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Research Article

The formation and development of industrial architecture in Central Asia (late XIX - early XX centuries)

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ABSTRACT

This article describes the introduction of new, more advanced materials and structures in the architecture of industrial, public buildings and bridges in Central Asia. This did not result in the replacement of one technique or structural element, but in the renewal of the entire architecture of the period. One of these materials was iron and concrete. New structures such as metal domes, reinforced concrete frames and metal structures appeared. The use of metal structures is considered using industrial buildings built in Tashkent as an example. Structural systems were first used in industrial architecture and then in the architecture of public buildings. The use of the frame system was first implemented in the buildings of the Cadet Corps and the Tsintsadze Circus. Several groups of structural systems are also considered in detail: frame-wall structural structure, metal-brick structural system, brick-reinforced concrete structure. Particular attention is paid to the development of structural systems in bridge construction.

Keywords: industrial architecture, bridges, trusses, construction science, reinforced concrete structures, frame systems.

I. INTRODUCTION

The second half of the XIX - early XX centuries was extremely important in the life of the peoples inhabiting Central Asia. During this time, significant social and technical transformations took place, which changed the life and appearance of the environment. All this was the basis of those huge transformations, which happened already in the middle of the XX century, when Central Asia is out of poverty, torn apart by constant military clashes of local feudal lords, the country turned into a flourishing and rich territory of several republics. This is especially evident in the progressive consequences of joining Russia.

Literature review

Considering the works devoted to the architecture history of the Turkestan Territory, the works of scientists should be noted, appeared in the late XIX - early XX centuries. Information about Turkestan Territory architecture formation processes, presented in them, to a large extent does not reflect the development of industrial architecture, however, a number of descriptions and illustrative materials of the residential and public architecture of Turkestan cities, allows analyzing the development and use of new building structures and materials.

Information about technical achievements in the Turkestan Territory in the late XIX - early XX centuries appeared in pre-revolutionary publications. So V.I. Masalsky [21] in his interesting descriptive works mentions new large structures. In the guides of A.I. Dmitrieva-Mamonova [12] and especially in the works of A.I. Dobrosmyslova [13], there is also information about new buildings. G.N. Chabrov [33] and V.V. Lunin [20]have local history and bibliographic descriptions of engineering and architectural activities in pre-revolutionary Turkestan. In the 80 of the last century, the first architectural studies appeared, among which the most interesting information in the works of V.L. Voronina [8] and V.A. Nielsen [25], as well as in the works of M. Yusupova [30].

All these studies are interesting, in their own way, they contain a lot of valuable and original information. They largely contributed to the architecture recognition of this time, but still, these studies did not reveal all the sides that determine the architectural construction level. They introduced an extremely wide layer of urban construction into science, analyzed the urban planning issues, revealed the creative persons of many outstanding architects who worked in Turkestan in the pre-revolutionary period, etc.

But they did not fully disclose that great work, which was carried out in Turkestan to introduce new progressive building materials into architectural construction and designs that have largely come to define the face of new architecture. The issues of construction of the largest hydraulic engineering and railway structures, which have

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become known all over the world, are not sufficiently touched upon. Insufficient attention is paid to the architectural construction of new industrial structures, where reinforced concrete, metal structures, etc. were mainly used.

II. MATERIALS AND METHODS

Various literary sources devoted to this topic served as materials for the analysis of the industrial architecture of Turkestan Territory. Field studies and photographs of the surviving buildings of this period were carried out, which made it possible to analyze the development of industrial architecture. Based on the results obtained, it was concluded that the introduction of new, more progressive materials did not lead to the replacement of one technique or structural element, but to the renewal of the entire architecture.

III. RESEARCH RESULTS

The developing construction technique, new structures entered architecture sometimes in a roundabout way - through the railways, bridges, industrial structures and others construction, as at that time they called "utilitarian objects".

Since the beginning of the XX century, the constructive system itself has become increasingly important in the architectural appearance. This was due, first of all, to the construction technology progress, as well as the engineering development. All this became possible because the material and technical conditions were created for the emergence and rapid development of structures. These designs provided a wide variety of architectural forms.

New types of buildings, especially for industrial purposes, required the use of large span structures with overhead lights. These requirements and also the need to ensure fire safety led to the use of steel and cast iron, and from the beginning of the XX century and reinforced concrete structures. During this period, calculation methods were developed and their gradual introduction into the civil and industrial buildings design. All this led, even with high safety factors, to huge savings in building materials.

Compressed elements of the structure - walls, pillars, columns - were made of baked bricks, and all bending elements - beams, consoles, lintels, brackets, and beams for stairs - were made of iron. For example, such mixed or combined systems were used in the buildings of the Real School and the Cadet Corps.

With the advent of calculation methods, the constructive meaning of a brick wall has changed, which was previously considered not only as fencing and supporting structure, but also as an inert mass absorbing the spacers of the arches with its weight. The minimum wall thickness required for strength and thermal engineering considerations has already been determined by calculation. Since the wall now worked only for vertical (compressive) loads and became lighter, it got the opportunity to grow in height, which led to an increase in the number of storey in brick buildings. An example is the Courts building and the Cadet Corps in Tashkent city.

