ATATÜRK ÜNİVERSİTESİ YAYINLARI
ATATURK UNIVERSITY PUBLICATIONS

Araştırma Makalesi *Research Article* DOI: 10.5152/Planarch.2023.23145

Construction System for Rural Tourism Facilities in the Eastern Black Sea Region: Timber-Concrete Composite System with Artificial Notches

Doğu Karadeniz Bölgesi Kırsal Turizm Tesisleri İçin Yapım Sistemi Önerisi: Yapay Çentikli Ahşap-Beton Kompozit Sistem

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ABSTRACT

The Eastern Black Sea Region is one of the regions where rural tourism potential is high in Türkiye thanks to its local architectural features. However, in addition to the numerical inadequacy of rural tourism facilities in the region, the construction of facilities that are not suitable for the architectural texture of the region threatens the natural components and architectural texture of the region. ,The main reasons for this situation are the land structure of the region, the climate, the supply of wood/timber materials used in the local architecture and the difficulties in maintaining the local construction techniques. In the study, it is aimed to examine the properties of the Timber-Concrete Composite (TCC) system selected as an industrial construction system that can be a solution to the accommodation facility needs in the region and to explain the properties of the artificial notched fastener, which is designed as a new fastener with high rigidity and composite efficiency in system elements, by conducting experimental (push-out and bending) studies. As a result of the study, it was evaluated that the artificial notched TCC construction system has the potential to be used in the construction of rural tourism facilities.

Keywords: Artificial notched connector, rural tourism, timber-concrete composite system.

ÖZ

Doğu Karadeniz Bölgesi, yerel mimari özellikleri ile Türkiye'de kırsal turizm potansiyelinin yüksek olduğu bölgelerdendir. Ancak bölgede kırsal turizm tesislerinin sayısal yetersizliğinin yanı sıra, bölgenin mimari dokusuna uygun olmayan tesislerin yapılması da bölge doğal bileşenlerini ve mimari dokusunu tehdit etmektedir. Bölgenin arazi yapısı, iklimi, yöre mimarisinde kullanılan ahşap malzemenin temini ve yerel yapım tekniklerinin sürdürülebilmesi kaynaklı zorluklar bu durumun başlıca nedenlerindendir. Çalışmada, bölgedeki konaklama tesisi ihtiyacına çözüm olabilecek endüstriyel bir yapım sistemi olarak seçilen; Ahşap-Beton Kompozit (ABK) sistem özelliklerinin incelenmesi ve sistem elemanlarında yüksek rijitlik ve kompozit verimlilik değerine sahip yeni bir bağlantı elemanı olarak tasarlanan yapay çentikli bağlantı elemanı özelliklerinin deneysel (itme ve eğilme) çalışmalar ile açıklanması amaçlanmıştır. Çalışma ile yapay çentikli ABK yapım sisteminin kırsal turizm tesislerinin inşasında kullanabilecek potansiyele sahip olduğu görülmüştür.

Anahtar Kelimeler: Ahşap-beton kompozit sistem, kırsal turizm, yapay çentikli bağlantı.

Introduction

The Eastern Black Sea Region is one of the regions with high rural tourism potential in Türkiye with its natural beauties, cultural heritage and rural architectural texture. Investments are encouraged and supported in order to revive rural tourism activities in the region. The vast majority of these incentives and investments are directed to tourism facilities in order to meet the demand for accommodation that has arisen in the region due to the developing tourism phenomenon. However, although the number of rural tourism facilities has increased in the region, it has not reached the desired level (Doğu Karadeniz Projesi [Dokap], 2019).

Geliş Tarihi/ Received 12.03.2023

Kabul Tarihi/ Accepted 17.07.2023

Yayın Tarihi/ Publication Date 13.10.2023

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Cite this article: Yılmaz, S., Vural, N., & Baş, G. Y. (2023). Construction system for rural tourism facilities in the Eastern Black Sea Region: Timber–concrete composite system with artificial notches. *PLANARCH - Design and Planning Research, 8*(1), 46-57. DOI: 10.5152/Planarch.2023.23145.

In addition to the numerical insufficiency of rural tourism facilities in the region, the construction of facilities that do not correspond to the traditional architectural texture of the region has also become a threat to the natural components of the region, especially the traditional architectural texture of the region, which is usually built with wooden building material. The main reasons for this situation are; wooden structures require qualified labour and time, they are not considered economical, prejudice formed in the region for timber structures, traditional timber structures cannot be built to meet today's comfort conditions and it is insufficient in terms of fire protection. These difficulties that encountered prevent the installation from reaching the desired level and prevent users from using unsuitable materials (concrete, brick, briquette, etc.) for buildings built in rural areas and directs to the method preference. This orientation causes the development of an architectural texture that is incompatible with the natural environment, distorted, unplanned and without identity, and difficult to compensate for problems (Bilici & Işık, 2018; Özçatalbaş, 2006).

In recent years, applications aimed at solving these problems, in which local building materials are used or individual precautions are taken in buildings, have been implemented, but they remain insufficient. In the tourism facilities to be built in the region, there is a need to use an industrial construction system that allows flexible designs that are compatible with the conditions and architectural texture of the region, can be produced quickly and easily installed, consumes low energy, resources and labor, providing higher fire protection instead of traditional construction systems with a holistic approach. In the selection of the system, the traditional architectural texture characteristics of the region, land structure and climate characteristics should be taken into account.

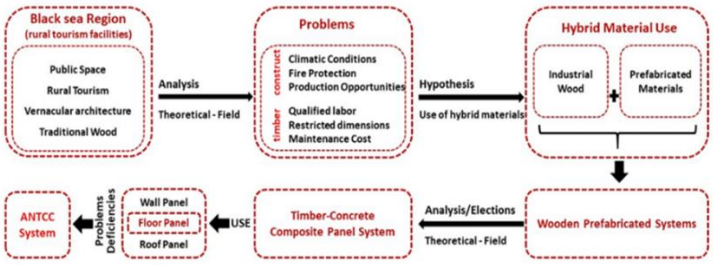


Figure 1. Hypothesis flow chart of the study.

In the rural part of the Eastern Black Sea Region, there is a characteristic architectural texture that usually uses timber material, and due to climatic conditions, the period during which a structure can be built in the region is short. For these reasons, a wood-based, Timber-Concrete Composite (TCC) system with high prefabrication possibilities may be preferred as an industrial construction system in tourism facilities to be built in rural areas of the Eastern Black Sea Region.

