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Specific Features of Historical Structures of Buildings and Road Facilities in Bulgaria in 19th and In the Beginning of 20th Century

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Abstract— **The aim of the study is an analysis of some constructive systems in Bulgarian architecture in 19th century and in the beginning of 20th century. In the historical development of Bulgaria this is the time of changes in all areas of life. The period is connected with the transition from the Middle Ages to the Modern Era and the perception of the changes brought about by the industrial development in Europe. The wooden and steel constructions used in cult and public buildings and facilities have been explored. The use of different types of materials for these structures is related to the functions of the facilities, their social and industrial significance. In the course of the study, the hypothesis of the unity of the construction system and its relation to the terrain is confirmed. The unity of the construction system is considered as a significant problem, because builders during this period follow the local historical tradition and good knowledge of the craft. Following the tradition they work with historic, traditional materials such as wood and stone. The change with the constructions and the materials comes with the liberation of the Bulgaria in 1878. At that time an accelerated development of industrial production began. The active construction of buildings and road facilities is connected with steel structures of prefabricated elements. Often, they also come into use due to the compromised peculiarities of the terrain. In the study in chronological order were analyzed cult buildings with brick massive constructions, with wooden constructions and industrial steel structures. A cult building rare for the Bulgarian architecture, such as the church in Istanbul, is accented. It is assembled from pre-fabricated steel profiles in order to be reversible, portable and easily replaceable structural elements.**

Index Terms— **Bulgarian buildings and road facilities; historical stone, wooden and steel constructions; industrial production; pre-fabricated steel profiles.**

I. INTRODUCTION

In the Middle Ages in Bulgaria (7-18 c.), stone masonry and constructions were traditionally used in the construction of public buildings and fortification facilities (palaces, churches and fortresses). The construction of these representative and significant buildings according to their functions is based on the long-standing long-live tradition of Proto-Bulgarians, nomadic tribes who migrate from Central Asia (Pamir, Hindukush) to Europe for several centuries. These tribes settled south of the Danube and the west of the Black Sea in the 7th century. They accept Christianity from a powerful enough empire, such as Byzantium. During this period, they unite the transferred knowledge of architecture from the time they migrate [1]. The construction of the buildings is made of stone masonry, masonry of mixed type with alternation of bricks and stone. Churche's plan schemes are basilicas and variants of domed temples. In them the builders show their creative energy in developing the tectonics of the temples and experiment in the domed structures. During the prolonged Ottoman rule (third quarter of 14th-third quarter of 19th c.) in the cult architecture were imposed strict norms for the height of the buildings. For this reason, the domes are blind or hidden under the double sided roof. During this period, churches are not distinguished from residential buildings, which often require the use of wooden structures. In these relatively light constructions, the coatings are steel or tiled. After Bulgaria became an independent state as a result of the Russo-Turkish War (1877-1878), the country was entering European investments mainly in road construction. Trains and bridges are being built. The structures are made of stone or steel. Steel structures are known for the construction of industrial buildings such as markets and a unique church for the Balkan Peninsula, such as the church "St. Stefan "in Istanbul.

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II. STONE MEDIEVAL TEMPLE AND BRIDGE CONSTRUCTIONS.

