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Evaluation of Structural Safety of a Steel School Building with Partially Modified Structural System

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Abstract
In order to meet the basic needs of foreign asylum seekers coming to our countries such as shelter, nutrition, and education, our government has established temporary shelters in different regions of our country. One of them is a completely disassembled steel school building with 23 classrooms, the carrier system of which is steel construction, in order to meet the educational needs of the temporary shelter located in the Ceylanpınar district of Şanlıurfa city. The roof of this school was designed as a plane truss system made of steel construction. The truss system, which was designed as a single part in the architectural and static application projects of the building, was separated from the symmetry axis and manufactured in two parts since it provides ease of transportation, manufacturing, and assembly by the contractor company. These parts were connected with bolts during manufacturing. In this study, as a result of the examinations carried out according to the regulations and standards in force at the time the building was designed, it was determined that constructing the system in two parts and connecting it with bolts does not pose a problem in terms of service safety of the building.

1. Introduction

Turkish people always offer a helping hand with compassion toward those in trouble. In recent years, as a result of the undesirable events in Syria, our country's south-eastern neighbor, many people had to leave their countries and seek refuge in neighboring countries. Turkey has been one of the countries that faced the greatest human migration among these neighboring countries. Our country has deemed it appropriate to keep the refugees in temporary accommodation centers in order to keep the first wave of immigration under control and to enable them to live in harmony with our people. For this purpose, 26 temporary accommodation centers established in 10 different cities have hosted Syrian refugees. In addition to the shelter needs of those staying in temporary accommodation centers, education services, health services, the opportunity to worship in houses of worship, and market services were provided to all school-age children, including pre-schoolers. In addition, non-professional asylum seekers were provided with the opportunity to acquire a profession through adult education centers.

One of the temporary accommodation centers established for Syrian refugees in our country is located in the Ceylanpınar district of our Şanlıurfa city. In this center, a school building with 23 classrooms and steel construction was built in order to provide educational services. In the following years, when the need for the temporary camp center disappears, it was preferred that the structural system is steel in order to ensure that the building can be dismantled and moved to another place where it is needed. The most important feature of the building is that it is completely dismantled and portable except for the reinforced concrete foundation.

Although steel material has a wide range of uses, the most used area is the construction sector. Steel carrier systems are used at a rate of 65% in

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industrial buildings, 15% in commercial buildings, 2% in residences, 3% in bridges, and 15% in other types of structures in Turkey [1]. As can be seen, the use of steel in residential buildings is very low. This may be because it is expensive compared to reinforced concrete structures and requires more qualified personnel. However, new steel multi-storey structures have started to take place in our cities. Due to reasons such as changing population balance, making new zoning regulations, and changing the existing design regulations, changes in the purpose of use or renovations are required in the existing building stocks. These effects cause the formation of mixed building groups, and even steel systems are preferred more because of their advantages [2].

The main objective of the projects planned to be built is to complete the work by meeting the planned time, cost, and adequate quality conditions. It is frequently encountered that the construction projects of which implementation projects have been prepared and the construction of which has been started by obtaining the license are continued by revising the projects according to the emerging needs. These revisions should be made in official ways, with the approval of the employer, contractor company, and control mechanisms. Otherwise, serious legal problems will inevitably arise between the above-mentioned authorities. In the thesis study conducted by S. Şavklı, the issue of regulating the legal rights on the contracts describing the rights and duties of the mentioned authorities was examined in order to prevent the conflicts that may arise between the employer, the contractor company and the control unit of the changes to be made in the implementation projects [3].

In general, these reasons can be sorted; earthquake and vibration effects, changes in the ground structure of the building, increase in the loads to which the structure is exposed, the possibility of deterioration of stability, changes in the purpose of use of the structure, project errors, application errors, inspection deficiencies, material errors, changing regulation conditions, etc. It can be said that the need for repair and reinforcement will arise in the structures affected by one or more of these facts. The repair and strengthening process varies depending on whether the structure is reinforced concrete, steel, wood, etc. It can be stated that the causes and solutions of the damage in wooden and steel structures are more obvious than the damage in reinforced concrete structures. In other words, the causes and solutions of damage in reinforced concrete structures are more complex than in wooden and steel structures. Damages in concrete and reinforced concrete structures can be seen mostly in the form of cracks, fragment ruptures, and segregation [4].