The TCC is a system created by mechanically combining timber and concrete with fasteners (Van der Linden, 1999). In this system, in which timber balances each other by working on the pressure of the concrete to attract, the materials (wood/timber and concrete) are more efficient in composite form than when they are used in the structure alone (LeBorgne & Gutkowski, 2008; Van der Linden, 1999). This system, has significant advantages compared to systems that use only timber or only concrete. The benefits in aesthetics, sustainability and economical savings due to fast erection time will undoubtedly be a significant factor to their widespread use. In addition, the performance of timber-concrete composite floors when subjected to fire is excellent. A large degree of safety is possible without risking structural collapse compared to only wooden systems.

The adaptation and use of systems that are rapidly increasing in use worldwide to the Turkish construction sector is a necessary issue to investigate, and it is believed that this system has a great potential for use, especially in the countryside of the Eastern Black Sea Region with a tradition of timber construction.

In the study, the characteristics of the TCC system selected as an industrial construction system that can be a solution to the rural accommodation facility needs of the region and can be applied faster and easier in the construction of facilities compatible with environmental values were examined; The applications of the Artificial Notched Timber-Concrete Composite (ANTCC) system, a fastener with high rigidity and composite efficiency value in the system elements, were explained specifically for flooring.

The realization of experiments on the behaviour of the TCC system within the scope of the study can contribute to the elimination of the lack of knowledge and experience for the TCC system. In addition, the benefits of preventing the destruction of nature with today's materials and workmanship are considered as a separate benefit. The study will contribute to the awareness of TCC systems in Türkiye, to the utilization of the potential of the timber-based construction system of a country such as Türkiye, which has high values in terms of forest areas, thus contributing both to the construction sector and to the creation of sustainable living environments.

Material and Methods

The rural tourism identity of the Eastern Black Sea Region has been shaped through highland tourism due to its land structure, vegetation, climate characteristics and the fact that it has a large number of plateaus suitable for rural tourism. However, although the speed of realization of tourism activities in the highlands has improved, the desired effect has not yet been achieved. One of the important reasons for this situation is the quantitative and qualitative inadequacies of the regional accommodation facilities (Republic of Türkiye Ministry of Culture and Tourism, 2023).

The numerical insufficiency of accommodation facilities in the region leads to the inability to meet the demand for accommodation and the average length of stay in the region remains below the average of Türkiye, although it has increased over the years. These negativities create obstacles in front of increasing the tourism-oriented income level of the region and negatively affect the competitiveness of the region.

The numerical increase of tourism facilities should be developed in accordance with the traditional architectural texture by preserving the regional values of the region through laws, national decisions and plans. With its advanced features, the TCC system is suitable for use in accordance with the architectural texture of the region, faster and more economical, while at the same time providing the expected comfort conditions. However, with the literature research conducted, despite the positive features and benefits they have, the issues that constitute an obstacle to the spread of the system in the local construction sector have been identified and listed as follows:

-Although the development rate of industrial building production in Türkiye is an open sector for development, it is not at the desired level due to reasons such as traditional system dominance in the building sector, insufficient technology and

infrastructure for industrial production, insufficient promotion (Amani & Niyazi, 2018).

-TCC system, which is a timber-based, industrial construction system, is a new technology for the region. In order for this system to be included in traditional architectural construction, its structural features and application methods should be known (Amani & Niyazi, 2018).

-The biggest impact on the performance of the TCC system is due to the connection efficiency. There are different types of TCC system connection elements in the literature. Experimental studies conducted by Dias (2005) and Yeoh (2010) have shown that notched connections offer the most suitable solution. However, the opening of notches to timber beams in the implementation of this connection system causes loss of labour, time and materials, and this situation causes economic negativity. In addition, the notches opening to the timber carrier reduce the cross-section of the timber carrier and weaken the system (Dias, 2005; Yeoh, 2010).

In the study, solution suggestions were developed by following the method steps given in Figure 1 for the identified problems. In this context, the characteristics of the TCC system, which was first selected as a construction system that can be a solution to the need for accommodation facilities, were examined; a new connection element with high rigidity and composite efficiency in the system elements, the artificial notched TCC system, was developed. The developed connection system was tested by real-time experiments (push-out and deflection) on the prepared experimental devices in the laboratory environment in accordance with the performance criteria determined depending on the strength and composite efficiency criteria. The dimensioning of the building elements used in the experiments was determined by the relevant regulations (Eurocode-4) and modulation studies performed on a standard accommodation unit (for two people). In the production of different structural elements of TCC systems (walls, roofs, etc.) although its use is available, this system is best known for its use as a tile (Dias, 2005; Yeoh, 2010). For this reason, TCC system laying applications are included in the scope of the study.

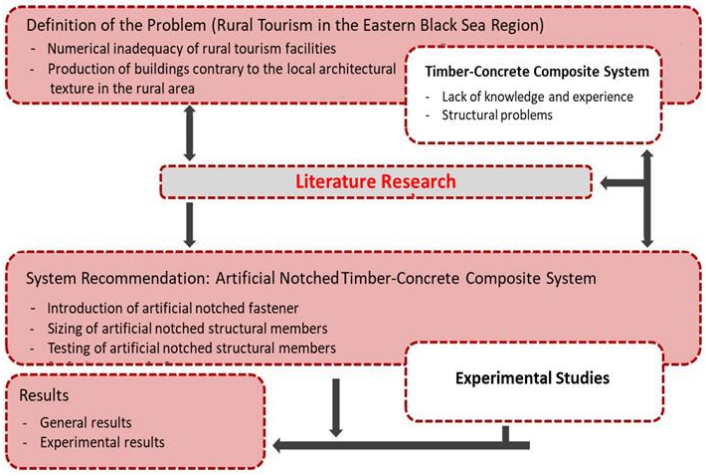


Figure 2. Method flow chart of the study.

Rural Tourism in Eastern Black Sea Region

Rural development is a set of economic and social policies aimed at improving living conditions in rural areas, enabling the population living in rural areas to benefit from economic, social, cultural and technological opportunities where they are located (Cengiz & Çelem, 2003). Rural tourism is one of the leading and most important sectors in achieving the goals set out in rural development strategies (Çeken vd., 2011). Rural tourism is the most important component of diversification of economic activities in rural development (Ün vd., 2012).

Türkiye has an important rural tourism potential with its geographical structure, climatic features and natural components. After 1990, with the aim of spreading tourism all year round, studies aimed at evaluating the current tourism potential of the regions have started to find a place in national tourism strategies (Devlet Planlama Teşkilatı [D.P.T.], 1990). The Highland Tourism Project initiated by the T.R. Ministry of Tourism (1990) is one of these studies.

