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Efficiency and Cost Analysis of Natural Masonry Construction Manufacturing

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Abstract

In this study, a sample project prepared for the construction of straw bale brick masonry; work time, cost, material and heat efficiency evaluations were made to compare straw home and brick masonry house construction. As a result of the literature search carried out towards this aim, the information obtained and the research findings were evaluated together. As a result, hay bales and land consolidation house construction, the calculations and evaluations made on the sample project show that the straw house construction is completed in a shorter time, the cost is lower and the heat efficiency is higher. Calculations made on the straw bale sample house project reveal that the straw house is more economical and energy-saving, so it can be preferred to the house.

Keywords: Straw Bale, Efficiency and Analysis, Natural Masonry Construction,Sustainability

1. Introduction

In the century we are in, the environmental phenomenon is the first in the events that are most prevalent in the international public opinion. Issues like hunger, nuclear catastrophes, uncontrolled growth of cities, the gradual disappearance of rainforests, acid rain, climate change, ozone layer perforation, and ongoing regional conflicts pose a common threat to all humanity.

In the countryside, structures can be designed and constructed by taking advantage of developing technology and natural ecological materials, which can be obtained from nature, by evaluating as unchanged climate and topography data. In recent years, "straw structures" have been used frequently in the world, especially in the traditional settlements where cereal production has been done. The Karaman region has the characteristics that can be an

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alternative to the reinforced concrete carcass construction system and perforated brick for the rural. With the introduction and promotion of straw-built buildings, the ecological and economic structures used by local materials can be brought into the physical environment. However, the houses to be built with straw bales should be constructed without harming traditional architecture and values, taking into account the preferences and enjoyment of the users. It is aimed to compare the efficiency and cost calculations of the houses made of straw bales over the crushed house sample project. In this study, the productivity and cost of straw house in the climate and environment conditions of Turkey, which is selected as the pilot region due to abundance of crop straw straws, low transportation cost and weather conditions suitable for straw bale house construction, are investigated. In the study, the comparison of straw house and masonry house production in terms of cost and efficiency in the environmental conditions of Karaman province was compared. Based on the prepared project, labor, material, time to finish, cost account and heat values, productivity cost account were made separately for the straw house and the paper house and the resulting values were compared and analyzed.

2. Implementation Process Of Straw Bale In Construction Sector And The Usage Areas Of Straw

In order to increase the yield and quality of the straw, it is necessary to determine the cutting time. Cutting should not be done until the seeds are fully formed. Straw, which is very sensitive to the weather, can be cut down in arid weather, food value can fall, if it rots and molds in humid weather, it may be animals to become ill. For the drying of sawn grass, it is provided that the grass is laid neatly in good weather and the inside of it evaporates to a minimum and it must be dried until it reaches twenty percent of the nets of leaves and shreds so that they can be easily collected and assembled with the machines. This condition is necessary for easy baling. In addition to being used as bait, It is evaluated as raw material in animal breeding, culture mushroom cultivation. Apart from all these areas, straw was used as paper in paper sector, as building materials in the construction sector, and as baskets, hats, wicker, seats, slippers, roof coverings during periods when the villagers were in economic difficulties. The use of straw as a building material in the construction sector, which is an important part of the research topic in many different sectors, is detailed. Straw bales containing cellulose with high-grade insulation properties reduce the change in the temperature of the interior air by preventing the incoming air from entering in such a structure.

Design of Straw bales; Making straw bales varies in 3 types; load bearing bale, non-load bearing bale, load bearing mixed system. Load Bearing Bale; The use of straw bales as building materials begins with the placement of straw in the place of the masonry stone. It is estimated that the earliest but not the oldest straw bale building is in Nebraska. In order for a balancer to be a good carrier, it is necessary to connect the rope to the steel rope by controlling the required and desired stability for the rope to move easily. Nevertheless, it is preferred that the roof is made of light materials, even if the balun is designed for Cargo Non-Load Bearing Bale; The burden of carrying the roof is the wooden carcass frame that falls and transfers this load to the ground. The well-designed and constructed load bearing (carcass) system is available for multi-storey straw bale construction. The advantages of this system are the availability of less dense balls with three or two connections compared to the bulk fill system. Load Bearing Mixed System; Straw bales are a mixed system of tay carriages as a third system which is different from the design of houses as a carrier and a carrier. This system, which is called load bearing mixed system, can be examined in three different areas as structure, coherence and non-permanent.

