110 YEARS HISTORY OF SYNAGOGUE CONSTRUCTION IN THE CAPITAL CITY SOFIA IN BULGARIA

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ABSTRACT

The paper make attempt to describe and analyse the complex construction of the 110-year old synagogue in Sofia using architectural and constructive documentation, developed at the Institute for Cultural Monuments in Sofia, in the late 1990s. During the second world war in 1944 a catastrophic bomb attack of the city of Sofia, provokes extensive damages in many masonry buildings and put at imminent risk the valuable historical and architectural heritage of the city. The condition of the structure of the synagogue after the bombing of Sofia in 1944 is described in detail. Additionally, the existing damages observed in the walls and vaults and the processes of corrosion observed in the steel roof are analysed after standing for 45 years (1944-1989) after the bombing and under the open sky. The approach of the specialists on the seismic vulnerability of the building at the moment of the introduction of the new earthquake regulation in Bulgaria in 1987 is thoroughly analysed. By taking into consideration the existing damages and the results of the analysis, a rehabilitation and a seismic retrofitting plan are proposed and applied by the application of innovative construction materials. The results of the numerical analysis are used as well to design a complex retrofitting system based on several techniques and giving the possibility to make the compromise between the safety and the conservation of building's historical characteristics, following in the same time the requirements of the national regulations.

Keywords: *110-year-old synagogue, monuments, ring-shaped girders, valuable historical and architectural heritage, marble columns*

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1. Introduction

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 planned 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 1 and 2). There is a gallery on seven sides of the octagon.

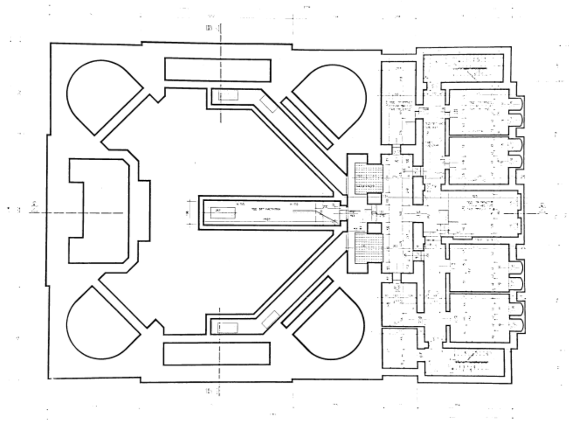

Fig. 1. Architectural Plan of the underground floor

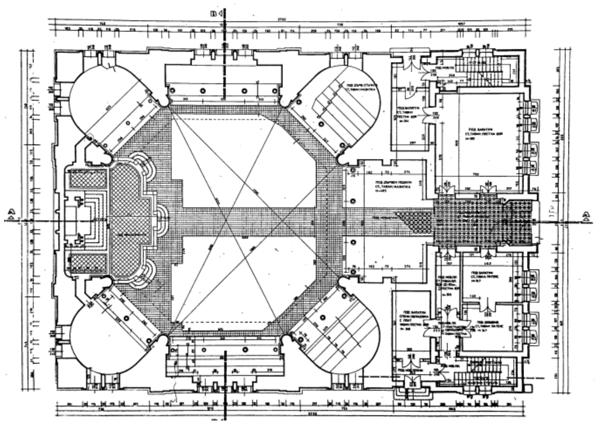

Fig. 2. Architectural Plan of the First Floor

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 (Fig. 3). 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 farm, 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 (Fig. 4).

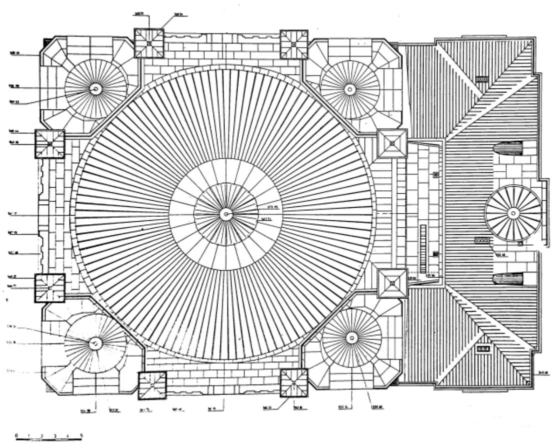

Fig. 3. Architectural Plan of the Roofs Lines

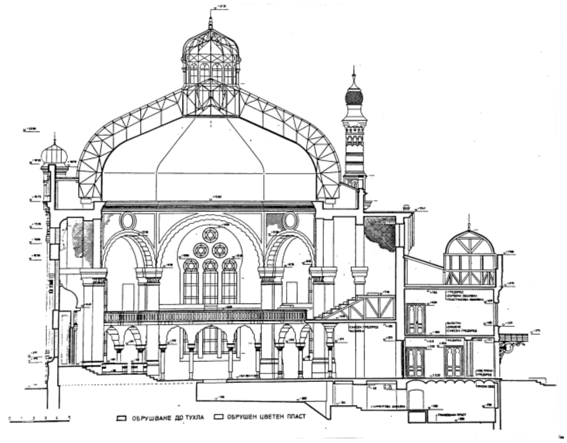

Fig. 4. Architectural Plan of the East-West Section

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. The construction of the coating on the long sides of the polygon is a cylindrical brick vault that steps on brick pilasters with trapezoidal cross-section and connects with the outer enclosing walls of the building. Thus, on the perimeter of the octagon there are brick vaults with two different openings, alternating in size. In order to shape the interior of the walls of the octagon, a brick wall is executed which, on the bottom of the brick vaults, steps on powerful brick pilasters. the wall on the brick vaults is 60 cm thick and continues to the level of the dome support ring. it ends freely, without a reinforced concrete belt and without being connected to other structural elements. 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 (Fig.5 and 6). 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.