A. *Basilica St. Sofia in Sofia*

The basilica of St. Sofia is an example of Byzantium masonry, based on the Roman technology. This church is a unique monument from the early Byzantine construction. It dates from the second half of the 5th century [2], [3], [1]. It is a three auditorium construction with total length 46,50 m and width 23,00 m (Figures. 1, 2, 3). The central part of the structure is divided into three auditoriums by massive masonry columns with a cross-type cross-section. They are connected one another by arches without capitals. The main auditorium after crossing with the transverse auditorium continues with a same height in the altar space and forms a Latin cross. On the crossing place of the two auditorium a square is formed marked by 4 columns that sustains the main cupola by means of 4 triangular spherical surfaces. The cupola is hidden from outside by tetrahedron. In 1878 the main architect of Sofia the Czech L. Bayer pay attention to the church keeping and restoration. The basilica "St Sofia" has almost 15 century history. It had been constructed for a long time. The structure has endured some strong earthquakes. The last reconstruction of the church has been made in 1930. Two investigations were made to evaluate the seismic vulnerability of the church[4] The first one is accomplished for the unstrengthen structure in 1989 by the computer programs COSMOS [5] using 3D brick finite elements [6]. The second analysis is performed in 1998. In this study the spatial model is composed from existing structural elements from one side and some new strengthening elements (two reinforced concrete shells above the existing masonry domes and six tension bars of the roof arches and vaults) on the other hand [7]. The analysis is made by the finite element method (FEM) using also the COSMOS computer program [5]. The model contains 2475 finite elements and 2283 nodes with 6 DOF (3 displacements and 3 rotations) in each one (Figure 3). The total number of equation is 12666. The shell elements have bending and membrane stiffness.. The shear deformations are taken into account. Elastic and isotropic material is assumed. The particular structural elements are defines as regions. The finite element mesh of each region has a maximal dimensions up to 1,5 m (Figure 4). The adjacent regions are connected each other by common nodes which guarantee displacement and rotation compatibility. Supporting nodes are entirely fixed. The geometrical characteristics of the structure are the following: the wall thickness varies from 1,10 to 2,00 m, the masonry vault thickness is 0,30 m, the new r/c shell is 0,10 m thick. The material properties of the brick masonry are: the Young's modulus is E=1350 MPa, the shear modulus is G=0,4E=540 MPa, the mass density is γ=1800 kg/m^3, but for the concrete they are: E=25000 MPa, G=0,425E=10625 MPa, γ=2500 kg/m^3. The basilica structure is analyzed under vertical load and seismic actions of 9th degree according to MSK-64 and Bulgarian design codes [8]. The first 3 periods of the undamped free vibration are obtained as T_1=0,287 sec, T_2=0,216 sec, T_3=0,197 sec. The internal forces and stresses are computed considering the first 50 natural mode shapes. The seismic analysis is accomplished by two simultaneous horizontal seismic signals given by two correlated horizontal spectra. As a result the stresses in the dangerous points of the structure are obtained for the following two combinations: 1st combination - max stress = stress caused by the vertical load + stress from the seismic action; 2nd combination - min stress = stress caused by the vertical load - stress from the seismic action. The characteristic stresses of the wall masonry are: compression stress is 0,9 MPa, tension stress is 0,03 MPa, tension stress under bending is 0,04 MPa, shear stress is 0,05 MPa but for the roof masonry they are 0,5 MPa, 0,005 MPa, 0,01 MPa, 0,01 MPa respectively. The vertical stresses σ_z and the tangential stresses in walls and columns caused by the vertical and seismic loads exceed the material strengths. As a result brick elements are in danger. The stress concentration around the tension members is observed. Full scale dynamic experiment is realized too [9]. The numerical and experimental results have good agreement.

Figure 1: St. Sofia inside view.

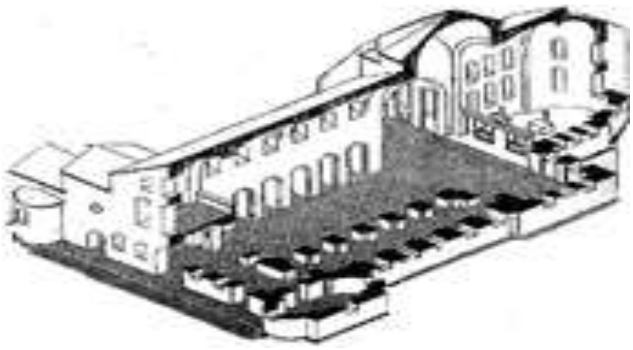

Figure 2: Axonometric plan-section.

Figure 3: FE model of the St. Sofia basilica

Many structural damages are detected [15]. Large cracks in vaults, domes and walls, soil settlements, deformations, decrease of the material strengths by the surrounding environmental effects, etc. are available. The main reason for damages are the past strong earthquakes. Some structural interventions are made during the last years to safeguarding of this unique and important monument in the center of Sofia. The investigations discovered that the structure responses as it is comprised of particular (isolated) fragments due to the deep and large cracks between them and insufficient contacts between the interventions. The structural spatial unity is slightly expressed. The basilica was very vulnerable to seismic actions. Therefore the effective structural measures were accomplished to restore the entire response of all structure. The cracks are filled up by injection of mix prepared by epoxide resin, stone powder and marble sand (Figs. 4, 5) [15]. A SIKA injection technology for restoration of the masonry continuity is applied. The large cracks are excavated 10 cm deep and enlarged to ease their injection. Some of cracks are filled up gravitationally discharging carefully the mix mortar from the roof after the cracks were preliminary closed by a thin surface coating. About 2 tones epoxide resin are used. Some masonry and masonry joints are rebuilt. The r/c floor plate and beams are strengthened. The new r/c vaults and domes with their supporting beams and rings are cast-in-situ on the old cracked brick masonry ones. The cracked masonry roof elements are hanged on the new ones by steel dowels (Figures 4, 5). The tension members of high strength steel bars are mounted in the arches and vaults. Their anchorage is in holes 50-60 cm in a diameter and 120 cm deep drilled in the walls or outside of the walls using the epoxide resin or cement mortar. They were tensioned by thread studs or nuts. Soil injection ate executed also. Some stone masonry foundations are enlarged and made deeper. Some temporary openings were blocked. An external r/c belt course is built at a level 0,00. Some tension members are assembled under the floor plate too[15].

An SIKA injection technology for restoration the masonry continuity is applied.

