Structural Safety Study of an Existing Wooden Roof Structure

Yujuan Zhu[1,*], Chao Huang[2]
[1]Gansu Province Building Materials Research and Design Institute Limited Liability Company, Lanzhou 730010, Gansu, China
[2]Lanzhou Railway Technician College, Lanzhou, 730050, Gansu, China
**Corresponding Author.*

Abstract: During the use of the wooden roof structure, different degrees of damage are caused by corrosion, substructure damage, uneven foundation settlement and other diseases, so the structural safety appraisal of the existing wooden roof structure has become one of the main problems to be solved. By taking the safety of the wooden roof frame of a silver company club in Silver City, Gansu Province as the research object, the structural safety research of the roof frame structure is carried out by the method of combining theoretical calculations and finite element calculation technology, and it is found that the theoretical calculation values of pine beams, tie bars, vertical rods and profiles near the supports are slightly larger than the finite element calculation results; the theoretical calculation results of pine beams, tie bars, vertical rods and profiles far away from supports are slightly smaller than the finite element calculation results; and the theoretical calculation results of pine beams, tie bars, vertical rods and profiles far away from supports are slightly smaller than the finite element calculation results. The theoretical calculation results of pine beams, tie bars, vertical bars and steel sections away from the support are slightly smaller than the finite element calculation results; the strength of some bars exceeds the permissible value, and the results of the study can be used as a reference for similar projects.

Keywords: Existing Wooden Roof Truss Structure; Theoretical Analysis; Finite Element Analysis; Structural Safety Assessment

1. Introduction

Wooden roof frame structure is one of the main structural forms of building structures in China. Since the war on poverty eradication, it has made the living standard of our residents greatly improved. But in China's rural housing construction as well as the overall situation of urban construction in the process of continuous improvement, but there are still more wooden structure building there are a large number of safety hazards, need to be further reinforced and repaired.

Existing building repair construction is a need to synthesize a variety of variable factors in the production process, there are many old office buildings in the city, due to a variety of reasons these buildings can not be completely replaced for the time being. However, due to its use for a certain number of years, different degrees of damage will occur, especially in the wood structure part, which needs to be further repaired and remodeled before it can be put back into use, and many problems will be encountered in the actual construction. However, at present, the research of wood structure in China is more centered on the reinforcement and repair of ancient wooden buildings, for which some problems have been studied by experts and scholars. For example, Hu [1] combined with the actual situation of the project through the adoption of effective technical management and construction measures to solve the problems of mosaic repair of the main building, repair of the wooden roof frame of the auxiliary building, reinforcement and waterproofing treatment of the main building. Xue [2] combined with the project examples, from the structural appearance, cause exploration, late treatment and other aspects of the wooden structure roof frame repair, remodeling situation for research and exploration. Xu [3] carried out seismic appraisal and safety appraisal of a school building in Lushunkou

District, and introduced the reinforcement measures of foundation base, wall and roof frame. Chen [4] explored, through engineering examples, how stone structure steel and wood roof frames of this type of open structure can be appraised for structural safety and seismic reliability by means of partitioning and overall force calculation and analysis, and Xiong [5] summarized the damage of different types of rural housing structures including masonry, raw earth, wood and stone structures based on the current situation of rural hazardous housing based on the data from the research of seven provinces in the country. Characteristics. Liang [6] introduced the typical situations encountered in the detection and repair of wooden roof frames in combination with specific projects, from the aspects of appearance performance of structural damage, cause analysis, and treatment measures. With the continuous improvement of China's economic construction, the general improvement of the living standards of residents and today's environmental awareness is becoming more and more mature, the development of wood frame houses is increasingly being emphasized [7-9].

Wooden roof frame structure with the process, due to corrosion, substructure damage, uneven settlement of the foundation and other diseases triggered by different degrees of damage, need to be identified through the test and reinforcement before they can continue to be put into use [10-12]. Therefore, for some of the wooden roof frame damage has been injured to put forward specific reinforcement measures, so that the old building to meet the current norms and standards at the same time the continuation of the historical lineage, is the existing wooden roof frame structural safety appraisal has become one of the main problems that need to be solved. Therefore, to a silver city in Gansu, a silver company club roof safety appraisal as a background, because the building has been put into use for about 52 years, has exceeded the service period and roof water seepage, wooden roof corrosion can not meet the normal use, in order to ensure the use of the silver company club safety. Through the mechanical calculation of the existing wooden roof frame structure, according to the theoretical calculation results of the wooden roof frame structural safety proposed research.