Implementation Steps of Straw Bale in Construction Sector; Plastered straw bale house is one of the ways of making home with low-cost and eco-friendly. This section covers materials and methods that can be used to build a straw-bale house that can survive for a hundred years and is energy-efficient and cheap to maintain.

- Preparation of the project and its area
- Preparation of foundation and upholstery
- Establishing the skeleton (carcass structure)
- Roof
- Construction of straw bale walls
- Surface coating (plastering of walls)
- Installation of windows and doors

- Exterior painting

3. Benefits Of Straw Houses In Terms Of Construction Sector And The Points To Be Considered On The Straw House Construction

3.1. Benefits of Straw Houses in Terms of Construction Sector

From the perspective of the construction sector, the benefits of straw houses are five in terms of insulation, sustainability, earthquake, environmental and economical aspects.

Benefits of straw houses for insulation; The straw has heat retention feature. The reinforced exterior of the straw bales reduces the heat losses caused by the structure of the building by 85% on average

Benefits of straw houses in terms of sustainability; Sustainability, in short, is defined as maintaining the ability to be continuous while ensuring the continuity of diversity and productivity. Our natural wealth is decreasing due to the constant increase of the world population and constant change of consumption habits. For this reason, in order not to waste our resources, we have to engage in the concept of sustainability and we need to evaluate and use waste materials that are suitable for recycling. In this way we have not wasted our natural wealth, we have been using it efficiently, and we have provided our resources to the future generations positively. Thanks to the materials obtained from the recycling, energy savings can be provided, which can be a great contribution to the economy, in addition to protecting natural resources. The problem is that the old iron bars are not discarded during the demolition but collected for recycling and sent to the industry to be sent back to the market as demolition, causing many processes to be carried out without having to do, for example without the need for certain operations in mines. Such operations may include reproducible pine, nylon, paper, coke boxes, tin, etc. This is because the problems arising from the storage of waste will lead to a reduction in the volume size, and if we consider the decrease in the number of transportation of garbage trucks, the problems will be solved with a great deal of energy, little storage space. Over the years, it seems to have made important contributions to the recycling state budgets. Because of the minimum level of destruction that can be given to our natural wealth, it gives us the chance to benefit wisely and accurately from natural resources and a world that can be lived to our future generations. Unlike timber used for timber scaffolds, straw can be grown in a sustainable production system in less than 1 year. Apart from a well-equipped definition, the term "sustainable" refers to a system that is built forever. If large crop straws are cleared from a field every year, the use of soil healing, co-cultivation, or alternation becomes necessary to sustain soil fertility and fertility.

Benefits of straw houses in terms of earthquake; Houses made of masonry are costly, and it contains earthquake risk. The straw bands should be flexible and the size measurements should be appropriate to the wood structure that we construct the carcass and the values that will make construction easier. Whilst reinforced concrete structures feel earthquake vibrations everywhere, bale structures extinguish earthquake vibration.

Environmental benefits of straw bale houses; Reduction of straw burning reduces carbon monoxide and nitrous oxide production. Removal of rice straw from wet areas for straw bale construction significantly reduces methane emissions from microbial dispersion. It is not necessary to remove all the straw from the center because it gives erosion control where the straw is. Straw residues that can be picked up can be baled and used during construction. Because the effective isolation of straw balls does not require active heating, the amount of CO2 emitted to the environment is also significantly reduced.

Benefits of straw houses in terms of economy; Straw bale walls are gaining importance in environments where energy is expensive compared to known more expensive construction systems. The building must be well insulated in order to benefit from the high efficiency walls of the bale houses at maximum yield. The ceiling or roof should have good ventilation, well insulated, insulated windows and doors. High volumes of insulation and bale walls make it possible to keep the windows open most of the year and allow fresh air to enter.

