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STRENGTHENING OF THE TIMBER ROOF OF THE SECOND TURKISH NATIONAL ASSEMBLY BUILDING IN ANKARA

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Abstract. *The Second National Assembly Building is one of the most significant examples of the Turkish Early Republican Architecture. Originally, it was built as the headquarters for the only party of the republic; however, its function was changed shortly after construction. It served as the parliament building for 36 years from 1924 to 1961. Even though it is mostly referred to as the parliament building, the structure had more changes in function over the years. The building has been used as "The Republican Museum". The study aims to assess the structural deficiencies in the timber roof and ceiling of the structure and explain the proposed strengthening process that is planned to start in the summer of 2014.*

Having been designed by Vedat Tek, who is one of the most important architects of the First National Movement, the building is among the few examples that reflect the characteristics of the period genuinely. It was constructed of masonry with two stories above the basement. The ceiling of the main meeting hall, which is 21 m x 15 m in dimensions, is supported by timber trusses at 3.5 meter intervals. The timber ceiling is unique with its historically invaluable engravings and ornamentations. However, due to the unexpected loads and material deterioration, the deflection on the ceiling exceeded 150 mm. Special work was performed on the ceiling to correct the deflection and reinforce the roof structure without disturbing the original unity of the adornments.

The process involved utilizing steel trusses during restoration. The study also explores the effects of these steel trusses on the masonry arches, which support both the roof and the masonry walls of the main meeting hall. A finite element model has been prepared to explore any possible damage from steel trusses to the structural unity of stone masonry walls and arches. For the analyses, the worst possible loading conditions in strengthening process and earthquakes have been assumed. This study also covers the principles of strengthening historical buildings so as to underline the importance of conserving the original unity of paintings, engravings and other elements of ornamentation.

1 INTRODUCTION

1.1 History of the Second Turkish National Assembly Building

The Second Turkish National Assembly Building, which is one of the most significant architectural works of the Turkish modern architecture, was built to replace the First National Assembly Building as it became insufficient to meet the growing needs of the Grand Assembly of the Turkish Republic. It was initially designed by Vedat Tek as the Headquarters of the Republican People’s Party, who is the founder party of the New Turkish Republic, and was opened for service in 1924. The building served as the Assembly Building until 1961 and then was converted to Republican Museum and has served as such ever since [1, 2].

The Assembly Building has two floors above the basement. It consists of the centrally located two-story high General Assembly Hall (Main Hall) and rooms along the hallways surrounding the Main Hall on its three sides. The Main Hall has important cultural and historical value as it witnessed important gatherings since the beginning of the new Republic. The Presidential Pulpit is centrally located between the main entries of the hall; the Ambassadors’ Lodge takes place at the right and left top corners; the Presidential Honor Lodge is on the left and the audience and Press Lodges are at the back side of the hall. The walls and the ceiling of the hall, which reflects the traces of classical Turkish architecture, are decorated with Seljuk and Ottoman decoration ornaments. The ceiling that consists of wooden panels with hexagonal stars is the most outstanding piece in terms of construction techniques [3, 4].

Figure 1: External and internal view of the Assembly Building.

1.2 Description of the Structural System

The Assembly Building was constructed with stone masonry. The hipped roof was designed with a suspended truss system. The General Assembly Hall displays a structurally independent behavior. The two-story hallways around the Main Hall and the other related service zones are connected to the Main Hall by timber flooring. This separation can clearly be observed at the roof of the structure. The stone masonry walls of the Main Hall are one-meter thick, which means that the Main Hall is more rigid than the connected surrounding secondary spaces. Therefore, the timber flooring connections at the mid-height level have been neglected during structural identification.

The structure that comprises the Main Hall has a rectangular plan with 27.5 m x 14.80 m. The height of the Main Hall reaches up to 14 meters from the foundation level. As it is seen in the Figure 2, there are two big arch-shaped openings on the one-meter thick stone masonry walls on the eastern and western wings. The plans and sections in Figure 3 show the 1.50 m x 3.00 m door openings at the ground floor level on the eastern and western façades. Also, there are 1.50 m x 3.00 m window openings on the southern façade of the structure. The northern façade does not display a structural continuity either. At 6.50 m away from the outer wall that frames the Main Hall, takes place a shallow arch that spans 11.00 meters and rises up to 8.20 meters height. The thickness of the wall at the two sides of the arch is one-meter. The southern outer wall also shows discontinuity. It contains an opening with 6.80 m span and 11.00 meter height.

