Determination of the Importance of Materials in Structural Cost via Architectural Project Examples

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ABSTRACT

One of the most important inputs in the building of a structure is financial sources. The correct guidance of these sources is distinctive for structural costs. The decision to use the materials determined by the architect is important in determining the cost. It is important that the material usage decisions are given correctly and thus the structural cost analysis is evaluated based on material. Structural cost is an area in which proper solutions can be developed throughout the process starting from the first stage of the design. The effect of material selection on structural cost has been examined in this study using important structures of significant architects as examples. The structures used in the study have been determined as; Farnsworth House, Fisher House, Glass House, Koshino House, Schröder House, Villa Kokkonen, Villa Savoye. Selecting examples of modern architecture in different countries was a significant criteria in this selection process. Because it was observed that local materials were used in every building according to the location. The use of local materials as well as the use of materials such as ferroconcrete or glass is a factor that affects structural cost. First, the unit prices of the current materials selected were calculated for the selected buildings. Afterwards, material selections suited to the structure were selected from among the alternative materials used today and cost was calculated using the unit prices of these new materials. It was determined that material selection has significant effects on structural cost. It was aimed to put forth the importance of materials in cost determination via selection of the sample buildings and the material study carried out. It is hoped that this study will contribute to the field of structure regarding the effects of material selection on the cost.

Keywords: Architecture, cost analysis, materials.

INTRODUCTION

Approximate cost of a structure is calculated by multiplying the total construction area with unit m^2 construction cost in the construction sector in Turkey. Whereas unit m^2 construction cost can be acquired from the approximate construction unit cost list published annually by the Ministry of Environment and Urban Planning.

Two types of cost calculations are made for buildings: Coarse and fine. That is why, there are two options while calculating the cost for constructions. For architecture, cost can be

determined as calculating the budget that is needed to construct the building. In other words, it is the financial resource needed to obtain a finished building from an architectural project. The first objective in construction is to ensure that maximum benefit is provided at minimum cost (Emlakwebtv, 2014).

Starting cost planning as early as possible enables the construction of the building at lower costs at the final stage. It is desired to complete the building cost during the initial decision stage (Bostancıoğlu, 2006). Knowing whether the capital allocated for construction will be sufficient or not as well as knowing the amount of resources that should be allocated will eliminate future problems. The first investment decision provides positive results for schematic design, making correct decisions regarding the development and application of the design as well as building cost. The pre-design stage is the period with the highest chance of decreasing building cost (Bostancıoğlu, 1999). If the cost is known during the first stage of the design, relevant choices and design solutions can be developed. It should not be forgotten that the first investment decision and the results obtained from the pre-project are not final with regards to cost. The final cost of the building is only clarified after the construction phase. In this regard, cost data should be stored starting from the design decision of the building to the completion of construction and this data should be transformed into information to be used later on.

There are many factors that affect building cost. The most important are the location of the building, the floor height and number of floors, whether the building has a basement floor or not, exterior wall type and construction technologies (Bostancıoğlu, 2006). In addition, the types of material that will be used in the construction also have significant effects on cost. Factors such as material selection, floor height are decided based on the function of the building. In other words, the function of the building is another factor that affects the cost. In addition factors such as the peripheral length of the building, the year of construction, plan type, climate conditions also affect the cost (Bostancıoğlu, 2006). Factors such as the location over a seismic belt, carrier system solutions, ground investigation, application and inspection of the project are cost increasing factors (Özkan, Muratoğlu, 2005). Cost is not important only during the construction phase of the building but also during the usage phase after construction. The maintenance, repair costs of the selected materials as well as the operational costs of the building should also be considered. For example; selecting materials such as wood, steel or concrete bring forth different results in terms of cost. A concrete material mostly requires plastering whereas wooden materials will require protection from moisture (Bostancıoğlu, 2006).

The success of construction projects in every period depend on the completion of the project in a timely manner at the planned cost. Even though factors such as building type, floor height, number of floors, climate conditions, exterior wall type are important; it is emphasized in this study that the material selection should be made during the pre-design period since it affects the building cost significantly. This study has tried to put forth the importance of making design with regard to the material at hand and the selection of the most suitable one from amongst the alternatives in order to decrease costs. This study has examined the importance of cost in building construction and has focused on the factors that affect cost with regard to material selection. It is hoped that this study will contribute

to future studies.

MATERIALS AND METHODS

Structures have been determined randomly from among structures that are important for world architecture. Care has been given to ensure that each selected architectural project is from different countries and are designed by different architects. The fact that different materials are used in the selected structures as well as the fact that they are pioneering structures of modern architecture and/or the works of pioneer architects have been effective in drawing the border for the selection process.

The total cost of the selected material was calculated by multiplying the unit costs according to the material item number issued by the Ministry of Environment and Urban Planning with the unit of the material during approximate cost calculation stage. The length in meters of the surfaces for which material change has been decided is calculated using the dwg formatted files. The drawings of the determined architectural projects were transferred to dwg format simultaneously which were then transformed into scaled architectural projects in the digital environment.

The cost of the current materials used in the study was calculated using the current unit prices. The unit m^2 construction cost of the new materials suggested for use in the buildings have been acquired from the approximate building construction list issued by the Ministry of Environment and Urban Planning. The unit costs of materials without corresponding item numbers have been determined as a result of a market study. Afterwards, the two numerical data were compared.