3.2. The Points to be Considered on Construction of Straw House

Cost, size, against decay, sustainability, resistance to fire and harmful insects, earthquake, heat, humidity, time advantages and such issues are important topics that should be emphasized during home construction of straw.

In terms of cost, Even if you use straw bales or other materials, it is costly to build a new house. Especially if you want a good result in terms of longevity and efficiency. However, straw is the most suitable form of construction with home. Water and moisture are the elements that should not be exposed to straw continuously. Even if the straw in structure gets wet, it is necessary to breathe through the surface of the outer coating to throw water around it. This should be covered with breathable finishing materials that will not interfere with air exchange. Because straw is an organic building element, it can house its living organisms and pests, as it is in wood. The solution is to cover the exterior. The fact that there is very little air in the new well-compressed straw bales removes situations that could cause fire and improves resistance to fire. On the contrary, in a tightly packed bales, even a small breeze can easily exacerbate. For these reasons, the most suitable wall is the walls made from over-compressed and flat straw bales. Straw is viable for some species of birds and insects. However, this danger is eliminated by the complex plastering of the straw bale surfaces. Because insecticide has been used for straws for some time, the straws are raised, insecticide may remain on the straw a little bit. Even the medicines that remain on the straws continue to protect the straw bales from the pests. Isolation of a building built with straw bales is good. It balances the ambient temperature in both hot and cold weather. Steam and moisture insulation is the biggest enemy of materials, so the roof and wall coverings and straw balls should be kept very well. In areas where the climate is cold, it is necessary to ensure the isolation of these areas, as the walls, roof and floor parts that come into contact with the outside air are likely to get wet and humid. Air circulation must be provided between the roof and the walls in order to minimize the amount of dust in the bases as much as possible.

4. Findings

4.1. Method of the Research

Construction of straw house and masonry house on the sample project prepared in this research was compared in terms of examining work time, cost and productivity, the results obtained from these researches were evaluated and the benefits provided during the project phase were researched. Through prepared straw house project, workmanship, material, time cost account and calculation of the efficiency cost of heat values was made. Again, cost and productivity calculations were made for the paper house over the same project. The straw house prepared in the scope of the research consists of a single story, 2 rooms, 1 living room, kitchen, and shower, inner partitions can be separated by simple elements. The straw is buried in a ground 20 cm above which the balancing plant should settle. Therefore, 50 x 50 cm sized concrete reinforcements are insulated on the compacted floor and heat-insulated, 10 cm thick simple reinforced concrete flooring is designed as the basis. Balls to be placed on the walls are framed with 5x10 and 10x10 skeleton woods as horizontal and vertical element load bearing systems. One of the considerations here is that straw balls of the size 35x45x110 cm in the bottom row must be placed on these spears, which are placed on the base joist to be cleaned 60-80 cm in the base, turning around the house. This aims to prevent segregation due to earthquakes. In addition, the bails will be reinforced by passing iron bars down from the top to the bottom, and two layers of twisted steel wires will be connected to each other and work together. The wooden pillars that are used vertically will be connected to the steel anchors with the basic strength. With the horizontal wood to be built and the simple roof, the lightest cover and any kind of load that might come to the roof will be easily transferred to the ground to secure the building against the earth. Here, necessary precautions have been taken both in terms of heat, water and humidity isolations and necessary applications have been made. By covering the inner and outer surfaces of the walls with rabiz wire, plastering of exterior walls using only cement and plastering of inner walls using plaster will help both for proper plastering and for protection from mice and similar animals. Precautions against fire and moisture should be taken with plaster. Gypsum plaster is the most appropriate measure against insects, pests and decay. While there are normal windows for ventilation on the southern surfaces of the building, small windows were built on the northern facade and they were designed for lighting and fresh air. The

straw bale used in construction is economical as material, and It is the most suitable homemade material in terms of sustainability with energy saving features. It also has high heat insulation.

