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RESEARCH ARTICLE

THE USE OF TRUSS SYSTEMS IN UNIVERSITY BUILDINGS: CASE OF ABANT İZZET BAYSAL UNIVERSITY

***Asena SOYLUK, Pelin SARICIOGLU, Aslı YILDIZ and Sinem ÖZYURT**

Department of Architecture, Gazi University, Turkey

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ABSTRACT

In universities, where a large number of people live together, steel truss systems are often used to pass large spans. In this study, Abant İzzet Baysal University in Bolu was examined in terms of steel truss system usage. The buildings of the university were evaluated from the point of view of the type of truss system selected and the building form. It has been determined that these systems are used for gathering purposes, social and sports facilities. The most preferred truss system for these buildings is the "Warren Type"which is lighter and cheaper than other ones.

INTRODUCTION

The introduction of technology into human life has changed the way of living and created new requirements. Until the industrial revolution, materials such as wood, stone, brick were used in as a building material, in the 18th century iron took their place. Iron was initially used only in industrial constructions, but it began to be used in residences over time (Eren, 2014). Iron went through three stages respectively; cast iron, wrought iron and steel. C*ast iron* is iron that has been melted, poured into a mold, and allowed to cool (URL, 2003). Compared to steel, cast iron has a lower melting point, and is more fluid and less reactive with mold materials, making it well-suited for casting. It does, however, have good compression strength, and was used prominently in building construction before the advent of the steel industry in the early 20th Century. *Wrought iron* is iron that has been heated and then worked with tools. Wrought iron has a much higher tensile strength than cast iron, making it more suitable for horizontal beams in construction. It was widely used throughout the 19th Century in building construction, but was replaced by steel in the 20th Century. Especially, the low resistance of cast iron and wrought iron to tensile stresses was limiting their use in building production. For this reason, steel has been obtained as a result of searching for materials that are more useful and have the qualities to overcome limitations.

****Corresponding author*: Asena SOYLUK**
Department of Architecture, Gazi University, Turkey

Steel is an alloy of iron and carbon and other elements. But it has a much lower carbon content than cast and wrought iron and that makes it strongest (Schulitz *et al*., 1998). The material steel allows large spans, integrated spaces, fluidity and lightness, for it has been frequently preferred especially in multi-storey buildings (Çelik, 2012). Steel has the highest strength-to-weight ratio of any construction material, so it can provide large spans, more space with smaller size sections compared to other building materials. Earthquake resistance, recyclability also make it a more preferred building material day by day. Increasing the designer's freedom is also influential in the spread of steelworks. Designs that are seen as impossible in the past, can be realized easily by steel elements (Marulyalı, 2001). Steel can be used in a building as structural elements such as column, beam, floor slab. When used as a beam, steel is divided into two parts; open-web girder and plate-web girder (Url, 2008). Due to the lightness of the open-web girders, they are able to pass larger spans that plate-web girders can not (Salmon *et al*., 1990). From an architectural point of view, the design of the truss begins with the selection of its system configuration. The layout of the truss is arranged according to the usage conditions of the structure, the roof type, the geometrical dimensions of the building, the climatic conditions, the type of connection with neighboring building elements, technical and economical conditions (Eyyubov, 2011). Spans in excess of 80 m can be economically achieved by truss systems. Also, truss systems are preferred in large span structures as they are lightweight and installation tubes can be passed through the gaps. These systems are particularly

suitable for situations where the roof is exposed to significant loads, for the deflections are rather small and can be kept under control (Chudley and Greeno, 2008). The shapes of trusses can be triangular, parallel chord, trapezoid, polygonal, arches and frames. According to the shapes, the trusses have the following names (Deren *et al*, 2008) In Figure 1, the types of truss systems are shown schematically.