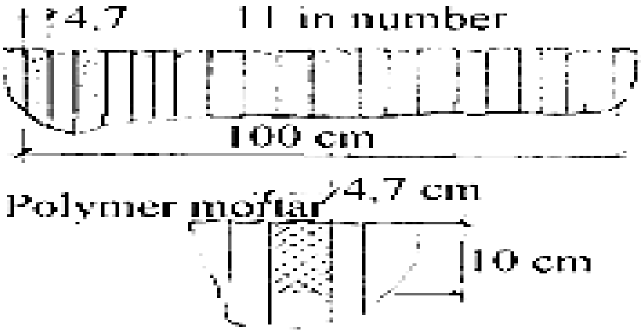

Figure 4: Filling of cracks

Review Stage

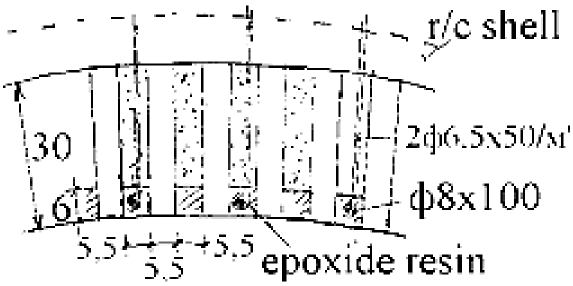

Figure 5: Anchorage of anchors in the vaults

B. Kadin Bridge

Kadin Bridge is an arch bridge over the Struma River near to Nevestino, Kiustendil region. The bridge was built in 1470 on the order of Vizier Isaac Pasha during the reign of Ottoman sultan Mehmed II. Nowadays the bridge is still in use with a limited load-carrying capacity of 200 kN vehicles[10]. The bridge was proclaimed a monument of culture in 1968. The structure is a close-spandrel deck-arch stone bridge with a total length of 100.00 m and includes three main spans of 14.80 m + 20.00 m + 13.50 m. Additional two spans help to capture the capacity of the spring high level of the river water. They have spans of 4.80 m and 3.00 m. All arches are approximately semicircular shaped and have a total width of 6.00 m. The bridge deck is 5.60 m wide and has symmetrical longitudinal slopes of 10‰. The stone parapet is 0.40 m wide and the height varies from 0.40 to 1.00 m. The main piers have dimensions of 5.00x6.00 m. The material used for the bridge construction is high quality granite. The piers are supported by timber piles. The bridge structure survived one of the strongest earthquakes in Bulgaria in 1904 with a magnitude of 7.8 of the Richter scale and epicentre in the Struma River region.

Figure 6: Kadin bridge.

C. The Old Bridge

The Old Bridge or Mustafa Pasha Bridge is a stone arch bridge as shown in Figure 7, over the Maritsa River near to Svilengrad (with an old name: Mustafa Pasha). The bridge was built in 1529 on the order of Vizier Mustafa Pasha. The bridge is proclaimed as a monument of culture with an owner the Road Infrastructure Agency. The structure is a close-spandrel deck-arch bridge with a total length of 286.00 m and includes 18 main spans with a widest span of 18.00 m. Additional two spans help to capture the capacity of the spring high level of the river water. The bridge arches are shaped according to the typical Arabian style with tapered crowns of arches. The total width of the bridge is 7.00 m. The deck has a stone parapet 0.33 m wide and the height varies from 0.40 m to 0.80 m. The three middle piers have dimensions of 9.50x6.80 m; the remaining piers have dimensions of 3.50x6.80 m. The piers stone footings are timber pile foundations. The bridge structure survived one of the strongest earthquakes in Bulgaria in 1928 with a magnitude of 7.0 on the Richter scale with epicentre near to Popovica.

Figure 7: The Old Bridge.

III. Nineteenth Century Constructions

A. TYPICAL CONSTRUCTIONS

1. Rila monastery

The constructions in the first three quarters of the 19^{th} c. in Bulgarian architecture are stone and wooden. They are connected with the historical tradition. The example of Rila Monastery represents building traditions after the medieval long way of development of the architecture. According to historical sources the Monastery was found in 927-941 by St. Ivan Rilski. In the course of centuries the Monastery passed through several stages of reconstruction. It was burned down several times and rebuilt again. The present Central Building was re-constructed in 1816-1847. In 1960-1964 the east wing was re-built with a new structure.

