International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 / https://doi.org/10.14445/22315381/IJETT-V71I2P218

Volume 71 Issue 2, 143-156, February 2023

Original Article

The Role of Roofing Systems in Reducing the Cost of Construction - A Comparative Study Between Prefabricated and On-Site Cast Ceilings

Doaa Sameer Abdullah[1], Raed Salim Ahmed Al-Nuamman[2]

[1,2]*Department of Architecture, University of Mosul, College of Engineering, Mosul, Iraq*

[1]*Corresponding Author : raeedalnumman@uomosul.edu.iq*

Received: 09 December 2022 Revised: 06 February 2023 Accepted: 11 February 2023 Published: 25 February 2023

Abstract *- Ceilings and floors are an important part of any building in terms of energy conservation, performance and cost. As it is known that the initial stage of construction, which is the stage of building the basic structure of the building, represents the equivalent of about 35-40% of the cost of the building, so it was necessary to study the construction systems that help reduce the cost of this stage, especially the ceilings and floors. Ceilings are considered one of the basic structural elements of buildings. The costs spent on these elements during the construction phase represent about 8-11% of the total cost of the project, so it has become necessary to resort to innovative solutions that rationalize these costs. The study aims to explore the least expensive system used in ceilings and floors of buildings by comparing A set of systems for the construction of concrete ceilings and floors common locally; this was done through the modeling of an existing case study according to the construction systems common locally (cast on-site, prefabricated construction of various types) and thus limiting the costs achieved for ceilings and floors in order to explore the least expensive system.*

Keywords *- Roofing system, Construction costs, Housing, The least expensive, Affordable.*

1. Introduction

Ceilings are the most important element in any building due to the safety and protection they provide from external conditions, rain, cold, and others. Therefore, choosing a good ceiling leads to better results for users from an economic and environmental point of view in any building. In particular, ceilings and floors, as ceilings are considered one of the basic structural elements of buildings, and the costs spent on these elements during the construction phase represent about 8-11% of the total cost of the project [1].

Given the importance of ceilings, many studies dealt with the issue of ceilings from several aspects. Carretero and García [2] conducted a study in which the focus was on a comparison between ceiling systems, but in terms of environmental impact, for 11 types of ceilings for residential buildings, from the point of view of sustainability and its economic, social and environmental indicators, social. In order to reach results that help decision-makers determine the appropriate type of buildings, according to the environmental impact of the type of roof, where they evaluated the life cycle, which is a methodology for distinguishing and estimating the expected environmental impacts that are related to all stages of the life of the product or system, a group of roof patterns were selected in This study is (traditional patterns) and avoiding uncommon or unconventional patterns, and the main points on which the analysis was based on in this study are carbon dioxide emission, embodied energy and waste generation, which are included in the environmental indicators, as well as the cost of implementation, the time spent on work, and the cost and percentage Maintenance, which is included in the economic and social indicators of sustainability, the study concluded in terms of carbon dioxide emission that flat roofs' emission rate is greater than inclined roofs. As for the percentage of waste and the amount of labor required, inclined roofs generate a high waste rate and require more labor compared to flat roofs. Therefore, the study recommended that it must be taken into account, in addition to the aesthetic factors, the roof is chosen for any building, taking into account the environmental, economic and social aspects.

While Tubelo and others [3] conducted a study that looked at the possibilities that allow identifying the design aspects that can be improved in housing within certain limits in terms of cost, which are the performance and costs associated with building and operating a residential unit, and the study sample consisted of two separate homes. This study focused on A set of points on which the samples were compared: thermal comfort, construction costs, and operating costs. The researcher conducted some tests and comparisons

regarding the materials and treatments of the building envelope, and then two groups of building envelopes were selected from among 108 models. After that criterion for thermal comfort was determined within temperatures of approximately 18-29 degrees Celsius, which will be used in calculating the need for heating and cooling. As for the costs, the first comparison was between the building envelope as it is in reality with the improved covers of the study, and data installed on the web were adopted regarding thermal comfort prices.

While Abuseif and Gou [4] recommended that choosing a good flat ceiling that is suitable for any building and any climate is based on the characteristics of the ceiling and the presence or absence of insulation in addition to the cooling methods used after they made a comparison between 10 types of different ceilings among themselves, in several aspects, including in terms of the materials that make up the ceiling, in addition to the reflective additives, the method of insulation, and others, a comparison was made between the aforementioned types. The comparison included several aspects, the most important of which is the suitability of different types of roofs for different climates. A comparison was made between six regions with different climates. The extent of the roof's suitability for this climate and its suitability for the building to adapt to weather conditions, and also the ceilings were compared in terms of performance and heat gain the study recommended an attempt to explore the possibilities of merging some ceilings with each other to reach better solutions.

As for ALBATAYNEH and others [5], they conducted a study in which they focused on ceiling insulation and its role in improving thermal performance and reducing energy demand in low-cost housing. Where the study tried to prove that reducing leakage in buildings is the most effective and least expensive solution for low-income housing, where a single residence was chosen as a sample for the study, and the Design Builder program was adopted in simulations and also in climate control and in real time During the tests, annual energy savings were calculated For heating and cooling In addition to that, the calculation of the actual consumption of heating and cooling, with the adoption of different materials for ceilings and also walls with different treatments, where 15 cases were reached by making changes in terms of thickness of insulating materials and in terms of changing some materials, and so on, and on the basis of which the comparison was made, the study concluded The greater the thickness of the insulation material, the more it will lead to energy saving, and that there is a difference between the effect of ceiling insulation compared to the effect of wall insulation, as it appeared that wall insulation affects reducing heating consumption, while the ceiling has a significant impact on reducing the cooling load.

As for the thermal performance of the roofs, Gaggino et al. [6] conducted a study that reviewed at its beginning a brief history of the technological progress and development of roofing tiles, and through the technological development that took place, environmental goals were taken into account, including the impact on the environment and the reduction of energy use and focus on the side of waste, waste, and emissions, in addition to the quality of materials, buildings, and others. The study aimed to determine the thermal performance of the roof of a house built with different types of roofing tiles in Cordoba, Argentina. Therefore, the study took plastic and recycled rubber as the main material in this research, with a comparison to other traditional materials, which are concrete tiles, ceramic tiles, and zinc sheets, with reliance on a wooden structure for all cases. The final comparison was made between the four models in many aspects (thermal conductivity, weight, air permeability, bending resistance, freezing, water absorption, etc.). In terms of costs only, the Zarate trade company was relied on with regard to materials, equipment, and labor, in addition to other administrative details. However, the results showed that the main alternative proposed in this study, which is roof tiles made of recycled materials, is the most expensive among the rest of the types, while it was the best among All in different proportions from all other cases included in the study with regard to thermal performance.

While Le. and others [7] conducted a study that focused on the carbon footprint of roof covering materials, where three types of roofing tiles (concrete, clay, and metal) were adopted, and their quantities were calculated for the study sample in order to be able to calculate their environmental impact in the stages of the life cycle, where it starts from mining and production of materials, then the process of transportation and construction, then the stage of use, and then the period of demolition and waste treatment or recycling, depending on the type of material. The study reached a set of results regarding the three materials, which will help in choosing roofing materials that have a lower carbon footprint in order to reduce the impact on the environment, as it was found that metal sheets are the most carbon-intensive, while the demand for embodied energy was the highest is roofing tiles concrete. In terms of reducing the environmental impact during the stages of demolition and waste treatment, the focus was on recycling, so metal sheets were the best, and the study encouraged, during decision-making, that there should be an integration of environmental assessment.

