opens with the altar apse and the preserved facade of the Holy Gate to the superstructure of the church, on the western facade of St. Sophia Cathedral. The Holy Gate consists of two arches, framed by keel-shaped plat bands, smaller in size for pedestrians, larger for driving. The semicircular columns of the window frames have capitals, which in the interval between the arches are additionally decorated with an exquisite decorative element. The decoration of the lower tier of the Holy Gate has been preserved since its construction at the end of the XVII century. Above the arches of the Holy Gate, almost coinciding with

them on the axes, there are two windows of the altar apse, slightly recessed in the niches. On the sides of the windows are small niches-loopholes, with a semicircular end. Above the windows is a simple pattern of the profiled belt and above it a flat cornice. The upper part of the apse wall protrudes on cantilevers, obviously imitating the machicolation of fortress towers. Also, the width of the protruding part of the wall is decorated with peculiar ears. Above the great arch of the Holy Gate is a kiosk.

The last element of the completion of the Church of the Exaltation is a small dome of late Baroque form, with a cross, resting on a round slender drum. Judging by the design of the drum, it was originally light. The drum is decorated with a cornice, which consists of shelves and a row of curbs, at the base of the drum there is a roller. Narrow windows with a semicircular end have plat bands in the form of a frame with a roller around the perimeter. On the sides of each side of the plat band-roller, there are two constrictions. The windows of the main building are sewn with sheets of iron along the contour of the openings.

#### 4 CONCLUSION

The Vozdvizhenskaya Church over the Holy Gate is a unique monument of architecture of the XVII century, it is part of the ensemble of the Bishop's Court, which includes buildings and structures of religious, civil, fortress architecture, built in the period from the XVI to the XIX centuries. The building consisting of three volumes of different function: The Holy Gate, the church, and the passage gallery is an important compositional accent of the historical ensemble, and also crowns a significant, from the point of view of ideology, structure - the Holy Gate, which divides the world into two parts: spiritual and secular.

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## Eduardo Torroja. The habitat of his revolutionary research models

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**ABSTRACT:** Eduardo Torroja Miret (1899-1961) was one of the most relevant engineers of the history of civil engineering and architecture. He played a major role in the scientific and technical revolution of reinforced and pre-stressed concrete in the first half of the twentieth century. He is internationally acclaimed not only for his innovative works, but also, like the Spanish engineer Agustín de Betancourt, for his many-faceted professional activity: designer, scientist, researcher, manager, and teacher. This paper reveals the research result on the path he followed to design and build the most suitable habitat for his revolutionary and timeless research model which allowed him to bring together the most relevant international protagonists of avant-garde engineering and architecture of the Modernity, and create international associations that, like the International Association for Shell Structures, have remained active since then, leading the advancement of new structural types.

### 1 INTRODUCTION

Eduardo Torroja Miret (1899-1961) was born at 13 Lope de Vega Street in Madrid (Spain), on August 27, 1899, into a family with a great scientific tradition. He born under the sign of the Science and grew up knowing the importance of the research and teaching. Research to advance and teach to make the advancement come true. This marked his professional life in a resounding way.

His father, Eduardo Torroja y Caballé (1847-1918), was an architect and a mathematician. Professor of Algebra and Analytical Geometry at the University of Valencia (1873) and, later, of Descriptive Geometry at the University of Madrid (1876). He renewed Spanish mathematics and spread the projective geometry of the German mathematician Karl Von Staudt. He was vice president of the Spanish Mathematical Society and of the Spanish Association for the Progress of Sciences. In 1983 he joined the Royal Academy of Exact, Physical and Natural Sciences. Eduardo Torroja grew up influenced by his father's passion for mathematics and his relevant role in the regeneration of this field of knowledge in Spain, which directly led to profound changes in teaching. At that time, at the end of the 19th century, important changes took place in Spain that traced a new course, not only in the field of mathematics, but also in different branches of Science. Suffice it to recall here the important scientific regeneration carried out by Ramón y Cajal and Leonardo Torres Quevedo, among other prominent Spanish scientists.

Eduardo Torroja Miret was born in the last year of this century that was undoubtedly the protagonist of

the Spanish scientific construction revolution. Undoubtedly, it was this leadership capacity of his father and his dual activity that infected Eduardo Torroja, and his brothers, with the passion for Science and Teaching. Three of them; José María, Antonio and Eduardo were, like their father, members of the Royal Academy of Exact, Physical and Natural Sciences.

In 1918, the same year in which his father died, Eduardo Torroja entered the Higher Technical School of Civil Engineers of Madrid, at the age of 19. He graduated as an engineer in 1923 at the University of Madrid, being the most outstanding student of his university promotion. That same year he started working at the Hidrocivil Company founded by José Eugenio Rivera, who was his professor and the introducer the use of reinforced concrete in Spain.