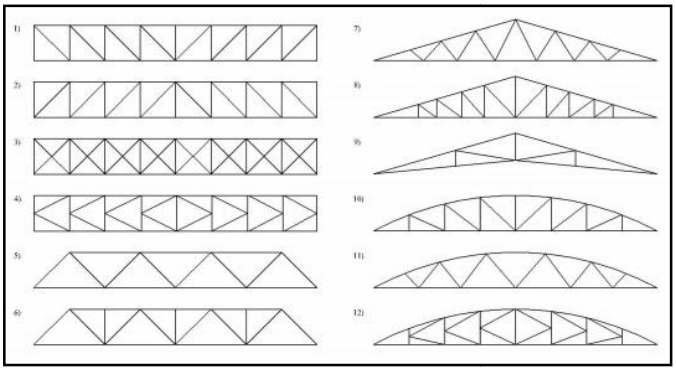


Figure 1. System Types

1.Pratt Truss 2.Howe Truss 3.X Type Truss 4.K Type Truss 5.Warren Truss 6.Warren Truss (Vertical Bar) 7.Fink Truss 8.Belgian Truss 9.Scissor Truss 10.Bowstring Truss 11.Bowstring Truss(Alternate) 12.Bowstring – K Type Truss (from left column to right column)

Warren-type trusses are one of the most economical solutions because it reduces steel weight and construction cost for small areas. The system consists of equal length pressure and tension elements. An angle of 40-50 degrees should be provided between the header and diagonal elements. Pratt-type trusses are formed by connecting the vertical and diagonal elements to the head elements. The Howe-type trusses are more suitable systems for situations where the roof is less loaded and its form is exactly the opposite of the Pratt truss. Fink truss is suitable for very inclined roofs. The vertical load is transferred to the supports with the header and diagonal elements. Bowstring truss consists of a curved top chord meeting a bottomchord at each end. The vertical load is transferred to the supports with the header, vertical and diagonal elements (Kumar *et al*, 2016).

Use of Steel in University Buildings

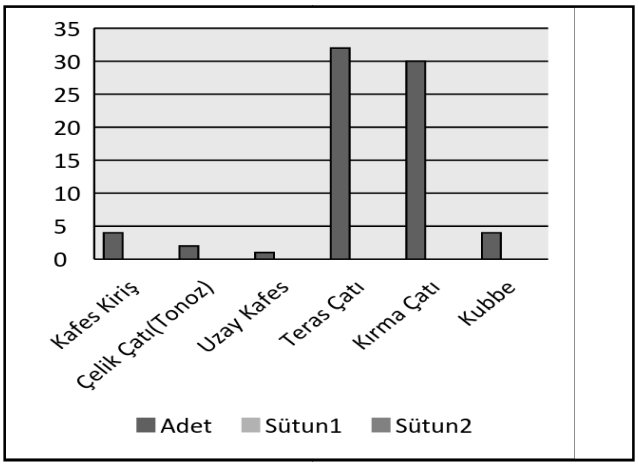
Universities aim to provide students professional skills with practice, research and academic activities. In addition to the educational activities, it can not be separated from the campuses in places where social and cultural activities can be performed outside the classroom. Universities provide students with social and cultural interaction by directing them to various activities outside of education. In this context, the selection of materials to be used in universities which have many functions together is gaining importance. Although reinforced concrete structures are highly preferred, large spans and earthquake factors make steel use imperative.

THEORETICAL FRAMEWORK

The method of working is the analysis of the truss systems used in the buildings of Abant İzzet Baysal University. First, the buildings in the campuses are grouped according to the use of truss systems and their functions as social purposes and sports purposes. Meanwhile, formal evaluations of the buildings have been also made at the end of the chapter. The data obtained in the study are supported by schematic drawings, tables and graphics.

Abant Izzet Baysal University, located on the 1st degree earthquake zone, was established in 1992 in Bolu. Apart from the central campus, there are also six campuses (D100 Karayolu, Gerede, Mengen, Mudurnu, Seben and Yeniçağa) belonging to the university. Each of the campuses contain various facilities such as dormitories, eating and drinking units, faculties, institutes, congress centers, sport fields etc. Thus, long span buildings are often needed in the university, and this necessitates the use of steel constructions in campus buildings. This problem is mostly solved with truss systems in the university. In the center campus, truss systems were used in Social Activity Center, Convention Center, Semi Olympic Swimming Pool, Outdoor and Indoor Sports Fields, whereas plate-web girder systems were used in Minder Sports Hall and Social Facility Building. In the College of Physical Education, space frame system was also used. The use of truss systems is less common in other campuses. In the Gerede campus, open-web girder system whereas in the Mengen campus, truss system was used in Sports Halls (Table 1).