As for the study of Victoria and others. [8], its beginning stated that there is a great need for housing units in the United Kingdom; in addition to that, carbon and cost are among the basic criteria now for construction projects, and both must be improved. The study aimed to compare two models of single dwellings, which differ in themselves in wood material, as one of the samples was of crushed wooden gables. In contrast, the second sample improved the first sample by replacing the milled wooden beams with complete

wooden beams with the addition of wood wool insulation. The comparison was made Between the two models in terms of cost and carbon footprint; the study results were that the whole wood option is the best in terms of cost by 28% and embodied carbon by 55% less than ground wood. As for the construction stage, the gable structure of both models is similar, but the difference between them is the insulation, as traditional insulation does not require any effort compared to the insulation of wood wool, as it is done by the blowing process that requires energy. As for the use stage, the study concluded that the embodied carbon and the use of water and operational energy would also be equal. As for the end-of-life stage, the demolition stage for the two models, it is assumed that the costs for demolition and embodied carbon are equal. However, the difference between them is that waste treatments and disposal for whole wood will be less than for Milled wood; in addition to the above, whole wood has other advantages, including reuse and recycling. Therefore it is superior to milled wood in terms of cost, life cycle, and carbon.

Table 1. Shows the field of previous studies and the location of the current study - the source - the researcher

The study	The study sample	sample type	indoor environment	structural aspect	insulation	Humidity	environmental impact	sustainability	carbon footprint	Building materials	cost	measurement tool
Carretero and García study[2]	11types of roofs						●	●	●	●	●	Databases and regulations
Study: Tubelo and others[3]	Two single dwellings	Single housing	Thermal comfort							●	●	TAS Program and ASHRAE Guideline
Abuseif and Gou study [4]	10types of Roofing Floors		adaptation to the outside		●							
ALBATAYNEH and others study [5]	Single dwelling	Single housing	Thermal comfort		●					●		Design Builder program
Gaggino and others study [6]	4types of Roofing Floors	Single housing					●			●	●	CEEMA2CON software And Zarate trade company
Le and others study [7]	3types of Roofing Floors								●			
Victoria and others study [8]	2types of wooden gables	Single housing			●		●		●		●	
Gandhe [9]	5 types of roof slab holes shapes			●							●	Excel
Hajiah and Saber study [10]	Two types of roofing materials		Heat flow			●						digital simulation
Saeed and Alhakeem study [11]	3models of Roofing Floors	Convention Hall		●							●	ETABS program
The current study, 2022	6types of Roofing Floors	Multi-storey housing		●						●	●	Autodesk Revit, AutoCAD, Excel program

While the Gandhe study [9] focused on reducing the amount of concrete used in the production of hollow core slabs, which will lead to a reduction in the production costs of concrete slabs by changing the shapes of the gaps, as the study identified five groups of shapes as follows (square, circular, elliptical, dome, and frustum), this was done by changing the thickness of the concrete, as the thickness of the slab was changed to three different dimensions, which are 250 mm, 200 mm, and 150 mm. The study used an Excel program in the analysis and design of slabs. The study concluded that using square-shaped holes reduces the amount of concrete used in casting the slab, meaning that the square shape achieves the maximum saving of concrete from the rest of the other shapes.

Moreover, each of Hajiah and Saber [10] in their study of the roofing system, which is the only part of the building envelope that was focused on, where two types of white and black materials were adopted for the roofs, where a comparison was made between the two types of roofs regarding energy and moisture performance in the long term, in this study When making the comparison, it was assumed that throughout the year the internal air temperature would be constant, while the outside air was subject to the different weather conditions of Kuwait City. A digital simulation of the roof systems was conducted for this study with regard to heat flow and annual moisture accumulation within the roof layers, in addition to predicting energy performance through digital simulation as well, when the roofs were exposed to the weather conditions of Kuwait City. In terms of moisture problems, the study concluded that black roofs are less than white roofs, and also, in terms of energy, white roofs are better than black roofs.

As for Saeed and Alhakeem [11], they conducted a study aimed at finding the best system for ceilings without using columns in terms of aesthetics and impact on the design of the foundation and structural deflection in addition to estimating costs and the ability to build and maintain each system, as the study compared three types of ceiling systems, which are Ribbed slab system and Precast prestressed hollow core slab system and steel concrete composite floor system, after the calculations and analysis conducted in the study, it was concluded that the hollow core system is the best system in terms of durability, speed of implementation, and ease of use in addition to the low costs. However, at the same time, it represents a great challenge. This is due to its large weight and the difficulty of adjusting to it in addition to transportation.

Table 1. summarizes the many aspects that the aforementioned studies focused on and the location of the current study among them.

Previous studies indicated many aspects through which it is possible to reduce the costs of building roofs, some of which (1) focused on the impact of roofs in terms of environmental treatments, including attempts to innovate new sustainable materials for roofs to reduce the environmental impact in the process of its construction, while others focused (2), on the role of specific types of roofs in creating a better environment for users at reasonable prices, and another (3) focused on the Environmental impact and carbon footprint of roofing materials, while another group of studies focused on (4) the use of recycled materials and the role of these materials in reducing costs, And also the role of recycling in reducing waste.

It is worth noting that the application aspects were mostly focused on the housing aspect, specifically individual housing. From these studies, it is clear that the field of housing is the best to address this problem because it affects a large segment of society. As shown in Table 1, these studies, in their entirety, did not address the construction cost of the ceilings accurately and separately from the rest of the structural system, which includes the costs of materials, construction costs (labor) and the costs of molds used in construction operations, Fig. 1. Thus, their role in achieving an affordable building structurally.

The research aims to explore the role of the most common structural system locally for ceilings and floors in reducing the cost of the structure on the one hand and to identify the least expensive system to achieve an affordable building locally where the lack of accurate information represents the research problem in determining the role of the structural roof system in reducing or increasing the construction costs of multi-floor residential buildings to achieve low-cost housing.

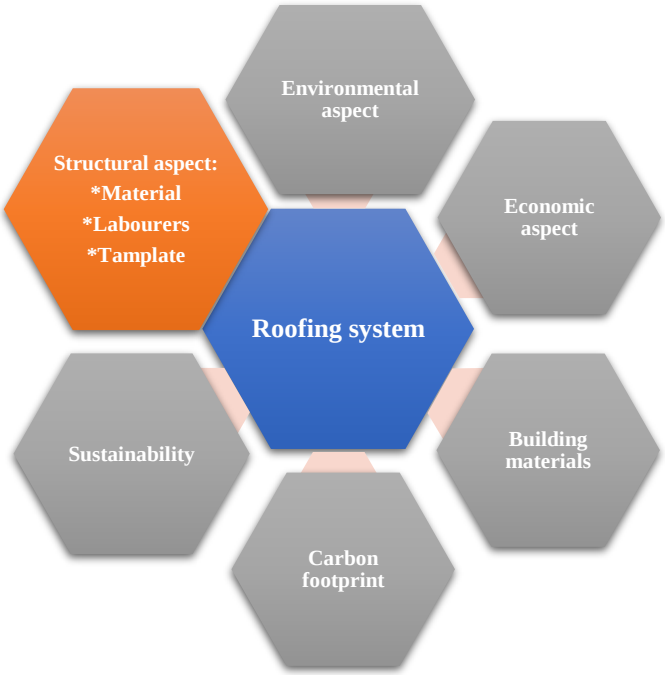

Fig. 1 Shows the field of the current study and previous studies - source - the researcher

This research assumes that achieving low-cost housing depends mainly on choosing the appropriate structural system. Since ceilings are one of the most important elements in construction systems, their role will be crucial in reducing construction costs and thus achieving affordable buildings, especially in multi-floor residential buildings. In order to verify and test the research hypothesis, the research will compare the costs achieved when constructing different types of ceiling systems for one case study to verify the least expensive system on the one hand and to accurately investigate the cost of building one square meter of those ceilings.