The Monastery was erected as a closed complex of buildings, surrounding an inner yard in the form of an irregular quadrangle (Figure 8). The outer architecture has the characteristics of a fortress. The walls were built by using stone masonry and have window openings. The width of the walls varies in proportion to their height from 1.6 m at the foundations to 0.8m at the top. The front elevation consists of two main elements - arches and columns. The inside walls have timber structures filled with brick masonry. The floor and roof structures are made of timber. The roof was repaired in the twenties. The Central church is constructed in Byzantium Athos monastery traditions. It is domed basilica. The monastery housing wings have four storey's and contain more than 300 monastic accommodations, 4 chapels and numerous guest-rooms and storerooms. The most interesting of all premises is the large monastery kitchen, called "magernitsa"[11]. It is a massive tower in the form of a pyramid, which passes through all floors and ends up over the roof in a dome. It was erected on 4 massive arches on a square base and reaches the height of 22 m. The pyramid structure was built due to 10 consecutive rows of arches arranged over one another on a base in the form of an octagon. With its structure, tectonics, spatial solution and architecture this part of the Rila Monastery is a unique achievement.

Figure 8: Plan of Rila Monastery.

The main Church "Holly Virgin" in the Rila Monastery was built in 1834-1838 in the middle of the monastery yard. With its layout, design and front elevation solutions, the church represents an astonishing achievement of Bulgarian architecture during the age of the Revival. It is a five-domed building with two lateral chapels and a gallery opened to the West, to the North and to the South (Figure 9). Three large domes with high drums form the axis of the main space of the church, which has the impressive dimensions of 14/31m. Wide-span arches at the transverse axes of the domes create a complex cross-like composition. The one-storeyed arched gallery is interesting with its unequal spans between the columns and blind domes at the roof. The western wall of the church bends into a triple yoke-like gable, which forms the main cornice of the building. The walls of the church were erected by using layers of stones and bricks. The complicated architectural and structural composition of the Church "Holy Virgin" represents the emphasis in the whole monastery complex. This remarkable religious monument is an integral part of the thorough harmony of the monastery complex.

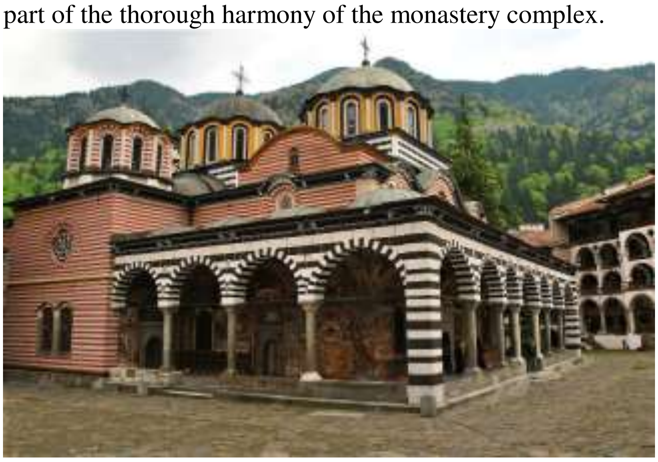

Figure 9: Church Holly Virgin.

Seismic Monitoring System of Rila Monastery

Bulgarian government takes various measures aimed at preserving Bulgarian cultural heritage, which holds Bulgarian national spirit and national identity. One strategic line is to finance research work on the reactions of respective structures to seismic forces. The following paragraph is aimed to present the approach and the results of a research performed at CLSMSE-BAS. The objective of the research was to determine the dynamic characteristics/parameters of the Rila Monastery building, as well as the church "Holy Virgin". The dynamic characteristics were determined in result of analysis of registered real earthquakes, regenerated by a system for seismic monitoring. The latter had been created by using equipment donated by UNESCO. The equipment involved consists of 4 digital accelerographs, produced by the Swiss company GEOSYS [9]. The digital accelerographs include an accelerometer block SSA-20 and an operational computer block GSR-20. Three independent seismic channels in SSA-20 register three perpendicular movement components. The operational computer block is a 12-byte system for recording seismic data. The seismic monitoring system ensures: Registration of seismic signals, featured as input signals for the respective structure; Registration of the movements of specific structural points in result of the impact of seismic forces. Two earthquakes have been registered with the system described in the preceding paragraph. The earthquake on 03/07/1998 had a magnitude of M=3.7. The epicenter was at a distance of 27km to the Northwest from the Monastery with seismic focus at a depth of 13km. The earthquake on 10/09/1998 had a magnitude of M=3.1 and the epicenter was at 48km to the Northeast from the Monastery. Due to the analysis of the data recorded during the earthquakes the fundamental vibration period, the frequency (fl=3.613Hz; Tl=0.277sec) and the frequency spectra of amplification of the three structural components at level 1157m compared to the ground level (1139m) were determined. The dynamic characteristics obtained could be used for analysis of seismic loading (Figure 10).