Within the scope of the Highland Tourism Project (1990), 26 highlands have been declared Tourism Centres (TC) in Türkiye (Figure 2). With the regulations made, it is aimed to encourage tourism movements, investments in highland tourism facilities, which will be built in compliance with the Decisions of the Environmental Regulation Plan commissioned by the relevant Ministry, provided that the natural texture, natural resources, highlands and cultural values are protected, in these regions.

In the strategies developed within the scope of the highland tourism centre project initiated by the Ministry of Tourism in 1990, the Eastern Black Sea Region is at the centre of highland tourism. The rural tourism identity of the region has been shaped through highland tourism due to the land structure, vegetation, climate characteristics and the fact that it has a large number of plateaus suitable for rural tourism. In addition, the scattered settlement pattern of the region and examples of timber civil architecture have also been a factor in the prominence of the region in terms of rural tourism (Doğaner, 2001; Esen, 2016).

In the Tourism Strategy 2023 action plan (Figure 3) prepared by the Ministry of Culture and Tourism in 2007, tourism development corridors were created and the natural and cultural texture of a route determined in this context was renewed and developed for tourism purposes based on certain themes. Among the 7 thematic development corridors created, the “Highland Tourism Corridor” is located in the Eastern Black Sea Region (Republic of Türkiye Ministry of Culture and Tourism, 2007).

After the applications for the development of highland tourism initiated by the Ministry of Culture and Tourism, the studies in the region have shown rapid development and the highlands have become the focus of tourism mobility due to their recreational use.

These developments have led to the challenge of some differences in the functions of the highlands (Somuncu vd., 2014). Table 1 shows the structural changes that occurred in the highlands during the historical period.

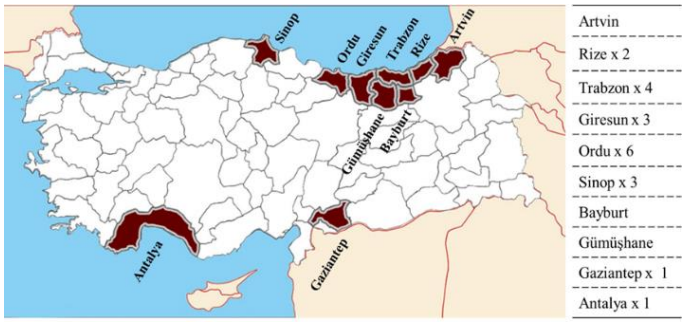


Figure 3. Information about the distribution of Highland Tourism Centres to provinces (Republic of Türkiye Ministry of Culture and Tourism, n.d.).

Rural Tourism Facilities in Eastern Black Sea Region

Within the scope of Türkiye's 2023 Tourism Strategy, it is aimed to use natural, cultural, historical and geographical values in a conservation-use balance and to increase the share of world tourism income by popularizing alternative tourism types. Based on the studies carried out in this direction, there has been an increase in the number of tourists visiting the Eastern Black Sea Region, and due to this increase, enterprises in different capacities have started operating in all the regional provinces in order to meet the increasing accommodation needs. However, when the tourism statistics of Türkiye are examined (Table 2), it is understood that this number remains limited in the Eastern Black Sea Region. This inadequacy on rural tourism facilities causes the average length of stay in the region to remain below the average of Türkiye (Table 3). The Ministry of Culture and Tourism adopts the strategy of extending the stay periods in the region. For this reason, in order to increase the number of accommodation and overnight stays of tourists coming to the region, he emphasizes rural tourism of the region, especially through highland tourism, suggesting increasing the number and quality of accommodation facilities as an important requirement (Bilici & Işık, 2018).

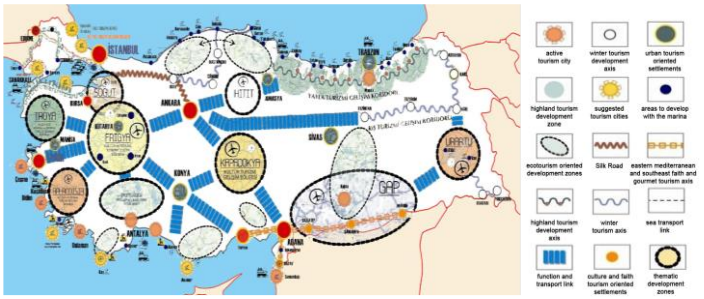


Figure 4. Tourism development corridors in the Turkish Tourism Strategy 2023 Action Plan (Republic of Türkiye Ministry of Culture and Tourism, 2007).

Figure 5. Unauthorized construction in rural areas and work of destruction in the areas (Yılmaz, 2023).

In the academic studies carried out, emphasis is also made on increasing the period of stay. Also, Eleventh Five-Year Development Plan (2019-2023) also includes measures related to the period of stay and increasing bed capacity (D.P.T., 1990).

Although it is necessary to carry out studies on various issues such as promotional activities, transportation and infrastructure services, incentive and support applications in order to increase the duration of accommodation, the primary factor that stands out in this regard is the numerical improvement of accommodation facilities to an adequate level. The numerical increase of tourism facilities should be developed in accordance with the traditional architectural texture, preserving the regional values of the region. But;

Table 1. Changes in the functions of springs during the historical period (Somuncu vd., 2014).

Periods	The Main Reasons for the Change in the Highlands
1950 and before	It is the period when traditional highland activities are carried out and the main function is animal husbandry.
1950-1980	It is the period when migration from the countryside to the city begins; the population migrating to the highlands decreases relatively; some highlands begin to be abandoned.
1980-1990	It is the period when recreation and tourism activities in the highlands develop; the return to the highlands begins.
1990 and later	It is the period when there is an increase in recreational activities and tourism investments; the function of the highlands has changed significantly.

- The climatic characteristics of the region narrow the time interval in which the structure can be built, the construction process of timber structures produced by traditional construction methods is longer compared to other construction systems,
- Difficulties in obtaining traditional timber materials due to the inability to make effective use of the forest's existence due to various laws,
- Production limitations of traditional wood materials,
- Timber structures require qualified labour and time, are not considered economical due to the need to protect wood,
- Prejudice formed for the fire protection of timber structures,
- The modern comfort conditions of traditional timber structures (lighting, heating, etc.).
- Problems such as inability to build a suitable structure, the sloping land structure of the region, climate characteristics that cause intense energy requirements, transportation infrastructure that causes difficulties in the supply of fossil fuels, as well as increasing the initial investment and usage costs of rural tourism facilities in the region, such difficulties prevent installation from reaching the desired level and prevent users from using materials unsuitable for the region (concrete, brick, briquette, etc.) in structures built in rural areas and directs to the method preference.