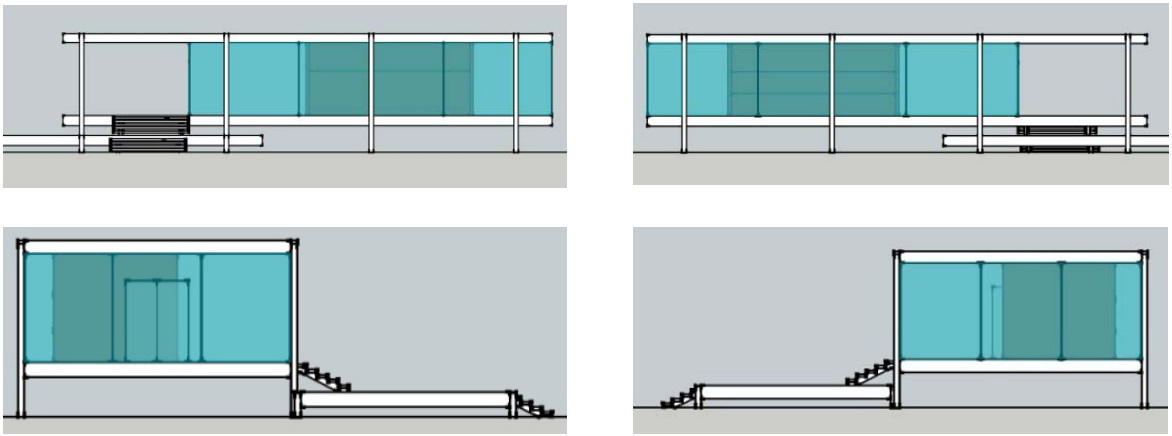
PROPERTIES OF THE SELECTED ARCHITECTURAL PROJECTS

Seven architectural projects have been determined within the scope of this project which are Farnsworth House, Fisher House, Glass House, Koshino House, Schröder House, Villa Kokkonen, Villa Savoye. These structures have been observed to be the representatives of modern architecture in different countries. The fact that these structures are in different countries has brought about with it variations in the material used. This in turn causes material cost differences as well as the difference in the effect of local material use on the total cost.

One of the selected structures, the Farnsworth House was designed by Ludwig Mies van der Rohe between 1945-1950. The building is located in Illinois/USA. With a steel skeleton system structure, it is built over a total area of 318 m² which can be broken down as 112 m^2 open terrace, 53 m^2 semi-open terrace and 147 m^2 closed area (Islakoğlu, 2005). The Farnsworth weekend house made up of a single rectangular mass is positioned inside a flat and wide environment surrounded with large trees. There is no other structure in its vicinity and the house looks south towards the Fox River (Islakoğlu, 2005). There is a secondary and completely wooden rectangular mass inside the 147 m² of glass rectangle in which there are also wet places. There is not much variety on the façades with regard to

color and material. Steel and glass are used as material. All stell surfaces and furnishing planes are white. Transparent materials have been preferred for the remaining surfaces without any color. Nature and greenery can be seen to reflect from the glass surfaces (Islakoğlu, 2005).

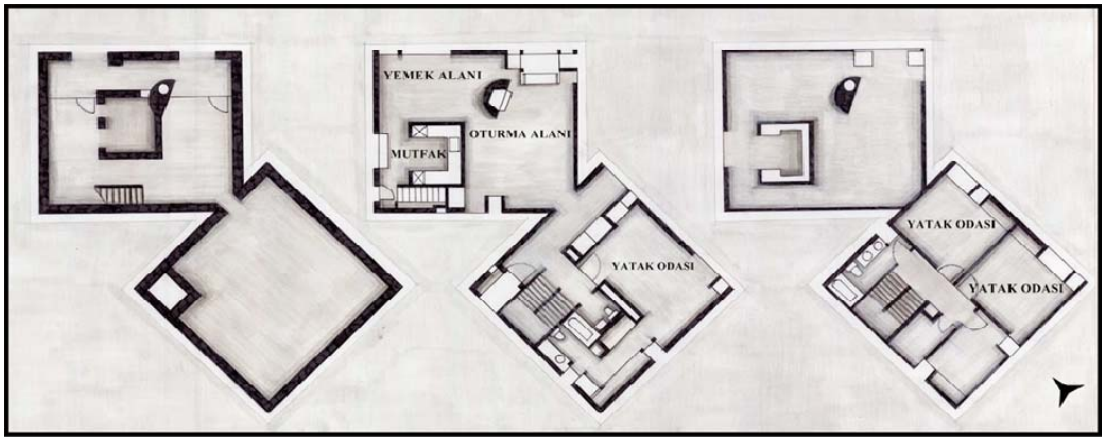
Photo 1. Farnsworth house (Architecture.lego.com, 2014).