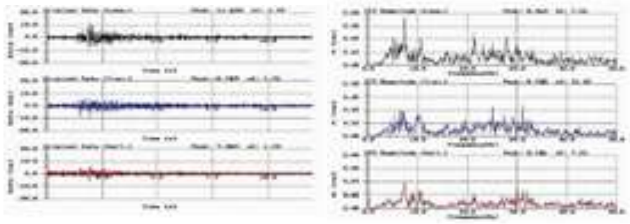

Figure 10. Accelerograms

2. St. Dimitar church in Kyustendil

The roof of St. Dimitar church demonstrates the timber construction on the second part of 19^{th} c. The church is located in the town of Kyustendil placed in the South-west of Bulgaria. It was built between the 1864 and 1866. It is rectangular in plan dimensions: width 15,60 m. and 26,65 m. length. The whole church with bell tower is high about 12 m. The roof structure of the church is made entirely of wood elements. Inside the church are constructed by two rows of wooden columns, passing through the arch of the roof structure and reaching the inclined beams of the roof of the building. On the columns at the level of the floor - ceiling beams and above the level of the roof, longitudinal beams are situated, bearing by both sides respectively the weight of other parts of the roof structure. On the level of the top of the stone walls have developed two uninhabited galleries with wooden floor beams. At one end floor beams rely on the stone walls of axes A and G (Figure 11). The inner end of the beams are based on the main longitudinal beam, which in turn is supported on wooden columns. Above this elevation wooden columns continue up to a height of 1,96 m. Above the galleries, columns are united with one purlin, which lies on them in the distances marked in digital axes. Purlin rests on columns by pillow. The slope of the roof (32^o) is formed with inclined ribs which lie in the lower end on the stone walls. The rehabilitation of the timber beams supports was performed through the fixation with steel triangle and steel bolts. Anchoring of purlins to the outside wall is recommended to be done using the steel lashes and steel bolts (Figure 12). Strengthening of the damaged structural element (console-pillow and beam-purlin) with steel are performed by steel lashes and steel bolts also. Using the numerical analysis of the timber roof of the church is shown the potentials of a three-dimensional computer modelling and simulation of a building structure. However it is shown: how the science of engineering in particular, and advanced computer modelling including finite element methods, can be used to increase the understanding of a whole structure and also demonstrate how to apply this method to a historical building structure (Figure 13).

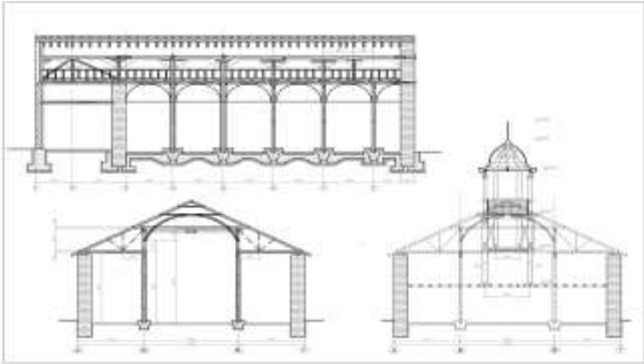

Figure 11: Cross Section of the Church St. Dimitar.

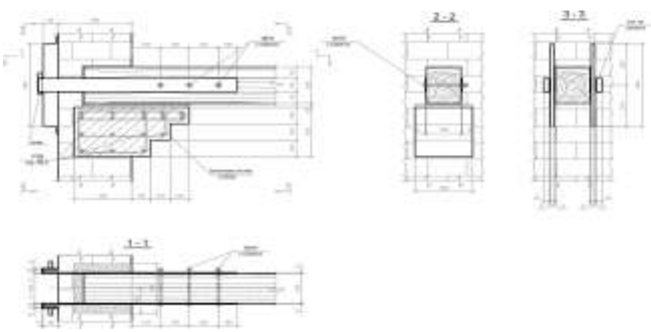

Figure 12: Anchoring of purlin to the outside wall by steel lashes.