This orientation causes the development of an architectural texture that is incompatible with the natural environment, distorted, unplanned and without identity, and difficult to compensate for problems (Figure 4-5). Also, according to the Pasture Law, settlement in the highlands, etc. although it is clearly stated that it is not possible to build dwellings, the construction of many illegal structures in the highlands of the region also accelerates this situation.

Table 2. Tourism facilities in the Eastern Black Sea Region (Ministry of Culture and Tourism, 2023).

Province	YEAR OF 2004			YEAR OF 2018			YEAR OF 2021		
	Ministry Certified Facilitate			Ministry Certified Facilitate			Ministry Certified Facilitate		
	Use	Room	Bed capacity	Use	Room	Bed capacity	Use	Room	Bed capacity
Artvin	7	368	737	13	616	1229	12	638	1268
Rize	6	321	647	13	799	1626	17	1015	2094
Trabzon	18	848	1666	61	3424	7003	100	5017	10395
Giresun	11	372	708	31	895	1772	31	864	1710
Ordu	8	360	731	34	1420	2871	40	1784	3608
Gümüşhane	1	37	73	6	267	526	6	267	526
Total	51	2306	4562	158	7421	15027	206	9585	19601

Table 3. The number of arrival and accommodation days to the tourism facilities of the Region (Ministry of Culture and Tourism, 2023).

Province	YEAR OF 2004 Ministry Certified		YEAR OF 2018 Ministry Certified		YEAR OF 2021 Ministry Certified	
	Person	Day of Accommodation	Person	Day of Accommodation	Person	Day of Accommodation
Artvin	50212	1.5	69163	1.59	69978	1.66
Rize	50840	1.4	46926	1.61	86345	1.65
Trabzon	130746	1.4	401932	1.85	406113	2.06
Giresun	48470	1.2	124753	1.48	110554	1.59
Ordu	33510	1.3	245816	1.47	294297	1.46
Gümüşhane	4589	1.3	21685	1.93	25970	1.76
Total	53061	1.35	151712	1.65	165542	1.69
Average Türkiye		3.29		2.87		2.62

System Recommendation: Timber-Concrete Composite System

In the study, where the use of an industrial construction system compatible with the conditions and architectural texture of the region instead of traditional construction systems with a holistic approach is considered in the tourism facilities to be built in the Eastern Black Sea Region, a timber-based, high prefabrication possibilities, Timber-Concrete Composite (TCC) system using the composite use of timber and concrete materials and the positive properties of both materials was selected as the construction system. This system, which is created by mechanically combining timber and concrete with fasteners (Figure 6), has significant advantages in terms of usage, transportation and environmental decals compared to systems that use only timber or only concrete. The advantages of the system are listed here:

The advantages of TCC structures built with a timber system can be listed as follows:

- They are more rigid and stronger than traditional timber systems, increasing the earthquake resistance of the structures with the rigidity it provides.
- Wide spacing provide freedom in planning with the ability to pass.
- Structures with better acoustic performance are built.
- They provide significant solution of vibration-induced problems.
- They provide fire protection between floors more effectively than timber systems.
- Reducing the heating and cooling energy consumption of structures by creating a high thermal mass (Dias, 2005; Lukaszewska, 2009; Yeoh, 2010).

The advantages of TCC structures built with a reinforced concrete system can be listed as follows:

- Cracking occurs under the influence of tensile force and therefore reduces the cross section of reinforced concrete, which loses its efficiency, resulting in more efficient cross sections by using a timber beam or timber plate instead. In girder systems, the space between the beams is used for technical deconstruction services. The cost is low compared to the suspended ceiling and the installation time is short.
- They have a low intrinsic weight value. There is a decrease in the load affecting the foundation. It allows foundations with a smaller cross section, with a decrease in weight compared to reinforced concrete systems.
- A decrease in mass/weight significantly reduces the earthquake effect (Dias, 2005; Lukaszewska, 2009; Yeoh, 2010).
- They offer the aesthetic superiority of wood. They provide an advantage in terms of architecture with its natural and warm effect. They have the advantages that wood has in terms of sustainability.
- These systems have low embedded carbon energy. They require quite little energy compared to the production of concrete and steel materials and structures, and there is less carbon dioxide emission to the atmosphere during their production. Timber sequesters greenhouse gases released by other materials and construction activities by storing carbon in its structure (Dias, 2005; Lukaszewska, 2009; Yeoh, 2010).

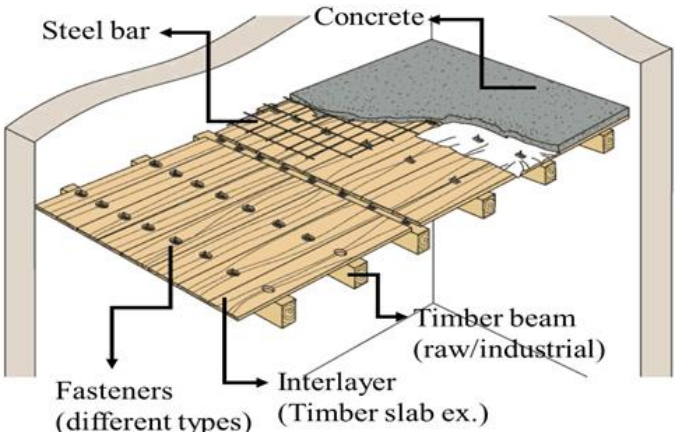


Figure 6. TCC floor application (Dias, 2005; Yeoh, 2010).

With all these benefits, the TCC system has a positive impact on the solution of environmental problems such as global warming, air pollution, water pollution, excessive resource consumption, energy consumption and solid waste production, which are especially seen as the main problems of the 21st century. Due to this effect, the adaptation and use of systems that are rapidly increasing in use worldwide, especially in America and Europe, to the Turkish construction sector is a necessary issue to investigate, and it is believed that this system has a great potential for use, especially in regions with a tradition of timber construction. However, despite these positive features and benefits they have, there are issues that pose obstacles to the spread of the system in the local construction sector. They are summarized as follows:

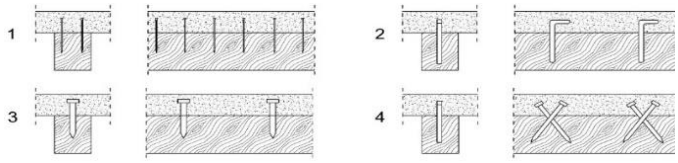
• Although the development rate of industrial building production in Türkiye is an open sector for development, it is not at the desired level due to reasons such as the dominance of the traditional system in the building sector, insufficient technology and infrastructure for industrial production, and insufficient promotion. In European countries, the share of industrial production in the construction sector is between 30 and 50%, while in Türkiye this figure is only in the range of 2-3% (Amani & Niyazi, 2018).

