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Impact of Construction Systems on Project Timelines: A Case Study of Multi-Floor Affordable Residential Buildings

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ABSTRACT

The time required to implement projects is one of the basic elements for evaluating the performance of these projects, as the project is considered successful if it is delivered on time, and there are many and multiple reasons that lead to delay in the project time. Delay in time is considered one of the important problems that affect the performance of projects. This research aims to know the role of the structural systems used in the construction of multi-storey concrete buildings in reducing construction time and thus reducing the total time required to implement projects. A group of structural systems commonly used locally in the city of Mosul were applied, such as (1- Traditional building system - in-situ pouring of concrete 2- The Tunnel system and 3- The prefabricated system - pre-casting of concrete, in addition to 4- A proposed system within the study, which is a combination of 1 and 3) on a model of a multi-storey residential project, in view of the great need for residential units and the importance of implementing them at an appropriate time compared to the cost achieved from that. This can be considered the optimal time for implementation while maintaining the necessary efficiency for these projects. To test the research hypothesis which states that the construction system has an important role in achieving the optimal time for project implementation, the data obtained from each system was extracted and compared, then the completion rates for the first 100 hours of work were calculated. In an attempt to determine the system that achieves the optimal time required for construction, it was concluded that it is difficult to determine the optimal system directly, but it can be considered that the prefabricated building system can be considered the optimal system on the one hand, and the time and Mixed System can be considered the optimal system in terms of cost, and the results. The study may help decision-makers who are specialists in the construction industry to take appropriate measures and determine the appropriate construction system in constructing projects.

1. INTRODUCTION

Today's construction industry places great emphasis on project completion time, as it is a critical factor influencing project outcomes, as the saying “time is money” has become a reality, this is due to the fact that every delay not only results in the loss of time but also increases project costs because of potential penalties and compensations [1, 2], as time is one of the elements. Time is a fundamental metric for evaluating project performance, and a project is typically deemed successful if it is delivered on time.

Some studies have determined that (time and cost) are the basis for evaluating any project and its quality [3], while (building type) is also considered a strong influence on project time, as small residential and educational projects require more time than larger industrial projects [4]. (Time, quality, and cost) have been identified as among the basic goals of every project [5], and a measure of the performance of any project. They have been considered as main goals, but they are contradictory at the same time. Given the importance of time, there are many factors that may affect the time of project implementation and in the various stages. There are factors in the stage before obtaining the project and during project implementation, and all factors affecting the project time are different for each country from the other, meaning that each country has its own factors and may also differ from one city to another within one country [6], and even the factors affecting time. It includes different types of projects, such as new construction projects, equipment projects only, renovation projects only, or construction and renovation projects [3]. For example, in Malaysia, based on 359 construction projects, the projects that are completed on time do not exceed only 18.2% of public projects and 29.5% of private projects. As for the rest of the projects, they exceeded their specified time, therefore, by rates amounting to 49.7% [2].

Numerous factors can impact the timeline of a project, and consequently, the final cost, including the type of construction, the location, the customer, the productivity of the worker, which includes technology, which is the mix of labor / equipment, and the type of contract [7], as well as the reasons related to financing and delay in payment for additional work in addition. To the delay in the payment of funds to the suppliers by the contractor, and also changes in the design by the owner are all considered among the main reasons for the delay in construction [8]. All this in addition to the type of project, the owner, the financing entity for the project, the contractor, the consulting engineer, the design, the materials, factory and equipment, labor, environment, contract for the project, changes, scheduling and control, government relations [6], and often the most important problems facing the construction industry that lead to delays or lead to stopping construction on the site and non-completion of project paragraphs are weather conditions and lack of labor [9]. And many other reasons, and although many studies dealt with the causes of delay in the construction of projects, most of the studies did not focus on the impact of the structural system, as choosing the appropriate structural system is one of the important and fundamental decisions that are taken when starting any project. This is from several aspects, including: if the system is commensurate with the type of building in terms of functionality and aesthetics, in addition to the importance of the impact of this system on the economic side of the project [10], meaning that choosing the structural system as a first step will directly affect the project time, and this is what the study aims at, which is an impact. The type of construction system depends on the time of project implementation.