In 1923 Eduardo Torroja started to work as engineer in an incredibly special moment because the 1920s are one of the most revolutionary periods in the international history of engineering and architecture of the twentieth century. It was in this decade when took place three events that marked relevant changes not only about the technology of these disciplines of knowledge, but also that of all about social feeling in music, dance, painting, sculpture, and literature. The thought model forever changed.

Two of these events refer to relevant technological milestones reached in the 20th century the beginning of the scientific development of reinforced concrete and the appearance of the first prestressed concrete patent, which was registered in Paris by Eugene Freyssinet in 1928. This same year, the first International Congress of Modern Architecture/CIAM was held at the Sarrazar Castle. From that

moment Concrete and Modernity will grow up together, and a new concrete structural shape was born, Thin Concrete Shells. These new structures were the point of union of both and they became the one of the most radical symbols of this new paradigm -less, is more- constituting a Modern wide legacy of new spatial structural forms of great slenderness and flatly naked.

It was at the beginning of this special decade, in 1923 when the French engineer Eugene Freyssinet (1879-1962) built his famous Orly hangars, a 20th century concrete shell masterpiece, regrettably destroyed during World War II (1944), and was when the famous German company Dyckerhoff & Widmann, founded in 1865 (Kurrer 2018), built what is internationally acknowledged to be the first thin concrete shell dome at Jena, Germany. In 1928 the German engineer Franz Dischinger, recognized as the father of these new structures, published his calculation and dimensioning system. But this system, which was logically manual, was complex, long, and often insufficient to design new shell shapes. A fact pointed out by Eduardo Torroja (Torroja 1934). In 1934 Wilhelm Flügge published the first text on the theory of shell structures “Statik und Dynamik der Schalen”, which was translated into English in 1960 under the title “Stresses in Shell”, and which for more than twenty years was a reference for the structural design of shell structures.

These facts reveal the enormous difficulty that existed in the 1920s to access the incipient technical knowledge, for any engineer or architect eager, for this knowledge of the newly born concrete shell structures, and newborn prestressed concrete. But for Eduardo Torroja this fact was just an exciting reason to get directly involved in the development of these new materials and optimize their use in innovative structures. His work and research soon made him stand out internationally. From the beginning, Eduardo Torroja showed a special capacity to “change things”- to innovate. It is enough to remember now the Aqueduct of Tempul (1925-1927) one of the world’s first prestressed concrete structures. It has 20 m long reinforced concrete girders and 57 m cantilevered center span, was built using an ingenious prestressing system (Torroja 1958). This aqueduct can safely be called the first modern cable-stayed bridge (Schlaich 2016).

In 1927 Eduardo Torroja founded his own engineering office and at the beginning of the 1930s he founded ICON Company “Investigaciones de la Construcción” (Construction Research) intended for scientific research with reduced physical models. He wanted to participate in the Thin Shell Adventure of the Modernity, and he knew that the way was to research. Under his management, ICON Company specialized in testing models as a method for analyzing structural behavior. That approach enabled him to build largescale thin shells at a time when there were no reliable structural engineering methods able to ensure their feasibility. His micro-concrete models

made in the 1930s for the Algeciras Market (1934-1935) and Recoletos Jai-alai Court (1935-1936), both on a scale of 1:10, received acclaim. Eduardo Torroja is known internationally as the father of scientific tests on reduced physical models (Cassinello & Torroja 2018).

## 2 MATERIALS AND METHODS

### 2.1 *Construction technical institute*

#### 2.1.1 *Institute foundation 1934*

In the 1920s and 1930s, while Eduardo Torroja was building pioneering works of engineering and architecture, in Spain the world of construction was very precarious as well as the knowledge of the avant-gardes that were produced at that time an international level. For this reason and because he wanted to change the things, in 1934 Eduardo Torroja and six more professionals, architects and engineers, they founded the Instituto Tecnico de la Construcción y la Edificación (Construction and Building Technical Institute) that today bears his name Instituto de Ciencias de la Construcción Eduardo Torroja (Eduardo Torroja Institute of Construction Sciences). The team was formed by Eduardo Torroja, Modesto López Otero, Alfonso Peña, Gaspar Blein, Manuel Sánchez Arcas, José María Aguirre, y José Ángel Petirrena. They believed that it was possible to change things and that to achieve this it was not only necessary to know and spread the knowledge of the international avant-garde of architecture and engineering, but also to participate in their advancement by researching, spreading, promoting, and teaching. It was the first Research Institute founded in Spain by individuals. An important and strange fact. Unfortunately, in 1936 the Civil Spanish War began. Spain was paralyzed.

#### 2.1.2 *The resurgence of the institute 1940s*

In 1939 when the Civil Spanish War was ended Eduardo Torroja was appointed professor at the Madrid School of Engineering. He comeback to work harder than before. During the 1940s he combined his work as designer, research, professor, manager, and leader of several national and international association. The Institute resumed its activities, under the direction of Eduardo Torroja, where more and more research activities were developed united to the activities of spread and teaching knowledge.

