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RESEARCH ARTICLE

Evaluation of the load-bearing wall design of Edirne Old Harbiye Barracks according to the Turkish Building Earthquake Code (TBEC-2018)

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Abstract

The masonry construction system consists of stone, brick, and mortar, in which the wall element acts as the vertical load load-bearing and generally allows low-rise buildings. The buildings built with this system are mostly seen in rural areas today, but also in traditional and historical textures in city centers. Stone, brick, mortar, etc. used in the masonry construction system. The materials are materials with a low stretching rate but are resistant to pressure. In this case, against the driving force of a possible horizontal load source, the bearing walls will inevitably be damaged because they do not allow sufficient oscillation. In Türkiye, earthquake-resistant building design principles and calculation methods related to the behavior of masonry structures against earthquakes are guiding at this point. Inspecting the masonry structures planned and built in the past in terms of compliance with today's conditions and regulations is important for the sustainability of the structure. Making a building that has a negative profile in terms of compliance with the masonry construction rules is important for both the structure and the health of the user. In this study, the compliance of the load-bearing walls in the architectural design of the old Harbiye Barracks building, which is currently used by the Faculty of Architecture of Trakya University, to the rules regarding the wall design in the current regulation, Türkiye Building Earthquake Code 2018, is investigated. As a result of the study, it was seen that the building showed different suitability in different blocks. While the occupancy-to-space ratio of the b block on the bearing wall is better, it has been determined that the block does not fully comply with the rules.

1. Introduction

It can be said that the historical masonry buildings that have survived to the present day are structures that have been in existence for many years and maintain their resistance against various horizontal and vertical loads. The vertical load-bearing walls and the gaps opened in the masonry construction system that resists these loads play an important role in maintaining the resistance of the wall. The earthquake-resistant building design principles defined in the Turkish Building Earthquake Regulation [1] (TBEC-2018) should be handled meticulously, examined in detail for each building type, and meticulously made necessary arrangements after

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the earthquakes. Regular and careful planning of the structural elements of the building is of primary importance, especially in providing resistance against earthquake and wind loads from horizontal loads.

As one of the traditional construction methods, it is important to consider the masonry construction technique, which is still used in the construction of rural houses and historical buildings in city centers, in terms of its behavior in earthquakes. According to the census made in 2000, it was determined that there were 651.920 masonry buildings in Edirne. Considering that it was built with the modern technique, it is important to examine the building according to the construction conditions of today and to take measures against earthquakes when necessary. In all countries on the seismic belt, earthquake regulations are revised every time there is a new earthquake as a result of damage assessment studies. In Türkiye, the earthquake code has been revised after every major earthquake since its first creation (1940) [2]. Revision dates are given in Table 1.

The existing regulations during the design and construction of these structures, which were built many years ago, have been revised [2-5] and the last regulation published in 2018 is in force today. According to this regulation, the principles under the title of "Turkish Building Earthquake Regulation" are taken into consideration. In this regulation, Türkiye's seismic hazard map was updated, the site-specific earthquake hazard definition and deformation-based design procedure were improved, new sections were added about the design of non-structural structural elements, special rules for the design of cast-in-place and precast reinforced concrete building structure systems, earthquake design of mild steel buildings, wooden buildings, tall buildings, seismically isolated buildings, and structural modeling rules for piled foundations, minimum concrete strength increased to C25 (compressive strength is equal to 25 MPa) to be used in all seismic zones and requirement of minimum cross-sectional dimensions for columns in the earlier code was modified as 30×30cm [6].

Studies on the horizontal load performance of masonry structures show that the most effective factor in the damage or survival of the structure is the walls in the masonry buildings. It is stated that the standing of the load-bearing walls in the masonry structures ensures that the building is also standing [7]. However, the architectural plan, which is considered in the first stage of the building design in the discipline of architecture, and the load-bearing structure system, which is considered in the late stages of the architectural plan in the discipline of civil engineering, should be examined in one go in the masonry construction system. In the masonry construction system, the load-bearing structure cannot be considered independently of the architectural plan and function. The masonry construction system contains rules limiting the architectural design in terms of construction conditions. For this reason, every condition that must be appropriate in the regulation directly affects the architectural plan and facade design.

