Latif Onur UĞUR[1]

Rıfat AKBIYIKLI[1]

Ali ATEŞ[1]

[1]University of Düzce, Faculty of Technology, Civil Engineering Dept., Turkey

INVESTIGATION OF SKELETON CONSTRUCTION COSTS OF VILLA BUILDINGS WITH DIFFERENT CARRIER SYSTEMS

Keywords: Wood carcass, Steel carcass, Reinforced concrete carcass, Construction cost

Abstract

In this study, engineering designs were made using wooden, steel and reinforced concrete conveyance systems of a two-story villa with the same architecture. The cost of the rough construction was compared by subtracting the quantities and discoveries of the calculated projects. When the skeleton costs are analyzed, it is understood that the wooden carrier system is the most expensive solution. It is also clear that the reinforced concrete carrier system is the cheapest method. When the cost analysis results are evaluated at the origin of the skeleton construction; it is determined that reinforced concrete structures are cheaper than steel structures. According to the analysis results; it is clearly understood that the cost of building skeleton is much lower than that of reinforced concrete structures and wooden carcass structures. However, when considering the economic life span of the structures, maintenance costs, recycling characteristics and behavior against depression; it should not be forgotten that steel structure system structures will be more advantageous than reinforced concrete structures.

1. Introduction

As in every sector, building construction is carried out by using various conveying systems in the construction sector as well. In addition to the factors such as the purpose of use, the place to be built, the number of storeys and the factors such as safety, aesthetics, usage period, function of construction, recycling and cost are important factors in selecting building materials. **[1-3]**

Reinforced concrete is the most important building structure accepted in the world today. Reinforced concrete is a building material formed by using concrete and steel together. The construction period of the reinforced concrete structure is made according to the construction made with steel and wood carrier materials. As the floor weight increases, the weight of the building increases, so a serious foundation thickness is required. Because the steel is not as homogeneous and isotropic as the steel, the error in static calculations is greater. The first investment cost of reinforced concrete construction is the use of crops, which is less than steel and lumber. The reinforced concrete structure affects the environment and quality of life negatively during the production. The negative effect on the production of steel and wood structures is less visible, quick and easy to produce**.** [4]

Steel structures are a more durable construction systems due to their flexibility. The steel, which is light compared to the reinforced concrete structure, is constructed in a much shorter time, it can work in all kinds of weather conditions, these materials are not damaged from water. This reduces labor and time costs. **[5]** After disasters, repairs and maintenance are made faster and less costly than concrete. Reinforced concrete structures after catastrophe are very costly and time consuming. [6]

The structure is called "wooden structure" when the structural system of the structure is constructed from wooden building material. Wood is a light construction material compared to the load it carries and it can behave ductile against earthquake loads. Wood is long-lasting. If you think that reinforced concrete and steel have a life of 100 years, wooden material shows resistance for centuries with routine maintenance of 10-15 years. In addition, the wood has a limited load-bearing power and prevents the construction of multi-storey and wide-span structures.

Heat insulation of wood is much higher than concrete. While the coefficient of thermal conductivity of the wood is 0.13-0.20 W / mK, the thermal conductivity of the concrete is 2.5 W / mK. This allows heating in winter with less energy and cooler in summer. [7]

The lightness of the wood and its use in thinner sections causes a "buckling" problem. The reason why the wood has lost its mechanical properties over time is to increase the "deflection". Another characteristic of wood is that there is very little "unit strain" between "yield stress" and "break point". Wood is not ductile as steel. The steel can reach up to 20% of its unit elongation after reaching the break point. With this feature, steel structures can consume much more earthquake energy. **[8-21]**

2. Aim and Method

In this study, dimensions, floors, floor class, earthquake zone are the same; it is aimed to compare the skeleton building costs when a two-story villa with different carrier systems is constructed with different carrier systems. Designed as an individually designed villa; reinforced concrete, steel and wooden conveyor systems.

The grounds for the construction of two storeyed villas with the same architecture in the project were calculated as ground grade "tight sand" (Ground safety tension = 30 t/m^3). A two-storey villa was designed on this ground. Sta4-Cad program, steel system and wooden carcass account Sap 2000 and Etabs programs were used for this project. The concrete, steel and wooden "skeleton" quantities of the villa project prepared with the help of the data obtained from the calculations are made. These items are prepared for building elements with different construction systems. These building elements are columns, beams and floors. Reinforced concrete foundation is included also.