4.2. Sample of the Research

The sample of the study is the straw and masonry house in the environmental and climatic conditions of the Karaman province of Turkey, (Figure 4.1).

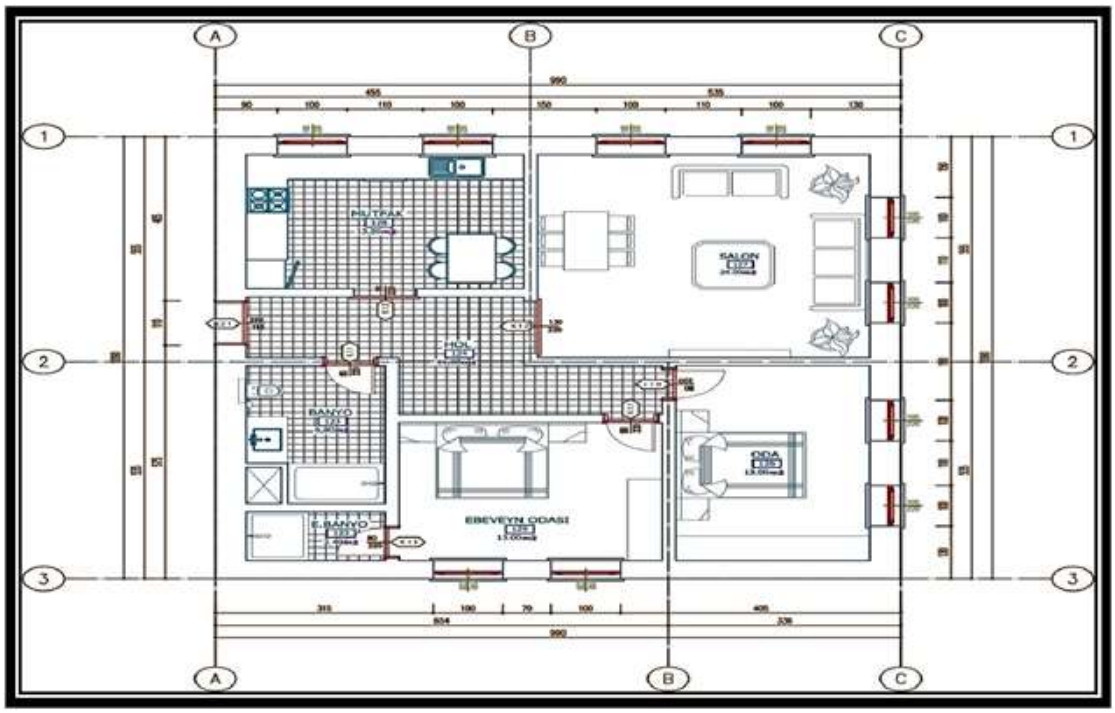

Fig. 4.1. Straw and masonry house, sample house plan prepared for heat and efficiency cost analysis