Studies indicate that most of the severe damage and collapses in masonry structures are due to inadequate wall units, weak mortar, lack of vertical enclosing elements, irregularities in the plane and vertical, insufficient connection of bearing walls, insufficient length of bearing walls, unrestricted triangular walls and heavy cantilever elements [8].

Table 1. Earthquake regulations in Türkiye

1940	Italian Building Regulations for Construction to be Made in the Earthquake Zones
1968	Regulation on Structures to be Built in Disaster Areas
1975	Regulation on Structures to be Built in Disaster Areas
1998	Regulation on Structures to be Built in Disaster Areas
2007	Regulation on Buildings to be Built in Earthquake Zones
2018	Turkish Building Earthquake Regulation

In this study, the compliance of the architectural design to the masonry load-bearing wall design rules in the TBEC-2018 regulation was investigated in the Edirne Old Harbiye Barracks, which was built as a military high school/barracks but is used as the building of the Faculty of Architecture in Trakya today.

1.1. Material and method

Current conditions for masonry construction rules are given in the TBEC-2018 regulation. With this regulation, which contains more detailed rules than the "Regulation on structures to be built in earthquake zones 2007 [9], which was in force before that and remained in force for many years, many details regarding the construction of structures are given. The architectural plan, section, and views of this building were obtained and its compliance with the architectural plan was checked with metric measurements made on-site. However, considering the rules recommended in TBEC-2018, the length of the bearing wall of the Edirne Old Harbiye barracks building was checked, and the rules to be followed in the architectural design of the masonry building were examined on the scale of the sample building.

2. Design principles for master structures according to TBEC-2018

Ensuring the sustainability of the structure set up in structural design is possible with the geometric form of the structure, the continuity of the load-bearing system, sufficient strength, rigidity, and ductility [10]. Continuity in the Structural System is the necessity of having sufficient rigidity, stability, and strength to ensure that the earthquake loads are transferred continuously and safely from the roof to the foundation floor in the building load-bearing system and each element constituting the load-bearing system. When the structure is exposed to horizontal loads, the structural system elements must work as a whole and transfer the incoming horizontal load properly. The rules that should be applied in the architectural plan in the design of masonry structures in TBEC-2018 and the rules that should be left to be left are given below (Table 2).

Regarding the masonry construction rules, the necessary technical information for these concepts is given in detail under the title of "Special Rules for the Design of Masonry Building Bearing Systems Under the Impact of Earthquake" in SECTION 11 of TBEC-2018. Within the scope of this study, the evaluation of the structural formation of the building concerning the architectural design was made based on the rules related to solid-empty wall lengths. The relevant articles in the regulation mentioned below are given in a table (Table 2).

The suitability of the rules given above, which should be applied in the architectural plan design of masonry buildings in TBEC-2018, in the building of Edirne Old Harbiye Barracks is examined in Chapter 3, where the field study is discussed.

3. Case study: Architectural and structural analysis of Edirne Old Harbiye Barrack Building

In the case study, the history of the building, its architectural features, and structural analysis were discussed together with the general information about the building.

3.1. Architectural features of the building

Old Harbiye Barracks; It is located in Edirne province, Merkez-Meydan district, and Harbiye Çeşme Street. The building was built in 1871 as a military school. However, it changed many functions until it reached its present form. The building, which was used as a high school, hospital, and teacher's school over time, was transferred to Trakya University and used as the Faculty of Architecture (Fig. 1 and Fig. 2).