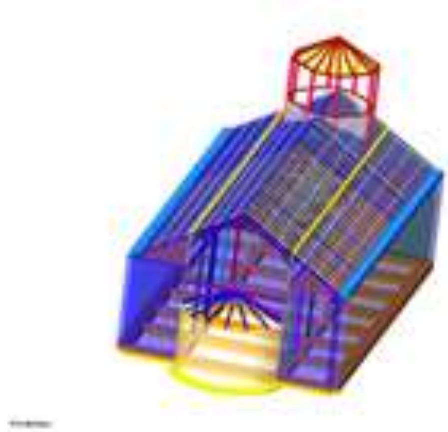

Figure 13: 3D dimensional computational model for structural system

3. Belenski bridge

Belenski bridge (Figure 14) is a stone arch bridge placed over the Yantra River near to Byala, Rousse region (Figure 14). The bridge was built in 1867 on the order of Mithad Pasha – statesman of the Danube Province in Ottoman Empire. The bridge builder was the famous local master Kolyo Ficheto. The bridge owner is the Agency "Road Infrastructure" and it was proclaimed a monument of culture in 1980. The structure is a close-spandrel deck-arch bridge with a total length of 276.00 m and includes 14 spans of 12.60 m. All arches rise 4.335 m above the ground. All arches are approximately semicircular shaped and the roadway is 9.00 m wide. The arches are built of two rows of stones with a total height of 0.8 m. The bridge deck has a stone parapet and with dimensions of 0.2x0.9 m. The material used for the bridge construction is a high quality limestone. The arch piers have dimensions of 5.40x9.00 m. Part of the piers footings have a pile foundation consisting of timber piles 6.00 m long with diameter of 0.20 m and distance between them of 0.30 m. The remaining part of the piers footings are bedded on a solid gneiss rock. The bridge structure survived one of the strongest earthquakes in Bulgaria at 1901 with a magnitude of 7.2 on the Richter scale and epicenter near Shabla.

Figure 14: Belenski bridge.

B. IRON BRIDGES AND CHURCHES IN THE 19TH C.

The next examples represent the penetration of modern era in the area of construction idea. After the Liberation from Ottoman domination Bulgaria join to the modern European processes of constructions.

1. Lom Bridge

The Lom Bridge (Figure 15) is a steel trough-truss structure as shown in Figure 24 over the Lom River near to the Danube riverside town of Lom. The Italian bridge designer and contractor are unknown. The bridge owner is the Municipality of Lom and it was opened to traffic in 1890. Nowadays the bridge is still in use with a limited load-carrying capacity of 200 kN vehicles. The bridge is a 5-span structure with a total length of 117.5 m. Each of the spans consists of two parallel Pratt-type trusses with a distance between them of 5.70 m. The trusses have 10 panels with a total length of 23.50 m and height of 2.20 m. The bridge deck is 8.70 m wide. The truss chords are parallel and have a "T"-shaped cross-sections fabricated by two angle sections, back to back with a steel plate between them. The angle sections are additionally strengthened by steel plates. The truss diagonal members have "I"-shaped cross-section fabricated by four angle sections, back to back with a web of steel plate. The diagonal members are riveted directly to the chord members without gusset plates. All fabricated cross-sections are fastened by a riveting. The floor beams are placed at the lower joints of the trusses and are hot-rolled "I"-sections, 500 mm deep. The bridge deck has five stringers, placed at a distance of 1.14 m. The stringers also have an "I"-shaped cross-section, 270 mm deep. The concrete deck slab is 120 mm thick. The bridge superstructure has a lower lateral bracing made of hot-rolled angle sections. The truss supports are steel hinged on the one of the pier and steel rollers on the other pier. The bridge abutments and piers are made of stone masonry. The piers are supported by timber piles.

Figure 15: Lom Bridge

2. Stambolov Bridge

The Stambolov brige is an example of quick penetration of steel construction in the road system in the 19th c. It is a steel deck-truss arch structure over the Yantra River at Veliko Tarnovo town (Figure 16). The bridge was designed and built by the Austrian "Waagner-Biro" company and is opened to traffic in 1892. The structure consists of two parallel Pratt-type truss arches with a distance between them of 5.60 m. The truss arches are 8.60 m high at the abutments and 1.20 m at the middle. They have 26 panels with a total length of 81.60 m. The bridge deck is 7.30 m wide. The upper horizontal chord and lower parabolic arch chord of the trusses are "U"-sections, 500 mm deep and fabricated by four angle sections with dimensions of 80x80x10 mm, back to back with a steel plate between them of 20 mm thick.

The outside flanges are additionally strengthened by steel plates with dimensions of 50x240 mm. The vertical and the diagonal members of the trusses have "I"-shaped cross-sections fabricated by four angle sections with dimensions of 120x70x7 mm, back to back with a web of 10 mm thick. The diagonal members are riveted directly to the chord members without gusset plates. The floor beams of the bridge are "I"-shaped, 600 mm high, fabricated by angle sections. The stringers also have an "I"-shaped cross-section. All fabricated cross-sections are fastened by a riveting. Lateral "X" bracings are placed at the upper and the lower chords and at the panel ends.

The bridge is supported on the abutments by steel hinged bearings. The abutment's foundations are bedded on the solid rocks. The bridge structure survived one of strongest earthquakes in Bulgaria at 1913 with a magnitude of 7.0 on the Richter scale.

Figure 16: Stambolov bridge.

3. The orthodox church of St. Stefan in Istanbul

The orthodox church of St. Stefan in Istanbul (Figure 17 and 18) is situated near the Golden Horn in the historical part of the peninsula between the Fener and Balat districts. This church is under the supervision of the Bulgarian Churches Foundation in Istanbul. On the Balkans, however, shared maintenance between Bulgaria and Turkey has led to problems for many architectural monuments. The temple, like many other Bulgarian religious buildings in Turkey and Turkish religious buildings in Bulgaria, has the status of an architectural monument and has been maintained by both countries according to the Bilateral Agreement on Cultural, Scientific and Educational Cooperation (1997) between the governments of the Republic of Bulgaria and the Republic of Turkey.