3. Structurel Design According to Carrier Systems

3.1. Architectural Information

The total floor area consists of rooms with a villa, kitchen, bathroom-wc, entree, balcony and usage area designed as a floor 110 m^2. The ground floor plan and a section of the drawn architectural project are given in Fig. 1. and Fig. 2.

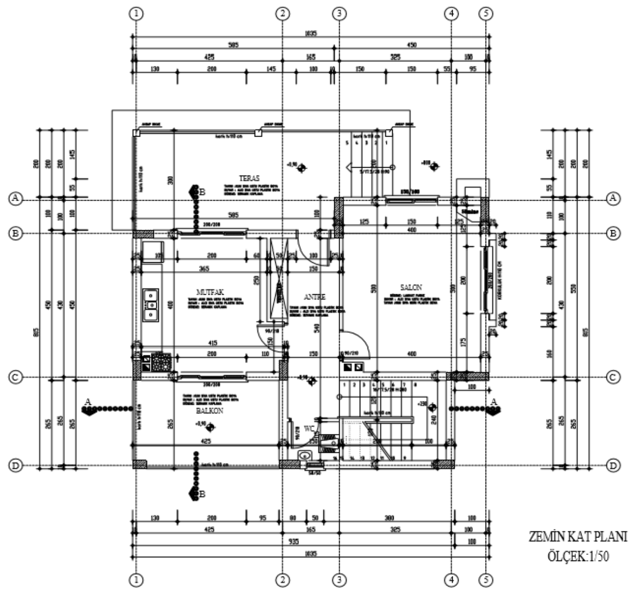


Fig. 1. Architectural Ground Floor Plan

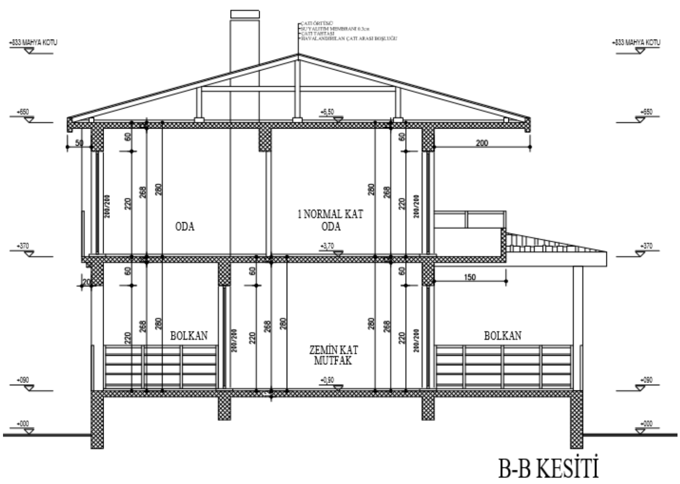


Fig. 2. Architectural Cross Section

3.2. Floor and Basic Properties

The basic and ground properties used in the study are designed to be the same. The basic design was checked by determining that the soil safety stress was 30 t/m^3 in the ground survey report generated on the ground where the structure was to be constructed. Other information required for basic design is given in Table 1.

Table 1. Ground Information for Reinforced Concrete Foundation

Ground safety tension:	30 t/m^3
Local ground class:	Z2
Ground bearing coefficient:	7000 t/m^3

The two-storey reinforced concrete, steel construction and wooden carcass structure that are created are designed to be 30 cm radial base. The basic structure created was analyzed in the Sta4-Cad program and the design was continued. The resulting stress distribution in the analysis is given in Fig. 3. Each of the colors resulting from the analysis constitutes one of the safety stress ranges. Table 2. shows the values of the soil safety stresses corresponding to these colors.

Table 2. Colors - Stress Scale

Colors	**Corresponding Safety Stress Scale (t/m^2)**
Red	≥ 5,47
Orange	4,93-5,47
Yellow	4,39-4,93
Light yellow	3,85-4,39
Green	3,31-3,85
Turquoise	2,77-3,31
Blue	2,77-3,31
Dark blue	2,23-2,77
Navy blue	1,15-2,23
Dark navy blue	≤1,15