Although the buildings are under strict control during the project and construction phase, sometimes important productions can take place without the approval of the construction control mechanism. When this situation is noticed, dismantling the production and having it done again according to the project cause serious time and economic losses. When such a situation is encountered during the construction of buildings, two options can be made. The first is to dismantle the wrongly made production and have it rebuilt in accordance with the approved project, which is the most correct method. However, it is inevitable to encounter serious time and economic losses with this option. The second option is to evaluate whether manufacturing not suitable for the project endangers the safe use of the building by checking it and evaluating it in a report. If the experts state in their reports that manufacturers that are not made in accordance with the project do not endanger the safe use of the building, the building is allowed to be used in its current form. Thus, the economic and time losses that will be encountered by dismantling the productions that are not made in accordance with the project and having the productions made in accordance with the project are prevented. When it is determined that the usage safety of the building is in danger, manufacturing not suitable for the project should be dismantled and it should be ensured that they are made in accordance with the project.

2. Material and Method

2.1. General Features of the School Building

The general architectural geometry of the building is similar to the letter "U", its long dimension is approximately 61 m and its short dimension is 24 m. The building is planned as a total of two floors, the ground floor and, the first floor. The ground floor consists of 11 classrooms, an administrative section, a canteen, a ladies' prayer room, a boiler room, and convenience facilities. The first floor consists of 12 classrooms, an administrative section, a teachers' room, a men's prayer room, and convenience facilities. The usage area of the classrooms is 520 m^2 on the ground floor, 570 m^2 on the first floor, and a total of 1090 m^2. The passage of the school building between the ground floor and the first floor is provided by three stairs. The general view of the school building is shown in Figure 1.

Figure 1. General view of the school building considered in the study

The building is placed on a 0.5 m thick reinforced concrete raft foundation. The total height from the foundation level is 8.9 m, with a basement height of 0.60 m, a ground floor height of 3 m, a first-floor height of 3.3 m, and a roof height of 2 m. The design of the building started in 2016 and revision projects were prepared in 2017. The static design was made according to the Regulation on structures to be built in disaster zones 2007 (TEC 2007), which was in force at that time [5]. The steel construction and joint calculations of the building were made according to the Principles on the Design, Calculation, and Construction of Steel Structures 2016 [6]. The necessary information for the material, soil, and earthquake calculation of the building is presented in Table 1.

Table 1. Information for the material, ground, and earthquake calculation of the school

Concrete grade	C30	Soil Type	D
Rebar of the reinforced concrete	S420	Unit Volume Weight of Soil	21 kN/m^3
Steel	S235	Effective Ground Acceleration Coefficient (A_0)	0.4
Safe Bearing Capacity	100 kN/m^2	Building important factor (I)	1.4
Local Soil Classification	Z4	Structural behavior coefficient (R)	4.0
Bearing Coefficient of the Soil	10^4 kN/m^3		

3. Results and Discussion

3.1. Evaluation of the Existing Situation of the School

When the approved architectural project and static application projects of the building are examined, it is understood that SHS 120x120x5 tube section columns are used on the reinforced concrete raft foundation, the ground floor ceiling consists of composite flooring, and the roof section consists of a single part truss system with bars. It is planned that the roof trusses will be manufactured in one piece in the workshop and assembled on-site. The contractor company decided that the roof trusses, which are thought to be manufactured as one piece, would be difficult to assemble both in transportation and in the construction area, and decided to manufacture them in two parts by separating the large span trusses from the symmetry axis.

The roof trusses, manufactured by the contractor company as two parts, were connected with 5 M22 bolts at the construction site. During the manufacture of some roof trusses, the strut bars in the symmetry axis were manufactured incorrectly, as shown in Figure 2.