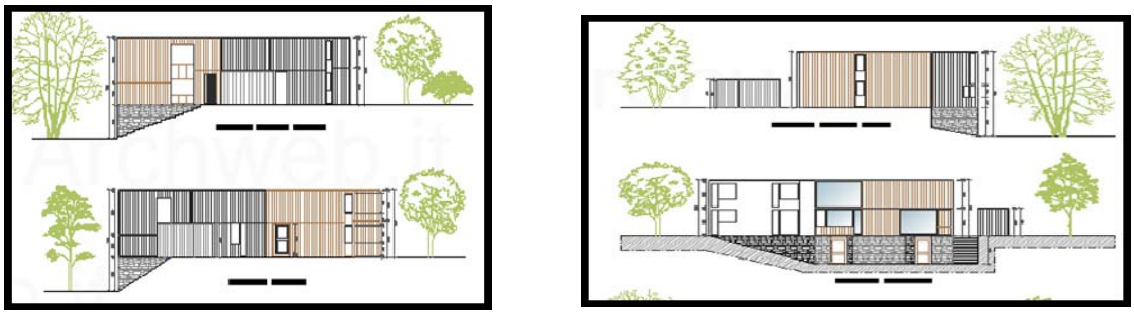
Drawing 1. Application views arranged in sketchup for the farnsworth house.

Fisher House was designed by Louis Khan during 1964-1967 and built at USA Philadelphia, Pennsylvania state (Greatbuildings, 2014). Louis Kahn has used a simple geometry that allows an intermediate passage between two equivalent cubes by connecting them at a single and narrow point. With this plan, the structure is a reference point to develop ideas of modernism by allowing the main design principles to be read clearly (Wikipedia, 2014b). The structure has been built on an inclined land the foundation of which was made by stone setting. Cedar veneer was used on the top section of the structure as local material. Whereas the window profiles are made of wood (Booher, 2009). The reason for selecting local materials is to decrease the cost of the building. The stone and wooden materials used on the exterior façade of the structure have also been used inside (Wikipedia, 2014b).

Photo 2. Fisher house (Philly.curbed, 2014).



Drawing 2. Fisher house (Andrewwbest83, 2014).

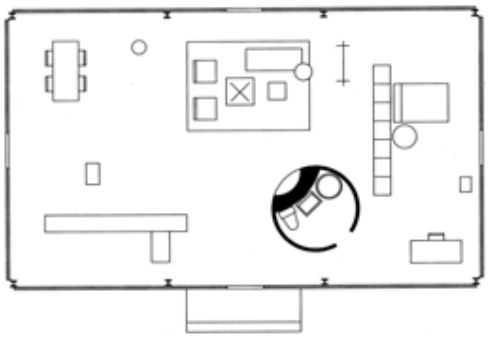


Drawing 3. Fisher house (Philly.curbed, 2014).

Glass House has been designed by Philip Johnson in 1949. The structure is located at Connecticut/USA (Wikipedia.org, 2014a). It has a steel skeleton structure and is made up of a 102 m^2 single rectangular volume. The structure is a glass mass made up of 8 units of I profile steel columns and is supported by a framework (Islakoğlu, 2005). IT is located amidst tall and wide trees on a high but flat terrain overlooking the scenery (Emlakansiklopedisi.com, 2014). The furniture that make up the living, studying, resting, dining and kitchen units are distributed inside the glass mass. The section of the structure made up of sink, toilet bowl and shower make up about a 5m^2 closed space. When the plan scheme is examined, it is observed that a fireplace has been placed to the section of the

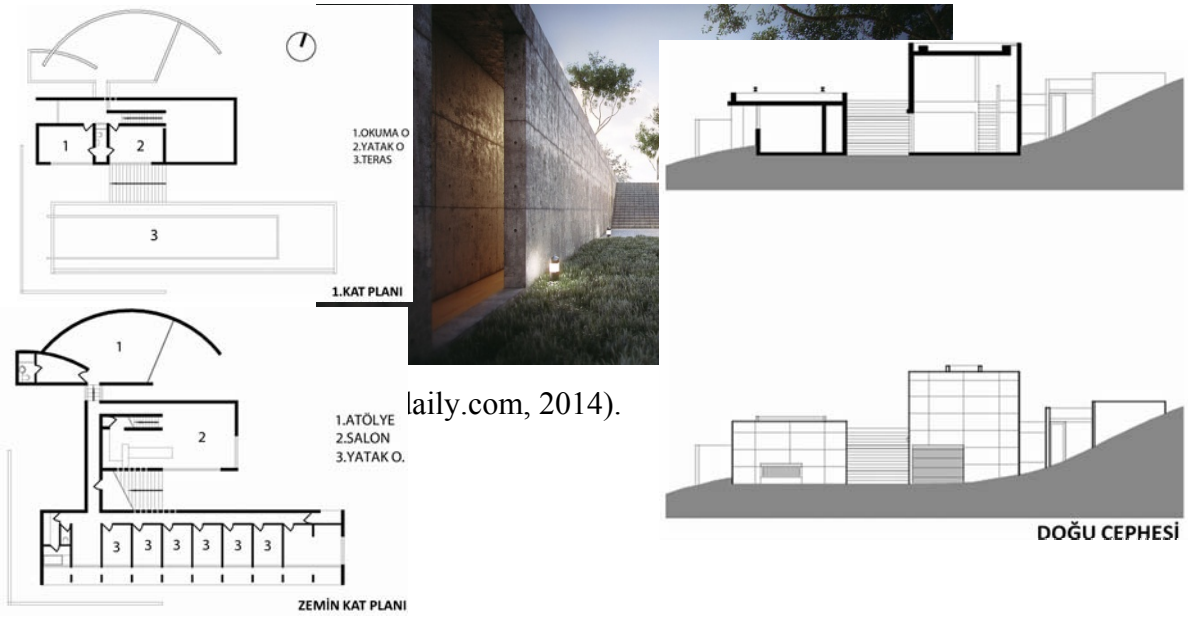
cylindrical bulk with brickwork to the right of the entrance. When the surfaces of the structure are examined, it is observed that dark gray steel material is used apart from the glass surfaces and that red bricks have been used at the sub-basement level (Islakoğlu, 2005).