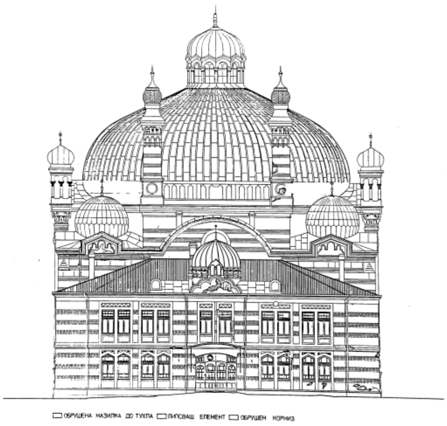

Fig. 5. Architectural plan of the West Elevation

Fig. 6. View of the West Elevation

2. An analysis of the condition of the construction of the synagogue after the bombing and staying of the construction 45 years under the open sky.

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 (RCS), which includes a part of the outer enclosing walls and part of the floor structure of the building. Restoration works using (RCS) without steel roof reconstruction, were completed in the early 1970 [5].

From the studies on the state of construction of the building, the presence of cracks in the brick masonry of the middle and intermediate vaults, semi-compartments and facade walls of the prayer hall was established. On the ground floor of the prayer hall, the area of brick masonry affected by cracking is about 230 square meters, and the first floor is about 170 square meters or a total of 400 square meters. The total length of macro-cracks with a width of more than 5 mm is about 50 m [5]. Highly affected by corrosion were the steel profiles used for main and secondary load-bearing elements at the stairwells in the two-story body west of the prayer hall as well as the lobes above the openings in the brick columns of the ground floor and the first floor, the floor structure on the first floor in the prayer hall and some columns supporting it. In the steel roofing structure, there is evidence of corrosion processes. They are due to the lack of protection of the steel structure, unsupervised, local leaks and insufficient ventilation. In individual parts (around the central cube), corrosion processes are more pronounced at the locations of leakages. In these, the metal structure is laminated and after removal of corroded products metallic shine is achieved [5].

3. Investigation of the load-bearing capacity of brick masonry

The main supporting elements of the building that resist the action of the horizontal forces are stone masonry, brick masonry and steel farms. 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 farm. All the brick walls of the building are made of solid single bricks with dimensions: 7x14x25 cm and 6 kg on a brick. The average strength was 27.85 MPa of the NISI-tested bricks at the BDS25-78 stress strength, with no significant difference between the individual results (not exceeding 10%). The steel truss of the main dome of the building are made of steel with a normative strength of 300 MPa.

4. Establishing the geological picture of the earth's layers

On the site of the Synagogue, two shrimps were made, from which the geological picture of the earth layers and the level of the ground water was established at a depth of 3.90 m from the terrain. The soil taken from the lowermost layer of the shrub 2 is characterized by BDS 676-85 as a sandy clay with an organic carbon content below the permissible limits. By analysing the result of the samples, the soil on which the building is laid can be counted against the II group according to Table 1 of 1987 anti-seismic norms [1].

5. Seismic analysis and retrofitting of the 110 years old masonry structure of the synagogue in Sofia, according requirements of the existing in 1987 national regulations.