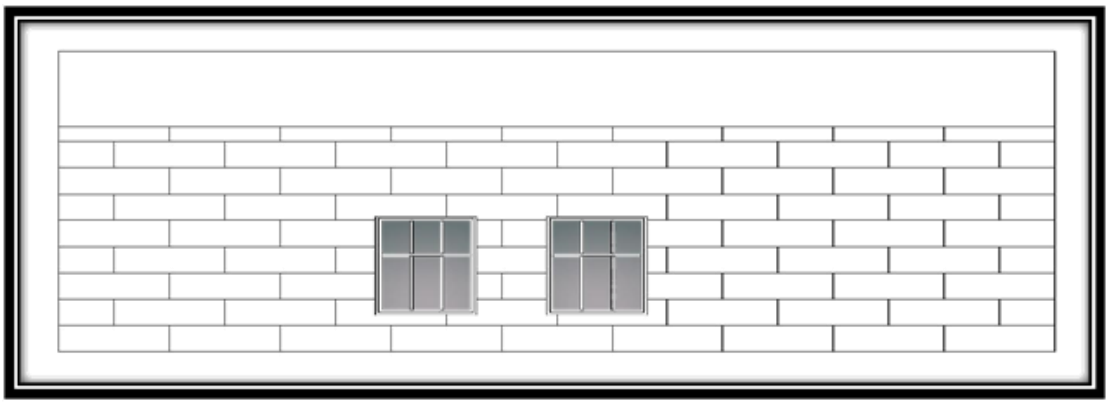

Fig. 4.2. Northern frontal view of the sample house

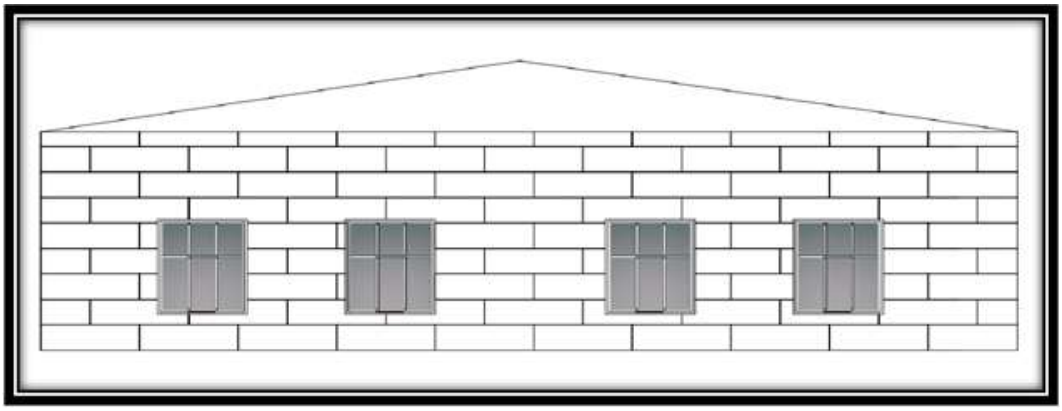

Fig. 4.3. Southern frontal view of the sample house

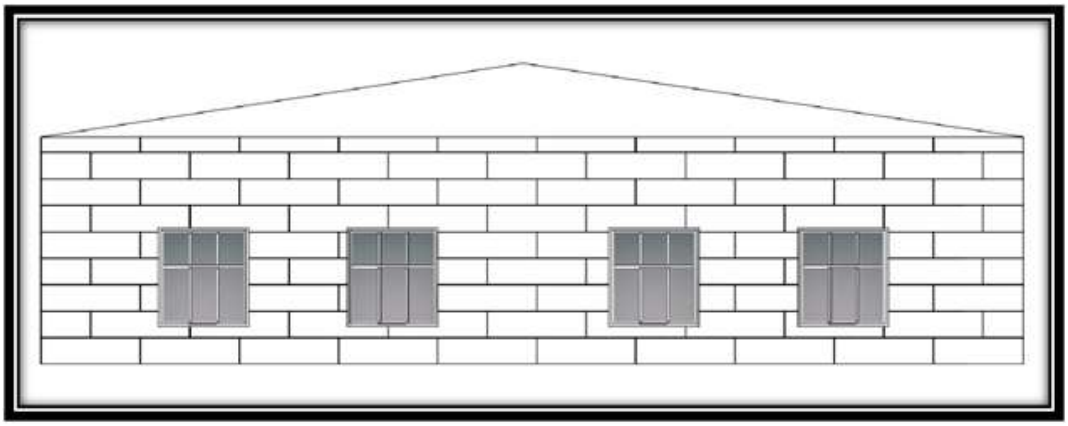

Fig. 4.4. Eastern frontal view of the sample house

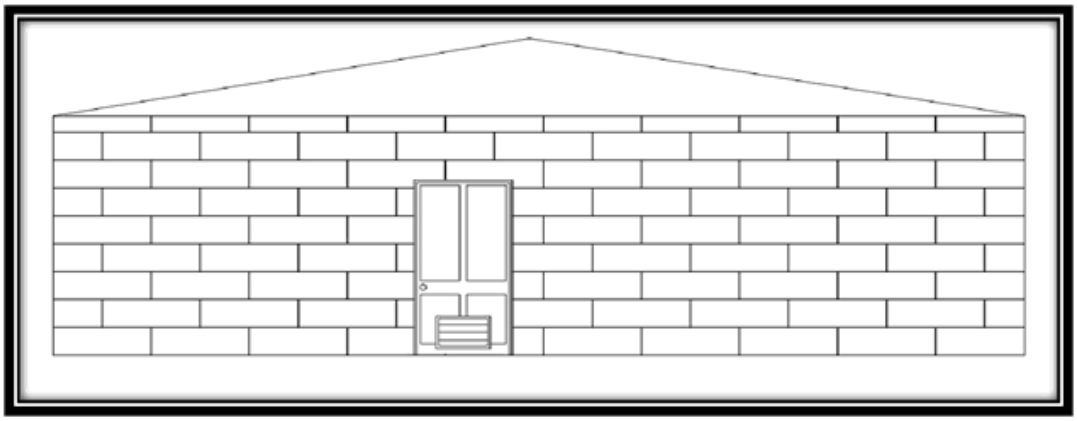

Fig. 4.5. Western frontal (entrance) view of the sample house

4.3. Findings of the Research

As a result of the calculations made on the basis of the project drawn with the findings obtained as a result of the research, findings that will be obtained as a result of benchmarking in terms of cost and efficiency will contribute to the type of structure we will prefer.

4.3.1. Account of the Wall on Plan;

In the following Table 4.1, the areas of the walls were calculated by calculating the total surface areas and window and door space areas from the sections in Figure 4.2, Figure 4.3, Figure 4.4 and Figure 4.5.

Table 4.1. Wall areas account table

Section	**Calculation**
Appearance surface area of Figure 4.2	9,90 x 2,80 = 27,72 m^2
Window area of Figure 4.2	2 x 1,50 x 1,00 = 3,00 m^2
Straw bale area account of Figure 4.2	27,72- 3,00 = 24,72 m^2