Figure 2. Roof trusses manufactured in two parts

Due to this faulty manufacturing, separation up to 30 mm has been detected from the squareness of the uprights in the part where the mentioned roof trusses meet on the symmetry axis. After this situation was determined by the control unit, it was concluded that the issue should be evaluated and reported by the expert team in order to eliminate the concerns about whether the manufacturers made in this way endanger the safety of the building. The report, which is the basis of the study, has been prepared by the authors for this purpose.

3.2. Evaluation of the Buildings Made Different from the Implementation Projects of the Building in Terms of Structural Safety of the Building

Using the static and architectural application projects of the school building, a three-dimensional model was created in the Idecad Static structure analysis program, taking into account the regulations and standards in force in the years it was designed [7]. The building model in which the roof trusses made of steel profiles are considered as one piece is shown in Figure 3.

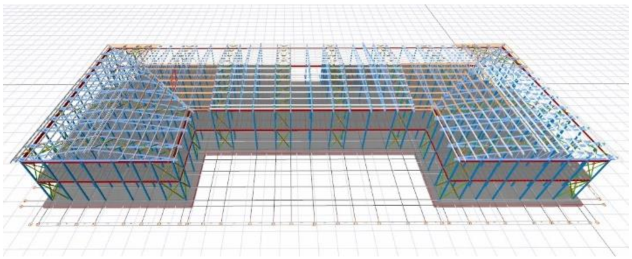

Figure 3. Building model in which the roof trusses are formed as one part

As a result of the examinations made by the control unit of the building, trusses made in two parts by separating from the symmetry axis in the building and trusses deviation from the squareness of the strut bars on the symmetry axis were determined. The model created by considering this situation of the building is shown in Figure 4.

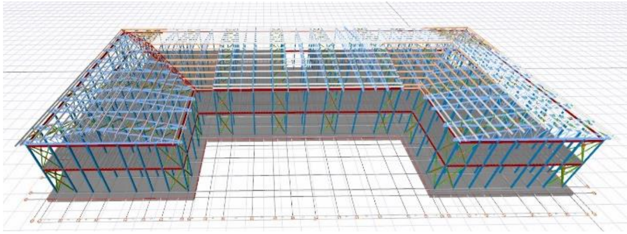

Figure 4. Building model in which the roof trusses are formed in two parts

Both building models were analyzed under the influence of constant loads (G, Q), vertical loads such as snow loads (S), and horizontal loads such as wind (W) and earthquake loads (E). The reports created as a result of the analyzes were examined and the results were evaluated.

3.3. Evaluation of the School Building with Roof Trusses Consisting of One part

As a result of the analyzes made in the building model, in which the roof trusses are considered as a single piece, it has been determined that the foundation, columns, beams, composite floors, and roof trusses that make up the structure safely carry the loads on them. Since it will take a lot of space to give the analysis results of all structural components of the building here, the stresses occurring in the elements of the roof truss which are the longest and have the highest loads, TRS031 have been examined. This roof truss is shown in Figure 5.