Figure 2: Arch-shaped opening on the east and west wing walls.

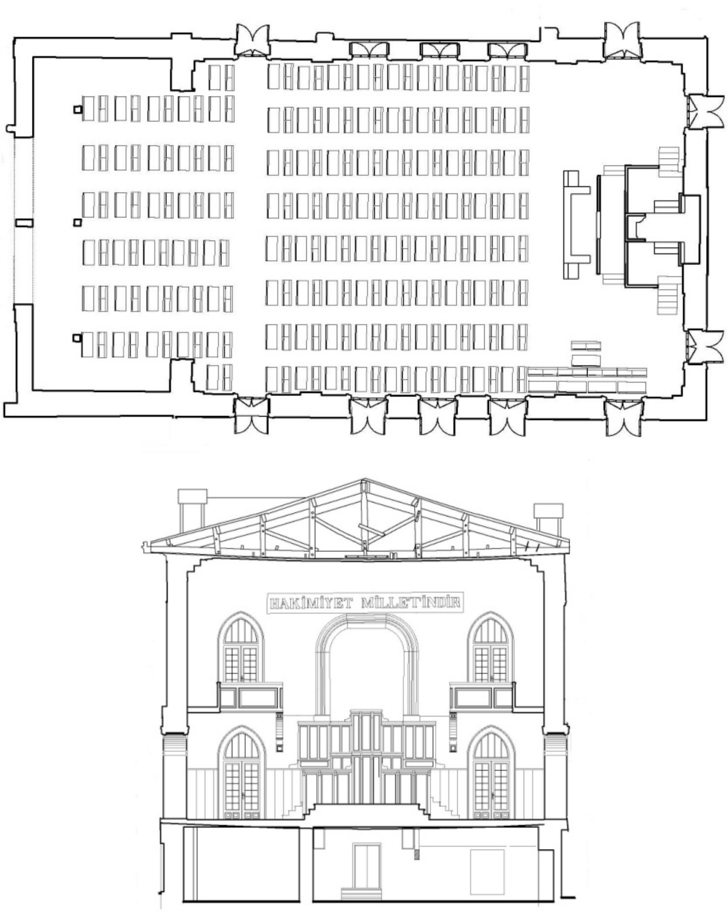

Figure 3: General Assembly Hall (Main Hall) in plan and section [5].

The suspended roof trusses are designed as independent structures that have an on center distance of 3.50 meters and span 14.8 meters. As shown in Fig. 4, the ceiling over the Main Assembly Hall is made of timber beams and timber deck. The timber beams are supported by the suspended trusses. Roofing is made of timber beams and flat tiles.

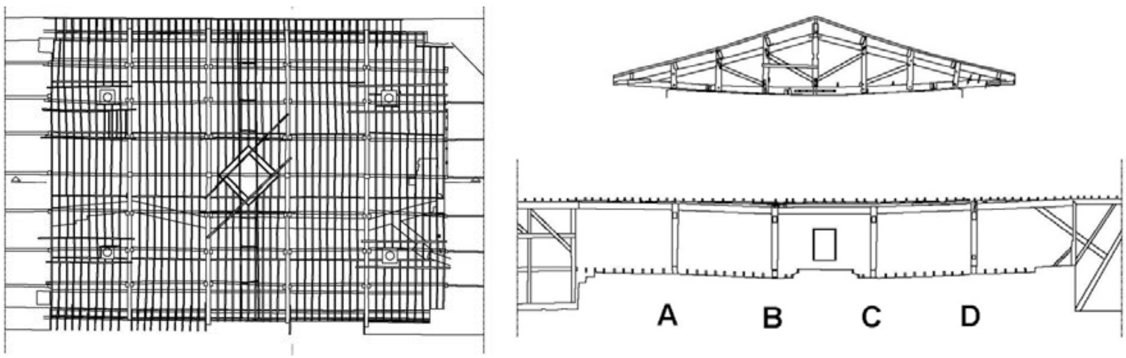

Figure 4: Plan and sections of the suspended truss over the General Assembly Hall [6].