In 1940 he was appointed Director of the Spanish Central Laboratory, in such a way that Eduardo Torroja directed the two main scientific entities related to research in the country, a fact that, together with his innovative work, placed Spain in a prominent place in the international discussions that were taking place on materials, structural design, new calculation methods, production systems and standards. In 1941, the Eduardo Torroja Institute became part,

as a member, of the Spanish Higher Council for Scientific Research (CSIC). In 1944 Eduardo Torroja delivered his acceptance address as fellow of the Royal Academy of Mathematics, Physics and Natural Sciences, as was his father.

In 1945, when the Second World War ended, a feeling of unity was created, and various international entities and associations were founded to promote the construction development and reconstruction of the devastated places. This year Eduardo Torroja was elected President of the newly created Réunion Internationale des Laboratoires d'Essais de Matériaux, RILEM. He took an active part in the creation of the Comité Européen du Béton, CEB, whose membership, despite the name, included both the United States and Russia, and which played a decisive role in the development of European technical standards for reinforced concrete. The Eduardo Torroja Institute not only led the technical and scientific development of Spain, but also contributed to the progress of civil and architectural construction at an international level. In 1949 Eduardo Torroja founded the AEHP "Asociación Española de Hormigón Pretensado" (Spanish Association of Prestressed Concrete), attached to the Technical Institute of Construction and Cement, an active means of information and dissemination. Two years later, in 1951 the FIP Fédération Internationale de la Précontrainte (International Federation of Prestressing) was founded, by Freyssinet, whom he succeeded as president in 1958. In that role, he promoted the creation of the FIP-CEB Joint Committee to harmonize reinforced and prestressed concrete standards.

It was in 1949 when Eduardo Torroja decided that his Institute, which had international relevance, it needed a new and modern habitat where it could develop, at an international level, all the research, dissemination, promotion, and teaching activities in the same space. He did not want a regular Research Institute without these other activities. He wanted a new and revolutionary Institute research model.

### 3 RESULTS AND DISCUSSION

#### 3.1 *New habitat of the institute*

##### 3.1.1 *First step of the buildings design*

Eduardo Torroja start to design the new habitat to his Institute in 1949 and he inaugurated in 1953. He spent a lot of time to get it because his Institute was not at that moment an individual and free institution, as was founded in 1934, it belongs since 1941 to the Spanish Higher Council for Scientific Research (CSIC). For this reason, he communicated the need to build a new headquarters and asked for the permission and a place to build it (Torroja 1949).

Meanwhile, he analyzed the program and buildings of the principal research institutes and laboratories all

over the world. It included the analysis carried out by the directors of 32 laboratories and/or research centers in the construction sector, belonging to 17 different countries: Germany, Australia, Belgium, Canada, Denmark, Spain, United States, Finland, France, Holland, India, England, Italy, Norway, Portugal, Sweden, Switzerland. He published these in the journal *Informes de la Construcción*, which was founded at his Institute in 1948. He wanted to know what happened in the international context. After that he decided the final program spaces that he needed. He thought that it was essential not only to investigate but also to disseminate its results, and above all, to teach how they should be applied to achieve progress. Those who were researching and building new knowledge must teach it in the same research Institute. In this way his Institute will be as a knowledge fabric.

The Spanish Higher Council for Scientific Research offered to Eduardo Torroja a place in Madrid city, but he thought that it was insufficient to house its ambitious program. But instead of saying it was inappropriate, he did three different projects in this place to show that he needed a bigger and different one. Presenting this project, it was an intelligent strategy to get that he wanted.

##### 3.1.2 *Construction of his new knowledge Fabric*

Finally, Eduardo Torroja found the perfect place. It was a plot of approximately 5 hectares located in a pine forest on the outskirts of Madrid. The architectural design of its main building consists in eight interconnected one -or two- storey wings. The ground plan of the eight-wing building resembles a comb with uneven teeth adapted to the terrain. It intentionally adopts the form of the Greek letter 'phi', generating five open landscaped courtyards that wrap around the long façades (Figure 1).

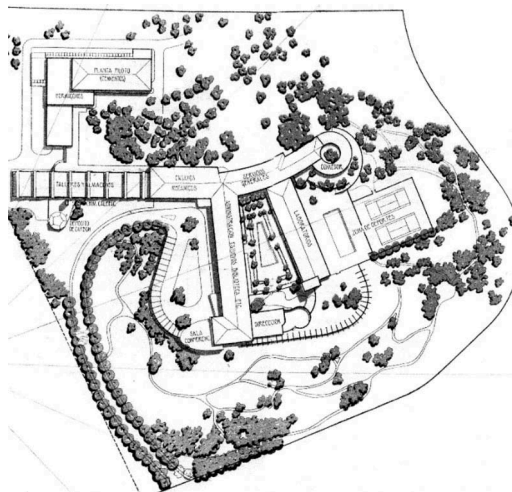


Figure 1. Ground plan of the new Eduardo Torroja Institute.