2. Materials and Methods

In this section, the materials and methods used in the comparison will be presented

2.1. Materials

In this study, reinforced concrete ceilings were relied upon as they are the most common and used locally in the city of Mosul, which consists of reinforced concrete material. 30mpa As for the reinforcing steel, it was of various diameters, according to each type of construction system.

2.2. Methods

The research methodology consisted of several steps, as it began with the analysis and structural design of the different roof systems (which will be mentioned in the next paragraph) in accordance with the case study model in terms of determining the thickness of the concrete for the roof and the quantities of reinforcing steel used in all types except for the study case itself, where it was Including them within the samples and comparing them with the rest of the types proposed for the practical study, and after completing the structural design and determining the measurements and dimensions of the ceiling elements and the quantities of iron used in each type, the second phase of work began, which is the process of counting the quantities, which it will be discussed in the following sections, and then after that the field visits and interviews began with the engineers in the companies that were relied upon to determine the initial costs that will be relied upon during the cost calculation stage to reach the final cost of the roof construction operations to make the final comparison and achieve the required research goal, which is to reach the least expensive system locally.

2.3. Common Construction Systems for Multi-Floor Buildings

2.3.1. On-site casting system

This system depends on the on-site construction of all paragraphs related to the building implementation process and has several types, including:

Flat Slab System

It is a type of construction system in which the ceilings are based on columns with the presence of circumferential bridges only without the presence of bridges connecting the columns, and they are of the same thickness.

Slip Framework System

The sliding formwork system is an automatic moving system and has several advantages, including reducing the time as well as reducing costs. It can also be used horizontally and vertically; that is, the vertical and horizontal elements constructed with reinforced concrete are assigned, such as ceilings, columns, and walls. Also, templates are considered one of the most important components of any project in terms of cost, as the percentage of the cost of the template reaches the total project cost (10-20) percent [20].

2.3.2. Precast System

The precast concrete system is considered one of the systems in which the manufacturing takes place outside or near the project implementation site, is in locations that are easily accessible, and is subject to supervision during the manufacturing process, as economic advantages in addition to the strength and durability of the elements characterize these precast elements. [13].

Double T Section Slab

This structural element is considered one of the most cost-effective elements, and it is also versatile in that it can be used both horizontally and vertically. The most important characteristic of it is its stability when installing and transporting [21].

2.3.3.Prestress System

This precast and prestressed structural system is characterized by being a structural system with a lighter weight than the fully cast system. Also, it has been proven that the buildings and structures that are built with the prestressed system are characterized by speed, economy, and quality in terms of materials and manufacturing [15].

Hollow Core Slab

The hollow slab is a prestressed concrete piece that contains voids in its middle that reduce the weight of the slab, i.e. reduce the amount of concrete. Thus, it leads to a reduction in its cost, and at the same time, the presence of these voids helps to exploit them in the electricity supply and hidden mechanics. It is mainly used for ceilings and floors, in addition to other uses [23].

Solid Slab

It is a non-hollow board and does not contain any kind of protrusions, but it is of equal thickness on all sides, and it also has different dimensions and thicknesses depending on the type of space that will be covered.

Hollow Slab

This type may be similar to the specifications of the hollow Core, but it differs in terms of dimensions, as it is smaller in size.

2.4. Practical study

2.4.1. Case Study

The research hypothesis will be tested on a realistic case study, a residential complex in the city of Mosul (Al-Hadbaa Residential Complex). This complex was chosen because it is one of the complexes with economical housing advantages. It is a multi-floor building (3 floors). It is designed in accordance with the requirements and privacy of the Mosul family, according to the company operating the project [24].

This sample was executed in the traditional construction method. The following is Table (2), which shows information regarding the project as it appeared on the official website of the Iraqi Housing Department [18].

The project comprises 56 residential buildings, each consisting of 3 floors. Each floor contains 3 apartments, equivalent to 504 apartments in the complex as a whole, with a total area estimated at about 144,847,7484 square meters—Fig. 2.

Table 2. Shows the details of the project - the source - the Iraqi Housing Department

1	project name	The residential complex in Nineveh /Al-Hadbaa
2	Governorate	Mosul
3	Number of housing units' type (house/apartment)	504apartments
4	The name of the executing company	Mansour General Company
5	referral year	2004
6	The nationality of the executing company	Iraqi
7	Contract number/date	2004/3/8
8	Contract amount/dinars	42.775
9	Implementation period (day/month)	1334
10	Contractual commencement date	2004/6/27
11	Extra time granted (days)	1898
12	Completion date with extensions	2013/5/3

Fig. 2 Site plan for the source project - Nineveh Housing Department

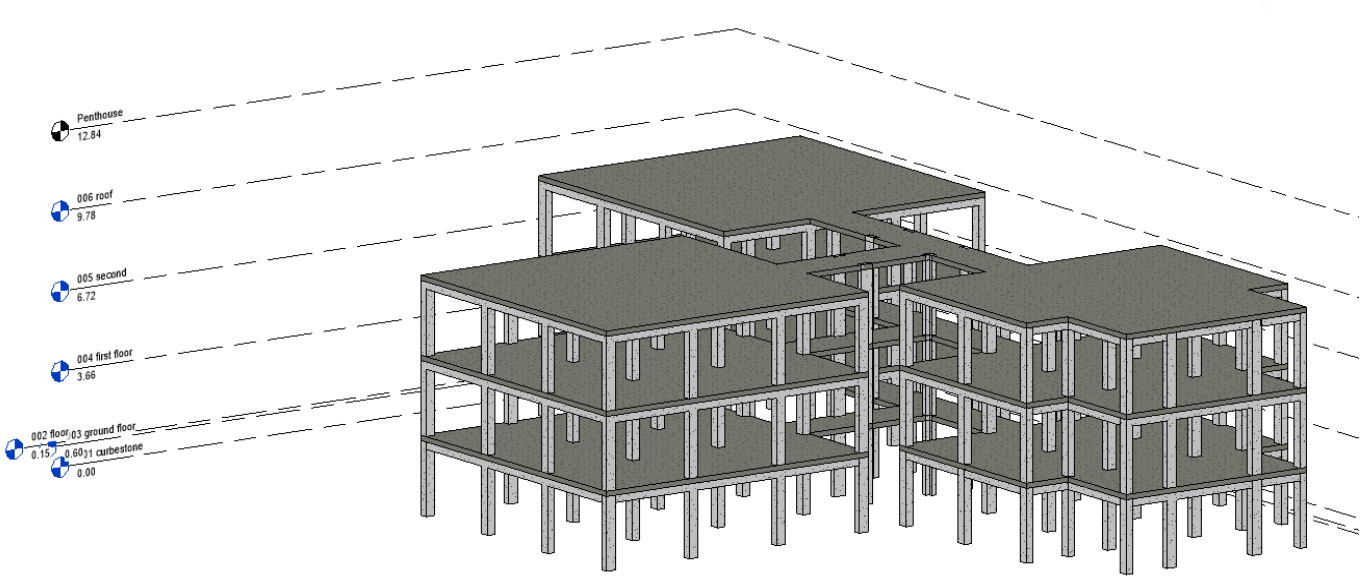

Fig. 3 A model of the residential building - the source - the researcher

Fig. 4 A plan for the residential building - the source - the housing department

2.4.2. Sample Selection

The sample (Building A) was chosen because it is the most frequently used in the project, consisting of two 3-bedroom apartments and a 2-bedroom apartment on each floor. That is, a total of 6 apartments with 3 bedrooms and 3 apartments with 2 bedrooms, as shown in Fig. 3. and the building plan in Fig. 4.