2 STRUCTURAL PROBLEMS OF THE SECOND TURKISH NATIONAL ASSEMBLY BUILDING

2.1 Inspected Structural Problems

The excessive deflection and vertical displacements in the transverse direction of the General Assembly Hall’s ceiling are clearly visible even to the naked eye. The suspended trusses at the roof are in good condition in terms of physical and chemical material properties. However, the working mechanism of the trusses is dubious due to the connection details and the geometrical layout of the members. As it can be seen in Figure 5, the connection between the post in the middle of the trusses and the tension members underneath is provided by only a simple metal plate.

The timber beams that support the ceiling are observed to be in fairly good condition. The mechanical system above these beams and the timber structural members that have been neglected during structural strengthening and maintenance processes increase the total load. Though indirectly, HVAC system units apply extra load on the trusses.

The most significant structural issues on the ceiling are the visible deflections and occasional cracks. The concern about keeping the historical and artistic value of the original ornaments that cover the entire ceiling makes it almost impossible to remove the ceiling deck tied on the timber beam, as it would be seen in the Figure 5.

Figure 5: Suspended trusses and cracks in ornamented ceiling plate.

No other significant structural problems were observed in the Main Hall during the visual inspections in its current condition. However, the load bearing walls supporting the suspended ceiling would pose a serious threat in an earthquake due to the discontinuity because of the arch shaped openings at the eastern and western wings.

2.2 Strengthening works for the ceiling truss

Dismantling and renewing the ceiling and the trusses to resolve the vertical displacements and excessive deflection is one of the last methods due to the probable damage that would be imposed to the originality of the structure [7]. Additional steel trusses that would be placed to provide extra support around the chandelier can be seen in the Figure 6. Using similar steel trusses has been proposed to control the excessive deflection and the vertical displacement without damaging the original condition of the ceiling, which can be seen in the same figure.

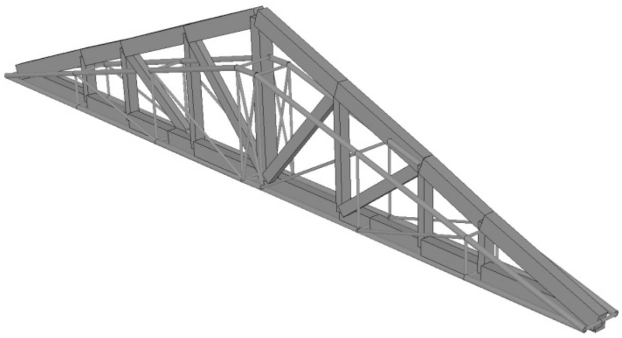


Figure 6: Additional steel trusses for strengthening of the roof structure.

According to the proposed strengthening project, the original trusses will be reinforced by using additional steel trusses. These steel trusses will be clamped to the wooden beams that support the ceiling with the least possible damage by using a special system that will provide false cambering. These adjustable steel clamps are designed with simple metal plate and bolt connection.

Special attention has been paid not to create fixed or restrained connections between the existing walls and the proposed steel trusses that will be used for strengthening. Fixed or restrained supports might impose additional lateral loads to the walls due to forces that would generate because of thermal expansion.

The features of the manufacture and construction of the steel trusses that are proposed for the two sides of the existing trusses are listed as follows:

- The additional steel trusses would be designed to be in contact with the existing trusses on either side only at the connection points as shown in Figure 6.
- Manufacturing the additional steel trusses out of a lightweight material would both decrease the additional forces that would be imposed on the structure and provide connection with the least possible damage to the originality of the structure. Heavy steel trusses might require drilling large holes on the ceiling. This would destroy the original value of the ceiling.
- The additional steel trusses that would symmetrically be placed on both sides of the existing trusses would be connected by means of easily assembled connection members and bolts. Hence, the original trusses would not be damaged during assembly.

- Connecting the additional steel trusses to each other by means of an easily dismountable system perpendicular to the plane of original hanging trusses would provide general stability of the roof.
- All this assembly process could be performed without using crane or heavy equipment. Hence, the use of lightweight material becomes more crucial.
- The present deflection and vertical displacement values of the roof has been determined and recorded. If excessive deflection or displacement occurs during the assembly, instant intervention would be possible.

3 STRUCTURAL ANALYSES OF SUSPENDED TRUSSES

A series of structural analyses were carried out to identify structural damages and vulnerability of the ceiling of The General Assembly Hall of the Second Turkish National Assembly Building for collapse. Initially, static analysis was performed to check deflection in the ceiling and vertical displacement in the suspended trusses. Second phase involved dynamic analyses to determine the damage that the roof trusses might impose on the masonry walls during an earthquake.