Photo 3. Glass house (Wikipedia.org, 2014a).



Drawing 4. Glass House Plan (Wikipedia.org, 2014a).

Koshino House has been designed by Tado Ando between 1979-1980. The structure with a ground area of 242m² is located on an inclined and green space at the Kobe city of Japan (Wikiarquitectura.com, 2014a). The residence has been designed for designer Hiroko who is a friend of the architect and is made up of a semi-circle plan mass designed as a workshop as well as the solid boxes that are located at the two sides of the courtyard that make up the living and sleeping areas (Emlakansiklopedisi.com, 2014). The material selected by the designer for Koshino House is exposed concrete. This material has been used for the whole building. Even though no decorative element has been used in the building, transparent surfaces have contributed as decorations by combining with the light and shade works of nature (Wikiarquitectura.com, 2014a).

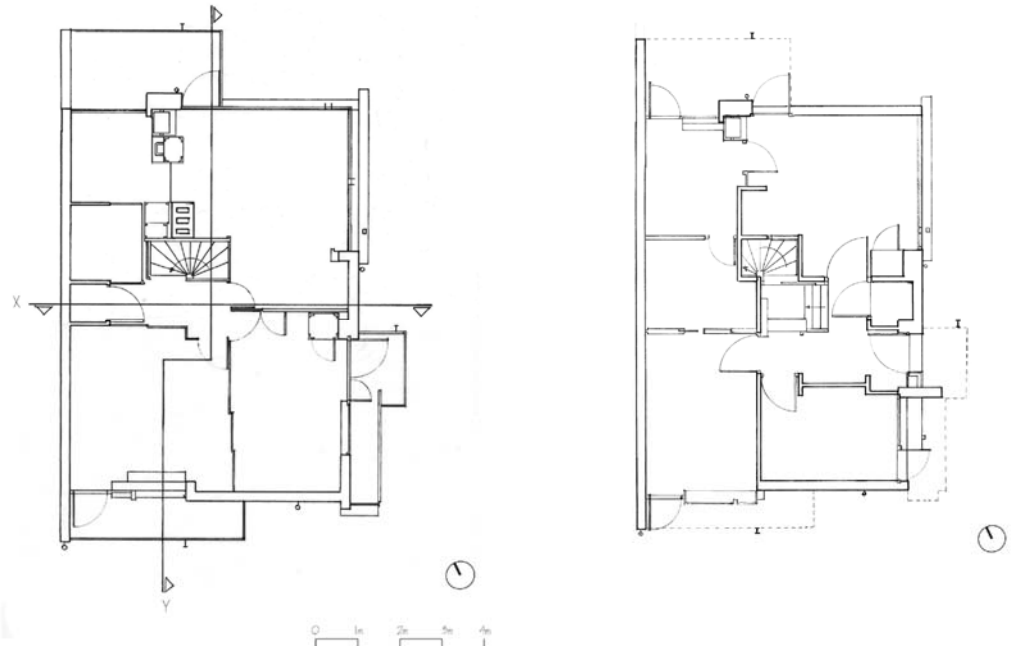


laily.com, 2014).

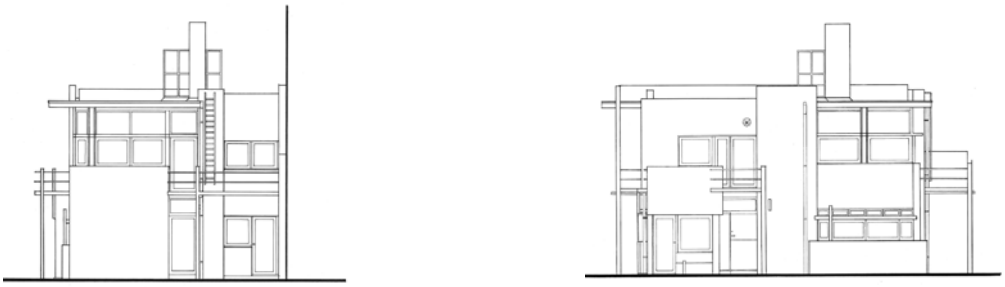
Drawing 5. Koshino house plans and views (Archdaily.com, 2014).

Schröder House has been designed by Gerrit Rietveld in 1924. The structure is located in the Netherlands. There is no room heap inside the structure with a concrete skeleton system structure and there are changeable open areas. The living area upstairs has been designed with rotating and sliding units and includes three bedrooms, a bathroom and living room areas when divided. The façades are made up of a connection of lines and places that are consciously divided. The surfaces that make up the façade have been placed as if they are parts jutting out of a cube (Mekanbellek.blogspot.com, 2014). Plaster and paint have been preferred for the solid surfaces of the exterior façades. Whereas transparent surfaces are made up of glass material divided by aluminum profiles in a modular manner.