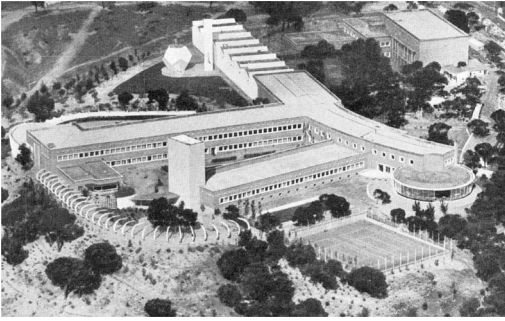


Figure 2. Eduardo Torroja Institute. General view 1953.

The Institute's program includes six types of different uses; a) those related to office work, b) laboratories and workshops for carrying out large experimental tests, c) places for international meetings and debate, d) those related to the dissemination of knowledge through the Institute's publications, e) those related to teaching, f) those destined to the expansion and human relationship between the Institute's workers, their guests and the participants in all the Institute's activities (courses, congresses, debates, conferences and meetings of international associations). In this way, the institute's activities not only included all those necessary to close the circle hat produces progress (research, dissemination, and teaching), but also included, as the Bauhaus did, places to enhance human relationships (dining rooms, fields of sports, gardens, and swimming pool) (Figure 2). It really was an attractive and humanized knowledge factory.

Torroja seized the opportunity afforded by the construction of the new headquarters to implement the institute's research findings on the rationalization of traditional construction, prefabrication and precasting (Cassinello 2014). He turned the construction site into a huge laboratory, a prefabrication school purporting to enhance the precarious resources available in Spain at the time. They prefabricated in reinforced concrete different elements as; windows, slabs, pavements, gargoyles and also ping-pong tables for the garden.

Eduardo Torroja designed for his Institute some innovative structures that shaped an organic architecture that was praised by Frank Lloyd Wright in 1958: We (who are) interested in engineering (organic) architecture in America have learned to keep a sharp lookout overseas for organic character in the work of our contemporaries. We found it in France, Italy and now in Spain in the admirable work of Eduardo Torroja. For him I have great respect.

These organic elements were the circular dining hall, the dodecahedral coal storage, the triangulated thin shell roof over the workshop and testing bays, and the peripheral pergola (Torroja 1958).

The institute's dining room is an architectural space of undoubted organic appeal. Its plant is circular,



Figure 3. The dining room of the Eduardo Torroja Institute.

22.44 m in diameter and has a free height of 3.50 m. It has a curved glass skin that can be opened integrating the dining room into the garden. It is possible because its roof structure converts it in a giant umbrella (Figure 3). It is made up of cantilevered steel trusses arranged radially with a variable depth of 0.84 to 0.22 m. The trusses rest on reinforced concrete columns arranged radially around a small circular interior garden.

The institute's workshops feature a triangulated thin shell roof over a 15.00 x 87.70 m rectangular floor plan. Each of its nine cylindrical vaults, set at right angles to one another, spans 10.00 m. The roof was built with small (I-80) steel shapes arranged in a welded-joint lattice in which all the triangles are equilateral and of the same size. The resulting triangulated thin shell vaults were light enough to be assembled on the ground and hoisted to their 7 m high final position (Figure 4).

The pergola sited on the west edge of the garden; it is formed by a continuous sequence of reinforced concrete ribs forming a lemniscate of Bernoulli (Figure 5). The zero curvature at the end represents the mathematical symbol for infinity. Here also, Torroja chose a geometric shape laden with significance, in this case to mark the institute's boundary. Each rib is a curved cantilevered beam springing from the reinforced concrete wall that retains the adjacent soil. The ribs are crowned by a steel mesh cover consisting of smooth steel rods and vaguely reminiscent of a hyperbolic paraboloid.

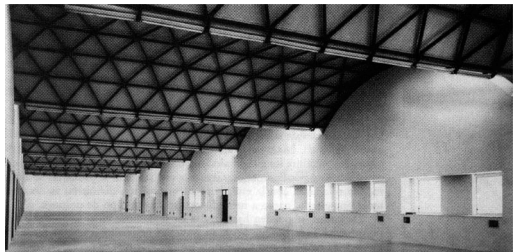


Figure 4. Workshop. Steel triangulated cylindrical vaults.

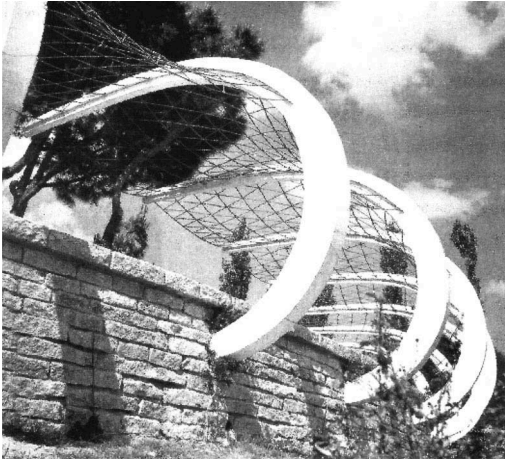


Figure 5. Reinforced concrete ribs.