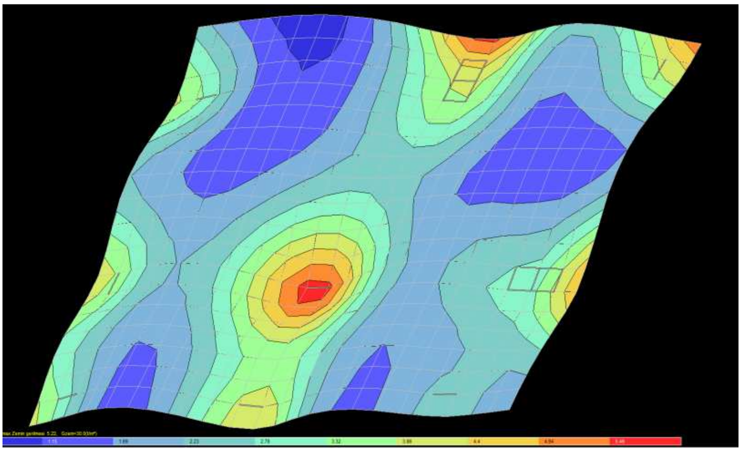


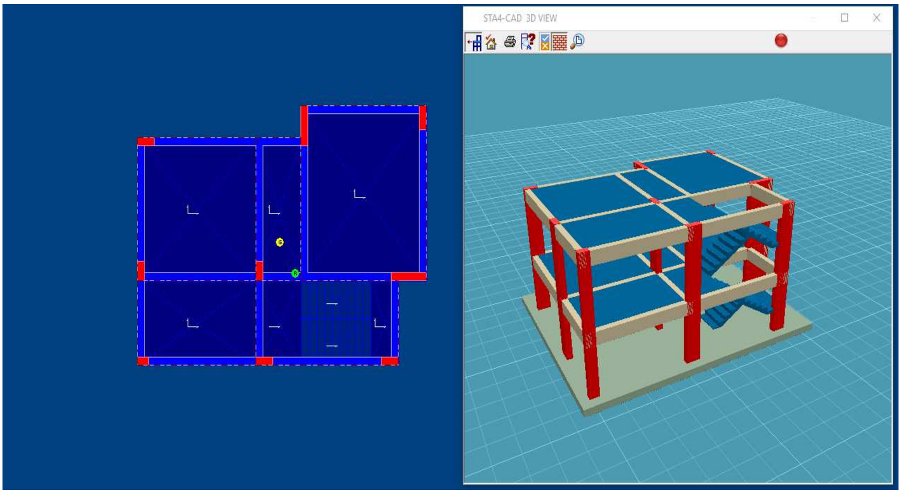
Fig. 3. Soil Stress Distribution

3.3. Reinforced Concrete Construction Properties

The supporting columns were chosen as 25x60 cm - 25x75 cm, pavement thickness 12 cm, beams 25x50 cm. S420 steel is used in construction elements. In the calculations, according to C20 class analysis for concrete, concrete type ductility level of concrete type was chosen as normal. Other information required for the reinforced concrete building model is given in Table 3. Reinforced concrete model created Fig. 4. shows the column application and form plans of reinforced concrete analysis results are shown in Fig. 8. and 9.

Table 3. Necessary Information for Reinforced Concrete Structure Model

Floor heights:	2,80 m
Number of floors:	2
Flooring system:	Plaque laying
Building importance coefficient (I):	1
Earthquake Zone:	Class 2
Effective ground acceleration coefficient (A0):	0,3
Conveyor system behavior coefficient (R):	4
fcd (Concrete pressure resistance to be used in calculation):	13000 kN/m^2 (C25)
fyd (steel yield strength to be used in the calculation):	365000 kN/m^2 (S420)
γconcrete (Concrete unit volume weight):	25 kN/m^3



a b

Fig. 4. Reinforced Concrete Structure Model (a) Reinforced Concrete Floor Plan, b) Reinforced Concrete Structure 3 Dimensional Appearance