Photo 5. Schröder house (Wikipedia.org, 2014c).



Drawing 6. Schröder house plan (Mekanbellek.blogspot.com, 2014).

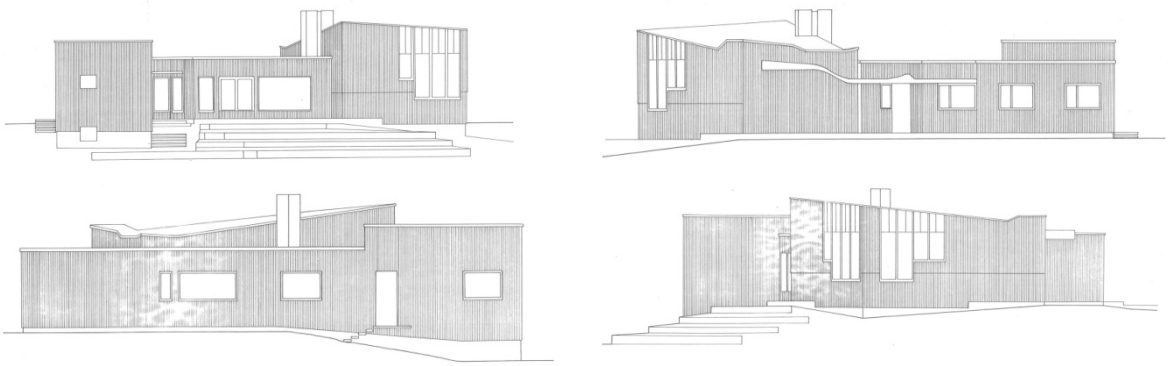


Drawing 7. Schröder house views (3dwarehouse.sketchup.com, 2014).

Villa Kokkonen has been designed by Alvaro Aalto in 1937. The structure is located in Finland (Bila, 2014). It has an asymmetrical design with two trapezoidal and one rectangular form. It is located on a high, inclined area that dominates the surrounding scenery. The asymmetric plan of the structure can also been at the façade and the plan. Fin wood has been preferred as coating material for the façade of the structure (Wiki/File, 2014).

Photo 6. Villa Kokkonen commons. (Wikimedia.org, 2014).

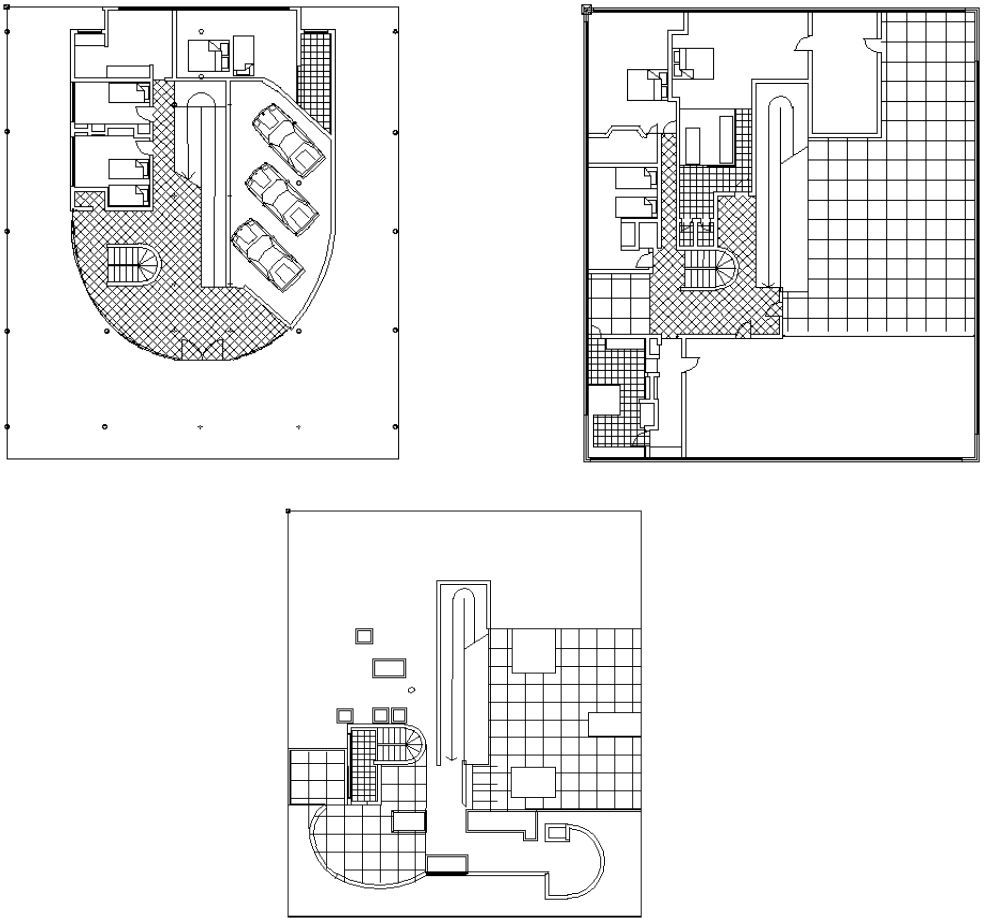
Drawing 8. Villa Kokkonen plan (Atlasofinteriors.polimi-cooperation.org, 2014b).