2.5. Types of Ceilings

In this research, one of the residential buildings was chosen from the residential complex, meaning that the calculations for the areas will be made based on one building and all the apartments in it, which are 9 apartments.

After making a slight modification to it in the case of traditional construction, the ceilings implemented on the site (flat ceilings) were approved. As for the precast ceilings, the dimensions have been changed to fit the modular dimensions of (60cm), and a model has been made for the ceilings, which are: Double T Section Slab, as well as other types of prestressed ceilings, Hollow Core Slab, Solid slab, and Hollow Block Slab, in addition to ceilings executed with sliding molds.

2.5.1. Draw Sections and Diagrams of all types

With regard to the type of roofs for traditional construction, the plans obtained from the Nineveh Housing Department were approved, and part of them are shown in Fig. (4).

As for the rest of the types of ceilings, they were drawn through the Revit program and then converted to the AutoCAD program. They are shown sequentially in Fig. 5, 6, 7, 8, 9, and 10, where the dimensions and reinforcement quantities were calculated. Approval was obtained by a civil engineer at the University of Mosul.

2.6. Counting Quantities and Calculating costs for all types

The Excel program was adopted in the process of counting the total quantities of ceilings, where some basic information was entered based on some tables that contain information regarding diameters, areas and weights of reinforcing steel, and the quantities of concrete and quantities of concrete and quantities of reinforcing steel were calculated based on entering a set of equations to reach the final output; during the calculations, a percentage of wastage was added, and it was unified on all systems with regard to reinforcing steel, and the percentage was 5%.

As for concrete, wastage percentages were calculated that included on-site casting systems, which were 15%. As for the calculations of the total costs for the construction systems for roofs, they included many aspects, including costs, Materials and labor wages, addition to mold prices, installation and transportation costs, in addition to profit rates with secondary costs associated with some paragraphs of some systems.

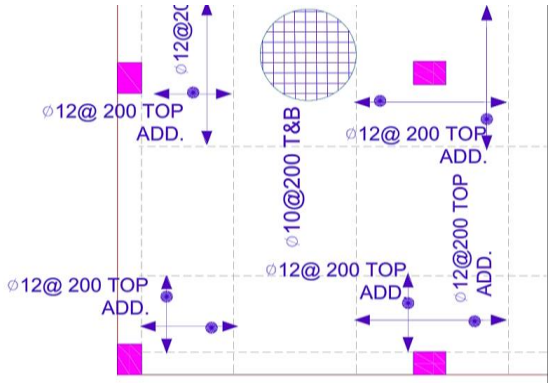

Fig. 5 A roof plan for the traditional building - the source is the Nineveh Housing Department

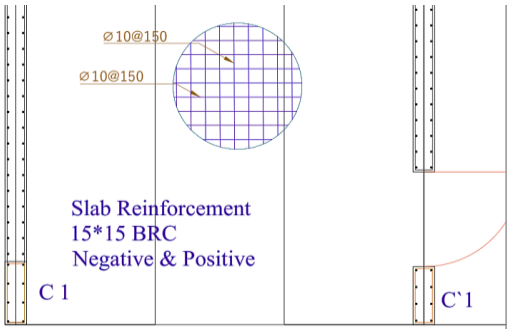

Fig. 6 Slip Framework slab roof plan - source – researcher

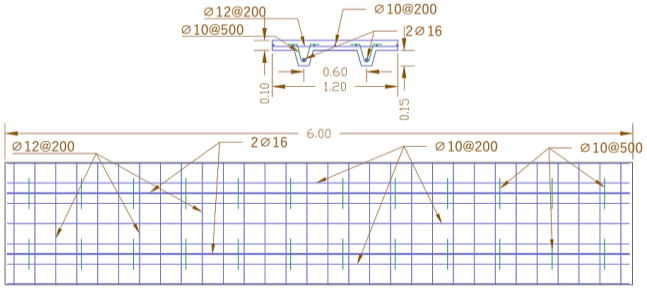

Fig. 7 Double T slab roof - source – researcher

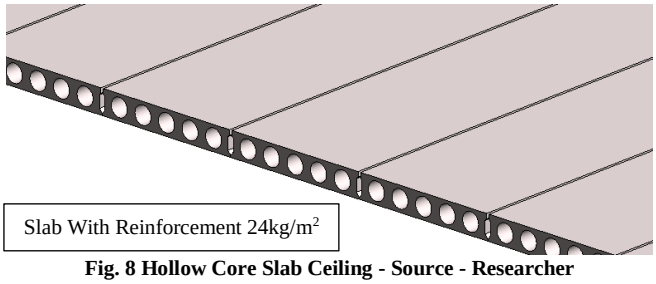

Fig. 8 Hollow Core Slab Ceiling - Source - Researcher

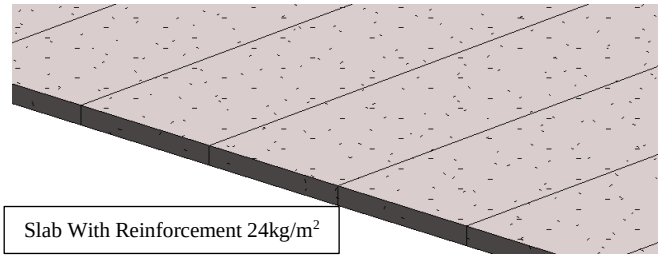

Fig. 9 Solid Slab Ceiling Source: Researcher

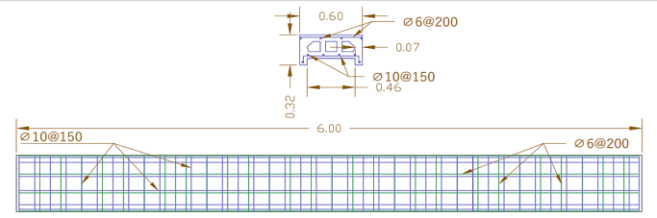

Fig. 10 Hollow Slab Ceiling Source - Researcher

With regard to costs, the local market prices have been approved by the Altanasoq Construction and Consultants Office in the city of Mosul, with regard to traditional construction, as for ready-made construction, and due to the difficulty of obtaining a well-known local entity that performs the process of estimating costs for ready-made parts in the city of Mosul. Eng. has been contacted. Sari Zahi Reda at Dijla-Precast Concrete Industries Ltd. In Baghdad governorate for cooperation regarding the cost of precast and prestressed ceilings. As for the sliding molds, the resident engineer, Eng. Aval Khairy smo of the French Village2 project in Dohuk Governorate.

The following are tables that show in detail the calculation of two models of ceilings, Tables 3 and 4. As for the rest of the ceilings, only the final results of the calculations were reviewed, Table 5, 6, 7 and 8, and then the final price per square meter was calculated for all types of ceilings, as shown in Figure No. 11.