I would like to draw your attention to the window and door openings, since they were given the least space in Central Asian architecture. And only at the end of the XIX century, these elements received not only a compositional, but also a new constructive meaning, since large openings reduced the weight of the walls and made it possible to use less material. In addition, the use of iron lintels created the prerequisites for the construction of wide openings with a flat end. And this is one of the anti-seismic measures that have found application during this period. Large openings have been used in almost all industrial buildings –Tashkent tram building, the locomotive shop at Tashkent railway station and civil buildings – Cadet Corps, the building of the Court Regulations, the Real School, as well as residential rich houses (many of these houses have survived in Kokand city). Many large display windows have appeared in commercial buildings.

Since girder systems rest on walls only at individual points, and not around the entire perimeter of the wall, as was the case with vaulted ceilings, a solid wall plane has become unnecessary. The wall, in combination with the iron lintels, began to acquire the frame appearance.

The first buildings where the frame system was applied were the building of the cadet corps and Tsintsadze circus.

If all the constructions of the XIX-XX centuries are systematized, then several groups can be distinguished. These constructive systems were developed first in industrial architecture, and then in civil.

1. *Frame-wall structural structure*. This system is characterized by the use of an internal post-and-beam frame in combination with load-bearing external brick walls. This structure was applied in the buildings of the Real School and the Cadet Corps. These are brick vaults on metal beams and a hidden metal frame in the buttresses.

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2. *Metal-brick constructive system*. This system became widespread in the construction of industrial buildings. It is based on external and internal bearing brick walls and bent iron elements (as well as wooden beams and rafters). An example of such a structure are the buildings of the Tashkent tram, the locomotive shop in Tashkent and workshops at the Perovsk (Kyzyl-Orda) and Turkestan stations, factories in Bayram-Ali, etc.

3. *Brick-reinforced concrete structure*. This system appeared at the beginning of the 19th century. The difference from metal-brick is that bending elements and whole floors were made of reinforced concrete. For the first time, such a structure was used in the Tsintsadze Circus and the Courts building.

All of these structures appeared in the late XIX - early XX centuries. All of them influenced architectural forms, mainly on the form of coatings. In addition, on the basis of such systems, the internal space was freed from intermediate supports. The interiors have become more spacious. And overlapping spans have increased due to improvements in computational methods.

The lanterns use in industrial construction gave a distinctive character and variety to the architectural appearance of buildings.

Overlappings on metal beams look very impressive. The gaps between the metal beams were covered with a non-combustible material (brick). Due to this, a peculiar look is given to the interior in the building of the cadet corps and the building of the Courts. These vaults heels are made of curved brick, which hides the lower belt of the beam.

The trusses supporting the roof were made of wood or iron. In buildings where large spans were required and where the building is visible from below and should have a light and elegant appearance, metal trusses were used.

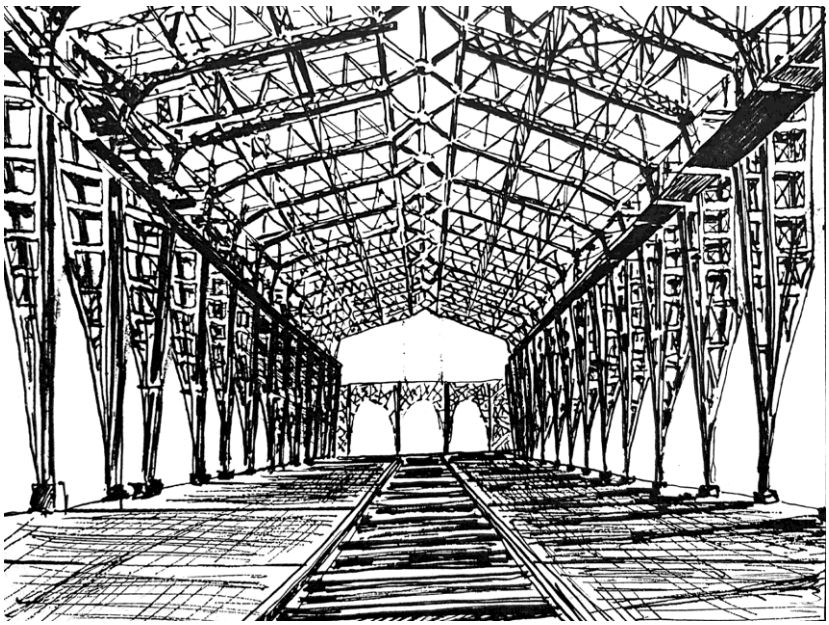

Fig. 1. Construction of a locomotive shop

The farms in all industrial buildings were of various configurations. In Tashkent tram buildings, triangular-type trusses with various shapes of the lantern are used. In the building of the locomotive shop at the Tashkent station, the farm is visually a continuation of the metal supports (Fig. 1). The farm outlines of workshops at the station Perovsk (Turkestan) are very interesting (Fig. 2). In addition to using various types of trusses, I would like to draw your attention to the metal dome of Schwedler system in Tsintsadze circus building (Fig. 3).