Drawing 9. Kokkonen house views (Atlasofinteriors.polimi-cooperation.org, 2014a).

Villa Savoye has been designed by Le Corbusier during 1926-1931 and is located at Poissy/FRANCE (Ceylan, 2014).Villa Savoye has a U shaped floor plan but a rectangular first floor plan and thus is perceived as a cube form on the whole (Restoraturk.com, 2014).The plan of the structure covers an area of 347 m^2 (Wikiarquitectura.com, 2014b).Corbusier emphasizes the form of the structure by using horizontal bands on the windows (Restoraturk.com, 2014).White paint has been used for the exterior façade whereas wood and ceramic (30x30-100x100) has been preferred for the interior.

Photo 7. Villa savoye (Galinsky.com, 2014).



Drawing 10. Villa savoye plans (Wikiarquitectura.com, 2014b).

COST CALCULATION FOR ARCHITECTURAL PROJECTS WITH CURRENT UNIT COSTS

The areas of the selected sections were determined after which the current cost of the structures was calculated using the current unit prices of the materials used. Farnsworth House was designed by L.Mies Van Der Rohe during 1945-1950 (Islakoğlu, 2005). It was determined that heat insulated tempered glass was used on the façade. The façade cost was decided to be calculated because of the special material used. The area of the façade was determined as 142.4 m². The current unit price of heat insulated tempered glass was determined as 60 TL as a result of market analysis. The façade costs of the structure in terms of the current unit price of the material used was calculated as 8554 TL.

Fisher House was designed by Louis I. Khan. It was determined that wood, glass and metal has been used on the façade (Wikipedia, 2014b).The façade cost was decided to be calculated because of the special material used. When the areas for the materials used were determined, it was seen that wood area was 298.990 m², glass area was 57.350 m². The current wood unit price was determined as 40 TL and the current glass unit price was determined as 74 TL as a result of market analysis. Wood cost for the structure based on current unit prices was determined as 12.052 TL, glass cost as 4.253 TL. The total façade cost was determined as 16.305 TL.

Glass House was designed by Philip Johnson in 1949 (Wikipedia.org, 2014a).Heat insulated tempered glass has been used for the façade of the structure. The façade cost was decided to be calculated because of the special material used. The area of the materials used for the façade was determined as 117.12 m². The current unit price of heat insulated tempered glass was determined as 60 TL as a result of market analysis. The façade costs of the structure in terms of the current unit price of the material used was calculated as 7027 TL.

Koshino House was designed by Tadao Ando during 1979-1980 (Wikiarquitectura.com, 2014a). Exposed concrete is used on the outer walls of the building. The current façade cost was decided to be calculated because of the special material used. When the area of the façade is calculated, it was observed that 59.38281 m³ exposed concrete was used. The current unit price of exposed concrete was determined as 115 TL as a result of market analysis. The façade costs of the structure in terms of the current unit price of the material used was calculated as 6864 TL.

Schröder House was designed in 1924 by Gerrit Rietveld (Mekanbellek.blogspot.com, 2014).The current façade cost was decided to be calculated because of the particulate design of the façades. There is a total of 129.45 m² area covered with coarse and fine plaster and painted with water based paint which accounts for a paint consumption of about 33,6 LT in total. It was determined as a result of the market study carried out that the unit price of the plaster used for the façade was 10.50 TL and that of the paint was 20.45 TL. When the unit price of the material used is considered, the total plaster cost was calculated as 1359 TL, paint plus labor total cost was 1842 TL adding up to a total cost of 3201 TL.

Villa Kokkonen was designed in 1969 by Alvaro Aalto (Bila, 2014).What makes the structure unique is that Finnish wood has been used on the façades. The current façade cost was decided to be calculated because of the particulate design of the façades. When the façade area was considered, a total of 200.23 m² Finnish wood was calculated as the total consumed amount. It was determined as a result of the market study carried out that the unit price of the Finnish wood today is 200 TL. When the total cost of the material used for the façade of the structure was calculated with the current unit price of the material, a total cost of 40530 TL was determined.

Villa Savoye was designed during 1926-1931 by Le Courbusier (Ceylan, 2014). In addition to the unique façade of the structure, the interior space is also unique. Hence, it was decided to calculate the cost for interior flooring for this structure. When the flooring area of the structure is calculated, it was determined that 229.89 m² 30x30 ceramics were used, 150.11 m² 100x100 ceramics were used in total. It was determined as a result of the market study carried out that that unit price of 30x30 ceramics is 42 TL and that of 100x100 ceramics is 77 TL. When the current unit prices of the materials are considered, the total cost of 30x30 ceramics was determined as 9.793 TL, that of 100x100 ceramics was determined as 11.558 TL for a total flooring cost of 21.351 TL.

COST CALCULATION FOR THE ARCHITECTURAL PROJECTS USING THE SUGGESTED NEW MATERIAL UNIT PRICES

The areas of the predetermined significant structures were determined, after which the current costs were calculated using the suggested new materials.