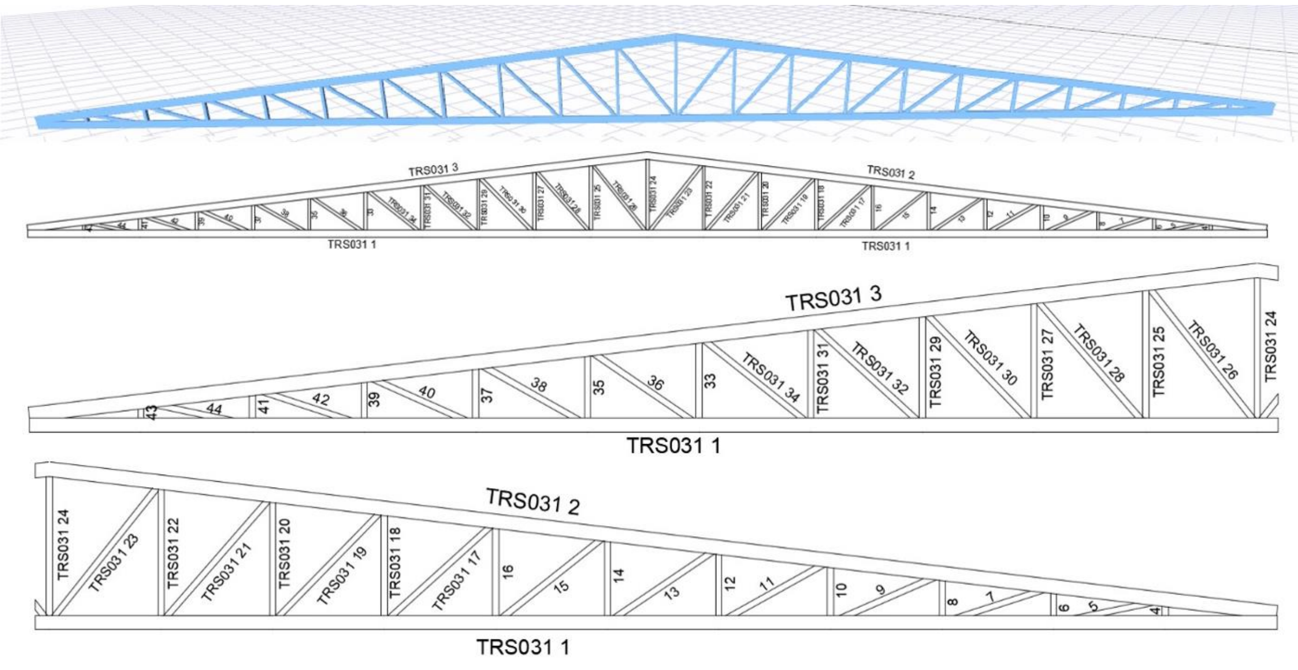

Figure 5. One-part roof truss (number TRS031)

If the internal forces consisting of external loads acting on the structural system of the building are accepted as demand, the ratio of the demand to the section capacity is expressed as the PMM ratio (demand/capacity ratio). The internal forces of the elements forming the truss under the influence of the most unfavorable load combinations and the resulting PMM ratios are shown in Table 2. After examining the table, it was understood that the PMM ratios were less than 1.0. This shows that the examined trusses can safely carry the loads acting on them.

Table 2. Axial force and PMM ratios in one-part roof truss no. TR031

Name	Member	Section	Load combination	Axial force (kN)	PMM ratio	Strength check
TR031-1	Bottom bar	RHS 80x140x6	G-0.7Ey	-176.57	0.55	√
TR031-2	Top bar	RHS 80x140x6	G-0.7Ex	-192.15	0.61	√
TR031-3	Top bar	RHS 80x140x6	G-0.7Ex	-196.05	0.61	√
TR031-4	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-7.11	0.081	√
TR031-5	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	10.73	0.12	√
TR031-6	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-4.78	0.055	√
TR031-7	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	10.56	0.12	√
TR031-8	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-2.59	0.03	√
TR031-9	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-4.58	0.059	√
TR031-10	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	2.57	0.029	√
TR031-11	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-7.28	0.095	√
TR031-12	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	3.75	0.043	√
TR031-13	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-7.41	0.099	√
TR031-14	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	4.56	0.052	√
TR031-15	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-5.98	0.081	√
TR031-16	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	4.42	0.05	√
TR031-17	Cross	SHS 60x3	G-0.7Ey	-4.57	0.064	√
TR031-18	Vertical	SHS 60x3	G+0.7Ey	3.45	0.039	√
TR031-19	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-5.96	0.085	√
TR031-20	Vertical	SHS 60x3	G+S	-14.81	0.194	√
TR031-21	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	12.64	0.143	√
TR031-22	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-9.58	0.13	√
TR031-23	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	11.86	0.134	√
TR031-24	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-3.07	0.043	√
TR031-25	Vertical	SHS 60x3	G+S	-10.26	0.139	√
TR031-26	Cross	SHS 60x3	G+S	11.50	0.13	√
TR031-27	Vertical	SHS 60x3	G+S	-15.10	0.198	√
TR031-28	Cross	SHS 60x3	G+S	14.99	0.17	√
TR031-29	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-2.20	0.028	√
TR031-30	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	2.49	0.028	√
TR031-31	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-5.47	0.068	√
TR031-32	Cross	SHS 60x3	0.6G-0.7Ey	72.01	0.072	√
TR031-33	Vertical	SHS 60x3	G-0.7Ey	-3.38	0.041	√
TR031-34	Cross	SHS 60x3	G-0.7Ey	-5.27	0.072	√
TR031-35	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	3.72	0.042	√
TR031-36	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-6.27	0.084	√
TR031-37	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	2.59	0.029	√
TR031-38	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-6.34	0.083	√
TR031-39	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	0.79	0.009	√
TR031-40	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-3.68	0.048	√
TR031-41	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-1.22	0.014	√
TR031-42	Cross	SHS 60x3	G-0.7Ey	-1.79	0.023	√
TR031-43	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-3.50	0.04	√
TR031-44	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	6.52	0.074	√