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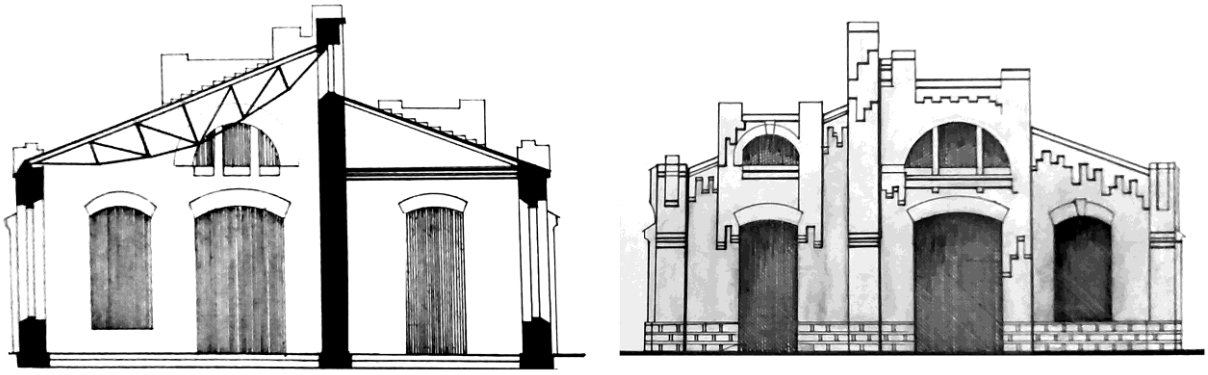

Fig. 2. Small workshops at Perovsk station (Turkestan). Incision. Facade.

One example of how builders and designers take into account anti-seismic measures is the use of linked posts and beams. The racks were made of I-beam and trough iron fastened together. Corner posts were most often made from corners set against the outer and inner surfaces of the walls. [18, p.108]. Large windows and gates were installed in the front walls of buildings, and usually flat ceilings with metal beams were used.

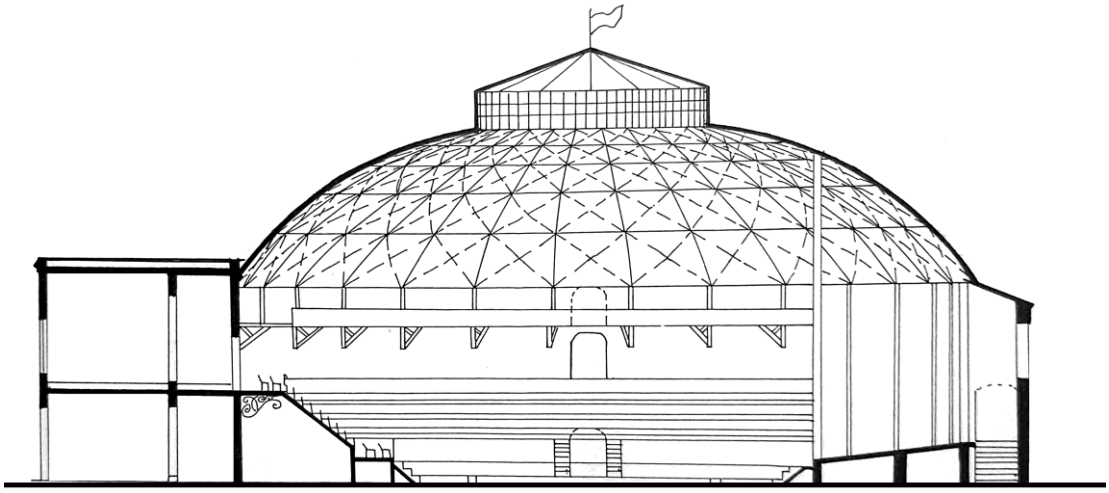

Fig.3. Tsintsadze circus project.

Very interesting staircases were arranged in Judicial Institutions building, the Cadet Corps, the Real School and the Tsintsadze circus buildings. These stairs construction was made using metal, and in the circus building and reinforced concrete. A spiral metal staircase was used in the Grand Duke Nikolai Konstantinovich Romanov palace.

The period from the end of the XIX to the beginning of the XX centuries is also significant in that it gave birth to a new technological area of architecture - industrial architecture.

The industrial architecture of those years is in most cases of great interest. These are usually buildings made of baked bricks - quite solid and expressive in appearance. [25, p.88]. Attention is drawn to Tashkent tram construction, repair shops, a locomotive depot at Tashkent station, slaughterhouses, a merchant Ivanov's plant and a soap factory in Bayram-Ali (Fig. 4).

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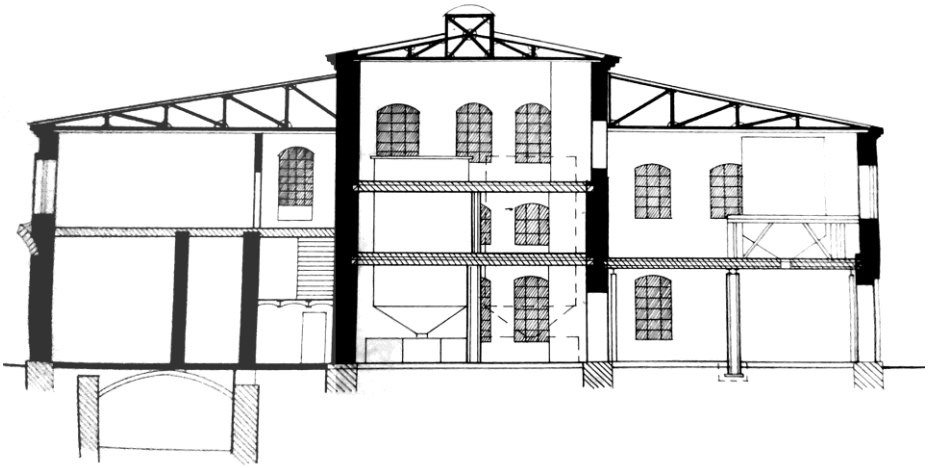

Fig. 4. Section of a soap factory in Bayram Ali

These buildings are interesting, first of all, because it was here that new floor structures were applied. Due to the use of various profiles trusses and a lantern, these buildings have a peculiar architectural appearance.