Appearance surface area of Figure 4.3	10,90 x 2,80 = 30,52 m^2
Window area of Figure 4.3	4 x 1,50 x 1,00 = 6,00 m^2
Straw bale area account of Figure 4.3	30,52- 3,00 = 24,52 m^2
Figure 4.4 Appearance surface area	9,90 x 2,80 = 27,72 m^2
Figüre 4.4 window area	4 x 1,50 x 1,00 = 6,00 m^2
Figure 4.4 straw bale area account	27,72- 6,00 = 21,72 m^2
Appearance surface area of Figure 4.5	10,90 x 2,80 = 30,52 m^2
Door area of Figure 4.5	10,90 x 2,80 = 30,52 m^2
Straw bale area account of Figure 4.5	30,52-2,42 = 28,10 m^2
The straw bale quantities we need	24,72 + 24,52 + 21,72 + 28,10 = 99,06 m^2

The bale sizes are designed as 35x45x110 and we calculate how many bales are required according to this. 1 piece bale surface area for this is 0,35 x 1,10 = 0,385 m^2 99,06 square meters of straw bale and masonry material used at home are calculated in Table 4.2 below.

Table 4.2. Table of unit accounts of straw bale

Straw bale (35x45x110)	99,06 / 0,385	258 pieces

On the other hand, the balance of straw bales will provide thermal value and the amount of brick material to be used on the outer side of the building is calculated in the following table.