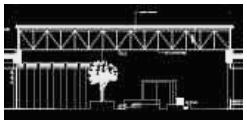
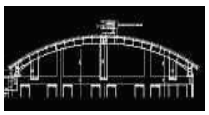
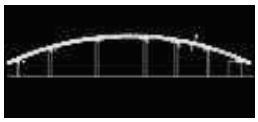
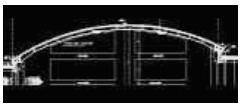
Truss systems were prefered in buildings where social, cultural and sports facilities have been carried out (Table 1). The type of truss system used is related to the distance of the long span. The space frame system was preferred in the Collage of Physical Education, which has the largest span. In other buildings, steel trusses and plate-web girders were used. When the roof types of the center campus buildings of Abant İzzet Baysal University are examined, it is observed that terrace roof type is mostly used (Graphic 1). This is because of the recent increase in the physical usage of the university and the more preference of the terrace roof than hipped roof in the newly built buildings. Because the functions such as faculties, dwellings, administrative buildings and dormitories are more common than social, sports and gathering purposes buildings, the percentages of terrace roof and hipped roof are higher. However, all the buildings built with roof steel are used only for social, cultural and sport activities (Table 1).

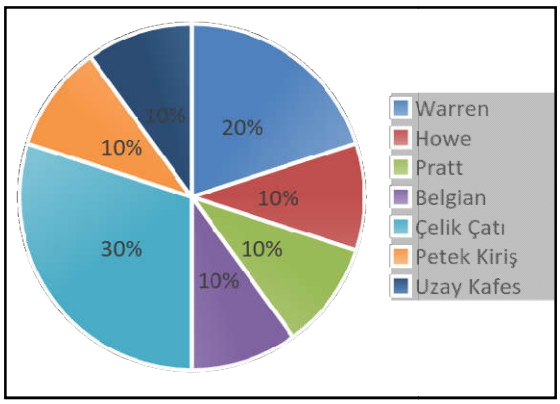


Graphic 1. Roof Types Used in the Abant Izzet Baysal University

When the proportions of the systems made of steel material are examined, it is seen that the most used system is truss system (Graphic 1). "Warren Type" system is also the most preferred system among the truss system types (Graphic 2).

Table 1. Steel Framed Buildings in Abant Izzet Baysal University, Archives of Directorate of Construction and Technical Works

Name of Buildings	Campus	Function	Type of Truss	Schematic Drawing	Long Span	Floor Area	Total Area	Number of Floors
Social Activity Center	Center Campus	Mixed Use	Warren Type		11.00m 21.00m	2190 m2	3802 m2	2
Semi Olympic Swimming Pool	Center Campus	Swimming and Sports	Howe Type		32.00m	1660 m2	3453 m2	4
Convention Center	Center Campus	Cultural and Social	Pratt Type		29.00m	2971 m2	7388 m2	5-2
Outdoor and Indoor Sports Fields	Center Campus	Sports	Warren Type		33.30m 28.60m	2500 m2	2500 m2	1
Mengen Sports Hall	Mengen Campus	Sports	Belgian Type		26.40m	1220 m2	1700 m2	2
Minder Sports Hall	Center Campus	Sports	Vaulted Roof-plate web girder		19.00m	1.250 m2	2.000 m2	2
Social Facility Building	Center Campus	Mixed Use	Vaulted Roof-Plate web girder		42.60m	1370 m2	4200 m2	3
Gerede Sports Hall	Gerede Campus	Sports	Vaulted Roof-Open-web girder		21.20m	1090 m2	1090 m2	1
Collage of Physical Education	Center Campus	Sports	Space Frame System		44.80m	2500 m2	3800 m2	2



Grafik 2. Truss System Types Used in Abant Izzet Baysal University

Use of Truss System for Social Purposes Buildings

Social Activity Center

Social Activity Center located in the west area of the central campus of the Abant Izzet Baysal University and built with reinforced concrete system has two floors (Table 2.a).