From the constructive point of view, the building presents a complex combination of different outline and shape elements, which differ in static and dynamic behaviour. 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. Efforts in the dome are determined for two types of work - permanent and long-lasting and short-acting. Efforts of seismic impacts are determined by summing up the formula's efforts: $N_d = \sqrt{\sum_{i=1}^{n} N^2{}_{id}}$ the anti-earthquake norms of 1987, from 30 forms of its own oscillations. The normative effort is obtained from the different types of loads with the corresponding coefficients of routines. The dome is statically and dynamically examined as a bar-shaped spatial structure, having 474 knots and 1112 rods. The study was conducted separately for two cases of support of the dome at the points of reference: Supporting at each bearing point three rods particularly connected to each other, allowing free rotation around the support assembly. This method of support corresponds to the actual execution of the support assembly, provided that the horizontal rigidity of the brick columns is not taken into account; Supporting from a vertically incomplete articulated rod and two horizontally elastically yieldable rods. The elastic constant of the horizontally adjustable rods is determined by the submissiveness of the bricks on the brick columns on which the dome steps, which columns are assumed to be firmly tucked into the massive brick pilasters; In both accepted ways of supporting the dome, the support knots cannot take bending moments. 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. The floor structure of the intermediate gallery, part of which is made of a solid reinforced concrete slab, and the rest of the steel beams and reinforced concrete slab is accepted as a horizontal non-deformable disk. The columns supporting the intermediate gallery are hinged at both ends (top and bottom) and are considered elastically indivisible. Covering over the basement in the low body, drawn from steel beams and Prussian vault, and over the first floor - steel beams and reinforced concrete slab, are treated as rigid floor diaphragms. The cover over the second floor in the low body is a wooden beam - work and is regarded as a horizontally deformable horizontal diffract. The overall solution of the building was obtained, the system being broken down into 108 tables and each of them accepted in three degrees of freedom. Efforts are determined by the finite element method. The supporting structure of the high and low body is approximated with 598 end elements having 645 knots. In the dynamic study the efforts of the first eight forms of their own oscillations were taken into account (Figures 8, 9, 10). The calculations were performed on a computer type MTX-32 bit velocity (IBM-RS2) using the program SAP80. V85.03. The dynamic study of the stressed and distorted state of the spatial steel roof structure (domes) was obtained from the decision of 2791 iterative equations with the aid of 43 blocks. Efforts are made of six forms of oscillation. The coefficients of the own oscillations are derived from the single vectors using a specially designed program product. The efforts for the high and low body are attributed to each node (645 in number) included in the outline of the end elements (598 in number). The dynamic characteristics of the building are derived from the solution of 3198 equations. Eight forms of its own oscillations are reported. Seismic impact efforts are obtained by summing up the effort of 8 forms of its own oscillations. Since the dome is solved for two ways of support, those that are larger are adopted for dimensioning efforts. The dimensioning of the dome is made according to the requirements of [2,3] for heavier loaded rods. The load-bearing capacity of the high and low body masonry has been verified by defining the main tensile and compressive stresses on sloped sites at certain points, and then these voltages are compared to the allowable computational resistors according to [4]. Calculation resistors for the main stress and compressive stresses were adopted as masonry brick brand 25 and 1.0 MPa solution according to the "Design Standards for Brick Structures" -1985. For the fragments of brick masonry with cracks, an additional coefficient of performance condition has been introduced, referring to the calculation values of the main stresses, namely: -for main stresses -0.65; for main stresses-0.75. On the basis of the research carried out: on the building of the Synagogue - Sofia, the following conclusion can be made:

5.1 Spatial steel roof structure

With a few exceptions, the cuts on the rods of the steel roof structure are able to absorb the ensuing effort. For only two single filling rods from the bottom ring at the footsteps of two of the farms and one bar on one of the farms, the carrying capacity is lower than required in the range of 10-30%. The steel roof structure has a high degree of static indeterminacy and has a high degree of ductility, with a large number of bars that are loaded significantly less than their load bearing capacity. This allows for a redistribution of effort between the other elements of the structure in case some of the rods are cut off from work due to loss of stiffness or insufficient carrying capacity without resulting in complete destruction. Based on the above, it can be assumed that the roof structure has the necessary security. The cuts of the brick columns on which the roof structure rests receive low stress pressures in the masonry, which ensures their security.

5.2 Buildings belong to the high and low body

Examination of the stress state of the building indicates that in many locations of the structure, the values for the main tension and compression stresses are greater than the limits allowed by the norms. Pressures and tensions exceeding significantly the normative values are obtained in the following places: at the tips of the cylindrical vaults of some elements on the side of their support on the brick pilasters, the values of these stresses reaching 2.4-2.5 MPa; the tops of the cylindrical arches on the side of their support on the outer enclosing walls, the values of these stresses being within the range of 0.7-0.8 MPa; in some elements in the middle of the brick domes, in the areas of their connection with the outer walls; The tension stresses in these sections exceed significantly the permissible values; in the middle sections of the vaults supporting the surrounding brick wall along the perimeter of the octagon, the values of the main stresses being in the range of 0.5-0.8 MPa; in the steps of stepping the above-mentioned vaults on the brick pilasters, the main tensile stresses reach values of 5-6 MPa; in the middle areas of the longitudinal and transverse walls of the low body and in the joints of the low body with the high. In the areas where the calculation of the main stresses is exceeded, there is a real risk of demolition of the brick masonry. Significant major stress pressures exceeding limit values are obtained in the following places: in the middle sections of the brick domes, with the stresses moving within the range of 7.5-9.0MPa; at the points of engagement of some elements, the stresses being within the range of 9.0 MPa; in the middle sections of the longitudinal and transverse walls of the low body. The exceeding of the normative values of the main stresses is a serious prerequisite for the demolition of the masonry in these areas. The cubes, stepping on the four brick vaults, and the cube above the central entrance of the building, which are made of wooden construction, have low seismic resistance. They may experience significant damage and destruction in the event of earthquakes with projected seismic intensity. The four brick-built bell towers are also not anti-seismically insured and can be severely damaged or destroyed in earthquakes with projected seismic intensity. The same applies to the ventilation shaft. Based on the results of the study and the efforts made in the elements of the construction, a reinforcement project has been developed, which is not discussed in this article. Strict adherence to the project will preserve the building in the course of an earthquake with the expected seismic characteristics of the territory of Sofia and will guarantee the lives of the people.

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