The change in the cost when aluminum composite panels are used for the façade of the Farnsworth House instead of the unique material used has been calculated. In order to do this, the area of the façade was calculated to be 142.4 m². It was determined as a result of the market study carried out that the current unit price of aluminum composite material is 120 TL. In addition, the current price of the windows opened on the façades with new dimensions was determined as 60 TL as a result of the market study carried out. In the study carried out, 111.35 m² composite panel area and 31.05 m² glass area were multiplied by the unit prices and the total cost was determined as 15225 TL using the new materials.

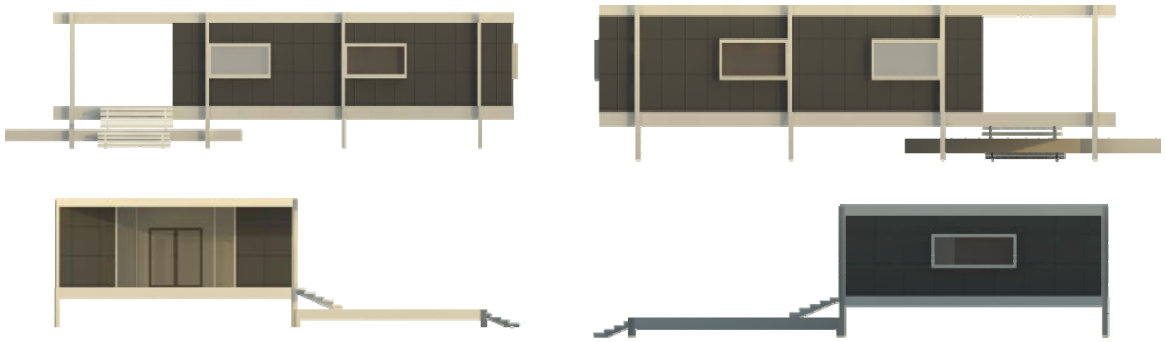


Figure 11. Sketchup application view of the suggested material for the farnsworth house.

The change in cost was calculated for the Fisher House when composite stone is used instead of the unique material of the original structure. In order to do this, the total façade area of the structure was determined as 356.34 m². It was determined as a result of the market study that the current unit price of the composite stone material is 105.64 TL. In addition, the current price of the windows opened on the façades with new dimensions was determined as 74,16 TL as a result of the market study carried out. In the study carried out, 298.990 m² composite stone area and 57.350 m² glass area were multiplied by the unit prices and the total cost was determined as 35836 TL using the new materials.

The change in cost was calculated for the Glass House when aluminum composite panel is used instead of the unique material of the original structure. In order to do this, the total façade area of the structure was determined as 128.15 m². It was determined as a result of the market study that the current unit price of the composite stone material is 120 TL. In addition, the current price of the windows opened on the façades with new dimensions was determined as 60 TL as a result of the market study carried out. In the study carried out, 156.96 m² composite panel area and 56.01 m² glass area were multiplied by the unit prices and the total cost was determined as 22195 TL using the new materials.

Figure 12. Sketchup application view of the suggested material for the glass house.

The change in cost was calculated for the Koshino House when stone coating is used instead of the unique material of the original structure. In order to do this, the total façade area of the structure was determined as 299.68 m². It was determined as a result of the market study that the current unit price of the stone material is 21.80 TL. In the study carried out, 299.68 m² stone coating area was multiplied by the unit price and the total cost was determined as 6.533 TL using the new materials.