Table 4.3: Brick and insulation material calculation table		
Thermal insulation board, according to Karaman Province, the plate is 7cm thick and stone wool (50-70) (99,06 m^2)	99,06 m^2	6,92 packages
Bonding mortar	457,29 kg	17,76 bags
Plaster mortar	510,3 kg	19,84 bags
Decorative mineral plaster	306,18 kg	11,90 bags
Plaster net	112,27 m^2	2.19 balls
Plastic anchor	612,36 pieces	1,20 packages
Net corner profile	25,52 m	25,52 m
Perforated brick19x19x14,5 cm	99,06x (1m^2 ... 25 pieces)	2477 pieces

4.3.2. Economically Evaluation;

Because of the abundance of straw in the Karaman province, farmers living in this area prefer to evaluate the straw rather than leave it or try to destroy it by burning. This is an advantage in the production of straw bale, and it gives farmers opportunity to purchase suitable concretes by payin a certain amount for bales to farmers. It is possible to buy a balloon from 16 kg to 30 kg, excluding transportation, depending on the bargain, between 1,35 TL and 1,50 TL. The price here depends on the amount of demand.

If we consider that our demand for straw bale is small for the sample house, it is possible to supply a suitable feather as shown in Table 4.4, except for transportation. According to the distance, if we consider 1 truck transportation, we will bring the straw balls to our sample house with a very low amount. We provide this with very little wasted time to mount the straw bales as the exterior walls of our sample house. Approximately 258 pieces of balinese as external wall were found as a result of researches and determinations that 4 people could easily finish in 1 day.

Calculating that the brick is made for the sample house, if we calculate that only 1 worker put up a wall, which is 25 square meter, in a day, we will have finished the brick wall work with 4 wage. When we make with the material to provide the temperature values of the straw bale, we have found that the cost is high with obvious difference as seen in Table 4.4 and Table 4.5. It seems to be quite economical if we add labor difference, materials that should provide the thermal values of the straw bale when brick is woven and the difference between the amount given to the straw bale material and the amount given to the brick. We should not think only economically. We should act with the earthquake risk in mind that the material is natural and the region is very suitable for the conditions.

4.3.3. Straw bale cost;

Table 4.4: Straw bales cost calculation table

	Unit	**Unit Price (TL)**	**Cost (TL)**
Straw Bale	258 pieces	1.50	**387,00**
Labor (wage)	Wage for 4 days	150,00	**600,00**
Shipping (30 km distance) Truck	1 time	300,00	**300,00**
The cost of the outer walls of the plan with straw bales in Figure 4.1			**1.287,00**

4.3.4. Masonry wall and insulation cost;

Table 4.5: Masonry brick and insulation cost calculation table

	Unit quantity	Unit Price (TL)	Cost (TL)
Perforated brick 19x19x13,5 cm; 25 pieces per square meter (99,06 m^2 x25)	2477 pieces	0,61	1510,97
Thermal insulation board, according to Karaman Province, the plate is 7cm thick and stone wool (50-70) (99,06 m2)	6.92 packages	95,00	657,40
Bonding morter (457,29 kg)	17,76 bags	12,50	222,00
Plaster mortar (510,3 kg)	19,84 bags	13,50	267,84
Decorative mineral plaster (306,18 kg)	11,90 bags	17,00	202,30
Plaster net (112,27 m2)	2,19 rolls	85,00	186,15
Plastic peg (612,36 pieces)	1,20 bags	55,00	66,00
Corner profile with net	25,52 m	1,45	37,00
Labor (brick installation) 1 wage per 25 square meter (99.06 m2)	Wage for 4 days	150,00	600,00
Labor (Insulation installation) 1 wage per 5 square meter (99,06 m2)	Wage for 20 days	150,00	3000,00
The masonry wall and insulation cost of the plan in Figure 4.1			6808,69

When the cost estimate is used for both straw bale (Table 4.4) and for the isolated brick house (Table 4.5), it is seen that the house made with straw bales is very economical.