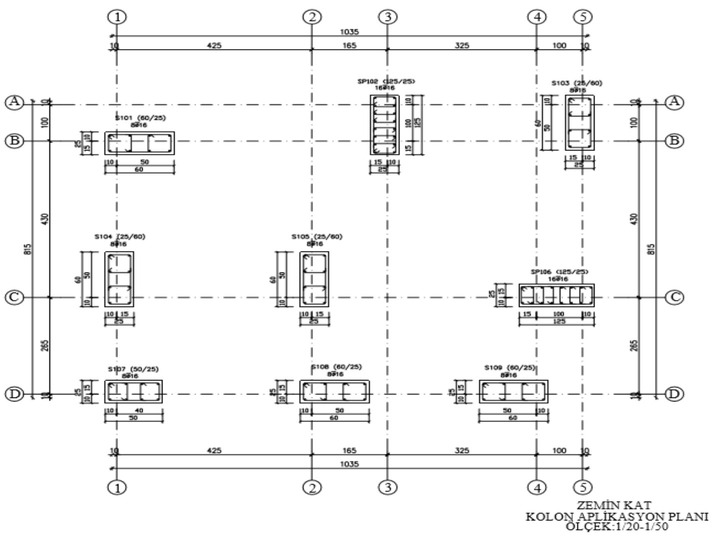


Fig. 5. Reinforced Concrete Column Application Plan

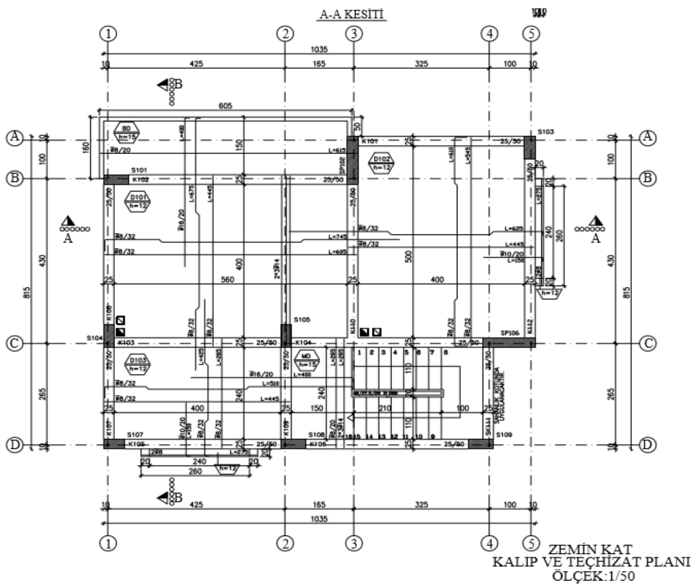


Fig. 6. Ground Floor Reinforced Concrete Pattern Plan

3.4. Steel Structure Properties

The supporting columns HE 240A steel, pavement thickness 10 cm concrete, main and secondary beams HE240A steel were selected. The calculations have selected St 44 steel for steel and because of the wide openings, the weir beams are sized with the main beam size. Other information required for the steel model to be constructed is given in Table 4. The perspective view of the created steel model is given in Fig. 7.

Table 4. Required Information for Steel Structure Model

Floor heights:	2,80 m
Number of floors:	2
Building importance coefficient (I):	1
Earthquake Zone:	Class 2
Effective ground acceleration coefficient (A_0):	0,3

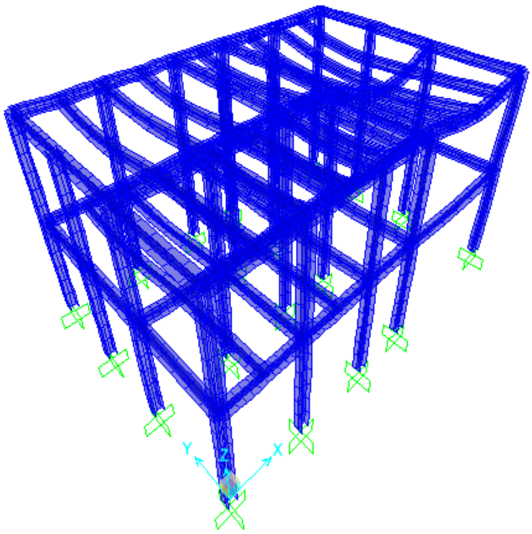


Fig. 7. Perspective view of steel construction

3.5. Timber Construction Properties

In the constructed building model, the dikes were chosen at 10x10cm, the floor thickness was 12cm, the beams and the girders were 10x10 cm cross section. The necessary information for the wooden structure model is given in Table 5. The constructed wooden structure model is shown in Fig. 8. and the column application plan is shown in Fig. 9.

Table 5. Information Required for Wooden Construction Models

Floor heights:	2.80 m
Number of floors:	2
Building importance coefficient (I):	1
Earthquake Zone:	Class 2
Effective ground acceleration coefficient (A_0)	0,3
Ec (Elasticity Module):	1.00E7 kN/m
γconcrete (Concrete unit volume weight):	8 kN/m^3