Table 3. Shows the final quantities and prices for flat slab ceilings

Flat Slab / Compressive Strength of Concrete 30mpa								
Price Of Concrete Supply (30mpa) IQD/m3		Concrete Casting Cost IQD m3	Wastage percentage in concrete 15%	Total Concrete volume (m3)	Price Of Concrete Supply (IQD)	Price Of Concrete Casting (IQD)	Total Price of Concrete (IQD)	
65,000		4,500	1.15	211.806	15,832,495	953,127	16,785,622	
Wooden Template Price (m2)			Total Area of Wooden Template (m2)			Total Wooden Template Price (m2)		
14,000			1265.646			17,719,044		
Price Of Steel IQD/Ton	Damage percentage 5%	Rebar Worker Wages IQD/ton	Other Costs IQD/Ton	Total Bar Weight of 1 Slab (ton)	Total other Costs	Price of steel (IQD)	Price of rebar worker (IQD)	Total Price of Steel (IQD)
1,000,000	1.05	100,000	8,000	18.5757	148,606	19,504,535	1,857,575	21,510,716
The amount of profits with administrative additions of 5% IQD/Piece			Price of Concrete & Steel of 1Peice (IQD)			Total Price of Roof (IQD)		
1.05			56,015,382			58,816,151		

Table 4. Shows the final quantities and prices for Double T Slab apartment ceilings

Precast System - Double T Slab / Compressive Strength of Concrete 30mpa							
Price Of Concrete Supply (30mpa) IQD/m3		Concrete Casting Cost IQD/m3	Total Concrete volume in 1 Slab (m3)	Price Of Concrete Supply (IQD)	Price Of Concrete Casting (IQD)	Total Price Of Concrete (IQD)	
65,000		30,000	115.253	7,491,477	3,457,605	10,949,082	
Price Of Steel IQD/Ton	Damage percentage	Rebar Worker Wages IQD/ton	Total Bar Weight of 1 Slab (ton)	Price of steel (IQD)	Price of rebar worker (IQD)	Total Price of Steel (IQD)	
1,000,000	1.05	150,000	14.6771	15,410,965	2,201,566	17,612,532	
Casting Tamplate Price IQD/Piece (1000 Piece)	Casting Tamplate Price IQD/Piece (1 Piece)	Steam Drying Cost IQD/m3	NO. Piece in Building	Net volume (m3)	Total Casting Tamplate Price IQD/Piece	Total Steam Drying Cost IQD/m3	Total Tamplate Cost IQD/Piece
16,000,000	16000	35,000	88	171.072	1,408,000	5,987,520	7,395,520
Other Costs IQD/Piece	Transport and installation fees IQD/Piece	The amount of profits with administrative additions of 20% IQD/Piece	NO. Piece in Building	Total Costs IQD/Piece	Total Transport and installation fees IQD/Piece	Total Price Of Roof (IQD)	
30,000	75,000	1.2	88	2,640,000	6,600,000	54,236,560	

Table 5. Shows the final quantities and prices for Slip Framework slab apartment ceilings

Slip Framework Slab / Compressive Strength of Concrete 35mpa	
Total Crane Cost IQD	Total Price Of Concrete (IQD)
1,638,889	21,854,073
Total Tamplate Price (m2)	Total Price of Steel (IQD)
12,004,992	56,540,320
Total Price Of Roof (IQD)	
92,038,274	

Table 6. Shows the final quantities and prices for hollow core slab apartment ceilings

Prestress System – Hollow Core slab / PC Strand Steel	
Total Tamplate Cost IQD/m2	Total Price Of Concrete (IQD)
10,190,822	17,090,726
Total Transport and installation fees IQD/m2	Total Price Of Steel PC Strand and Lab fees IQD/m2
8,870,400	11,874,931
The amount of profits with administrative additions of 20% IQD/Piece	
1.2	
Total Price Of Roof (IQD)	
57,632,256	

Table 7. Shows the final quantities and prices for solid slab apartment ceilings

Prestress System – Solid slab / PC Strand Steel	
Total Tamplate Cost IQD/m2	Total Price Of Concrete (IQD)
11,670,912	27,503,309
Total Transport and installation fees IQD/m2	Total Price Of Steel PC Strand and Lab fees IQD/m2
10,137,600	13,742,784
The amount of profits with administrative additions of 20% IQD/Piece	
1.2	
Total Price Of Roof (IQD)	
75,665,526	

Table 8. Shows the final quantities and prices for hollow slab apartment ceilings

Precast/Prestress System – Hollow slab / PC Strand Steel	
Total Price Of Concrete (IQD)	Total Price of Steel (IQD)
26,167,743	20,160,645
Total Transport and installation fees IQD/Piece	Total Tamplate Cost IQD/Piece
7,920,000	15,866,400
The amount of profits with administrative additions of 20% IQD/Piece	Total Other cost (Grease, clean and lift) IQD/Piece
1.2	2,640,000
Total Price Of Roof (IQD)	
87,305,746	