Table 2. Rules regarding bearing walls in TBEC-2018 masonry construction system

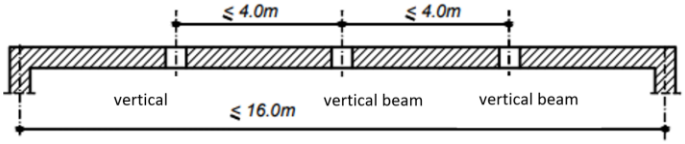
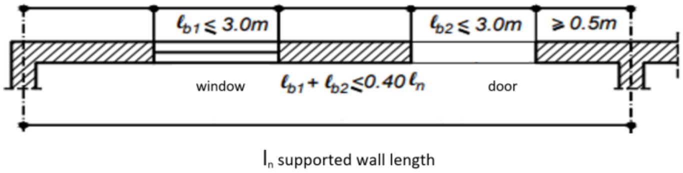
Number	TBEC-2018
11.5.2.	In unreinforced and confined masonry buildings, the maximum unsupported lengths of load-bearing walls and the distances between vertical beams shall comply with the requirements given in the image below. 
11.5.3	The rules given in the image below shall be complied with in the door and window spaces to be left on the load-bearing walls. 
3.A.2.	3A.2.1 – With the regular and symmetrical arrangement of the structural system in the plan, the inertial forces arising from the distributed masses on the floors can be transferred to the vertical load-bearing system elements in the most appropriate way. With the symmetrical structural system arrangement, eccentricities that may occur in terms of mass, stiffness, and strength can be prevented and a predictable earthquake behavior can be realized. 3A.2.2 – The load-bearing system should also be arranged regularly in the vertical direction. In this context, soft story and weak story arrangements that may occur due to sudden changes in story stiffness and strength should be avoided as much as possible.

Fig. 1. Old Harbiye Barracks Location, Satellite Image

Fig. 2. Monumental Entrance Facade

The building was built on an area of 23.957.50 m^2, close to the square (Fig. 3). It consists of a basement, ground floor, first floor, and roof. The rectangular building (Fig. 4) around the inner courtyard extends in the south-north direction. This building was created by combining the "Harbiye Building", which is given as block B in Fig. 5 with an "L" plan, covering the north and west wings of the inner courtyard, and the rectangular planned block A that covers the east wing of the courtyard, from the north and south corners. It was formed as a result of combining the rectangular planned block C, which was built as an additional service building on the east and parallel of this building, from the north and south corners during the Republic period (Fig. 5). In some of these joint parts, there are dilatations because they were made at different times. The short side length of the building is approximately 73 m, and the short side length is approximately 84 m.

Limestone, marble, cut stone, chipped stone, and brick were used in the creation of the load-bearing walls. The spaces outside the window were built with a row of cut stones and two rows of bricks in an alternating technique. The plan of the building on the ground and first floors is the same. While there is no basement in the A block, there is only a partial basement in the northern part of the B block. However, in this basement floor, the inner wall does not follow the entrance floor wall trace (Fig. 6). Along with the external load-bearing wall, there are dividing walls and supporting point vertical load-bearings-columns in the interior (Fig. 7). It is estimated that these columns were added to the structure later. These vertical additions, which are located in the middle of the space and disrupt the spatial integrity, create visual problems in these spaces used as classrooms today. However, some gypsum partitions were added in the process of transforming the building from the Military School to the Faculty of Architecture building, which is its current function. The part indicated as block C in Fig. 5 added during the Republican period was built with a reinforced concrete skeleton system. For this reason, that part was not taken into consideration. Block A and Block B, which were constructed at different times and have dilatation in between, were evaluated separately.