3.4. Evaluation of the School Building with Roof Trusses Consisting of Two parts

Roof trusses produced by the contractor company in the workshop are made of two parts in order to be easily transported and easily lifted and assembled. During the construction of the building, it was determined that most of the roof trusses, which were produced from two parts, came back to back during assembly, but a small part of the strut bars on the symmetry axis was not made perfectly vertical, resulting in separations of 30 mm between them. Considering this situation of the building, a three-dimensional model was created and analyzed. In this section, truss no. TRS031, which is considered in the case where the roof truss is a single part, is examined in detail. The general view of this truss and the part where the two parts are joined with bolts are shown in Figure 6.

Figure 6. Modeling of the roof truss as two parts (number TRS031)

The axial forces and PMM ratios formed in the elements of the TRS031 truss are shown in Table 3. Although there is a slight increase in the normal force value of the strut rods deviation from the squareness of the truss made in two parts, compared to the case where the same truss is one piece, it is understood from the examination of Table 3 that the existing cross-sections are capable of carrying these forces safely. In addition, in the evaluation, it was determined that the PMM ratios in all truss elements were less than 1.0. This result showed that the members that make up the examined truss have sufficient security to carry the internal forces on them. It has been determined that the five bolts connecting the roof trusses made in two parts are sufficiently secure to carry the cross-sectional effects on them.

It has been determined that the construction of some roof trusses in two parts does not pose a problem in terms of user safety of the building. As a result of two-part manufacturing, in case of any deformation due to the loads on the roof trusses, the formation of deformations in the roof covering is an inevitable result. In the observations and examinations made on the roof of the building, it was determined that there was no deformation. This observation supports the accuracy of analyzes and investigations.

Table 3. Axial force and PMM ratios in two-part roof truss no. the TR031

Name	Member	Section	Load combination	Axial force (kN)	PMM ratio	Strength check
TR031-1	Bottom bar	RHS 80x140x6	G-0.7Ey	-29.17	0.517	√
TR031-2	Top bar	RHS 80x140x6	G-0.7Ex	-19.45	0.703	√
TR031-3	Top bar	RHS 80x140x6	G-0.7Ey	-13.83	0.175	√
TR031-4	Vertical	SHS 60x3	G-0.7Ex	-3.38	0.717	√
TR031-5	Cross	SHS 60x3	0.6G-0.7Ex	-3.81	0.31	√
TR031-6	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-3.02	0.23	√
TR031-7	Cross	SHS 60x3	0.6G-0.7Ex	-3.22	0.126	√
TR031-8	Vertical	SHS 60x3	G-0.7Ex	-2.56	0.157	√
TR031-9	Cross	SHS 60x3	G-0.7Ex	-11.88	0.347	√
TR031-10	Vertical	SHS 60x3	G-0.7Ex	18.4	0.202	√
TR031-11	Cross	SHS 60x3	G-0.7Ex	-60.76	0.563	√
TR031-12	Vertical	SHS 60x3	G-0.7Ex	3.9	0.106	√
TR031-13	Cross	SHS 60x3	G-0.7Ex	-60.57	0.846	√
TR031-14	Vertical	SHS 60x3	G-0.7Ex	5.36	0.223	√
TR031-15	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-5.23	0.392	√
TR031-16	Vertical	SHS 60x3	G-0.7Ex	3.01	0.137	√
TR031-17	Cross	SHS 60x3	G-0.7Ex	-4.13	0.133	√