The dodecahedron was designed as a coal storage. This completely regular, unengaged sculptural structure that stands just outside the main entrance soon became an IETcc icon. This 8.60 m high thin shell with 22 cm thick reinforced concrete walls looks like it was folded into place. Torroja acknowledged that while the sphere is the geometric form with the highest volume to surface ratio, he explained that the dodecahedron, which encloses only a slightly smaller volume, is easier and less expensive to build and given the size of the storage, its geometry is aesthetically pleasing. One of the platonic polyhedral, it is attributed high spatial honors, generated as it is to the ‘golden ratio’.

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Figure 6. Dodecahedron and a group with Eduardo Torroja.

is attributed high spatial honors, generated as it is to the ‘golden ratio’ (Cassinello 2016).

### 3.1.3 Eduardo Torroja Institute - International leader

The new habitat of the Eduardo Torroja Institute allowed him to converter in an international referent. It was a relevant protagonist not only in the development of concrete and other materials, its construction techniques, and the creation of new patents, but it also became a place for meetings, congresses, debates, courses, and publications in which many of the protagonists participated, architects and engineers, of international Modernity. Among many others Frank Lloyd Wright, Richard Neutra, Bernard Ferhufus, Pier Luigi Nervi, Franco Levi, Mario Salvadori, Zygmunt Makowski, Marcel Loods, SOM (Skidmore, Owings & Merrill), David Steiman.

In 1959 the Eduardo Torroja Institute celebrated the 25th anniversary of its founding in 1934. In the commencement ceremony for the academic year presided by Eduardo Torroja, Pier Luigi Nervi, the keynote speaker, highlighted the Institute’s significant international endeavour (Nervi 1959). That same year, the Institute hosted the “International Colloquium on Non-traditional Processes for Thin Shell Construction”. At this meeting, at the proposal of Eduardo Torroja, the International Association for Shell Structures (IASS) was founded. The specialists participating in the colloquium, more than 100 in all, hailed from over a dozen countries: Argentina, Belgium, Brazil, Denmark, Finland, France, Germany, Italia, Japan, Netherlands, Norway, Poland, Portugal, Spain, Sri Lanka, Sweden, Switzerland, United Kingdom and Uruguay. Some of the most prominent designers of thin concrete shells chaired the working sessions. Andre Paduart, Wolfgang Zerna, Knud Winstrup Johansen, Herman Rüle, Nicolas Esquillan, Yoshikatsu Tsuobi, Ove Arup, Heinz Isler, among many others, were present. This international association has remained active since then, leading the advancement of new spatial structural types (Abel 2011).

Unfortunately, Eduardo Torroja was died in 1961 in his office at his Institute (Figure 7), but like the rest of the associations he created, the iass continues to be

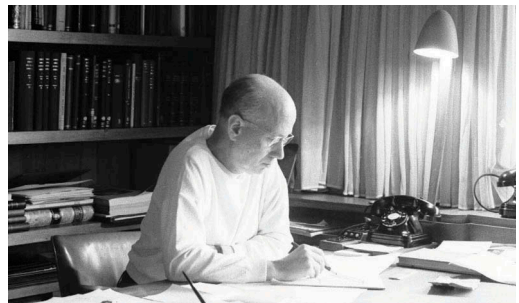


Figure 7. Eduardo Torroja in his office at the Institute.

active since then, leading the development of new spatial structural types. This intangible and timeless legacy of Eduardo Torroja is undoubtedly the most internationally relevant, despite his innovative and pioneering works of Modernity engineering and architecture.

#### 4 CONCLUSION

The unknown documents found at the Institute demonstrate Eduardo Torroja's great interest and effort in building a suitable habitat for his revolutionary research model. Not in vain it allowed him to make his dream come true. He built a timeless model of a knowledge factory.

As we were saying at the beginning, he born under the sign of the Science and grew up knowing the importance of the research and teaching. Research to advance and teach to make the advancement come true. This marked his professional life in a forceful way, shaping his model of thought and action.

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# Influence of projects of culture and art centers on urban development of Leningrad

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**ABSTRACT:** The article is an intermediate result of a step-by-step study of the culture and art center of Leningrad in the era of “constructivism”. It is impossible to identify the features of the culture and art center as a special type of building without analyzing their historical and modern urban planning role in the development of Leningrad. St. Petersburg). The study shows that the culture and art centers of Leningrad were designed as important urban planning elements that are part of building complexes (and sometimes ensembles) that form important urban planning nodes or district centers. This article discusses the culture and art center of the Moscow-Narva district of Leningrad (now the Moscow and Kirov districts): Gorky Palace of Culture (architects A. I. Gegello, D. L. Krichevsky, V. F. Raylian, 1925-1927), Gaz Palace of Culture (architects A. I. Gegello, D. L. Krichevsky, 1930-1935), Kapranov Union of Tanners House of Culture (architect M. S. Reizman, 1930-1931). Demolished in 2006) and the Ilyich House of Culture (architect N. F. Demkov, 1930-1931). It is established that the considered culture and art centers were important elements of the urban-planning ensemble in the system of the compositional and spatial framework of the city and/or part of the architectural and urban-planning complex of buildings of regional significance.