Fig. 3. View from the Courtyard

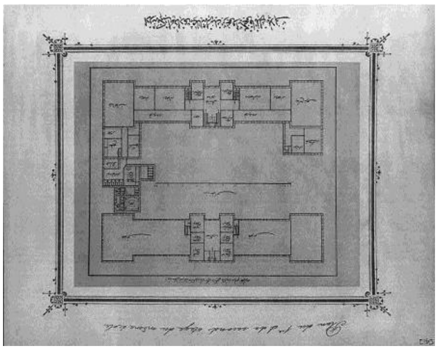


Fig. 4. First architectural plan of the Old Harbiye Barracks

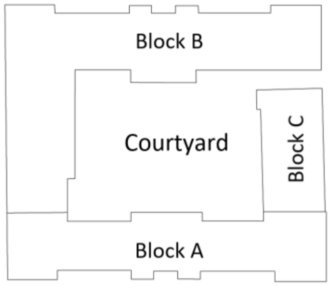


Fig. 5. Old Harbiye Barracks block layout

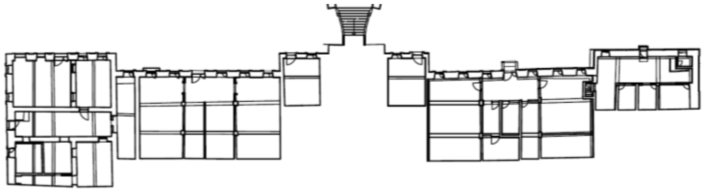


Fig. 6. Old Harbiye Barracks B block basement floor plan

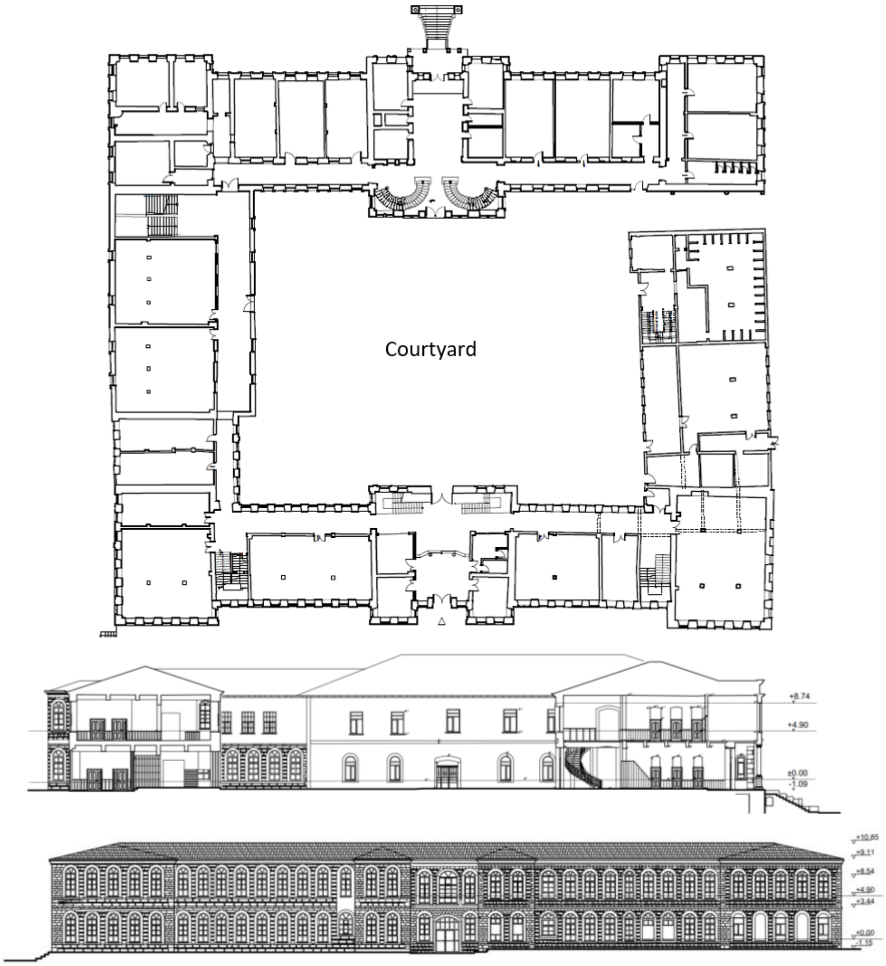


Fig. 7. Old Harbiye Barracks ground floor architectural plan, section, and view

3.2. Bearing Wall Analysis of the Building According to TBEC-2018

The type of masonry structure discussed in the study; The unreinforced masonry building given in TBEC 2018 has been determined as a building with limited/low ductility level, which is constructed using only masonry unit and mortar without using reinforcement inside the load-bearing walls. Accordingly, the positive and negative evaluations of the conformity of the Old Harbiye Barracks plans according to the masonry building design principles given in Table 2 in the previous section are given below in items (Table 3).

The dimensions of the door-window spaces of the load-bearing walls on the façade are given in Fig. 8 and the calculations are given in Table 4. In the axis arrangement indicated in Fig. 8, the main load-bearing axles are named and the intermediate axles are shown with dotted lines. Point-bearing elements (square columns) added to the structure, later on, are not included in the axis system.