Figure 17: St. Stefan church, front of view.

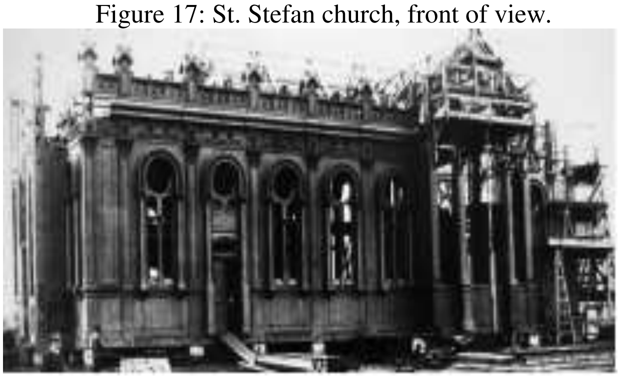

Figure 18: Construction phase of the church–iron structure

With the development of technology in Europe from the end of the 18th century in the buildings began to use cast-iron columns for halls spatially solved. The earlier European example is a building of the Sainte-Geneviève Library in Paris Between 1838 and 1850, is designed and constructed under the direction of the architect Henri Labrouste. In this case, the constructive solution of the vaults is united with the aesthetics of the iron decoration. (Figure 19). Since the middle of the 19th century, steel structures of pre-fabricated profiles have been increasingly used. An even newer solution represents the Cristal Palace in London from 1851 (Figure 20). Its specifications are temporary decision, rationality, less expense, and economical to build within the short time remaining. Bulgaria joined this revolutionary process in the 1890s.

The church of St. Stefan in its present form was built between December 1895 and July 1896, funded by the Bulgarian government. The designer was Hovsep Aznavur, an Istanbul architect of Armenian origin. The church itself was constructed by the Rudolf Phillip Waagner Company, and was made with a cast iron façade and steel sheets or rolled sections for the structural elements and ornaments. It was taken to lighten the weight of the building, which is to be lifted on a landslide terrain which is pre-erected with pendulous piles [12]. According to its plan, the temple is a single-apse three-nave basilica with a short transept and empora, and with an eclectic façade decoration style. Unique roof structural system of church of St. Stefan in Istanbul, together with its architectural design will be explained through its main portal frame systems with precisely designed geometry [13], with circular columns in the mid of the space, truss beams and roof detailing with bars. The constructions are without filler and have steel finishes. [14].

Figure 19: Reading room of the Bibliothèque Sainte-Geneviève

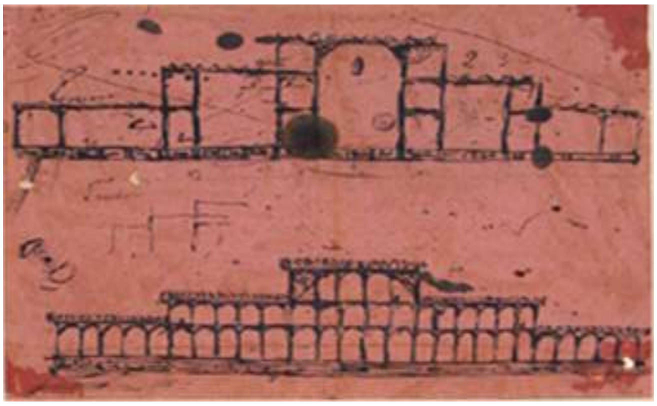

Figure 20: Sir Joseph Paxton (1801-65), Facsimile of the First Sketch for the Great Exhibition Building, About 1850, Pen and ink on blotting paper V&A Museum no. E.941-1983 Source:
http://www.vam.ac.uk/images/image/40943-popup.html

IV. CONSTRUCTIONS OF MODERNITY

1. Central Sofia market hall

The modern peculiarities of 20th c. are developed in the Central Sofia Market Hall in 1909. Its architectural design as the cover of the building has three parts in architectural planning, as main entrance axis, with two side areas for stalls (Figure 21) [16]. Then it has two different portal frame solution, one for main entrance axis and other one is for two side areas of the entrance axis. Its iron-steel roof structural system has a unique solution from the point of steel architecture. Central Sofia Market Hall has three parts in floor plan. One is the entrance hall which is main axis and narrower than the other two parts which are at the both sides of the entrance hall. The entrance hall has the full height of the building, where the other two has one floor upstairs. Then the both floors are having the half height for each of them. In the mid of the plan, main exit is perpendicular with the other corridor axis for the doors at the sides. There is a perimeter wall, surrounding whole building complex, having 4 doors and totally, 40 windows, which are designed for one storey building and now gives service for light for two storeys. The roof design is as gable roof for main entrance hall and as hipped roof for the side parts. Three of them have clerestory for daylight. There are 12 circular hollow section columns at the sides of entrance hall to get the loads coming from the roof levels (Figure 8). At the side ends of the building, the loads coming from the roof, are transferred to the perimeter wall (Figure 22).