The detailed drawings of the timber ceiling and roof structure were produced by laser scanner. Based on these drawings, a 3D analysis model was developed as seen in Figure 7. Fake area elements were introduced to obtain accurate transfer of the weights of the tiled roof cover, ornamented ceiling diaphragm and the other loads. The 3D roof structure was analyzed for static loads first with its present condition, then with the addition of steel trusses proposed in the strengthening project. The dimensions of all the members of the existing truss members were arranged according to accurate measurements obtained from laser scanner. Notable defects at the connection points (shown in Figure 5) and element connectivity releases were considered in the model.

In the analyses, the largest vertical displacement in the roof structure was calculated as 18.63 mm at the mid-span of the trusses at rows B and C in the sections in Figure 4. However, according to the laser scanner measurements, the largest vertical displacement value on the ceiling at the same location is 140 mm. There might be several reasons for the excessive deflection at the ceiling of the Main Hall. A detailed research such as material’s chemical properties and detecting the deterioration at the connection points is necessary to find the reasons for this deflection. Obtaining similar vertical displacements at similar locations, on the other hand, have been considered of significance in understanding the behavior of the roof structure when the analyses were performed according to the original geometric dimensions, disregarding the subsequently developed excessive deflection in the ceiling.

In the later phase, steel trusses that were proposed for strengthening were included in the model. According to this analysis results, the vertical displacement value at the mid-span of the trusses decreased dramatically to 0.91 mm. In both analyses, the results show similar decrease for the vertical displacements at the corresponding points.

4 SEISMIC VULNERABILITY ANALYSES

The 3D model of the General Assembly Hall was developed to identify the structural capacities of the parts that contain the arched openings on the eastern and western walls. The model was used for the analyses under the gravity loads during strengthening and under the lateral loads that would be generated in a possible earthquake. Two separate sets of analyses were performed to observe stresses that are generated on the General Assembly Hall walls due to earthquake loads before and after the strengthening of roof trusses [8].

As it is seen in Figure 7, the one-meter thick stone masonry walls that surround the General Assembly Hall were assembled by using 1700 area elements. The roof structure, which was prepared by using 321 frame elements for the previous set of analyses, is supported by area elements at their actual locations. Material properties of the structure were obtained through the previous studies for similar stone masonry and the suggested values in the Turkish Earthquake Code since no tests or material sampling was possible for the material characterization due to the legal cultural heritage status of the building. Masonry units and mortar were assumed as one homogeneous material with a constant modulus of elasticity and unit weight as 450 MPa and 24.5 kN/m^3, respectively. Linear elastic finite element dynamic analyses were carried out according to the inelastic spectrum suggested for Ankara region in Turkish Earthquake Code [9, 10]. For convenience in the evaluation of the results, the spectrum was applied to the building in two perpendicular directions as EQ_x in the longitudinal direction and EQ_y in lateral direction. Load combinations were made accordingly. Besides, allowable compressive stress values provided by the current Turkish Structural Design Code for stone masonry (f_c=0.3 MPa) was increased by 3 instead of decreasing the forces imposed by the excitation (i.e. R=1) in order to compare the results with the capacity. The allowable tension was assumed as 15% of the compressive strength, as 0.135 MPa. The allowable shear stress of the wall was calculated through the formula $\tau_m = \tau_o + \mu\sigma$ where τ_o, allowable stress for cracking (0.3 MPa), μ, the coefficient of friction (0.5) and σ vertical stress (0.45 MPa), thus, obtained the value 0.53 MPa for the allowable shear stress of the stone [11, 12].

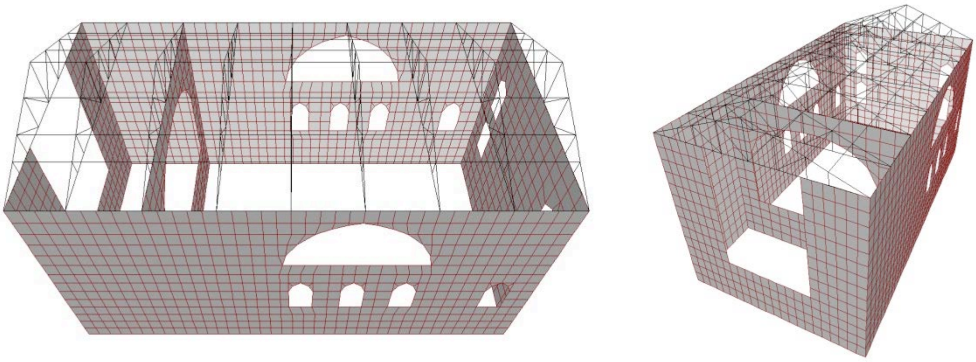

Figure 7: 3D Finite element model of the building.