## 1 INTRODUCTION

The relevance of the work is mainly related to the issues of urban planning regulation of territories where cultural heritage objects, including culture and art center, are located.

The list of works by Russian and foreign scientists devoted to the architecture of the first third of the twentieth century is quite extensive. The works of A. G. Weitens (2015), R. Dayanov (2017, 2018), M. V. Zolotareva (2017), B. M. Kirikov (2018), S. V. Sementsov (2011, 2012, 2017), T. A. Slavina, M. S. Stieglitz are devoted to the urban planning and architecture of Leningrad in the first third of the twentieth century. The architecture of the USSR, Sweden, and Germany of the twentieth century is dedicated to the works of Irina Seits (2018). The works of N. P., Dubrovina (2020), A.V. Mikhailov (2017), S. V. Sementsov, T. A. Slavina (2016, 2019) are aimed at the development of methods for the protection of cultural heritage objects. Monograph of B. M. Kirikova and M. S. Stieglitz (2008), dedicated to the monuments of constructivism of St. Petersburg, which covers the most significant buildings of all districts of Leningrad during the “constructivism” period, including a brief review of the urban planning situation. The article by Glizhinskaya A. A., Bergman A.V. and others (Glizhinskaya et al. 2019) is indicative, where the urban

planning ensembles of Leningrad in the 1930s and 1950s are considered. However, it is worth noting the insufficiently detailed and often generalizing approach to the study of the Soviet architecture of Leningrad. For example, the culture and art center, which are new and unique types of buildings and are included in the general lists of monuments of the architectural avant-garde, but are not considered in detail.

This article is devoted to culture and art centers in the structure of the Moscow-Narva district of Leningrad (according to the administrative division for 1922-1930).

## 2 MATERIALS AND METHODS

The methodological basis of the research is a comprehensive approach to the study of the architectural heritage of the 1920s-1930s, culture and art centers of Leningrad in the first third of the twentieth century. For the completeness of the study, it was necessary to study literary and archival sources, legislative acts on the topic of the study. A full-scale visual inspection of the objects and in-house processing of the obtained data were also performed.

To identify the urban planning role of the culture and art center of the Moscow-Narva district, it is necessary to solve the following tasks step by step:

- determination of the historical urban planning role of the studied objects in the structure of the Moscow-Narva district;
- analysis of the existing urban development situation;
- designation of the problems of urban planning regulation of the territories of culture and art centers, as well as land plots historically associated with them.

### 3 RESULTS AND DISCUSSION

Before proceeding directly to the analysis of the urban planning role of culture and art centers, it is necessary to say a few words about the administrative division of Petrograd-Leningrad. Administrative districts began to form in Petrograd after the February Revolution of the 20th century. A detailed history of the administrative-territorial division of Petrograd-Leningrad-St. Petersburg was prepared by the staff of the Central State Archive of St. Petersburg.

This article examines the Moscow-Narva district according to the administrative division of Petrograd-Leningrad in 1922-1930. During this period, the first center in the USSR was built—the Gorky Palace of Culture. In 1930, the Moscow-Narva district was divided into Moscow and Narva. The main urban development of the district in the 1920s and 1930s took place along two main thoroughfares: Stachek Street (now Stachek Avenue) and International Avenue (now Moskovsky Avenue) (Figure 1).

*Gorky Palace of Culture (4 Stachek Square, Saint Petersburg).* In the pre-revolutionary period, the Peterhof site was the largest industrial district of St. Petersburg and an unsettled working-class suburb. After the Great October Socialist Revolution of the 20th century, the Soviet government immediately took measures to decisively improve the living conditions of workers. The Narva outpost was included in the city, and the beginning of a radical reconstruction of the area was laid (Kirikov 2018). Already in 1924, large-scale works on the reconstruction of the district began. Vacant lots and landfills are being cleared, wooden houses are being demolished, and new buildings are being built: residential buildings, schools, nurseries, etc.

The development of this territory is described in detail in the book “Prospekt Stachek” by O. S. Grintsevich. Narva Square is undergoing radical changes. New residential buildings are being built, old ones are being reconstructed “with the formation of a square, the Gorky Palace of Culture is being built. The very first residential quarters of Leningrad were built on Traktornaya Street (1925-1926). In 1927, a large school building was built on Stachek Avenue, designed by architect A. S. Nikolsky.” Kirovskaya Square is being re-created, where the building of the district Council was built according to the project of architect N. A. Trotsky. Also, in the



Figure 1. Fragment of the Leningrad plan for 1925. Moskovsko-Narva district.