Table 3. Structural Properties Analysis

Structural properties analysis				
	BLOCK A		BLOCK B	
Number	Positive	Negative	Positive	Negative
11.5.2		There is an unsupported 12.3 m long load-bearing wall on the 9A-9B axis.		There is an unsupported 12.02 m long load-bearing wall on the 8A-8B axis.
		There is no reinforced concrete vertical beam.		There is no reinforced concrete vertical beam.
11.5.3	Except for the corners of the building, the length of the solid wall piece to be left between the intersection of the walls and the window or doorway closest to the intersection of the vertically intersecting walls is more than 0.50 m in plan.	The distance of the gaps opened on the load-bearing walls between the 9E-9F and 10E-10F axes to the wall intersection areas is less than 50 cm.	Except for the corners of the building, the length of the solid wall piece to be left between the intersection of the walls and the window or doorway closest to the intersection of the vertically intersecting walls is more than 0.50 m in plan.	
	the length of each door and window opening in the plan is not greater than 3.0 m.		the length of each door and window opening in the plan is not greater than 3.0 m.	
3.A.2.1 3.A.2.2	The load-bearing walls on the ground and first floors are designed symmetrically and in the same axis order.		The load-bearing walls on the ground and first floors are designed symmetrically and in the same axis order.	It was designed independently of the ground and first-floor layout on the north side of the basement floor.

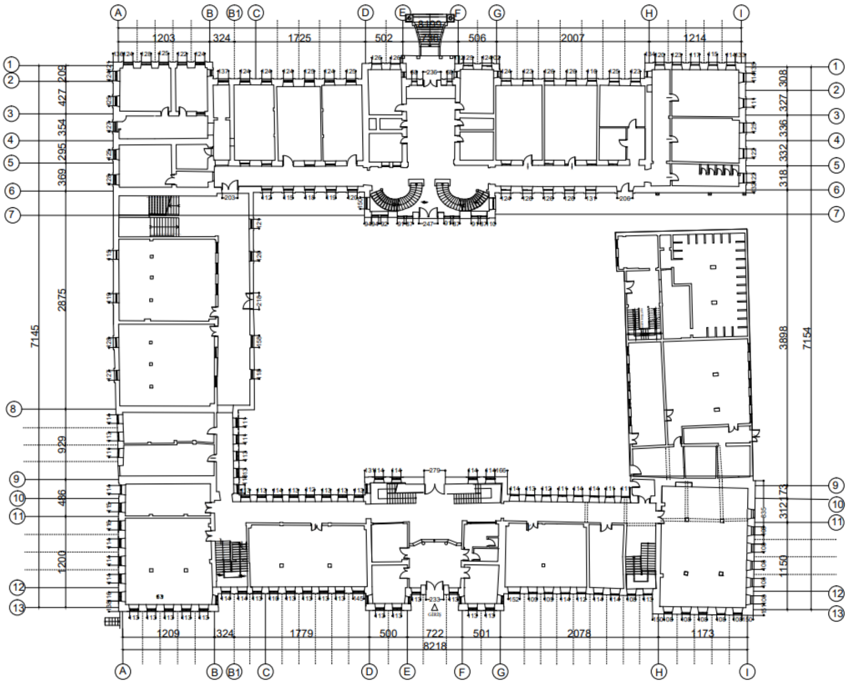


Fig. 8. Old Harbiye Barracks plan layout

4. Findings

According to the analysis made in Table 4, the sum of the lengths of the gaps on the unsupported load-bearing walls, lb total, should be less than 0.40×ln. When the load-bearing wall lengths of the A block, which was first built on the campus, are analyzed, it is seen that the total values of lb in all main axes exceed the values of ln. In block B, it was determined that a sufficient wall occupancy rate was provided in approximately 40% of the load-bearing wall axes, but the total lb values in the main axes in the remaining part exceeded the ln values.

5. Evaluation and conclusion

Research and studies on the seismic performance of masonry structures show that walls are the most important structural element that affects the severity of vulnerability [11]. If these walls remain undamaged or slightly damaged, casualties can be minimized.