Let's stop at Tashkent tram building. The horse tram in Tashkent was set up and operated by the Belgian anonymous society "Tashkent tram".

In 1908, the city signed an agreement with the "Tashkent tram" society, according to which the city provided the society with the construction and operation of railways with electric motors, both for existing networks, horse-drawn railways, and on new lines. [40, p. 186]

Tashkent tram construction consisted of two complexes. On August 17, 1910, one of the complexes was laid on the site between Gogolevsky and Kuropatkinsky avenues. On the other side of the site, two buildings faced Gogolevsky prospekt with their facades. In one of them there was a carpentry and paint shop, and in the other a smithy and a mechanical workshop. In the center of the site allocated for this complex, there was a shop and a cafeteria, located between the Central Station and the mechanical workshops building.

The entire complex architecture was made in the same style. The most interesting of all is the building of the Central Station (Fig. 5). It is a one-story brick building. In the plan it has a rectangle shape (45x17 meters) with turrets at all four corners.

I would like to draw your attention to the main facade, where the arched forms of window openings and decorative pointed turrets create a peculiar silhouette. The building contains elements of the Baltic Gothic.

In all this complex structures, interesting systems of metal large-span ceilings have been used. On the side facades, a lantern is clearly visible, which serves as additional overhead lighting.

When calculating the structures, the change in the truss length from the temperature difference was taken into account. All coverings are designed from cast iron, with the exception of the base plates, which are designed from cast iron. [43, p.7] In the end gables and brickwork, a metal frame is embedded, consisting of upper and lower chords and vertical posts, which serves as a binding agent for brickwork, protecting it from bulging and destruction in the event of seismic shocks. Engineer V.S. Heinzelman.

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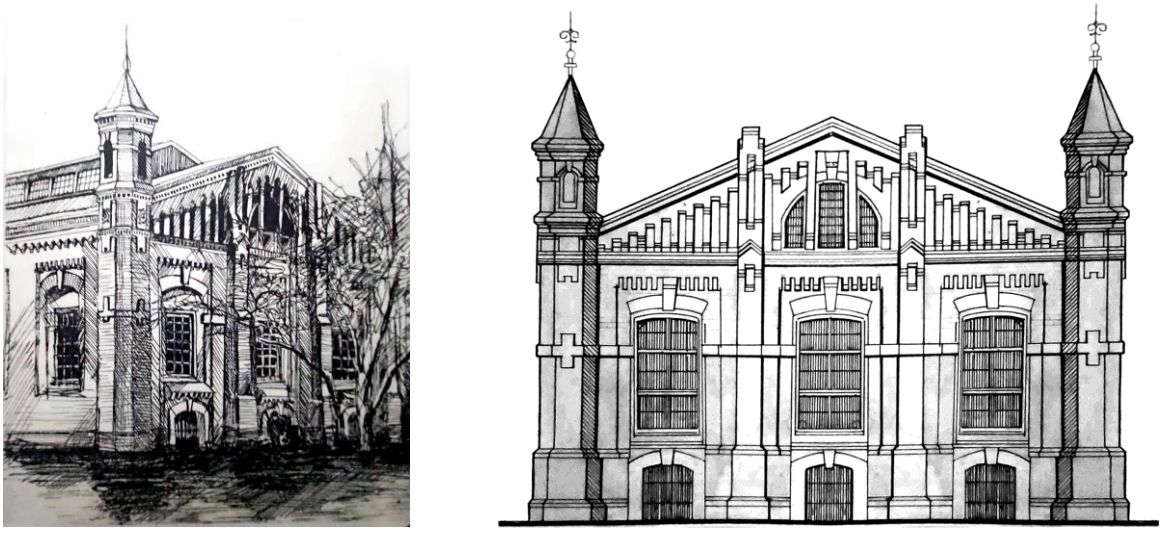
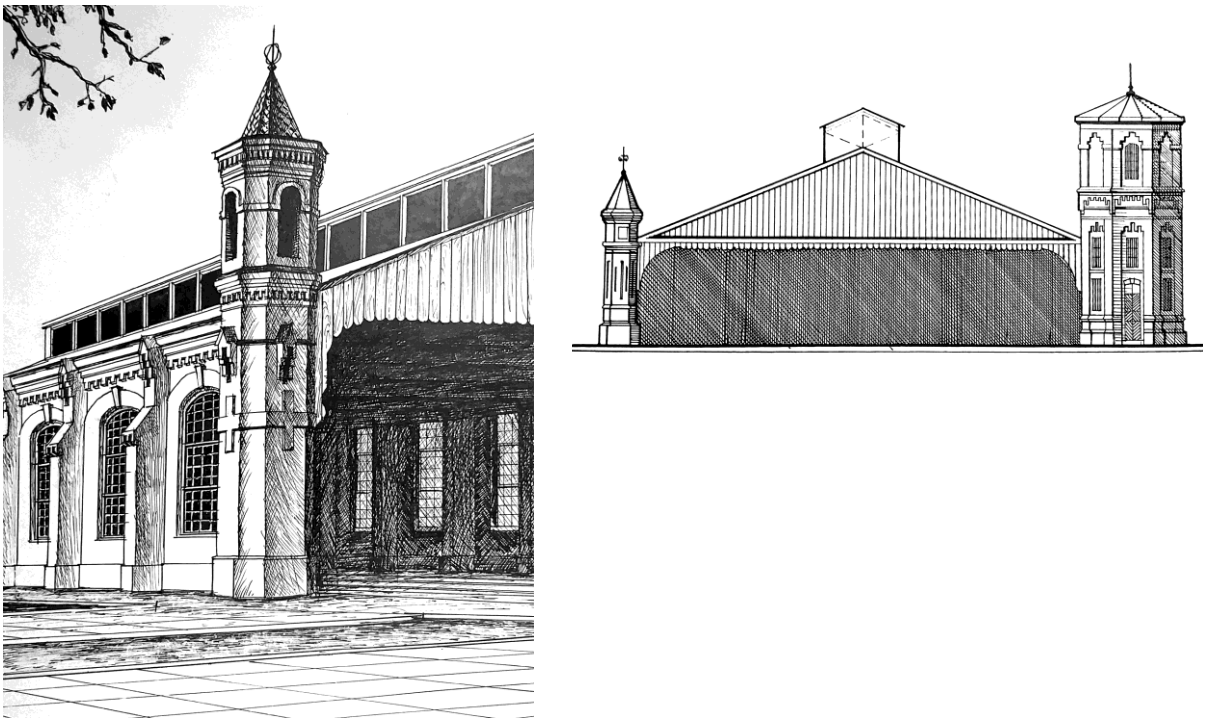