There is a possibility to enter both the ground floor and the 1st floor as it is located on a sloping ground. There are units such as restaurant, shops, ticket sales places, tea coffee kiosks, hairdresser, barber, post office, bank, ATMs, game room in the building. In the lecture hall "Warren type" truss system, which provides 610 m2 of free space, was used (Table 2.b). UNP profiles and angle bars were used in roof scissors measures varying from 21.00 m to 7.00 m. Areas outside of the truss system are covered with a terrace roof (Table 2.b).

Convention Center

The congress center, located to the west of the main campus area, is constructed with reinforced concrete system and has a construction area of 7388 m2. It houses amphitheater, offices, meeting rooms, exhibition areas, backstage and artist preparation rooms in various dimensions. Because of the inclined roof form, the upper level is 5 floors and the lower level is 2 floors (Table 3.b). The "Pratt Type" truss system was used in the auditorium with a capacity of 1185 persons in triangular form and an area of 880 m2. Thus, a 28.00m long span was provided without columns and curtains in the section where the audience sat.

Table 2. Social Activity Center, Archives of Directorate of Construction and Technical Works

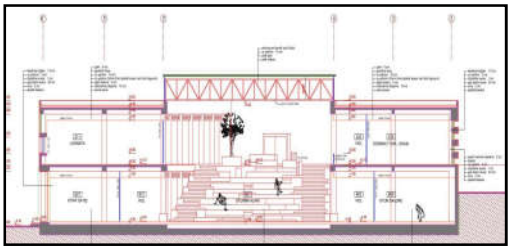
	
a.An Outside View of Social Activity Center	b.A Longitudinal Section of Social Activity Center

Table 3. Convention Center, Archives of Directorate of Construction and Technical Works

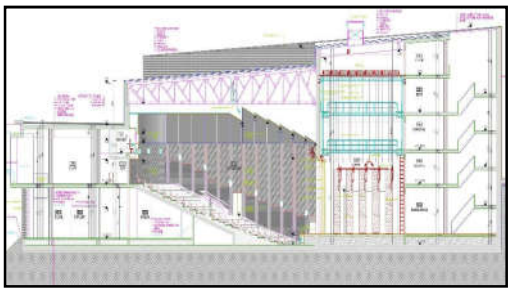
	
a.An Outside View of Convention Center	b.A Longitudinal Section of Convention Center

Table 4. Social Facility Building, Archives of Directorate of Construction and Technical Works

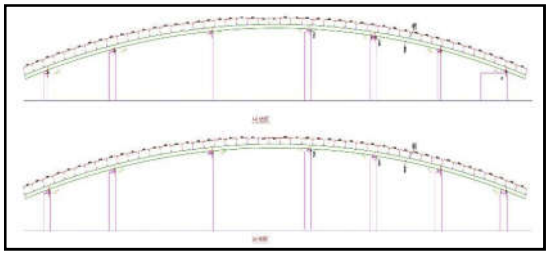
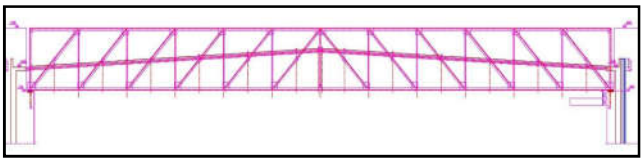
	
a. An Outside View of Social Facility Building	b. A Longitudinal Section of Social Facility Building

Table 5. Semi Olympic Swimming Pool, Archives of Directorate of Construction and Technical Works

	
a.An Outside View of Semi Olympic Swimming Pool	b.A Longitudinal Section of Semi Olympic Swimming Pool

On the upper part of the acoustic rotating panels located on the auditorium stage have the necessary technical units for the stage. These units are located on steel construction catwalks and transportation to cat roads is provided by sailor stairs (Table 3.b).

Social Facility Building

The three storey social facility building located in the east of the main campuses of the Abant Izzet Baysal University was built with reinforced concrete system and serves the student dormitories (Table 4.a).