2. Project Profile

The club of Silverlight Company is divided into front hall, center hall and back hall, 1～16 axis part of the front hall and center hall (originally for the club meeting place) was built in 1968, and the back hall was expanded to increase the 16～20 axis part (originally for the club dressing room) in 1981; the structural form is a single-storey open house. The total area of the building is 1821.6m2, the total length of the building (axial dimension) is 60.4m, the width (axial dimension) is 30.0m, the height of the first floor of the front hall is 5.45m, the height of the second floor is 4.0m, and the height of the roof ridge is 13.2m; the height of the ridge of the middle hall is 13.2m, and the height of the gable end is 8.0m; the height of the first floor of the rear hall is 3.5m, and the height of the second floor is 3.75m. The height difference between indoor and outdoor is 0.6m, and the layout is shown in Figure 1.

According to the on-site investigation, the structural form of the building is a single-storey open house (two-storey locally), the front hall is a two-storey masonry structure, which consists of brick walls, reinforced concrete cast-in-situ beams and plates to form a load-bearing system, and the middle part of the roof cover is a triangular steel and wood roof frame, with cast-in-situ slab flat roofs on both sides. The center hall consists of a load-bearing system of brick walls and triangular steel and wood roofing, with a single-span double-pitched roof and clay tile roofing. The back hall is the dressing room of the extension club, which consists of brick walls, reinforced concrete cast-in-place beams and slabs to form a load-bearing system, and the roof is a cast-in-place slab with a flat roof. The external wall of the building is constructed with 370mm thick No. 50 green brick, with a ring beam and closed, and the cross-section size of the ring beam is 370mm x 180mm.

Due to poor drainage around the building leads to uneven settlement of the foundation, settlement difference does not meet the specification requirements; upper load-bearing structure part of the local masonry wall breakage, cracking, masonry mortar strength does not meet the specification requirements; roof seepage, corrosion of the wooden roof rack, corrosion can not meet the requirements of the normal use of the function, the calculation of the wooden roof rack under the chord of the T-shaped combination of double angle steel stress does not meet the specification requirements. The current situation is shown in Figure 2.