• Timber material is one of the most widely used materials in the traditional architectural texture of the region. However, it has become an established idea in the region over time that timber material is insufficient in terms of fire resistance. This situation leads to the fact that timber structures are not preferred.

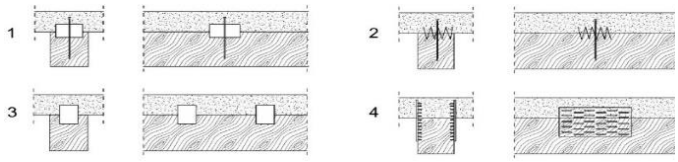
• The TCC system, which is a timber-based industrial construction system, is a new technology for the region. In order for this system to be included in traditional architectural construction, its structural features and application methods should be known. The most intensive research in the TCC system is the effect of fastener properties on the performance of the system, as the biggest impact on the performance of the system is due to the connection efficiency. In this system, structural efficiency is achieved by creating a mixed action between two materials (Dias, 2005).

There are different types of TCC system connection elements in the literature, and experimental studies have been conducted by different researchers on the physical and mechanical properties of these connection types. When the values obtained by the experimental studies performed by Dias (Ceccotti, 2002; Dias, 2005; Yeoh, 2010) are taken into consideration (Table 4), it is seen that notched fasteners offer the most suitable solution in TCC system applications and stand out as the most ideal fastening system.

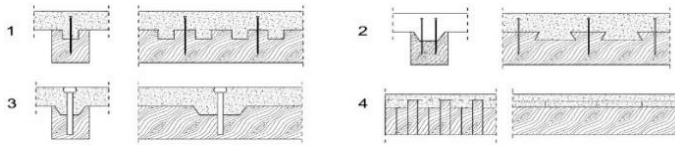
Table 4. Classification of fasteners according to rigidity (Ceccotti, 2002; Dias, 2005; Yeoh, 2010).



1: Nails, 2: Reinforcement Bars (glued), 3: Screws, 4: Oblique Screws



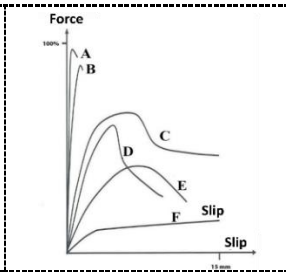
1-2: Metal ring and Threaded metal plate, 3: Steel Pipe, 4: Perforated steel plate



1: Circular notch and metal connection, 2: Square notches and metal connection, 3: Notches and pre-stressed steel reinforcement, 4: Nailed timber deck and corrugated steel plate

1: Steel grating glued to a timber beam, 2: Steel plate glued to the timber beam

A: Glued Connections
B: Notched Connections
C: Circular Notched/Studded Connections
D: Axially Loaded Screws
E: Metal Sheets
F: Spiked Connections



The efficiency of notched connections has been revealed by experimental studies conducted by Yeoh (2010) on different fasteners (Table 4). The length of the notch, the presence of a lag screw, and its depth of penetration into the timber were found to be the most important factors affecting the performance of the connection (Kuhlmann & Schänzlin, 2001; Van der Linden 1999). It was found that the notch length affects the strength and stiffness of the connection, and the lag screw provides ductility and improves the post-peak behavior (Yeoh vd. 2009b, 2011). Notched connections reinforced with dowels or metal anchors that allow tightening after the concrete curing have the advantage of reducing the gap between the concrete and timber caused by the concrete shrinkage within the notch (Gutkowski vd., 2004). However, in the implementation of this connection system, notching the timber beams causes a loss of labor, time, and materials, and this situation causes economic negativity. In addition, the notches opening to the timber carrier (raw/industrial) reduce the cross section of the timber carrier and weaken the system (Yeoh, 2010).

Table 5. Limits on sizes and reinforcements (TS 500 and TS EN 1995-1-1).

Magnitude	Symbol	≤/ ≥	Limit Values/Descriptions	
Interval between threads	e	≤	700 mm (TS 500)	
Thread width	b	≥	h/4m 50 mm	
Reinforced concrete slab thickness	t	≥	e/10 (TS 500)	
The ratio of the distribution-bar reinforcement in each direction on the reinforced concrete plate	Pd=Ad/(e.t)	≥	0,0015 - Ad=0,0015.t.e. (TS 500)	
Interval of distribution-bar reinforcement	Sd	≤		
Beam depth	h	≥	Ln/20	Single-span simply supported
			Ln/15	No deflection account required.
			Ln/10	Cantilever
			Ln/8	No deflection account required.
Number of transverse beams			1 piece	Interval from 4m-7m
			2 pieces	Interval greater than 7 m

Ad: Reinforcement cross-sectional area; Ln: span passed; Pd: Distribution reinforcement ratio in each direction in the reinforced concrete slab.

Table 6. Data on the placement (layout and number) of fasteners.

Length of Timber Beam/plate (m)	Number of Fasteners (number)	Fastener Axle interval (cm)	Fastener Position (cm)	
			Timber (a_{de})	Concrete (b_{de})
0 - 15 m	$B_s \geq L/50$ cm	$A_k \leq d_b*10$	$a_{de} \geq db*0.6$	$b_{de} \geq 2.5$ cm

Note: When installing fasteners, an axle is left missing in the middle of the opening of the timber beam or slab. a_{de} = Depth of penetration of bolt into concrete; b_{de} = Depth of penetration of bolt into timber; d_b = Bolt length; L = Interval. A_k: Fastener axle distance; B_s: Number of fasteners.

Timber-Concrete Composite System with Artificial Notch

Artificial Notched Timber-Concrete Composite (ANTCC) system is a type of connection developed as an alternative to different types of fasteners used in TCC system applications. The main purpose of the development of the ANTCC system is to obtain a type of connection that can be preferred in both renovation and new construction applications, can be applied easily and quickly, has economical, high strength and rigidity properties, and can eliminate the disadvantages of notched connections. The fastener that gives its name to the system is called an artificial notch due to the fact that it creates a gap in the concrete layer. This element is formed by using a decked bolt, metal washer and metal artificial notch to ensure load transfer between the timber layer (plate/beam) and the concrete plate (composite effect) (Figure 7).