There are laundry facilities, cafeteria, hairdresser, market, internet lounge, infirmary, cafe, game room, multipurpose hall, administrative offices and lobby in the social facility building. Two separate blocks are interconnected by a steel bridge and an inner courtyard is formed between them. The roof of the building is covered with 42.60 m long plate-web girders and UPN 160 profiles (Table 4.b).

Use of Truss System for Sports Activities

Semi Olympic Swimming Pool

The Semi Olympic Swimming Pool located in the east of the central campus area of the Abant İzzet Baysal University is 4

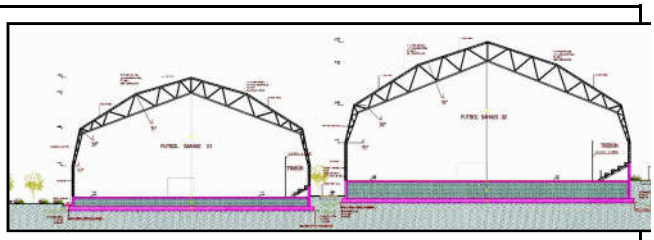
storeys. In the basement floors, there are changing rooms, sauna, offices, first aid room, referee rest room, meeting room while cafeteria and fitness room are on the ground floor. The swimming pool is 2m deep, 25m long, and 16m wide. There is also a training pool measuring 6x16 m on the side of this pool. With the possibility provided by the parallelogram form, the area for training on the edge of the pool and the stand for 171 persons were formed spontaneously. In the building constructed with reinforced concrete system, curtain walls of 30 x 210 m were carried out from the facade so that a plastic effect was obtained on the facade (Table 5.a). The whole structure is overlaid with a "Howe Type" truss system with a length of 32 m and a spacing of 4.5 m (Table 5.b).

consists of a multipurpose building and multipurpose sports fields. In the multipurpose building, administrative office, changing rooms, infirmary and cafeteria are located. One of the football fields measuring 30x50m has a tribune of 344 people and the 33.3 m opening is passed through with the "Warren Type" truss system. In the other one, there is a football field with a size of 25x40m and a tribune of 134 people. The 28.6 m opening was again passed through with the "Warren Type" truss system (Table 6).

Mengen Sports Hall

In Mengen Campus, there are gastronomy, culinary arts and cookery departments.

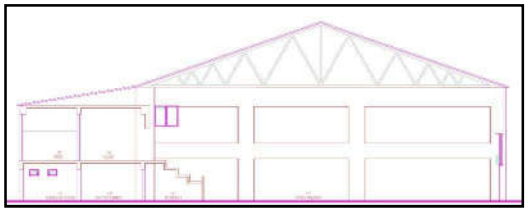
Table 6. Outdoor and Indoor Sports Fields, Archives of Directorate of Construction and Technical Works



A Longitudinal Section of Outdoor and Indoor Sports Fields

Table 7. Mengen Sports Hall, Archives of Directorate of Construction and Technical Works

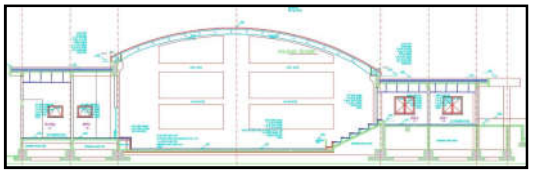
a.An Inside View of Mengen Sports Hall



b.A Longitudinal Section of Mengen Sports Hall

Table 8. Gerede Sports Hall, Archives of Directorate of Construction and Technical Works

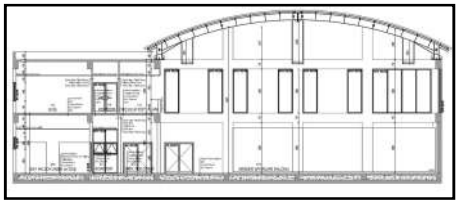
a.An Outside View of Gerede Sports Hall



b.A Longitudinal Section of Gerede Sports Hall

Tablo 9. Minder Sports Hall, Archives of Directorate of Construction and Technical Works

a.An Outside View of Minder Sports Hall



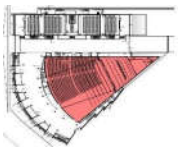
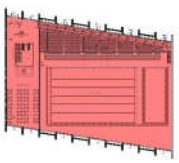
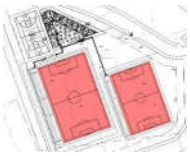
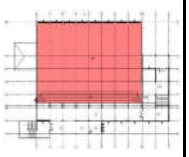
b.A Longitudinal Section of Minder Sports Hall