Fig. 5. Central station building. General view and facade

The depot building was built on the site between Leninsky Prospekt and Elizavetinskaya Street. The plot is rectangular, its dimensions are 63.7x141.0 m. The side facade of the carriage depot and the rear facade of the previously existing building faced Maryinsky prospekt. On the other hand, opposite these two buildings is the building of another carriage depot.

The main facades of the drive-out depots facing the courtyard are located on the same line, next to each other (Fig. 6). A residential building with services was located opposite the main facades. Entrances and exits are located at the corners of a limited area of the complex. The complex buildings are very similar in architecture and design. But there are minor discrepancies in the layout. In plan, these are two rectangles. The dimensions of one of them are 91.8x27.0 m, the other 52.6x27.0 m. There are turrets at the corners of the depot: one of the corners is occupied by a water tower. Lighting is provided through windows located on two side facades and through a lantern.



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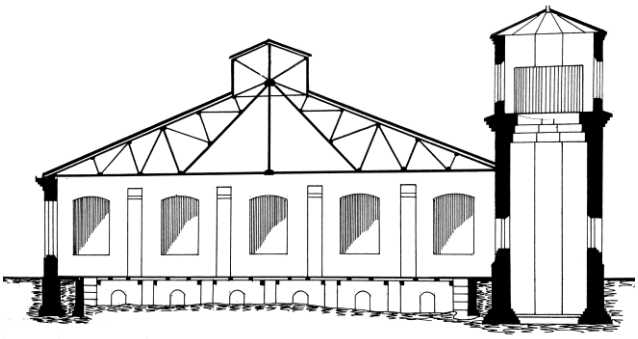

Fig. 6. Tashkent tram. Depot. General view, facade and section.

Both complexes are built in the same architectural style and with the same details. So all the buildings of Tashkent tram are made in the same manner and cannot be confused with any other building. This is one complex located in two different locations in the city center.

The side facades architecture is almost the same except for the buildings completion on the sides. The main facades of the carriage depot resemble a covered shed, since the entrance to the building has dimensions equal to the building width, that is, there are practically no gates.

The water tower is very interesting. Its height is 14.1 meters; it has three entrances and a passage to the workshop. The tower is three-tiered, completed with a hipped roof and gives the composition of the depot building originality and sharpness.

In the buildings of the depot, the structure of the Wigman Pogonso system trusses with a horizontal lower belt and a canopy is used. The lantern is located along the entire length of the roof, excluding the outer panels. The building was designed and built by engineer V.S. Geintselman.

Similar architectural forms were used in the main building of the stock slaughterhouse complex, which was then located on the city outskirts behind the old Beshagach gate.

«Out of all Turkestan Territory cities, only one Tashkent city has a comfortable slaughterhouse, built, if not according to the latest technology, then, in any case, in compliance with all conditions that meet modern requirements, with the installation of an ice-making, cooling and utilization department». [41, p. 81].

The area occupied by the buildings of the slaughterhouse is quite extensive - about three and a half dessiatines. It is cut by a street; on both sides there are buildings that housed the office of the slaughterhouse and an apartment for employees and workers. In the back of the courtyard there are slaughterhouses: the main slaughterhouse for cattle and small livestock, a utilization plant, a collection station for sewage, a pavilion for slaughtering horses and camels, a repair shop, a cattle-driving and quarantine yard, and others. Between the section for cattle and small cattle there is a cooling section, which functions only in the warm season.

The space-planning solution of the main building of the slaughterhouse is symmetrical. Its composition can be divided into three parts: the central part and the symmetrically located side parts. The dedicated center was crowned with peaked turrets and had three entrances bounded by small ledges. All three entrances are united by a triangular visor. The side parts each had a row of arched windows and an entrance. The tower was the dominant feature of the entire composition of the building. The slaughterhouse building was designed and built by engineer V.S. Geintselman.