The artificial notch is in the middle part of the element, the bolt with a header (it may differ depending on the diameter of the element used. On both sides, there are mounting holes left for connection to a timber beam or slab (Figure 7).

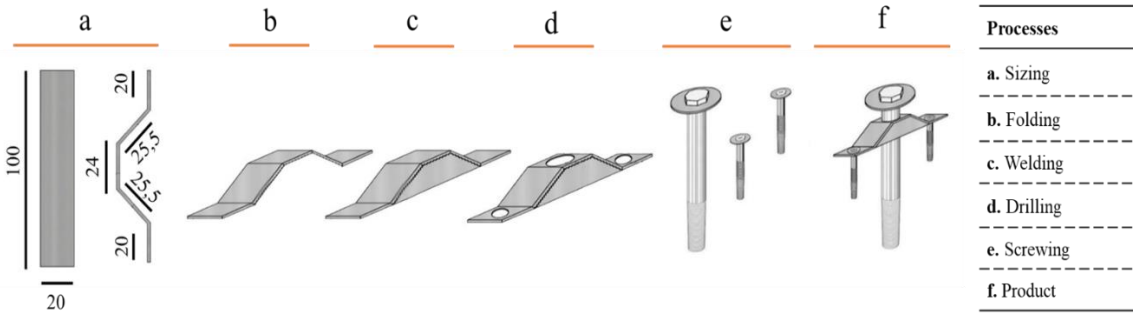


Figure 7. Information about the artificial notch fastener.

The trapezoidal middle part of the artificial notched fastener creates a closed and hollow volume in the concrete slab. Thus, the head bolt that provides the connection between the beam and the plate by passing through here is removed from the shear effect as a result of the relative displacement between the concrete decking and the timber element, trying to bend freely in the decked area and exhibiting ductile behavior. In order to increase the composite efficiency, ductility, and energy

consumption capacities, the adhesion between the artificial notched fastener and the concrete plate must be sufficient,the moment arm provided by the artificial notching to the decked bolt must be sufficient to allow bending, and the diameter of the capped bolt must be sufficient.

The following criteria were used in the dimensioning of TCC flooring elements in the study:

-The width and height measurements of the flooring elements have been determined by the modulation setup prepared for the design to be realized.

-The cross sections of the flooring elements, the width and length measurements of which have been decided, have been prepared using Table 5-6, which has been prepared according to TS 500 and TS EN 1995-1-1 standards.

Results

Within the scope of the study, experimental studies were conducted in order to compare the properties of TCC flooring panels used with artificial notched fasteners and TCC flooring panels used with notched fasteners.

In In these studies, notched TCC building elements were accepted as reference samples. Modulation studies were carried out on a standard (a room for two people) accommodation unit in order to dimensionalize the experimental elements. The modulation study was carried out on the minimum space dimensions determined in accordance with the requirements given in the relevant regulations and taking into account the production, transportation, etc. construction possibilities of the panels.

According to the study, the aspect measurements of the floor panels are 140 × 380 cm, and the cross-sectional dimensions are determined based on the data in Table 5 (for timber beams: the middle beam is 14 × 24 cm, the edge beams are 7 × 24 cm; the thickness of the concrete slab is 6 cm) (Figure 8).

Push-out and bending experiments were carried out on the experimental elements produced by adhering to the determined dimensions at the Karadeniz Technical University, Department of Civil Engineering, Structure and Materials Laboratory. Detailed information about the elements, materials, and equipment used in the experiments is given in Tables 7 and 8.

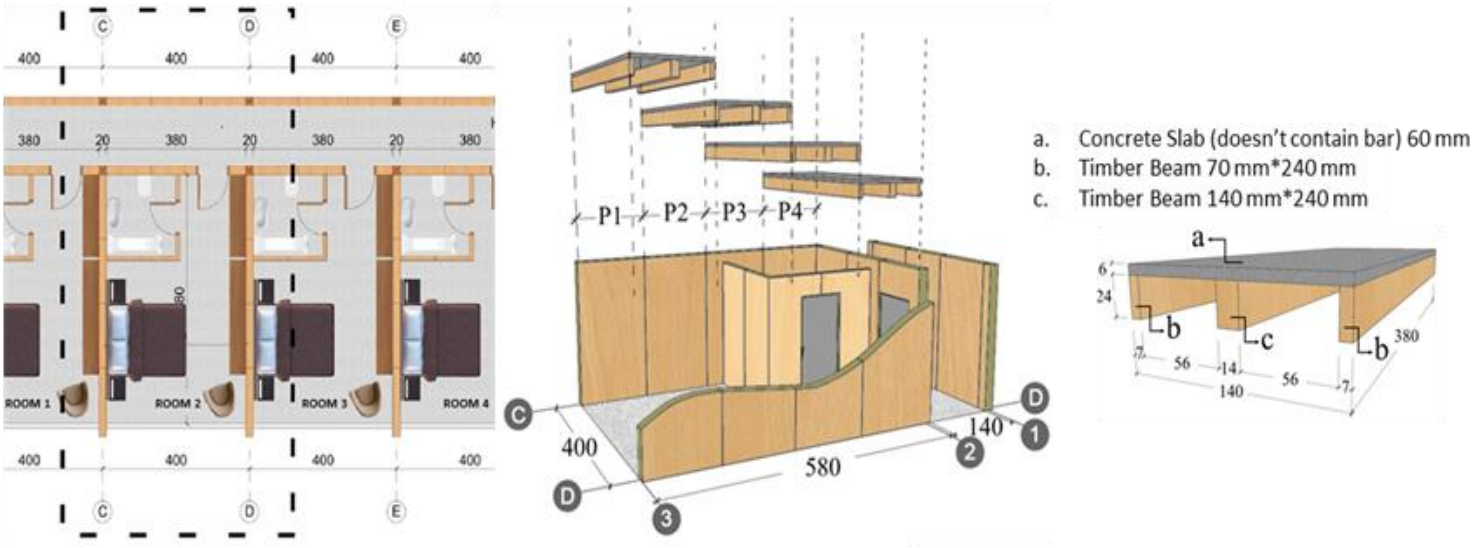
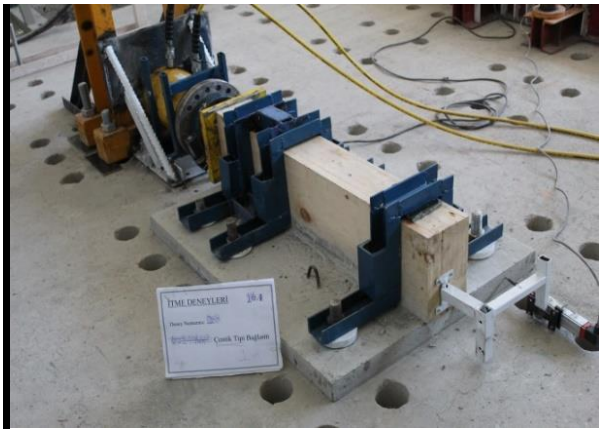
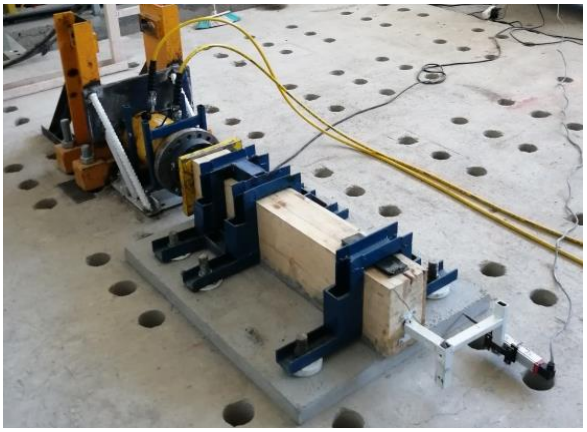