1. Gorky Palace of Culture; 2. House of Technical Studies; 3. Department store and factory-kitchen of Kirovsky district; 4. School named after the 10th anniversary of October; 5. Kirov District Council; 6. Residential complex on Traktornaya Street; 7. I. I. Gaz Palace of Culture; 8. Palace of Culture of the Union of Tanners named after Kapranov; 9. House of Culture named after Ilyich; 10. Moscow District Council.

1930s, on Stachek Avenue, multi-story residential buildings are being built, and in the depths of the residential development is the Kirov dispensary: the largest medical institution in Leningrad. The Gorky Palace of Culture becomes an urban planning, cultural and educational center of the new district, a symbol of the young Soviet architecture (Figure 2).

At present (January 2021), in general, the town-planning significance of the Gorky Palace of Culture has not been lost. The ensemble of Stachek Square and the beginning of Stachek Avenue is included in a single security zone. There is some densification of buildings around the Palace of Culture, for example, from the side of Ivan Chernykh Street, which disrupts the visual perception of the Palace of Culture from Stachek Avenue.

However, it is worth noting that the House of Technical Studies (architect A. I. Gegello, D. L. Krichevsky, 1923-1930), designed in the same complex as the culture Center, is not included in the

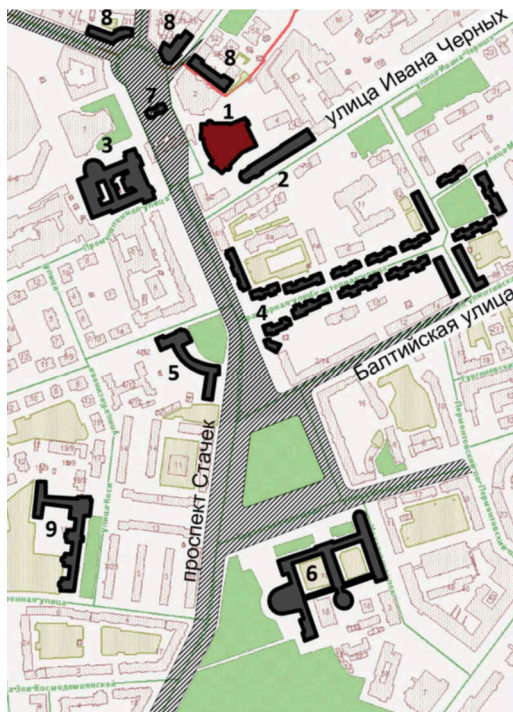


Figure 2. Gorky Palace of Culture. Site plan.

1. Gorky Palace of Culture; 2. House technical training; 3. Department store and factory-kitchen Kirov district; 4. Residential complex on Traktornaya street; 5. School of the 10th anniversary of October; 6. Kirovskiy District Council; 7. Narva triumphal gate; 8. The ensemble houses Stachek square, architect. N. A. Trotsky, CET. ing. A. V. Valevich, 1935; 9. Dispensary building of the Kirov district, architect. L. V. Rudnev, A. A. Lyalin, J. A. Svirsky, I. I. Fomin, 1928-1933.

ensemble of Stachek Square and is not included in the unified protection zone (Figure 3a). It is proposed to expand the single security zone of the site (according to the security zone no SZ-2(15)01) with the inclusion of the historical part of the House of Technical Studies in the ensemble (Figure 3b).

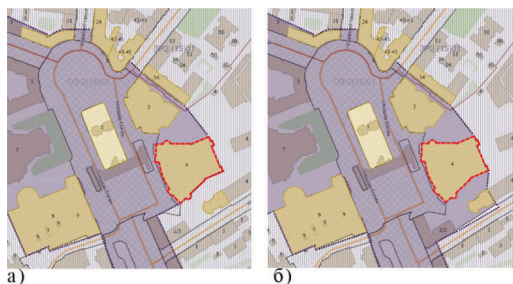


Figure 3. Gorky Palace of Culture, protected areas: a) the current situation; b) the proposed security zoning.

I. I. The Gaz Palace of Culture (72 Stachek Ave., Saint Petersburg). The development of the territory of Avtovo is considered in detail in the works of St. Petersburg local historians. For example, in the book of Glezerov S. E. "Historical districts of St. Petersburg from A to Z" it is said: "At the beginning of the twentieth century, Avtovo had a suburban character. Here were the cottages of poor Petersburgers, communication with the city was only on horseback or foot." A 1933 Guidebook notes that "this situation of the area was observed until the 1930s".

In the mid-1930s, the reconstruction of the Avtovo district began. The project for the development of the first quarters (the project manager was A. A. Ol) is based on the principle of radial planning. The center of the planning scheme was the Round (Komsomolskaya) Square.

The Gaz Palace of Culture was one of the first large public buildings in the area and was built at the Kirov Plant. There are several projects for the development of the Avtovo district and in each of them, the Gaz Palace of Culture is included in the panorama of one of the largest highways of the city - Stachek Avenue. Located with an offset from the red line of the avenue, the Palace of Culture according to the projects reveals Komsomolskaya Square for visual perception. On the reference plan of the Avtovo microdistrict (Figure 4). The Gaz Palace of Culture is part of a complex of buildings of regional significance, which also includes a cinema, a hotel, a House of Pioneers, a department store, higher educational institutions, and a metro pavilion (the project was partially implemented).