TR031-18	Vertical	SHS 60x3	0.6G-0.7Ex	-11.4	0.115	√
TR031-19	Cross	SHS 60x3	0.6G-0.7Ex	-14.4	0.632	√
TR031-20	Vertical	SHS 60x3	G-0.7Ey	-18.1	0.202	√
TR031-21	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	13.53	0.149	√
TR031-22	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-10.1	0.733	√
TR031-23	Cross	SHS 60x3	G+0.7Ey	7.16	0.283	√
TR031-24	Vertical	SHS 60x3	G-0.7Ex	14.64	0.748	√
TR031-25	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-9.72	0.719	√
TR031-26	Cross	SHS 60x3	G-0.7Ey	7.85	0.143	√
TR031-27	Vertical	SHS 60x3	G+S	-14.33	0.845	√
TR031-28	Cross	SHS 60x3	G-0.7Ey	35.51	0.909	√
TR031-29	Vertical	SHS 60x3	G-0.7Ey	-3.5	0.17	√
TR031-30	Cross	SHS 60x3	G-0.7Ey	35.51	0.909	√
TR031-31	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-4.94	0.377	√
TR031-32	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	4.61	0.064	√
TR031-33	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-8.39	0.915	√
TR031-34	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	7.12	0.08	√
TR031-35	Vertical	SHS 60x3	G-0.7Ey	2.26	0.095	√
TR031-36	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-5.08	0.328	√
TR031-37	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	3.14	0.144	√
TR031-38	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-7.37	0.433	√
TR031-39	Vertical	SHS 60x3	G-0.7Ex	1.42	0.09	√
TR031-40	Cross	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-7.37	0.433	√
TR031-41	Vertical	SHS 60x3	G-0.7Ex	-0.9	0.086	√
TR031-42	Cross	SHS 60x3	G-0.7Ey	-2.55	0.105	√
TR031-43	Vertical	SHS 60x3	G+0.75Q-0.53Ex+0.75S	-3.72	0.177	√
TR031-44	Cross	SHS 60x3	0.6G-0.7Ey	-3.81	0.127	√

4. Conclusion and Suggestions

In order to meet the educational needs of the refugees who came to our country, school buildings were made of steel construction in different regions of our country, as they are demountable. One of these buildings is a two-storey school building built in the Ceylanpınar district of Şanlıurfa city. As a result of the examinations and analyzes, it was determined that the roof trusses, which should be made in one part according to the static and architectural application projects, were manufactured in two parts and these two parts were connected with five bolts. In addition, it has been determined that the safe use of the structure is not endangered by the separations from the squares of up to 30 mm due to manufacturing faults at the joints in the symmetry axis of some roof trusses.

This finding is also supported by the fact that no deformation occurred in the roof covering system as a result of visual inspection. If any deformation had been detected due to the loads on the roof trusses, it would have been inevitable for this situation to manifest itself with the deformation that would occur in the roof covering.

As a result of the analysis and modeling, it has been determined that the roof trusses are made in two parts, so the safe use of the building does not endanger. Achieving this result has prevented financial and time losses. Due to the conclusion of this review as mentioned above, a gain has been made to our country's economy. The importance of engineering knowledge in solving different problems encountered has been understood once again.

It is hoped that the study, with its method and methodology, will be a guide for solving similar problems to be encountered in the future.

Contributions of the authors

Design/Concept and Modelling: RKP; Literature Search and Data Collection: FA; Drafting manuscript and critical revision of the manuscript: MAG.

Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study complied with research and publication ethics.

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