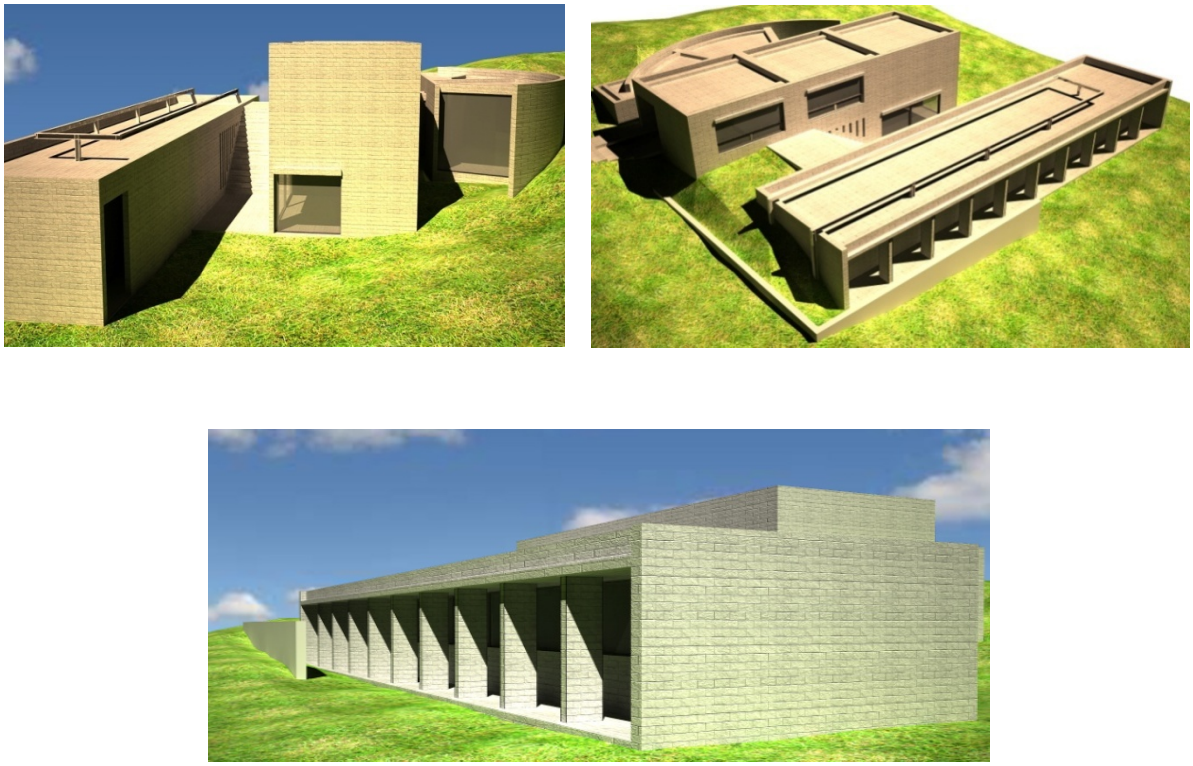


Figure 13. Sketchup application view of the suggested material for the Koshino house.

The change in cost was calculated for the Schröder House when flex concrete is used instead of the unique material of the original structure. In order to do this, the total façade area of the structure was determined as 129.45 m². It was determined as a result of the market study that the current unit price of the flex concrete material is 110 TL. In the study carried out, 129.45 m² flex concrete coating area was multiplied by the unit prices and the total cost was determined as 14239 TL using the new material.

The change in cost was calculated for the Villa Kokonen when aluminum composite panel is used instead of the unique material of the original structure. In order to do this, the total façade area of the structure was determined as 205.23 m². It was determined as a result of the market study that the current unit price of the aluminum composite material is 120 TL. In the study carried out, 205.23 m² aluminum composite panel area was multiplied by the unit prices and the total cost was determined as 25653 TL using the new material.

The change in cost was calculated for the Villa Savoye when ceramics is used instead of the unique material of the original structure. In order to do this, the total flooring area of the structure was determined as 515.27 m². It was determined as a result of the market study that the current unit price of the ceramics material is 95 TL. In the study carried out, 380 m² ceramics area was multiplied by the unit prices and the total cost was determined as 36.099 TL using the new material.

When the total cost of the aforementioned old and new materials is examined; cost increase was not observed except for one of the structures. This has been tabulated below (Table 1.).

Table 1. Old and New Material Cost Comparison for the Structures

STRUCTURE NAME	YEAR	APPLIED AREA	UNIQUE MATERIAL USED	CURRENT COST OF THE UNIQUE MATERIAL USED	SELECTED MATERIAL	CURRENT TOTAL COST BASED ON NEW MATERIAL	COST
FARNSWORTH HOUSE	1945	FAÇADE	GLASS	8554 TL	GLASS-COMPOSITE	15225 TL	**INCREASE**
VİLLA KOKKONEN	1969	CEPHE	FINNISH WOOD	40530TL	COMPOSITE	25653TL	**DECREASE**
GLASS HOUSE	1949	CEPHE	GLASS+STONE COATING	7267TL	GLASS-COMPOSITE	22195TL	**INCREASE**
SCHRÖDER HOUSE	1924	CEPHE	PLASTER PLASTER+PAINT	3201TL	FLEX-CONCRETE COATING	14239TL	**INCREASE**
VİLLA SAVOYE	1926	DÖŞEME	CERAMICS	21351TL	CERAMICS	36099TL	**INCREASE**
FİSHER HOUSE	1964	CEPHE	WOOD	16305TL	GLASS-COMPOSITE	35836TL	**INCREASE**
KOSHİNO HOUSE	1980	CEPHE	EXPOSED CONCRETE	6759TL	STONE EXPOSED CONCRETE+STONE COATING	13293TL	**INCREASE**

CONCLUSIONS

Construction material is defined as the element that shapes a structure, comprises its whole and enables the design to be actualized in real life. The material that surrounds the structure is directly related with techniques and economy. It affects the economy of the structure directly since it is one of the most important elements that make up the structure cost. Choosing the right material is important in order to ensure that the structure puts forth the maximum performance at minimum cost.

Today, there is a wide range of alternatives for the materials that can be used in construction. The architecture is responsible from selecting the best material among all these alternatives. The selected material should be authentic, should comply with the function and construction method of the structure as well as be in accordance with the physical environmental data.

Sample projects were examined in this study and material costs for the selected sections were calculated by taking into account the already existing materials as well as the suggested alternative materials via the unit cost method. As a result of these calculations, the ratio of the change in cost as a result of this change in material was calculated. The element that generally affected the selection of the current materials in the examined structures was emphasizing design decisions. Material characteristic was given importance in order to ensure this. However, the desired effect was provided via low cost materials. On the contrary, it was observed that the new suggestions did not fit the current characteristic of the structure and that they disrupted the integrity as a whole. Choosing the most expensive material during design stage does not mean that the architect has made the right decision. It is possible to say that these architects have considered material cost in addition to the effect of the material during the design stages of these structures which are among the most important examples of modern architecture. It is observed that material selection supports this simplicity in addition to the simplicity of modern architecture. It has been observed that this is for decreasing the material costs of the structure.

It has been determined as a result of this study that material selection and cost has direct effects on the total structure cost. It is hoped that this study will contribute to the field of construction regarding the importance of the effect of material selection.

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