The end of the XIX - the beginning of the XX centuries is characterized by the active construction of bridges, where various building materials were used - wood, metal, concrete and reinforced concrete. The enormous technical and aesthetic potential of metal was clearly manifested in the construction of railway bridges.

The emergence of a large number of city, highway and railway bridges has changed the subject environment surrounding a person. The creation of various structural systems of bridge structures, the designers attention to their volumetric-spatial composition and silhouette (especially in city bridges) influenced the development of architecture and the artistic culture of the XIX - early XX centuries in general.

If we compare metal bridges with stone bridges of previous eras, their differences are clearly visible. It lies in the fact that in a stone structure, the entire structure remains in the form of a monolithic mass of material. The material gives a feeling of strength, stability, weight. The design is not expressed, although the material, of course,

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experiences some kind of effort. In through bridges, wood or metal, the mass disappears. The bands of the used metal are like "force lines", make visible the forces experienced by the material. The determination of these forces between known points determines the shape of the structure. The design determines the shape. A new plastic is born.

There are very few examples of stone bridge construction in the XIX - early XX centuries. Basically, these are small urban and rural bridges over the Salar and Bossu ditches, Kokand-sai.

The peculiarity of the wooden bridge building of the XIX century is the use of almost all the main systemic wooden bridges, various mixed systems.

The first grandiose wooden bridge was the bridge over the Amu Darya. The construction of this bridge dates back to 1888. All four parts of the bridge are wooden on piles of a strut system with spans of 8.7 meters. Each bull is located on five piles, and the spans are covered by three rows of purlins with a triple row of struts. In the deepest place, a draw-off part with trusses of the Gau system was arranged, covering a span of 17.4 meters. The bridge was built by engineer Belinsky. [42, p. 8]

Also very interesting are two bridges across the Syr Darya built on the initiative of the Grand Duke Nikolai Konstantinovich. The first of these bridges was built in the village of Chinaz in 1895-1899, the bridge length is 390 meters. A strut system bridge with 25 spans out of which 24 are 15 meters long and one span is 23.9 meters. This span is blocked by the American Gau system for the passage of rafts. Structural analysis was done by engineer Esakov (Fig. 7).

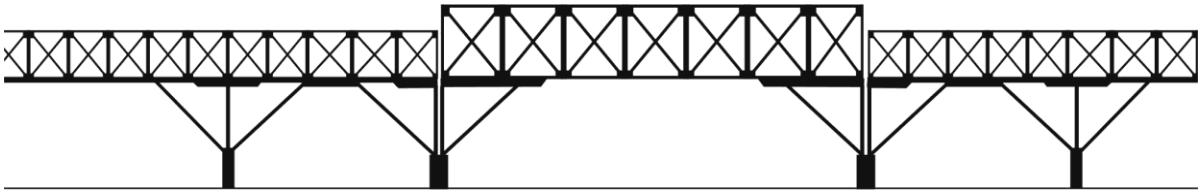

Fig.7. Bridge over the Syrdarya river in Chinaz village

The second bridge across the Syrdarya river was built near Zaporozhye village in 1907 (Fig. 8). The bridge had 12 spans with a total length of 217 meters. The constructed bridge is one-way, all spans are of different sizes, from 26 meters to 13.8 meters. The size of the spans increases gradually, due to which the bridge acquires individual architectural expressiveness. The spans are covered with truss trusses. The construction of the bridge was supervised by engineer G.M. Svarichevsky.

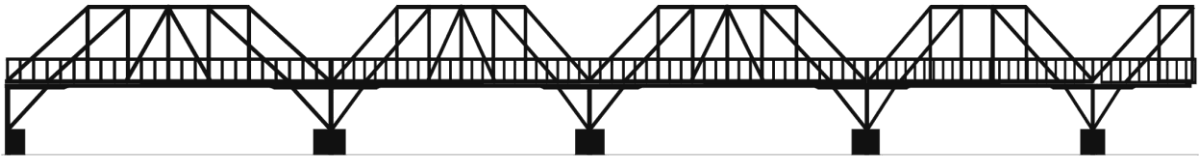

Fig.8. Bridge over the Syrdarya river near the Zaporizhzhya village.

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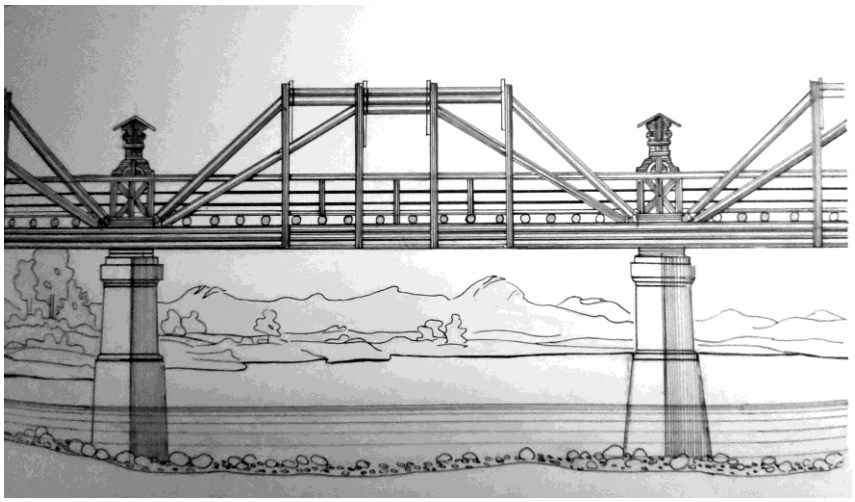

Fig. 9. Bridge over the Chirchik river near Iskander village.