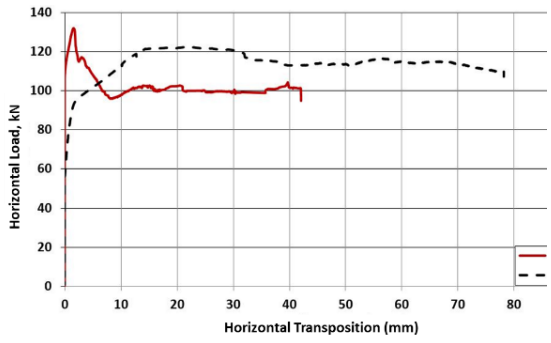
Figure 8. Determination of panel sizes.

Table 7. Information about push-out experiments, experimental elements and experimental results.

Sample	Connection Type	Fastener (mm)	Notch sizes, (cm)			Concrete plate sizes, (cm)			Sizes of beams, (cm)	
			Width	Length	Depth	Width	Length	Thickness	Section	Length
PO-1	Notched	2 Ø 16	14	15	3	75	100	6	14*24	100
PO-2	Artificial notched	2 Ø 18	-	-	-					







Sample	Yield load		Max Load		Initial rigidity
	P_y, (kN)	D_y, (mm)	P_u, (kN)	D_m, (mm)	K_i, (kN/mm)
PO-1	-	-	131.98	1.58	83.53
PO-2	1.56	92.73	122.21	14.10	59.44

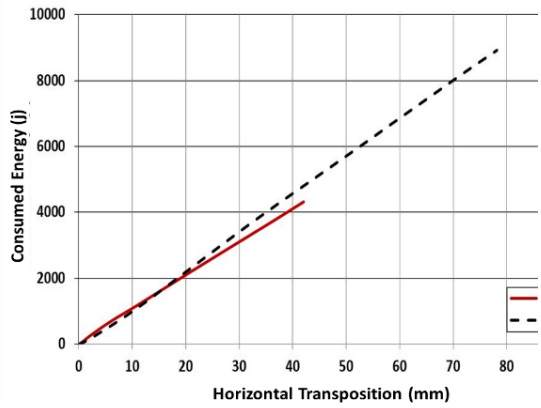
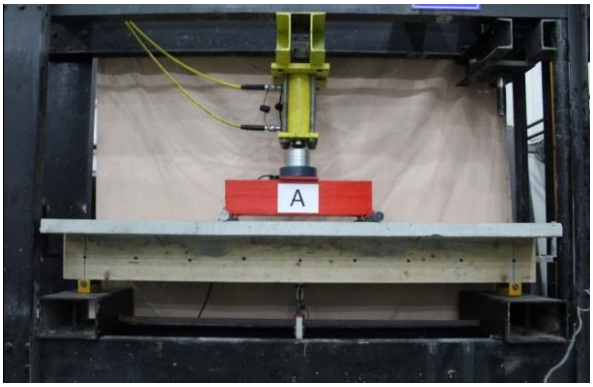
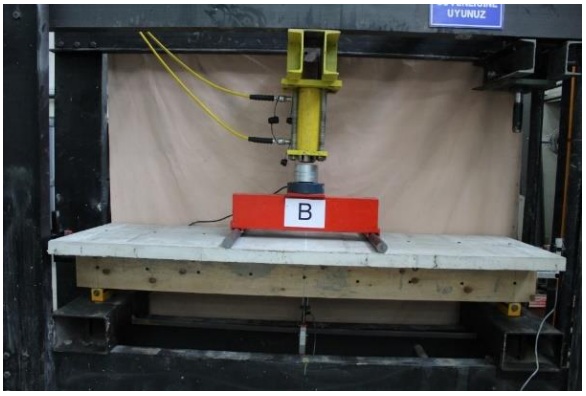
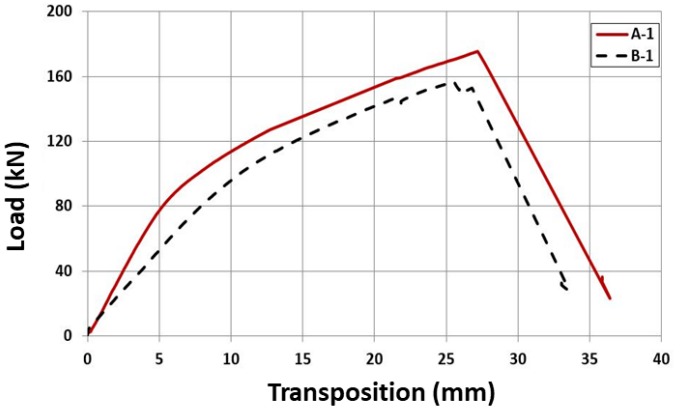


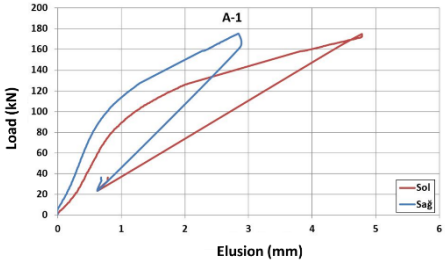
Table 8. Information about bending experiments, experimental elements and experimental results.