The research assumes that the structural system used in the implementation of the project has a major role in reducing or increasing the project implementation time. Therefore, the study aims to explore and determine the role of the structural system in reducing or increasing the project implementation time. This will be done by conducting a comparison between a group of construction systems implemented in different construction methods, Figure 1 on one of the types of buildings in which the time factor is very important, which is the type of multi-storey residential buildings due to the increasing need for housing units in the world in general and Iraq (Mosul Governorate) especially.

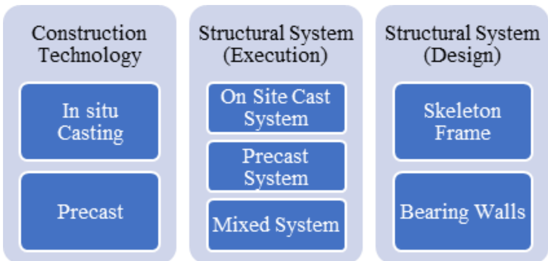


Figure 1. The systems that have been focused on in the practical study

2. RESEARCH METHODOLOGY

In the context of organizing the research process and achieving the specific goals to reach the research results, the methodology used in the research can be summarized in the following steps:

1. Determine the types of structural systems that are most common locally in multi-story buildings and that will be adopted in the study.
2. Determine the study sample that will be studied.
3. Re-designing the structural structure of the sample in accordance with the specified structural systems.
4. Collecting preliminary information related to time and cost.
5. Applying the collected information to the study sample, conducting the comparison, and obtaining the results.
6. Evaluate and analyze the results. The collected data is evaluated and analyzed to draw study conclusions.
7. Research recommendations and conclusions.

3. THE MOST COMMON STRUCTURAL SYSTEMS LOCALLY IN MULTI-STOREY BUILDINGS

Concerning material selection and construction methodologies, the study prioritized the usage of those that are most common and readily available locally [11, 12]. This preference is informed by the financial implications of importing materials and technologies from abroad, which would invariably augment the overall construction costs. In terms of materials, the practical study for constructing building structures was based on two materials (concrete and rebar). These materials were chosen due to their prevalent utilization in the construction of multi-storey buildings and their wide local availability. As for the construction systems and construction methods used, they are the most widely used methods in constructing multi-storey buildings locally.

3.1 On-site cast System

In this system, all building construction processes take place within the site, and it has several types, including:

1. Flat slab System:

In this system, roofs are supported by columns without the presence of intermediate beams, and it is used in the construction of educational, residential, and other buildings [13].

2. Tunnel System:

This system is one of the construction systems that is characterized by the speed of completion, and it is a mold that is shaped closer to the box and is made of steel, as it is characterized by the possibility of completing a full slab of reinforced concrete in one day, and this system is more economical in the event that the work is similar as in residential complexes In which the work is very large, in addition to the buildings being all the same [1].

3.2 Precast System

The building that is created in this way goes through two stages, where the first stage is outside the site (in factories), so all the pieces that make up the building are created, and these factories may be very far from the project site and therefore they will need a way to transport them to the site, or the factory may be It is close to the project site and therefore the process of transporting the pieces is easier. As for the second stage, it begins after transporting the components that make up the building to the site, which is the building installation stage, and the installation process takes place in different ways [14]. This type of system has a set of advantages, including:

(1) Formwork in prefabricated construction can be reused a large number of times, thus reducing formwork costs [15].

(2) Prefabricated construction helps reduce the number of workers on site and thus reduce noise [16, 17].

(3) Work continues and does not stop from time to time due to weather conditions, thus reducing the final construction time [9, 15].

(4) One of the biggest benefits of relying on off-site manufacturing is reducing construction periods, by creating the elements in the factory at the same time that the site work is being completed, as precast foundations are rarely adopted, so it is possible to complete the site work and create the foundations on site. In conjunction with prefabrication work [18].

(5) Because the manufacturing process takes place inside

factories, it is subject to good control and management of materials compared to the on-site casting system [14].

3.3 Precast System and in situ casting (Mixed System)

This system through which the building is constructed in two ways, where part of the building is made of prefabricated elements (created in factories) and installed inside the site, and the other part of the building is a site casting of reinforced concrete.