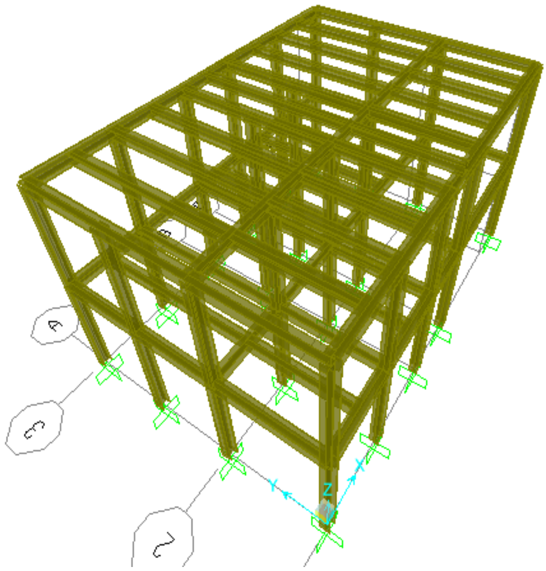


Fig. 8. Perspective View of Wooden Carcass Construction

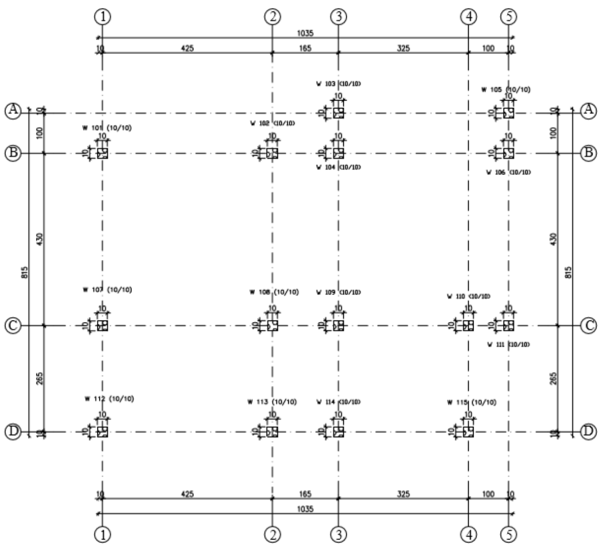


Fig. 9. Column Scheme of Wooden Carcass Construction

4. Quantity and Cost Analysis According to Structural Carrier Systems

4.1. Quantity and Cost Analysis according to Reinforced Concrete Carrier System

The quantity information of the structure constructed with reinforced concrete conveying system, the unit prices of the related works in the structure and the total cost of construction are given in Table 6. (TL shows Turkish Lira)

Table 6. Quantity and Dispersion of Reinforced Concrete System

	Unit	Quantity	Unit Price (TL)	Cost (TL)
Concrete	m^3	72	165.15	11,890.81
Mold	m^2	341.6	38.43	13,127.68
Accessory (Thin)	ton	5,9	2,440.47	14,398.77
Accessory (Thick)	ton	2.3	2,420.14	5,566.32
Total				**44,983.58 TL**

The total cost of the reinforced concrete conveying system is calculated as TL 44,983.58 .

4.2. Quantity and Cost Analysis according to Steel Construction Carrier System

The quantity information of the structure constructed with the steel construction support system, the unit prices of the related works in the structure, and the total cost of the construction are given in Table 7.

Table 7. Metrage and Exploration of Steel Construction Carrying System

	Unit	Quantity	Unit Price (TL)	Cost (TL)
Steel construction				
Concrete	m^3	17.6	165.15	2,906.64
ST44 (HE 240 A)	ton	23.291	2,340	54,500.94
Reinforced concrete foundation				
Concrete	m^3	33	165.15	5,449.95
Accessory (Thick)	ton	1.2	2,420.14	2,904.16
Mold	m^2	35.48	38.43	1,363.49
Total				**67,125.19 TL**

The total cost is calculated as 67,125.19 TL when the radial base thickness is 30 cm and the floor thickness is 8 cm reinforced concrete.

4.3. Quantity and Cost Analysis according to Wooden Carcass Carrier System

The quantity information of the structure constructed with the wooden carcass carrier system, the unit prices of the related works in the structure and the total cost of the construction are given in Table 8.

Table 8. Quantity and Exploration of Wooden Carcass Carrier System

	Unit	Quantity	Casualties (%7)	Unit Price (TL)	Cost (TL)
Wooden	m^3	54.78	3,834	1,375	84,719.25
Foundation					
	Unit	**Quantity**		**Unit Price (TL)**	**Cost (TL)**
Concrete	m^3	33		165.15	5,449.95
Accessory (Thick)	ton	1.2		2 420.14	2,904.16
Mold	m^2	12.6		38.43	484.21
Total					**93,557.59 TL**

When "pine timber" is used as wood carrier material, the total cost is calculated as TL 93,557,59 .