In the structure setup, which was examined in detail in the building, it was determined that the gaps opened especially on the facade load-bearing walls were above the limit values given in the TBEC 2018 regulation. Columns added later after the construction of the building are descriptive of this situation. It is estimated that vertical columns were added later to support the structure, due to the gaps opened during the planning and construction of the structure, reducing the load-bearing feature for the walls, which are the main bearing structure of the masonry construction system. The fact that these added columns were built with reinforced concrete shows the use of mixed materials in the building. The fact that the bearing elements are composed of local materials with different properties complicates the analysis of seismic behavior. Determining the properties of the parameters and materials used in the analysis is important for the correct determination of the structural behavior [12]. However, it is emphasized that masonry structures should be strengthened even if they are not damaged.

Table 4. Calculations for A and B block door-window gaps

Parameter	Axis number	Supported wall length (ln)	0.4×ln	The sum of gap lengths lb total	< ln
BLOCK B	1A-1B	1203	*0.4	623	481.2
	1D-1E	502	*0.4	252	200.8
	1F-1G	506	*0.4	249	202.4
	1H-1I	1214	*0.4	589	485.6
	2B-2B1	324	*0.4	137	129.6
	2B1-2D	2050	*0.4	746	820.0
	2E-2F	736	*0.4	372	294.4
	2G-2H	2007	*0.4	863	802.8
	6C-6D	1444	*0.4	584	577.6
	6D-6G	1744	*0.4	1086	697.6
	6G-6H	2007	*0.4	839	802.8
	A1-A3	636	*0.4	249	254.4
	A3-A4	354	*0.4	127	141.6
	A4-A6	669	*0.4	253	267.6
	A6-A8	2875	*0.4	489	1150
	A9-A11	486	*0.4	229	194.4
	A11-A13	1200	*0.4	574	480.0
	I1-I3	635	*0.4	225	254.0
	I3-I5	668	*0.4	247	267.2
	I5-I6	318	*0.4	122	127.2
	I9-I13	1635	*0.4	648	654.0
BLOCK A	9A-9B	1209	*0.4	565	815.2
	9B-9D	2038	*0.4	1048	815.2
	9D-9G	1723	*0.4	689	735.0
	9G-9H	2078	*0.4	1045	831.2
	9H-9I	1173	*0.4	540	469.2
	10B1-10D	1779	*0.4	904	711.6
	10G-10H	2078	*0.4	900	831.2
	12B-12D	2038	*0.4	1048	815.2
	12E-12F	722	*0.4	459	288.8
	12G-12H	2078	*0.4	1045	831.2
	13A-13B	1209	*0.4	565	483.6
	13D-13E	500	*0.4	226	80.0
	13F-13G	501	*0.4	226	200.4
	13H-13I	1173	*0.4	540	469.2

Since the building has a courtyard, there is a combination of masses extending in different directions with each other. In TBEC 2018, it is recommended that the masses constructed in different directions are separated from each other by dilatation joints. While there is a dilatation joint because the building was built at different times between the A block and the B block, there is no dilatation within the L-shaped block B itself. However, in masonry structures, the construction of a partial basement changes the rigidity and center of mass of the structure. Masonry structures with low ductility levels show sudden and brittle fracture behavior during earthquakes. As a solution to this situation, reinforced masonry buildings are recommended in the regulation to increase the ductility level of masonry structures, and horizontal and vertical reinforcements can be placed in the construction of load-bearing walls to increase energy absorption capability and durability [13]. Besides this, as a solution to the weakness of unreinforced masonry structures against dynamic loads, a strengthening method using natural fiber-reinforced mortar can be proposed and used to prevent the brittle collapse of unreinforced masonry structures [13].

As a result of the analysis made in this study, it is seen that blocks A and B, which were built in different periods and have different structural features, have similar occupancy-vacancy ratios. It is thought that these two blocks, which were built in different years, were designed with the understanding of the building having a holistic design language, thus creating spaces in similar proportions. Structural errors during the planning and construction of these structures, which are resistant to horizontal and vertical loads with their load-bearing walls, can endanger the structural health of historical and cultural buildings, especially those that are intended to be permanent for many years. Along with the concerns about the design, it is necessary to consider the structural setup of the building in the early stages of the design.

The behavior of the building against earthquake load, which is one of the horizontal loads, should be considered as a whole, and risk analysis by evaluating the walls together with the beam, floor, and roof is necessary to reveal precise data.

Conflict of interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Data availability statement

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