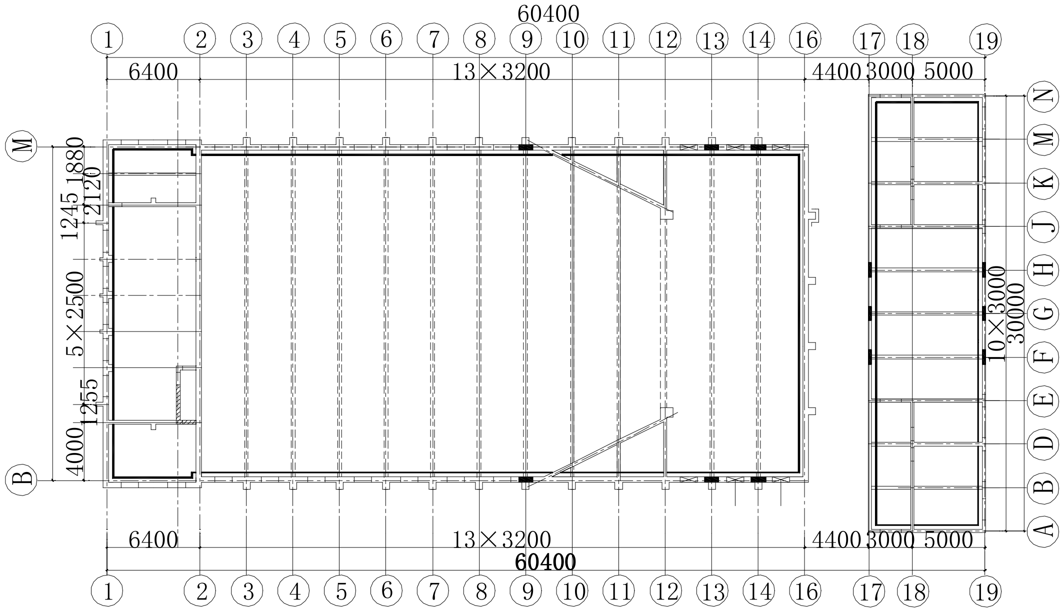

Figure 1. Silverlight's Club Floor Plan

Figure 2. Map of the Current Status of Silverlight's Club

3. Calculation and Analysis of the Internal Force of the Roof Frame

At present, because the building has been put into use for about 52 years, has exceeded the service period and the roof water seepage, wooden roof rack corrosion can not meet the normal use, in order to ensure that the silver light company club use safety, the roof structure of its bearing capacity identification calculation. Roof racking rod arrangement diagram shown in Figure 3. Load value: roof live load 0.5kN/㎡,The floor live load is taken as 2.0kN/㎡.

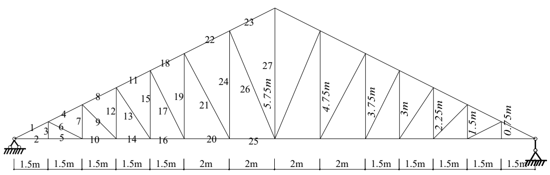

Figure 3. Roof Rack Rod Arrangement

According to the knowledge of structural mechanics, the roof frame model is simplified as a truss structure (static structure) simply supported at both ends, and the internal force calculation of some rods is carried out, and the calculation process is shown as follows:

$$cos\,\theta = \frac{11.5}{\sqrt{11.5^2+5.75^2}} = 0.8942;\ \ sin\,\theta = \frac{5.75}{\sqrt{11.5^2+5.75^2}} = 0.447 \quad (1)$$

Truncating along the 1 and 2 bars and taking the left support as the object of study, then:

$$\sum F_y = 0 \Rightarrow N_1 sin\,\theta = -136.6 + 15 + 2.4 \Rightarrow N_1 = -267\ kN \Rightarrow \sigma_1 = \frac{267\times10^3}{200\times250} = 5.34Mpa < [\sigma] = 16Mpa \quad (2)$$

$$\sum F_x = 0 \Rightarrow -N_1 cos\,\theta + N_2 + 8.5 = 106.5 \Rightarrow N_2 = 337\ kN \Rightarrow \sigma_2 = \frac{337\times10^3}{2\times7.288\times10^2} = 231.2Mpa > [\sigma] = 215Mpa \quad (3)$$

Based on the results of this calculation, it can be shown that the strength of the diagonal bars near the support meets the code strength requirements, while the lower chord bars near the support do not meet the code strength requirements.

Truncating along 1, 3 and 5 bars, taking the left side as the object of study and taking the distance to the support, then:

$$\sum M = 0 \Rightarrow 1.5N_3 = 15 \times 1.5 \Rightarrow N_3 = 15\ kN \Rightarrow \sigma_3 = \frac{15\times10^3}{3.14\times8^2} = 75Mpa < [\sigma] = 270Mpa \quad (4)$$

Based on the results of this calculation, it can be shown that the strength of the vertical rods close to the support meets the code strength requirements.

Along the 4, 7 and 10 rods, taking the left side as the object of study, then:

$$\sum M = 0 \Rightarrow 3\sin\theta N_4 + 8.5 \times 0.75 + 136.6 \times 3 = 15 \times 1.5$$
$$+4.8 \times 1.5 + 4.8 \times 3 + 15 \times 3 \Rightarrow N_4 = 244\ kN$$
$$\Rightarrow \sigma_1 = \frac{244\times10^3}{200\times250} = 4.88Mpa < [\sigma] = 16Mpa \quad (5)$$

Truncating along the 2, 3, and 5 bars and taking the nodes as the object of study, then:

$$\sum F_x = 0 \Rightarrow N_5 = N_2 \Rightarrow N_5 = 337\ kN \Rightarrow \sigma_5 = \frac{337\times10^3}{2\times7.288\times10^2} = 231.2Mpa > [\sigma] = 215Mpa \quad (6)$$

Based on the results of this calculation, it can be shown that the strength of the lower chord bar away from the near support does not meet the code strength requirements.