5. Evaluation

As a result of the cost calculations made on the rough construction of the projects prepared with different carrier systems; the production cost of wooden carcass structure is 2 times higher than that of reinforced concrete structure and the cost of steel construction is 1.4 times higher than that of reinforced concrete structure. For the structure based on this study, when the initial investment cost ranking is made in the rough structure, the cost of the wooden carcass carrier system is the highest, the cost of the steel construction carrier system is lower, and the cost of the reinforced concrete carrier system is the carrier system which shows the lowest initial investment cost among them. The cost values obtained for the initial investment as a result of the analysis and calculation of the quantities are presented in Fig. 10.

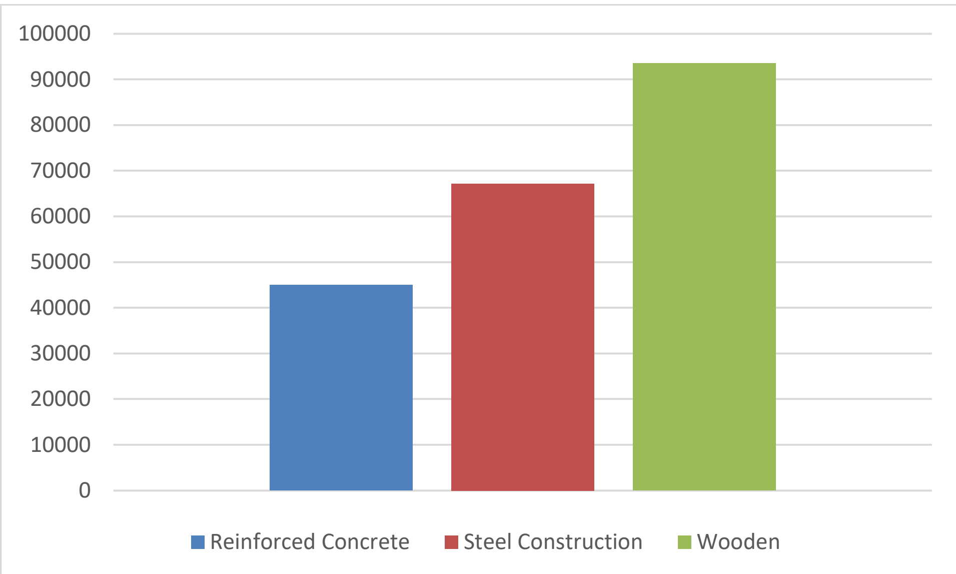


Fig. 10. Carrier System-Initial Investment Cost Graph

In this study, we compared the rough building costs of a two-storey villa with the same architecture using wooden, steel and reinforced concrete conveying systems. In addition to this, a survey has been carried out including the analysis of the service life and maintenance and repair costs of wooden carcass, steel construction and reinforced concrete conveying systems.

When economic life span, maintenance costs, recycling characteristics and anti-depressive behavior are considered;

- If the timber carcass construction is done regularly, it will be prevented from being damaged and worn out and its life will be extended. **[21]** The maintenance cost in the average 5 years is a value between 518 – 1,240 TL (2017 Unit Price-Wooden Material: Pine Timber) for 100 m2. **[22]**

- Although reinforced concrete structures have begun to be built in the near future, it is not possible to compare them with timber structures based on very old buildings. However, it is not thought that the life of reinforced concrete buildings built with today's technology will exceed 100 years. The maintenance-repair cost for reinforced concrete structures other than heavy maintenance is between 81,788 - 92,011 TL (2017 - Actual Price) for 100 m2. **[23]**
- Although the initial investment cost of the steel construction is high, it is more economical than a reinforced concrete structure compared to the total cost during the construction life. For a steel structure requiring maintenance and repair, the maintenance and repair cost of the structural element varies between 183,068-305,114 TL (2017 - Total Cost) for 100 m2, except for heavy maintenance, which varies according to the functionality of the structural element. **[24]**

Construction investment costs within the scope of this study; maintenance and repair costs of wooden carcass, steel construction and reinforced concrete structures; Considering the advantages and disadvantages of different carrier systems, the following expressions can be made: In the design of two-storey residence, the service life of the use of wooden carcass structure is extended. However, the initial investment cost and maintenance and repair costs are high. The initial investment cost of steel construction and maintenance and repair costs are less than the wood carcass structure. The initial investment cost of the reinforced concrete construction and maintenance and repair costs are the cheapest among them.

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