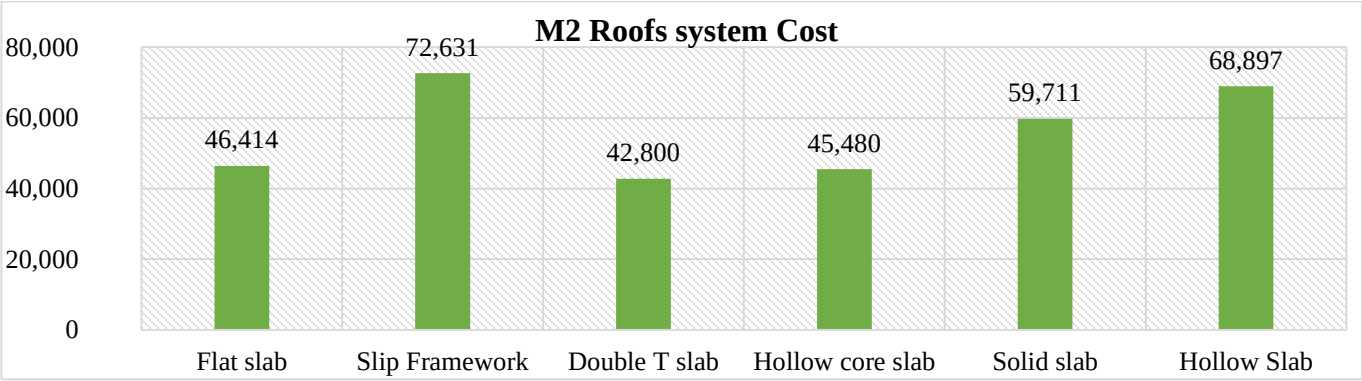

Fig. 11 Shows the prices of 1m2 for all roofing systems

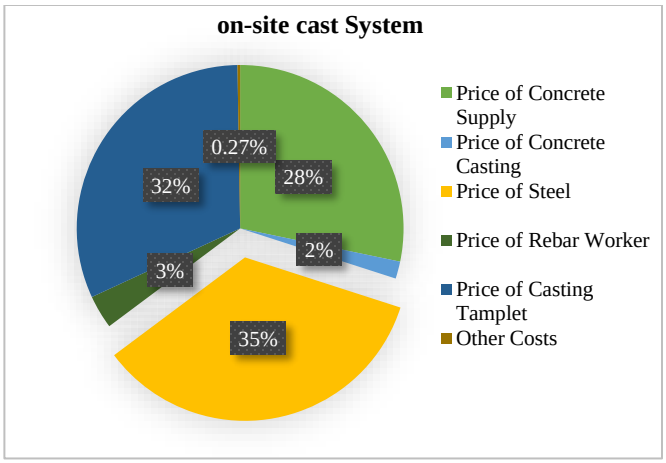

Fig. 12 Shows the final rates of flat slab ceiling prices

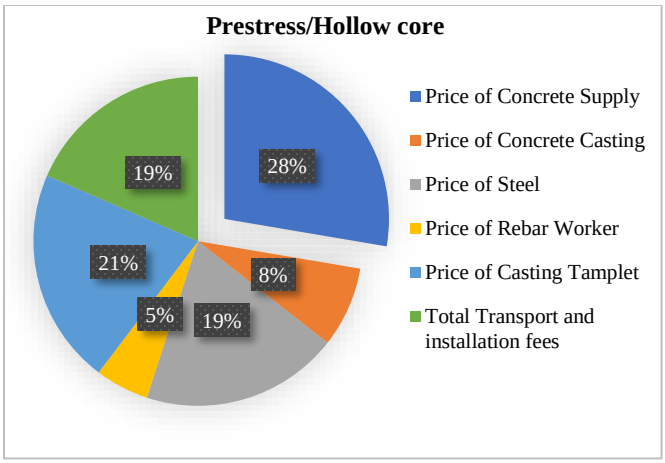

Fig. 15 Shows the final rates of hollow core ceiling prices

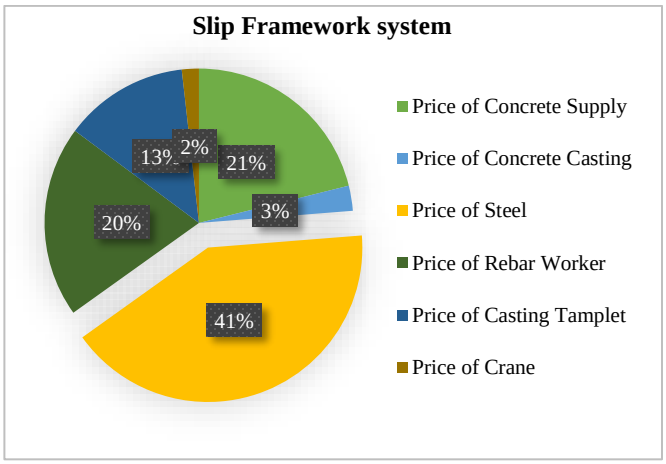

Fig. 13 Shows the final rates of slip framework ceiling prices

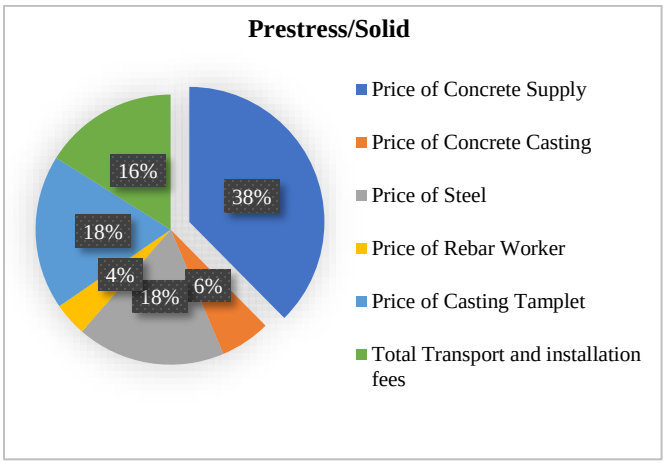

Fig. 16 Shows the final rates of solid ceiling prices

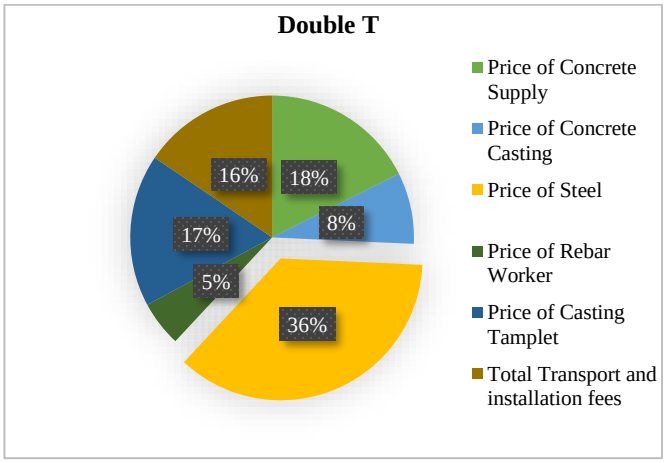

Fig. 14. shows the final rates of double T ceiling prices

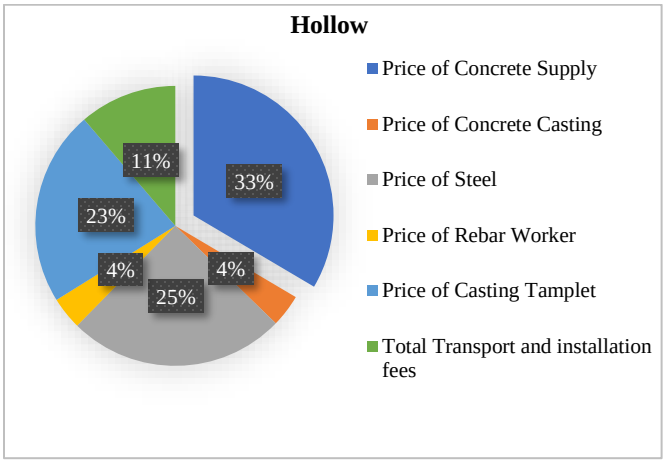

Fig. 17 Shows the final rates of hollow ceiling prices

3. Results and Discussion

3.1. Results

Through the practical study, the following results were reached. The results of the first ceiling system, which is the in-situ casting system (flat ceilings), where the total cost of apartment ceilings was 58,816,151 Iraqi dinars, equivalent to 46,414 dinars per square meter. In the materials stage, the proportion of concrete accounted for 28% of the total cost. As for iron, its percentage was 35%, while the percentage of molds was 32%, and the construction cost percentage was 5%, as shown in detail in Fig. 12. As for the ceilings implemented by the sliding mold system, the total cost of the apartment ceilings was 92,038,274 Iraqi dinars, equivalent to 72,631 dinars per square meter. In the materials stage, the

percentage of concrete formed 21% of the total cost, while the iron percentage was 41%, the percentage of molds was 13%, and the percentage of the construction cost was 1%. 23 As shown in detail in Fig. 13., while the Double T ceilings are of the precast type, the total cost was 54,236,560 Iraqi dinars, equivalent to 42,800 dinars per square meter. In the materials stage, the percentage of concrete constituted 18% of the total cost, while the percentage of iron was 36%, the percentage of molds was 17%, and the percentage of the construction cost was 15%, as shown in detail in Fig. 14.

The ceilings are prestressed, so the first type had Hollow Core Slab; its total cost was 57,632,256 Iraqi dinars, equivalent to 45,480 dinars per square meter. In the materials stage, the percentage of concrete formed 28% of the total cost, while the percentage of iron was 19%, the percentage of molds was 21%, and the percentage of the construction cost was 1%. 16 As shown in detail in Fig. 15, the second type, Solid slab, had a total cost of 75,665,526 Iraqi dinars, equivalent to 59,711 dinars per square meter.