Outdoor and Indoor Sports Fields

The sports complex planned to be built to the east of the central campus area of the Abant Izzet Baysal University

The sports hall located in the south of the campus area is made of reinforced concrete system, has a construction area of 1700 m2 and has 2 floors. On the lower floor, there are 26x14 m basketball court, tool store, changing rooms, teaching staff

Tablo 10. Plan Schemes of Buildings Using Truss System, Archives of Directorate of Construction and Technical Works

	Social Activity Center	Convention Center	Semi Olympic Swimming Pool	Outdoor Indoor Sports Fields	Mengen Sports Hall
Plan Type					

room, and on the upper floor there are units like tribune, cafe and foyer. The 26.40 m opening that includes the basketball court area and the tribune was solved with the "Belgian Type" truss system. Also, the system was supported with purlins parallel to the roof slope (Table 7).

Gerede Sports Hall

In Gerede Campus, there are Department of Textile and Clothing, Department of Motor Vehicles and Transportation, Department of Chemical and Chemical Engineering, Department of Machinery and Metal Technologies, Department of Postal Services and Design, Department of Information Technologies, Management and Organization Department. The sports hall located in the south of the campus area is made of reinforced concrete system, has a construction area of 1090 sqm and has one floor (Table 8.a). there are offices, changing rooms, warehouses, 277 seater tribune. For the tribune and the basketball court, 21.20 m openness was required, which was provided by the castellated beam. This system provided a more elegant appearance and the installation pipes were allowed to pass [Table 8.b].

Minder Sports Hall

The sports hall located in the north of the main campus area is made of reinforced concrete system, has a construction area of 2000 sqm and has two floors (Table 9.a). There are sports hall, rhythm training and dance hall, recreation room and dressing rooms for students and instructors on the ground floor. On the first floor there are functions such as archery education area, offices, seminar hall. Also, taekwondo and wrestling sports can be performed at the same time with folding curtain in the sports hall which has a rectangular shape with an area of approximately 515 m2. The 19 m openning that includes all functions was solved with plate-web girders according to DIN 17100 standard. It was provided three cats way to intervene to the under of the steel roof when necessary. The spaces outside the steel roof are covered with the terrace roof. As a result, a 3 meter level difference was created between the terrace roof and the steel roof (Table 9.b).

Formal Analysis of Buildings Using Truss Systems

A table showing the plan schemes of the buildings was created in terms of their usage of truss systems (Table 10). The areas where the truss system is used are shown as red hatching. According to this table, in the Social Activity Center, the Congress Center and the Mengen Sports Hall, truss system is partially applied whereas in the Semi-Olympic Swimming Pool and ooutdoor-indoor sports fields, the whole structure is solved with truss system.

Diagonal forms are used only in the Social Activity Center, Congress Center and Semi-Olympic Swimming Pool.

RESULTS

In the study, it is determined that truss systems find a wide usage in the buildings of the Abant Izzet Baysal University. Especially, these systems are included in the buildings where social, cultural and sport activities are carried out. The most preferred truss system for these buildings is the "Warren Type" system. In this system, the weight of the steel and construction cost for small areas decreases. Also, it is possible to use less material than plate-web girder and to easily make the desired geometric shape according to technical and architectural conditions. Steel elements are frequently used in campus buildings due to their ability to be used as aesthetic elements in the interior, to enable different building forms, to meet the need for wide openings and to perform well in earthquakes. Thus, at the Abant İzzet Baysal University located on the 1st degree earthquake zone, steel constructions were frequently preferred.

Conflict of Interest

No conflict of interest was declared by the authors

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