4.3.5. Evaluation in terms of productivity; Building information;

Table 4.6: Building information

tableBuilding width	m	19,90
Building length	m	9,9
Building height	m	3
Monthly average internal temperature	'C	21
Unit internal heat gain =U x(Ti-Td)	W/m^2	33(Δ T) x 0,083076452 (Table 4.9) or 1,709401709 (Table 4,10)
Air change number = nh min: 1, max: 2 assumable	1/h	1
Floor height	m	3

Window and door space areas;

Table 4.7: Window and door areas table

For every direction	Unit	Area (window, door)
Northern facade	M^2	3,00
Southern facade	$_M2$	6
Eastern facade	M^2	6
Western facade	M^2	2,42

Shadowing values by month;

Table 4.8: Shadowing factor table

Shadowing factors	Written by multipling 0,8
(ri) moon	0,6
(gi) moon	0,6

Heat balance account for straw bale wall;

Table 4.9: Heat loss calculator table for straw bale wall

Straw Bale's Wall Layers / Thickness and Thermal Permeability of Layers	*ExternalPlaster*	*FirstLayer*	*SecondLayer*	*Thirdlayer*	*Fourthlayer*	*InteriorPlaster*
Straw bale layer thickness(cm)	1,5	45	0	0	0	1
Straw Bale Thermal Insulation Coefficient lh=W/mK	1,4	0,038	0	0	0	0,7
Straw bale wall Total Heat Loss Value U=W/m2K	0,083076452					

Heat loss account of masonry brick wall;

Table 4.10: Heat loss calculator table for brick wall

Paper Brick Wall Layers / Thickness and Thermal Permeability of Layers	*ExternalPlaster*	*First Layer*	*SecondLayer*	*Third layer*	*Fourthlayer*	*InteriorPlaster*
Brick Layer Thickness (cm)	1,5	13,5	0	0	0	1
Thermal Insulation Coefficient of Brick Wall lh=W/mK	1,4	0,5	0	0	0	0,7
Total Heat Loss Value U=W/m^{2}K	1,709401709					

Td = The coldest heat in the winter
Ti = Heat to feel in the house in winter
Δ T =Ti – Td =21-(-12) =33
Heat balancing account on straw bale wall;
Q=A x U x Δ T =99.06 x 0,083076452 (Table 4.9) x 33 =271,58 W
Heat loss account on the masonry brick wall;
Q=A x U x Δ T =99.06 x 1,709401709 (Table 4.10) x 33 =5587,99 W
As a result, a high energy efficiency has been saved.

According to the calculations made, the houses made from straw bales have quite positive values compared to the masonry bricks in comparison to the masonry brick houses.

5. Conclusion And Evaluation

Because of the metric, cost and efficiency calculations made on the prepared sample project, it is seen that the straw house is lower cost, and it can be installed in a shorter period of time and has a higher energy saving in terms of productivity.

It is important to choose natural building materials such as straw bales produced from chemical cores (corn, barley, wheat, oat stalks) to build economical, energy-saving and ecological housing. Straw bales are manufactured under pressure and under the presses at the desired scale and mold spores are removed from the center. In this way, straw balls become a completely natural and hygienic construction material. Straw bales are used with other natural materials (wood, flax thermal insulation and clay plaster, etc.). Materials used in straw bales do not emit harmful SO x (sulfur oxides) or CO x (carbon oxides). The diffusion of natural materials has a positive effect on the climate within the building. It prevents condensation of water vapor in the structure and helps to regulate humidity. Straw bail walls can absorb excess moisture in high humidity without volume change. However, when the humidity level

drops (eg, the winters), it compensates the indoor humidity climate to create a comfortable environment for residents.

Low investment and operating costs

The straw-holed walls are less energy-consuming and require lower operating costs due to their thermal insulation properties and high heat accumulation function.

Easy installation

Wall systems made from straw bales are fast, easy building processes especially at home. Strength and mechanical strength of straw walls (which can also be made of straw bale panels) also allow for the construction of self-supporting partition walls. Straw bale wall systems are easy to work with. They can be cut in the desired length and are easy to install, allowing to save time and money.

%100 Ecological structure

From the production of building materials to the final destruction stage, the entire construction process is environment friendly. When production is done by straw, production of energy efficient panels requiring about 2.5 kW energy per square meter is saved. The destruction of a home made from straw bale walls or panels is also an environmentally friendly process. Walls or panels made from straw can be completely recycled. Wooden structures made from panel system can be easily removed and destroyed as a piece. After removal of the surface coating, it can also be composted on panes like walls made from straw.

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