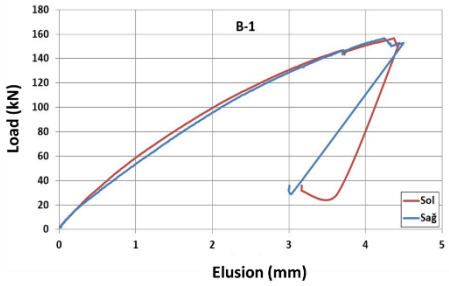
Sample	Connection Type	Fastener (mm)	Notch sizes (cm)			Concrete plate sizes, (cm)			Sizes of beams, (cm)	
			Width	Length	Depth	Width	Length	Thickness	Section	Length
A-1	Notched	4 Ø 16	14	15	3	75	250	6	14*24	250
B-1	Artificial notched	4 Ø 18	-	-	-	75	250	6	14*24	250











Sample	Max Load		Max Relative drift		Initial rigidity
	P_u, (kN)	D_m, (mm)	Left (mm)	Right (mm)	K_i, (kN/mm)
A	175.17	27.21	4.78	2.86	16.44
B	156.10	25.51	4.50	4.44	9.91

Table 9. Composite efficiencies of bending experiment elements.

Sample	P_u (kN)	D_m (mm)	D_{fc} (mm)	D_{nc} (mm)	Composite Efficiency, (%)	
					Serviceability limit state	Ultimate limit state
A-1	175.17	27.21	8.45	33.78	86.60	25.94
B-1	156.10	25.51	7.54	30.17	84.40	20.59

* In determining the composite efficiency of the experimental elements, the composite efficiency calculation formula given by Pault & Gutkowski (2008) was used.

Discussion

As a result of the experiments carried out, the evaluations were made in the thrust and bending headings as follows:

The contribution of the concrete in the notched area in the PO-1 (reference sample using notched system) element to the loadbearing capacity up to the maximum load has increased the initial rigidity. In the PO-2 (sample using artificial notched system) element, only the fastener carried the load. After exceeding the shear strength of the concrete in the decked area, the load on the PO-1 element began to be carried by the friction between the concrete surfaces and the connecting bolt. In the PO-2 element, on the other hand, it exhibited a more ductile behavior compared to the PO-1 element, since the load was carried only by the fastener. In the PO-2 element, bending has dominated the behavior of the fastener thanks to the artificial notch. When the energy consumption capacities of the PO-1 and PO-2 thrust experimental elements are compared, the energy consumed by the PO-2 element in the final case is calculated as 8912 Joules.

As can be seen, the energy consumption capacity of the PO-2 element is quite high compared to the PO-1 element. This result is due to the fact that the load is concentrated in the fastener and the system exhibits a more ductile and stable behavior compared to the PO-1 element. While the collapse occurred suddenly in both experimental elements, the damage to the timber beams also showed similarities. During the experiments, the relative displacement changes between the concrete slab and the timber decking were measured at the left and right ends of the experimental elements (Table 8). The deflection limits given in the relevant regulation (TS EN 1995-1-1; L/150-L/300) have been taken into account for the serviceability limit status. In the serviceability limit case, the composite efficiencies of A-1 and B-1 elements are quite close and have been calculated as 86.60% and 84.40%, respectively. At the time of collapse, these values were calculated as 25.94% and 20.59% for the A-1 and B-1 elements, respectively. As can be seen, the composite efficiency of the B-1 element used in the artificial notched connection type is quite close to the A-1 element used in the notched connection type (Table 9).

Conclusion and Recommendations

In the study in which the use of the TCC System in accommodation facilities to be built in rural areas of the Eastern Black Sea Region was investigated and a new type of connection, the artificial notched system, was experimentally examined, the following results were reached:

• One of the reasons why TCC systems are preferred in buildings is that they are more rigid, provide better thermal insulation and better acoustics than traditional timber floors. In addition, they have reduced mass compared to reinforced concrete flooring, wide clearance, better environmental properties, and the esthetic property of wood/timber, which are also effective in the use of the TCC system.

• The TCC system can be preferred in the construction of timberbased rural tourism facilities suitable for the land structure, climatic characteristics, and traditional architectural character of the Eastern Black Sea Region.

• Timber–concrete composite systems provide great savings in time and labor in terms of construction and bring efficiency with it. In this way, more economical rural tourism facilities can be built compared to traditional structures. The use of TCC system can eliminate the prejudice that timber material is insufficient in terms of fire resistance in the region.

• When the studies on the structural performance of the TCC system were examined, it was understood that notched connections are the most ideal connection type in terms of strength and rigidity values. However, these connections contain disadvantages such as the uneconomical opening of the notches to the timber element, the notches causing a decrease in the cross sections of the load-bearing elements, and the shrinkage caused during the concrete set process weakening the system strength by creating a gap on the notch surfaces. In addition, notched joints are also not suitable for renovation applications.

• Experimental studies have shown that heavy damage to concrete slabs occurs in notched fastener applications and the system becomes unusable. However, in notched-slab fastener applications, the damage is concentrated on the fastener in the metal notch created in the slab, and no damage occurs in the concrete slab. As a result, the adherence between the fastener and the concrete slab is preserved and the system does not lose its load-carrying capacity.

• In artificial notched fastener applications, the damage is concentrated in the fastener instead of concrete. Thus, the system showed ductile behavior and lead the system to consume more energy. In addition, in notched applications, while the concrete notch increases the load-bearing capacity of the structural specimen, due to the shear effect between the concrete slab and the concrete notch, the concrete behaves brittle and provides a limited contribution to the energy consumption of the structural specimen. Due to the damage concentration in the connector, cracks that may occur in the concrete slab under service loads will be prevented. In addition, leaving the notch in the concrete slab instead of the timber beam

prevents cross-sectional loss in the timber beam. This is one of the most important benefits of the proposed connector.

• In subsequent studies, the construction of a rural accommodation facility, especially suitable for the conditions of the region, using the TCC system can be further improved by multifaceted consideration of prefabrication rules, the development of different building elements (walls, roofs), and ensuring the integration of these elements with the developed flooring element.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept -S.Y., N.V.; Design-S.Y., G.Y.B.; Supervision-N.V.; Resources-G.Y.B.; Data Collection and/or Processing-S.Y.; Analysis and/or Interpretation-S.Y., N.V.; Literature Search-S.Y., G.Y.B.; Writing Manuscript-S.Y.; Critical Review-N.V.

Ethics Committee Approval Certificate: The authors declared that an ethics committee approval certificate is not required.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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