The bridge across the Chirchik River near Iskander village, also built by the Grand Duke Nikolai Konstantinovich, is very interesting in its architectural design and decorative details.

The bridge length is 91 meters. The wooden bridge consists of five spans, four of which are 17.4 meters long and one 22 meters long. Wooden trusses rest on stone abutments, which lend a special beauty to these two building materials combination. This bridge was also designed by engineer G.M. Svarichevsky (Fig. 9).

In 1899, a very original bridge was built across the Salar River. The bridge length is 17.4 meters. The bridge is single-span, wooden with stone supports. The bridge is interesting for its constructive solution. It can be called arched, due to the semicircular truss used here. The bridge also belongs to G.M. Svarichevsky (Fig. 10).

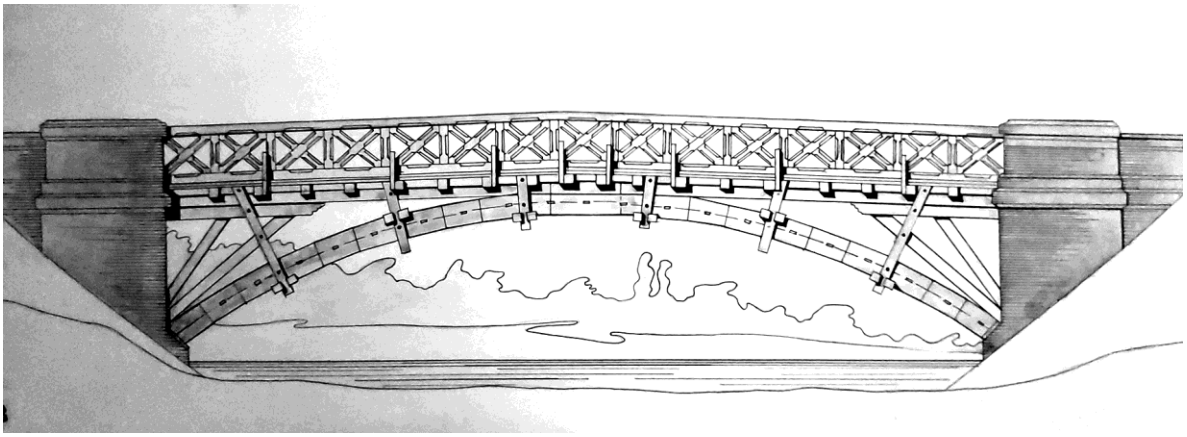

Fig. 10. Bridge over the Salar river

At first, wooden bridges were very much used, but even after the construction of metal and reinforced concrete bridges, they continued to operate for a long time.

Many bridges of the Trans-Caspian and Tashkent railways are examples of metal bridges. One of them is the grandiose bridge over the Amu Darya River, built in 1901. The bridge was built under the supervision of engineer S.I. Olshevsky, designed by engineer S.I. Yanushkovsky. The static calculation and principles of designing metal trusses were proposed by the bridge builder N.A. Belelyubsky. [25, p.169]

It was the first longest bridge in Russia - 1627.5 meters (the former Aleksandrovsky Bridge over the Volga had a length of 1462.8 meters). This bridge consists of 25 trusses of a triangular system with beveled ends and a ride on the bottom, each truss span 65 meters. Each span rests with one end on a fixed one, the other on a movable cushion on five steel rollers. The farms bottom is raised 6.5 meters above the highest waters horizon. The elevation was made so that the largest ships of the flotilla on the river could pass. There are 24 river supports located between the two coastal abutments. Building materials that were used in the construction of the bridge: stone, marbled limestone, were brought from a quarry near the Ziadlin station, for facing the abutments, stone was brought from

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Samarkand, fascines were brought from Tejen, iron parts were delivered by the Bryansk plant and the Mariupol plant. Work on the construction of the bridge began on October 17, 1898, and ended on May 27, 1901. The head of the construction work was the engineer of railways S.I. Olshansky (Fig. 11).

Fig. 11. Bridge over Amu Darya river

The bridge looks like a grandiose light grate, set high above the water. The clear rhythm of the uprights delimited by braces contributes to ease of perception. The lightweight openwork bridge belongs to one of the best examples of its kind, and in terms of the length and courage of the technical solution; it is one of the largest bridges of that time.

Metal bridges were thrown over Zaravshan, Tejen, Murghab, Siab rivers and others.

Almost all metal bridges are light and delicate. Their expressiveness is achieved through the use of new constructive techniques. The construction of these structures speaks of the high-tech courage of those years (Fig. 12).