In the materials stage, the percentage of concrete constituted 38% of the total cost; the percentage of iron was 17%, while the percentage of molds was 19%. The percentage of the construction cost was 12%, as shown in detail in Fig. 16., and the last type is Hollow Slab; its total cost is 87,305,746 Iraqi dinars, equivalent to 68,897 dinars per square meter. In the materials stage, the percentage of concrete constituted 34% of the total cost, while the percentage of iron was 25%, the percentage of molds was 22%, and the percentage of the construction cost was 8%, as shown in detail in Fig. 17.

3.2. Discussion

It's noted through the aforementioned results and costs that the largest percentage of all systems was for materials (concrete and reinforcing steel), for in-situ and precast casting systems, the largest percentage was for reinforcing steel, because these types of systems need larger quantities of reinforcing steel, as the percentages reached 15.21% for flat ceilings And 39.97% for the sliding formwork, as for the double T precast, it amounted to 12.45% compared to the quantities of reinforcing steel for the prestressed system, while in the prestressed system, it's noticed that the largest percentage is for concrete, because this system requires a different type of concrete in terms of strength than the concrete used in the systems.

The other, where the price of a cubic meter of concrete for the prestressed system is 90,800 Iraqi dinars, while the price of a cubic meter of concrete is 65,000 for other systems, where the proportions of concrete reached 14.20% for the hollow core system and 22.85% for the solid system, while it reached 21.74% for the latter system, the Hollow, while the labor force was The largest proportion of the sliding formwork system, which amounted to 23% of the total cost of ceilings. The reasons may be due to the novelty of this type of system locally. Therefore the labor force requires high skill, or the labor force may be of different nationalities from outside the country compared to local labor who work in traditional construction, as their percentage was the lowest among all labor cost ratios for all systems, as they did not.

The percentage exceeds 5% of the total cost of ceilings. In terms of templates, the largest percentage was for the flat ceiling system, which is the wooden template, as the percentage reached 32%, while the lowest percentage was for sliding templates, where the percentage of the template was calculated as 15% of the total cost, as mentioned in some previous studies. Also, these templates can be reused In other projects compared to the wooden templates that are used in traditional construction, as they are exposed to damage and, therefore, cannot be reused more than once.

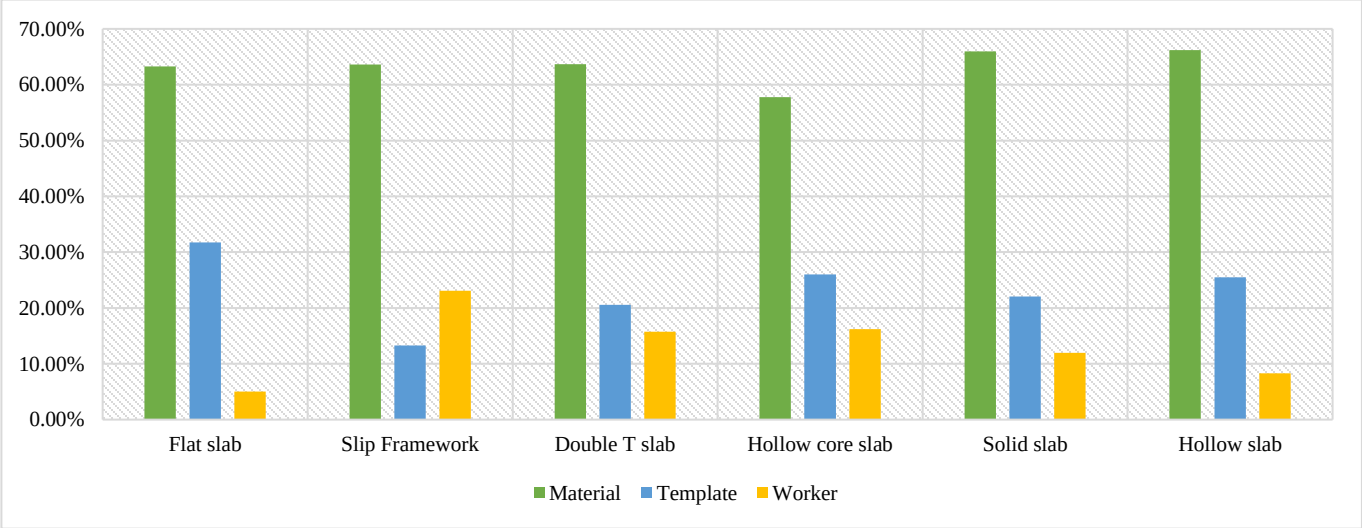

Fig. 18 Shows a comparison between all systems (for mold materials and labor)

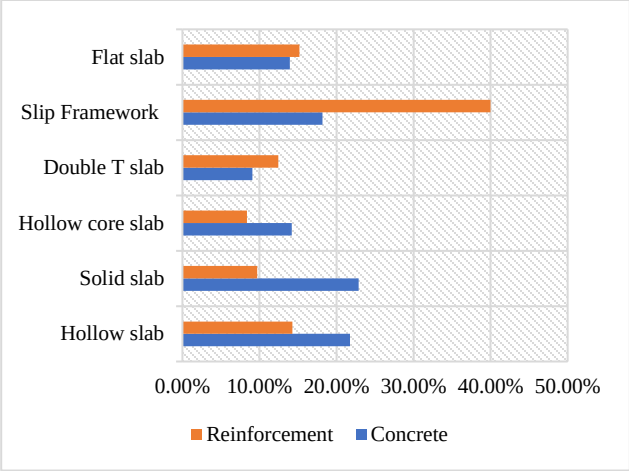

Fig. 19 Shows a comparison between all systems (materials with labor)

It is clear that there is a discrepancy between the prices of the systems in general and a discrepancy between the costs of the paragraphs in each system individually. Several reasons can explain this, (1) cost, material prices depending on their type, (2) The quality, molds and the possibility of reusing them more than once, as the more durable the molds are and they are reused in a large way, the lower their cost, (3) Skill, meaning the competence and skill of the labor force and (4) Mechanization, as the prestress systems mainly use machines, while the use of manpower in other systems constitutes the largest part, see Fig. 18. and 19.

Through the discussion, it became clear that this study dealt with detailed aspects to reduce the construction costs of ceilings for multi-floor residential buildings, which included changing the type of roof in addition to the method of construction, as this is an aspect that the rest of the studies did not address in this way in detail. As the studies focused on a group of other aspects, Fig. 1

4. Conclusion

Through the practical study of the ceilings and their results, it is clear that the precast ceiling system is the least expensive among the other systems, as the price per square meter reached 42,800 Iraqi dinars. Therefore, the adoption of this system in multi-floor housing will lead to a significant reduction in construction costs. Thus, it is possible to provide housing units which are at a lower cost compared to implementing them in other ways. At the same time, the sliding formwork system was the highest cost among all systems, as the price per square meter of it reached 72,631 Iraqi dinars because it may not be commensurate with the local reality of the city. The reason may be because this system is considered Somewhat modern. For this reason it was the most expensive among the other types, but in the future, it may be more used locally, and thus this will lead to reducing costs for this system.

Acknowledgments

Through the practical study of the ceilings and their results, it is clear that the precast ceiling system is the least expensive among the other systems, as the price per square meter reached 42,800 Iraqi dinars. Therefore, the adoption of this system in multi-floor housing will lead to a significant reduction in construction costs. Thus, it is possible to provide housing units at a lower cost compared to implementing them in other ways. At the same time, the sliding formwork system was the highest cost among all systems, as the price per square meter of it reached 72,631 Iraqi dinars because it may not be commensurate with the local reality of the city. The reason may be because this system is considered Somewhat modern, and for this reason, it was the most expensive among the other types, but in the future, it may be more used locally and thus will reduce costs for this system.