Currently, the site where The Gaz Palace of Culture is located has no designated protection zones, and the territory of the cultural heritage site coincides with the outline of the foundation of the historical part of the building. The historical site of the Palace of Culture, bounded by Stachek Avenue, Novostroek Street, Marshall Govorov Street, and Vasya Alekseev Street, is gradually being built up. The urban planning position of the Palace of Culture is very



Figure 4. Reference plan of the Avtovo microdistrict. Between 1945 and 1949. Architect A. A. Ol. Published in the catalog of the State Museum of the History of St. Petersburg "Architect Andrey Andreevich Ol".

vulnerable, it is necessary to establish a security regime on its historical territory (Figure 5).

*Ilyich House of Culture (152 Moskovsky prospect).* The Ilyich House of Culture, located on Moskovsky Prospekt, is one of the few examples of “pure constructivism” in Leningrad. The author of the project is N. F. Demkov.

One of the main axes of the development of the Moskovsko-Narva district was the International (now Moscow) Avenue. The territories along International Avenue were actively built up.

The Ilyich House of Culture building is built on the main highway of the district, which is the government highway of the city. The House of Culture is located opposite the House of the Moscow District Council of Workers ‘Deputies (1930-1935, architects I. A. Fomin, V. G. Daugulya, and B. M. Serebrovsky). The building is part of the composite and urban planning junction of the intersection of Moskovsky Prospekt with the Ring Railway (Figure 6).

The historical urban planning situation of the location of the Ilyich House of Culture as a whole is not disturbed. The territory of the cultural heritage site includes a section up to the red line of Moskovsky Prospekt. However, it is impossible to consider the House of Culture and the Moscow District

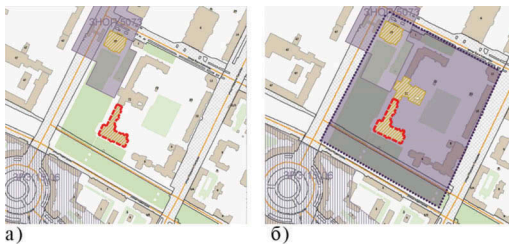


Figure 5. The Gaz Palace of Culture. Protected areas: a) the current situation; b) the proposed protected zoning.

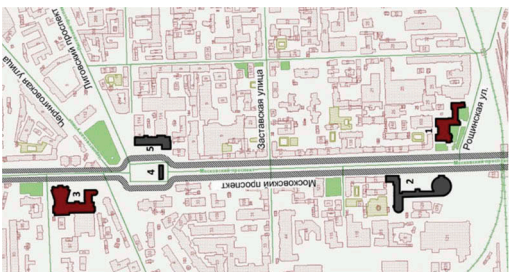


Figure 6. Ilyich House of Culture and Kapranov Union of Tanners House of Culture. Situational plan.

1. Ilyich House of Culture; 2. Moscow District Council; 3. Kapranov Union of Tanners House of Culture; 4. The Triumphal Moscow Gate; 5. Food factory with a kitchen factory (1932-1936, architect E. I. Katonin, E. M. Sokolov).



Figure 7. Ilyich House of Culture. Protected areas: a) the current situation; b) the proposed protected zoning.

Council as two independent objects, it is proposed to define a single security zone for these buildings (Figure 7).

*Kapranov Union of Tanners House of Culture (97 Moskovsky prospect).* Another House of Culture on Moskovsky prospect was intended for workers of leather and shoe production (the largest shoe factory “Skorokhod” was located nearby). The building was planned according to a two-part scheme: an asymmetric group of volumes of the club area with small halls adjoined the symmetrical theater building with a trapezoidal hall for 1300 seats. The realized building had bright and characteristic features of constructivism.

The House of Culture, which had fallen into disrepair, was demolished. In 2008, its external volumes and the design of the facades were recreated. Restored along the outer contour, the building is part of a new multi-story complex.

Kapranov Union of Tanners House of Culture also had a responsible urban planning position. The House of Culture was part of the complex of buildings of the production buildings of the Skorokhod factory, a food factory with a kitchen factory and was located on one of the most important highways of the city: International (now Moscow) Avenue in close proximity to the Moscow Triumphal Gate at the intersection of major highways.

#### 4 CONCLUSION

The study showed that culture and art centers of the Moscow-Narva district had an important urban planning significance. They were designed as part of urban-planning ensembles or complexes of buildings of regional significance. It is worth noting that such an important urban planning role of these objects is provided not only by architectural and urban planning techniques but also by cultural and social significance. That is, an important role was played by their historical functional purpose. Currently, as the study shows, the urban planning value of culture and art centers is very vulnerable and requires additional attention from specialists in the protection of historical and cultural heritage.