Figure 21: The front facade of the Central market hall

Figure 22: The main entrance door of Market hall from inside

2. Synagogue in Sofia

The synagogue building in Sofia is located in the central part of the city and was built between 1905-1909. Since 1955 it has been included in the list of monuments of culture in the Republic of Bulgaria. The exterior building is planed in a rectangular shape and the interior is shaped as a symmetrical octagon with two different lengths, symmetrically aligned with the main and axes. The total built-up area is about 1000 square meters (Figures 23, 24). There is a gallery on seven sides of the octagon. The prayer hall has a square in plan shape with dimensions 27x27 m. Its cover is made of a steel dome. The dome has a 24 m aperture and is constructed as a rod construction consisting of radial and ring-shaped truss construction. It is supported by individual brick columns, which in turn step on powerful brick pilasters that form the corners of the octagon. The dome is constructed of three types of radially located truss construction and has four ring-shaped reinforcement truss construction. A small dome with a 4,40-m-wide hole is built on the top ring-shaped truss, which is made of light, radially spaced steel truss. The main dome support of the large dome is at the points of radial truss construction that pass through the corners of the octagon and is executed by trapezoidal shaped bricks columns that connect to the outer ring walls by a 30 cm thick wall. Radial truss construction - of the second and third types are supported at their lower end by brick columns with dimensions 60/90 which step on cylindrical brick vaults that form the space behind the octagon. The construction of the short edge over the polygon is a brick cylindrical vault that connects to a part of a spherical brick dome that in turn connects with the outer surrounding walls. On the west side of the building, where the main entrance of the Synagogue, there is a two-story body with a basement used as an administrative building. It is related to the construction of the Synagogue, and the two bodies are a common body. The floor structures of the two-story building are made of steel I profiles, located at a distance of 80-100 cm, and a Prussian vault, stepping on the steel beams. During the Second World War, the building of the Synagogue was affected by the bombing, which damaged the roof, the northwest half-balcony, the balcony above it, and the window display windows in the prayer hall. The demolished part is restored with a reinforced concrete structure, which includes a part of the outer enclosing walls and part of the floor structure of the building. Restoration works were completed in the early 1970s. The main supporting elements of the building that resist the action of the horizontal forces are stone masonry, brick masonry and steel truss. Stone masonry is located in a small area at the bottom of the building and has high strength. This load-bearing capacity is determined by the strength of the brick masonry and the steel dome truss. All the brick walls of the building are made of solid single bricks with dimensions: 7x14x25 cm and 6 кg. on a brick. From the constructive point of view, the building presents a complex combination of different outline and shape elements, which differ in static and dynamic behavior. The way of support of the steel dome made it possible to examine the same in a simple way, as a spatial-rod construction was adopted for the calculation model. The number of the concentrated masses is assumed to be equal to 49, each mass having three degrees of freedom. In the study of the steel roof structure, the coefficient of significance is assumed C = 1,5 and the response factor - R-0,2. The structure has been investigated for 30 forms of proprietary oscillations. The construction of the high and low body of the synagogue building is examined together in a dynamic static study that corresponds to the actual situation. Due to the great complexity of the structure, each bearing element is broken into end elements which are connected to each other in a common network of end elements. Taking into account the type of foundations and foundation depths in the calculation scheme it is assumed that the base is elastically irreplaceable [16].

Figure 23: The front of View of Synagogue

Figure 24: The Inside View of Synagogue

V. CONCLUSIONS AND RECOMMENDATIONS

The old historical structures are living witnesses of the previous national achievements, traditions and culture [11-16]. Their value is great and it is very important to preserve them for the next generation. These structures are survived many catastrophic events but it does not guarantee their survival in the future. The structure damages from by natural phenomena or by human actions can cause their failure in some extreme situation. Each historic structure is unique. There are no standard or generally accepted method for analysis, maintenance and strengthening of these structures. An estimation of the present state is very important and necessary as a first step. Every historical object should have a passport with its specific peculiarities including all necessary data: monument history, geometrical characteristics, material and soil properties, crack propagation, atmospheric effects, dynamic characteristics, endured damages and repairs, results from monitoring, numerical and experimental results from previous analysis. The material properties can be obtained by using nondestructive methods such as rebound test, ultrasonic test, radiographic test, surface hardness test, permeability test. Crack depth and direction can be studied applying ultrasonic test around the crack zone before and after strengthening. Data obtained in laboratories or at the site can be treated by statistical methods. Finally all these data should be used to create adequate models for spatial analysis by the FEM and strengthening of the structure.

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