References

[1] Surendra, B.V., and Ravindra, R, "A Study on Affordable Roofing System Using Bricks as Infill," *Asian Journal of Science and Technology*, vol. 10, no. 4, pp. 9624-9627, 2019.

[2] M. J. Carretero-Ayuso, and J. García-Sanz-Calcedo, "Comparison between Building Roof Construction Systems Based on the LCA," *Journal of Construction*, vol. 17, no. 1, pp. 123-136, 2018. *Crossref*, http://dx.doi.org/10.7764/RDLC.17.1.123

[3] Renata Tubelo et al., "Comfort within Budget: Assessing the Cost-Effectiveness of Envelope Improvements in Single-Family Affordable Housing," *Sustainability*, vol. 13, no. 6, pp. 1-23, 2021. *Crossref*, https://doi.org/10.3390/su13063054

[4] Majed Abuseif, and Zhonghua Gou, "A Review of Roofing Methods: Construction Features, Heat Reduction, Payback Period and Climatic Responsiveness," *Energies*, vol. 11, no. 11, pp. 1-22, 2018.*Crossref*, https://doi.org/10.3390/en11113196

[5] Aiman Albatayneh et al., "The Effectiveness of Infiltration Against Roof Insulation Aimed at Low Income Housing Retrofits for Different Climate Zones in Jordan," *Environmental and Climate Technologies*, vol. 24, no. 3, pp. 11-22, 2020. *Crossref*, https://doi.org/10.2478/rtuect-2020-0082

[6] Rosana Gaggino et al., "The Comprehensive Comparison of Thermal and Physical-Mechanical Properties of the Recycled Rubber and Plastic Roofing Tiles Versus Roofing Tiles Made with Different Traditional Materials," *Advances in Civil Engineering*, vol. 2018, pp. 1-11, 2018. *Crossref*, http://dx.doi.org/10.1155/2018/7361798

[7] Andy Binh Duong Le, Andrew Whyte, and Wahidul K. Biswas, "Carbon Footprint and Embodied Energy Assessment of Roof Covering Materials," *Clean Technologies and Environmental Policy*, vol. 21, no. 11, pp. 1913-1923, 2019. *Crossref*, https://doi.org/10.1007/s10098-018-1629-9

[8] M. F. Victoria, G. Deveci, F. Musau and M. Clubb, "Life Cycle Carbon and Cost Assessment Comparing Milled and Whole Timber Truss Systems and Insulation Options for Affordable Housing," Advances in Civil Engineering, pp. 0-20, 2018.

[9] V. Gandhe, "Cost Effective Design Technique for Hollow-Core Concrete Slab for Typical Forms & Shapes of Cut Outs," *SSRG International Journal of Civil Engineering*, vol. 9, no. 9, pp. 22-26, 2022. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V9I9P104

[10] Ali E. Hajiah, and Hamed H. Saber, "Long-Term Energy and Moisture Performance of Reflective and Non-Reflective Roofing Systems with and Without Phase Change Materials under Kuwaiti Climates," *Gulf Conference on Sustainable Built Environment*, pp. 453-482, 2020. *Crossref*, https://doi.org/10.1007/978-3-030-39734-0_26

[11] Muneer K. Saeed, and Ahmad A. Alhakeem, "Selection of Optimum Structural Roof System in Saudi Arabia for A Conference Hall Without Interior Columns in Terms of Cost and Feasibility," *Innovative Infrastructure Solutions*, vol. 6, no. 1, pp. 1-14, 2021. *Crossref*, https://doi.org/10.1007/s41062-020-00377-w

[12] Kala Suresh Bhangennavar, and Basavaraj Saunshi, "Alternate Design Forms for An Industrial Structure," *SSRG International Journal of Civil Engineering*, vol. 9, no. 8, pp. 1-9, 2022. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V9I8P101

[13] Alfred A. Yee, "Social and Environmental Benefits of Precast Concrete Technology," *Prestressed Concrete Institute (PCI) Journal*, vol. 46, no. 3, pp. 14-19, 2001. *Crossref*, https://doi.org/10.15554/pcij.05012001.14.19

[14] Anagha Katti, and Milind Darade, "Project Crashing to Solve Time-Cost Trade-Off," *SSRG International Journal of Civil Engineering*, vol. 3, no. 1, pp. 10-27, 2016. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V3I1P103

[15] Alfred A. Yee, and Hon. D, "Structural and Economic Benefits of Precast Prestressed Concrete Construction," *Prestressed Concrete Institute (PCI) Journal*, vol. 46, no. 4, pp. 34-42, 2001. *Crossref*, https://doi.org/10.15554/pcij.05012001.14.19

[16] Debrah Kwame Donkor, and Shaibu Mahamud, "Comparative Assessment of Formwork Systems Used in Construction Projects in the Tamale Metropolis of Northern Ghana," *SSRG International Journal of Civil Engineering*, vol. 9, no. 2, pp. 44-50, 2022. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V9I2P104

[17] Saravanan J et al., "Low Cost Roofing Tiles Using Agricultural Wastes," *SSRG International Journal of Civil Engineering*, vol. 4, no. 3, pp. 58-62, 2017. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V4I3P115

[18] A. G. O. P. R. F. T. Site, Directorate of Housing, Ministry of Construction, Housing, Municipalities and Public Works, 2021. [online]. Available:Https://Alaskan.Moch.Gov.Iq/2021/12/24/%D8%A7%D9%84%D9%85%D8%Ac%D9%85%D8%B9-%D8%A7%D9%84%D8%B3%D9%83%D9%86%D9%8a-%D9%81%D9%8a-%D9%86%D9%8a%D9%86%D9%88%D9%89-%D8%A7%D9%84%D8%Ad%D8%Af%D8%A8%D8%A7%D8%A1/.

[19] Mitesh Mahendra Shah, and Abhishek Dilip Sawant, "Project Cost Management," *SSRG International Journal of Civil Engineering*, vol. 4, no. 11, pp. 1-3, 2017. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V4I11P101

[20] Emadaldin Mohammadi Golafshani, and Siamak Talatahari, "Predicting the Climbing Rate of Slip Formwork Systems Using Linear Biogeography-Based Programming," *Applied Soft Computing Journal*, vol. 70, pp. 263-278, 2018. *Crossref*, https://doi.org/10.1016/j.asoc.2018.05.036

[21] G. D. Nasser, M. Tadros, A. Sevenker and D. Nasser, "The Legacy and Future of an American Icon: the Precast, Prestressed Concrete Double Tee," *Prestressed Concrete Institute (PCI) Journal*, vol. 60, no. 4, pp. 49-68, 2015. *Crossref*, https://doi.org/10.15554/pcij.07012015.49.68

[22] Anagha Anirudh Galagali, "Time-Cost-Quality Trade-Off in Construction Project Management," *SSRG International Journal of Civil Engineering*, vol. 4, no. 8, pp. 24-31, 2017. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V4I8P104

[23] Donald R. Buettner, and Roger J. Becker, *PCI Manual for the Design of Hollow Core Slabs*, 2nd edition Precast / Prestressed Concrete Institute, 1998.

[24] E. Rammo, EMAD RAMMO, 2020. [Online]. Available: https://emadrammo.wordpress.com/page/2/