5 DISCUSSIONS OF THE RESULTS

Significant findings have been obtained from the static analyses carried out for the present condition and the strengthened condition of the timber roof structure of the General Assembly Hall to direct the attempts for preventing the excessive deflection at the ceiling.

Additionally, the analyses of the General Assembly Hall under gravity and earthquake loads have been informative about the effects of the proposed additional steel trusses on the behavior and performance of the arched openings on the eastern and western wings of the structure. According to the analyses results, the vertical loads due to the additional weight of the steel trusses have not caused significant changes on the performance of the walls and the arched openings. Even though the analyses are linear static, the alterations in the stress levels are negligible.

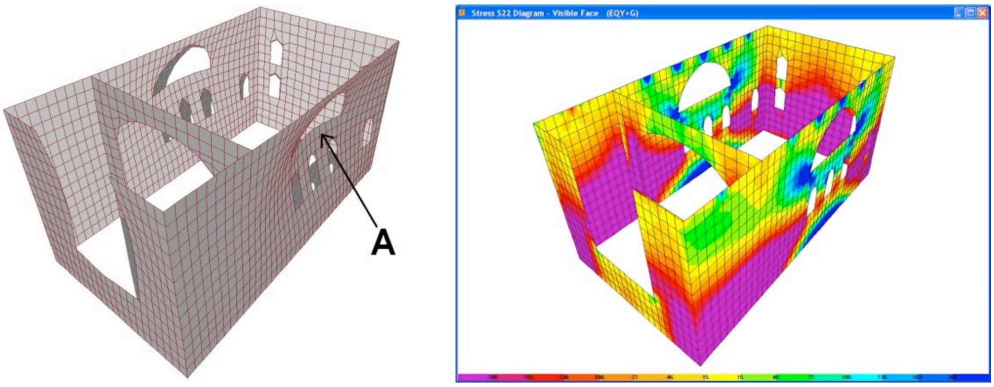

Figure 8: Displacements and stresses on the east and west wings walls.

Using hinges on the walls to support steel trusses have lead to a serious increase in the lateral displacement near the arched openings at +5.00 m above the ground, particularly in the transverse direction due to the increase in rigidity at the ceiling level. This can be attributed to the probability that the additional steel trusses would change the dynamic behavior of the structure. Figure 8 shows the displacement under G+Ey loading. The vertical displacement at point increased to 36.90 mm (Δ'_y=36.90 mm) from 26.53 mm (Δ_y=26.53 mm) after strengthening. Similarly, the maximum tensile stress at point A went from 0.14 MPa (f_A= 0.14 MPa) to 0.35 MPa (f'_A= 0.35 MPa) after strengthening. Because the structural analyses were not performed regarding the nonlinear material properties, these values would not provide enough information for an accurate interpretation about the structural fate of the walls. However, they provide significant findings about the importance of the details of the connection and support of steel trusses on the walls.

6 CONCLUDING REMARKS

In this study the analysis methods and possible solutions have been provided for the project that was proposed to resolve the structural deformation on the timber roof of the Second Turkish National Assembly Building in Ankara.

The analyses results performed under gravity loads provide information about the present capacity of the timber roof trusses and ceiling panels. The results also underline the vulnerability for more deformation.

The effects of the additional steel trusses, which are proposed to reinforce the roof trusses, on the structural performance of the large arched openings and consequently on the structural performance of the overall structure have been observed. According to the analysis results, the lightweight steel trusses would be added on both sides of the existing roof trusses; and they would stop the excessive deflection, which is expected to increase in time, on the ceiling of the General Assembly Hall. In addition, the excessive deflection on the ceiling would be corrected by means of a carefully crafted false cambering.

The analyses also show that the dynamic characteristics of the structure change. This change might lead to structural problems on the walls of the eastern and western wings in a possible earthquake. In order to minimize this risk, frictionless supports have been proposed on the masonry walls to support the steel trusses that are to be added on both sides of the existing trusses.

The strengthening process is planned to start in the summer of 2014. It would be performed very carefully in slow pace to maintain the originality of the ceiling ornaments.

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