Truncating along 18, 19 and 20 bars and taking the left side as the object of study, then:

$$\sum M = 0 \Rightarrow 7.5N_{19} = 4.8(1.5 + 3 + 4.5 + 6) + 15(1.5 + 3 + 4.5 + 6 + 7.5)$$
$$+8.5(0.75 + 1.5 + 2.25 + 3) \Rightarrow N_{19} = 63.1\ kN$$
$$\Rightarrow \sigma_{24} = \frac{63.1\times10^3}{3.14\times11^2} = 166Mpa < [\sigma] = 270Mpa \quad (7)$$

According to the results of this calculation, it can be shown that the strength of the vertical bars away from the near support meets the code strength requirements.

Truncating along 22, 24 and 25 bars and taking the left side as the object of study, then:

$$\sum M = 0 \Rightarrow 9.5N_{25} = 4.8(1.5 + 3 + 4.5 + 6 + 7.5) +$$
$$15(1.5 + 3 + 4.5 + 6 + 7.5 + 9.5)$$
$$+8.5(0.75 + 1.5 + 2.25 + 3 + 3.75) \Rightarrow N_{25} = 72\ kN$$
$$\Rightarrow \sigma_{25} = \frac{72\times10^3}{3.14\times12.5^2} = 147Mpa < [\sigma] = 270Mpa \quad (8)$$

According to the results of this calculation, it can be shown that the strength of the lower chord in the middle of the span cannot meet the code strength requirements

Meanwhile, using MIDAS/GEN2017 calculation, the maximum value of displacement is about 15 mm. the theoretical calculation and finite element calculation results are shown in Table 1.

Table 1. Statistics on the Results of the Calculations

Component Number	Component Material Material Properties	Sectional dimensions of members	Theoretical results		Finite element results		regulatory restriction(Mpa)
			internal force(KN)	stresses(Mpa)	internal force(KN)	stresses(Mpa)	
1	pine wood	200 × 250mm	267	5.34	261.3	5.2	16
2	Q235	2∠63 ×6	337	231.2	331.7	230.3	215
3	steel reinforcement	d=16	15	75	15	74.6	-
4	pine wood	200 × 250mm	244	4.88	243.9	4.9	16
5	Q235	2∠63 ×6	337	231.2	331.7	230.3	215
16	steel reinforcement	d=22	63.1	166	63.1	166	-
24	steel reinforcement	d=25	72	147	72	146.6	-

According to the calculation results in Table 1 and combined with Figure 3, it is found that the theoretical calculation values of pine beams, tie bars, vertical bars and steel sections near the support are slightly larger than the calculation results of finite elements; the theoretical calculation results of pine beams, tie bars, vertical bars and steel sections far away from the support are slightly smaller than the calculation results of finite elements.

At the same time, it is found that the strength of some rods exceeds the allowable value, which needs further reinforcement calculation and treatment before continuing to use. Therefore, it is necessary to focus on the reinforcement calculation of vertical rods and bottom chord members of this wooden roof structure.

4. Conclusion

By taking the safety appraisal of the wooden roof frame of a silver company club in silver city of Gansu province as the background, as the building has been put into use for about 52 years, it has exceeded the service period, and the roof seepage, wooden roof frame corrosion can not satisfy the normal use, in order to ensure the safety of the use of the silver company club, through the mechanical calculation of the existing wooden roof frame structure, based on the results of the theoretical calculations on the structural safety of the wooden roof frame to put forward the study. The research and analysis come up with the following main conclusions:

(1) Through the study, it is found that the theoretical calculation values of pine beams, tension bars, vertical bars and steel sections near the supports are slightly larger than the calculation results of finite elements.

(2) The theoretical calculation results of pine beams, tie bars, vertical bars and steel sections away from the support are slightly smaller than the finite element calculation results.

(3) The strength of some bars exceeds the allowable value.

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