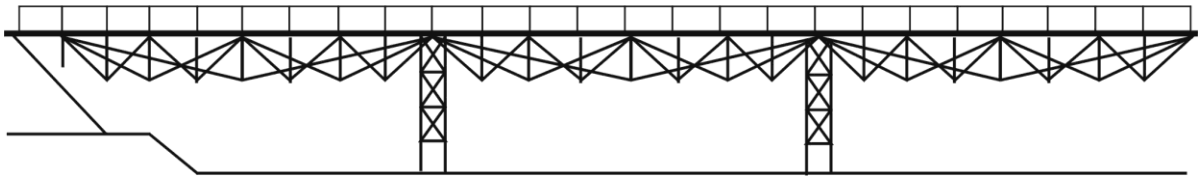

Fig. 12. Project of a bridge over Chirchik river

Already at the beginning of the XX century, projects of reinforced concrete bridges appeared. The first projects and calculations for them were made in 1907-1912. These include projects of a bridge over Chirchik river near Kuylyuk village (Fig. 13), a project of a bridge over Syrdarya river. The projects were drawn up by engineer G.M. Svarichevsky.

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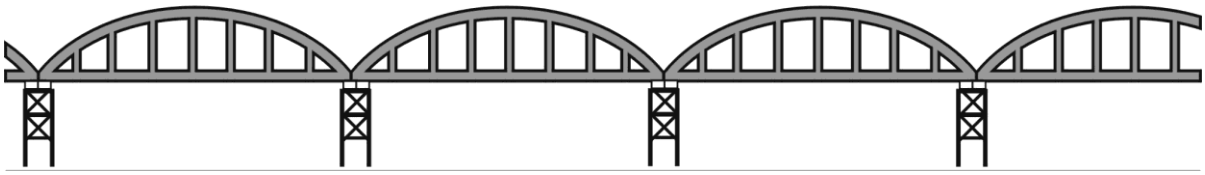

Fig. 13. Reinforced concrete bridge project across Chirchik river (1912).

The appearance of reinforced concrete structures once again proved that new materials and structures quickly found application in the Turkestan Territory. This is an expression of the high technical thought of those years.

IV. CONCLUSIONS

Analyzing the structures that appeared in the late XIX - early XX centuries, one can trace how they influenced this period architecture. With the advent of new types of buildings, both in industrial and civil architecture, new structures were used. In these structures application, a new look of architecture was formed. This period architecture differs from the architecture of previous eras.

The construction of large facilities entailed the construction of new buildings and structures that were completely unknown here before - bridges over large rivers and deep ravines with increased static load, industrial facilities for the repair and operation of steam locomotives, railway cars, depot buildings, warehouse facilities and passenger stations.

One of the progressive moments in the most construction objects noted above was the construction complexity and standard construction.

All major railway stations are a whole area where industrial, warehouse facilities, passenger stations, overpasses are located, as well as a whole system of residential buildings for service personnel.

Large hydraulic structures, as exemplified by the Murgkhab sovereign estate, are a complex of canals, dams, power plants, as well as industrial buildings for the processing of agricultural raw materials, and again, administrative buildings and residential buildings.

The same can be noted for industrial centers, inside the city, be it the buildings of Tashkent tram or Tashkent abattoir. Where, in addition to production workshops for various purposes, there is administrative, warehouse or residential buildings. Moreover, the architects paid equal attention to all buildings, all of them were built, in very high quality, in similar architectural forms and create a kind of ensemble. This is facilitated by the fact that often the architecture of the whole complex belonged to one author. So the railway buildings in Tashkent and other cities belong to the creation of G.M. Svarichevsky, complexes of the Tashkent tram and slaughterhouses - S.S. Heinzelman.

Studies of the local natural conditions of Central Asia played a very important role in the further development of architectural construction. They touched upon the study of local building materials - binders: ganch, loess, natural limestone, marble, granite, burnt brick; methods of their manufacture and ways to improve their strength characteristics. Of particular importance was the study of the effect of earthquakes on building materials and structures made of them. This work was carried out for the first time in the country, and on its basis the first Rules for construction in seismic regions were developed. Despite all the imperfections of these norms, they played a big role in giving the buildings great strength. High quality brickwork and thoroughness of other construction processes, which was one of the main points of the first rules of seismic resistance, led to the fact that these old capital buildings safely withstood many fairly large shocks, including Tashkent earthquake of 1966.

The need to construct buildings with large-span premises for the purpose of locating workshops with a large undivided interior space has led to the active introduction of metal floor structures. These are farms of the most varied spans and outlines. Farms with parallel belts (the building of a locomotive shop in Tashkent), triangular (the building of the Tashkent tram) and trapezoidal ones with different shapes of lanterns made it possible to create buildings of various compositions and rather large sizes in the plan.

Observation of the results of the earthquakes in Andijan in 1901 and the creation of the Rules for anti-seismic construction led to the fact that along the longitudinal walls of industrial workshops began to build buttresses at equal distances, which increased the spatial rigidity of the wall, and outwardly gave it greater plasticity and rhythmic alternation. Soon, this technique was used in civilian buildings (Cadet Corps, Real School, 2nd Women's

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Gymnasium, etc.). In some cases, the installation of buttresses was caused by the need to tie the internal metal frame to the metal floor beams.

The use of metal structures for large-span rooms has led to the introduction of metal vaults (factory in Bayram-Ali) and domes (Tsintsadze circus in Tashkent) providing a very striking interior with increased interior space, which also contributes to the protection from summer overheating so characteristic of Central Asia.

And if in the West and in Russia the progress of technical and architectural thought was prepared gradually, all with increasing development, then in Central Asia it was a real revolution in the field of monumental construction, caused by a change in the social foundations of life, the active invasion of very progressive capitalist relations and the subsequent development of industry, transport, agriculture, construction of a new type of irrigation facilities, railways and railway structures, industrial buildings, mansions of the new nobility, residential buildings of a new type, etc.

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