4. CASE STUDY

Conditions for selecting the sample for the practical study:

The study sample, represented by Al-Hadbaa Residential Complex, was chosen based on a number of affordable housing standards that apply to it. Usually, it is preferable for affordable housing buildings to be multi-storey [11, 12] and not single dwellings, due to the high cost of land, and all residential buildings in the complex consists of three floors and therefore no elevators were used in it because the number of floors is small and also due to the high cost of elevators. The entire complex contains only two types of apartments and three types of residential buildings, meaning that there is repetition in the design and this is also one of the requirements for achieving affordable housing. This project is considered one of the latest projects completed in the city of Mosul.

The research hypothesis will be tested on the study sample. This project is considered one of the economic residential projects, with a total area of about 144,847,748 m^2 (Figure 2). This project consists of a group of buildings, numbering 56 residential buildings, and each building consists of 3 floors, and each floor contains 3 residential apartments of different sizes, in addition to the staircase area and movement corridors [19]. The project was referred to the executing company in the year 2004, but the construction period of the project was not continuous and went through many interruptions, as the project was completed in the year 2013, according to what was stated on the official website. To the Iraqi Ministry of Housing [20]. The project site was divided into four parts, and each part consists of 14 residential buildings (Figure 3).

Figure 2. Site plan for the source project

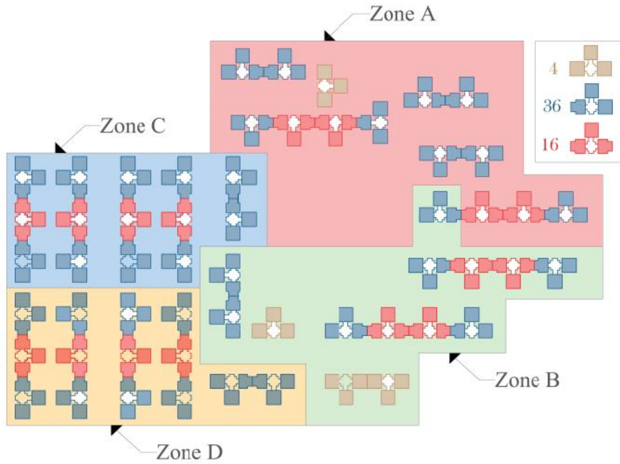


Figure 3. The division of the site into four areas to conduct the practical study

5. REDESIGN

The four parts of the site will be implemented using four different construction systems, and then a quantitative comparison will be made between these systems, which includes a comparison of the time spent implementing each system in addition to the construction cost. Therefore, the structural design must be done for the different types of construction systems, where a sample design has been redesigned. Study in accordance with the different construction systems and determine the dimensions of the elements and the necessary amount of reinforcement, in cooperation with a specialized civil engineer.

5.1 Flat slab System

The first system is the traditional building system (structural system), which was applied to (Zone A), where the traditional local construction method common in the city of Mosul, which is on-site construction (on-site concrete pouring), was adopted, and the original plans of the project were approved (Figure 4), mock-up. A three-dimensional model of a residential building showing a reinforced concrete structure for the building. Figure 5 shows a plan of a type of apartment.

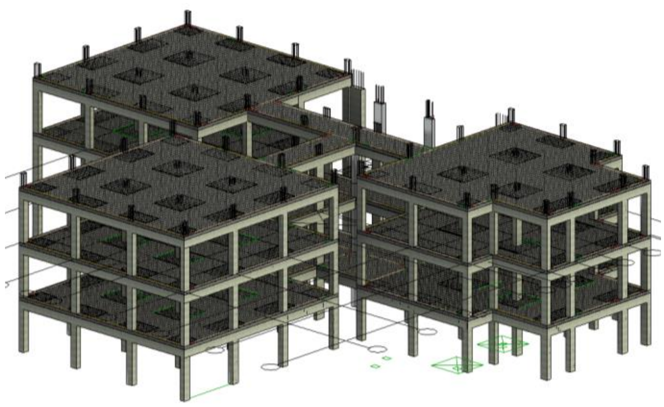


Figure 4. A structural model of a residential building

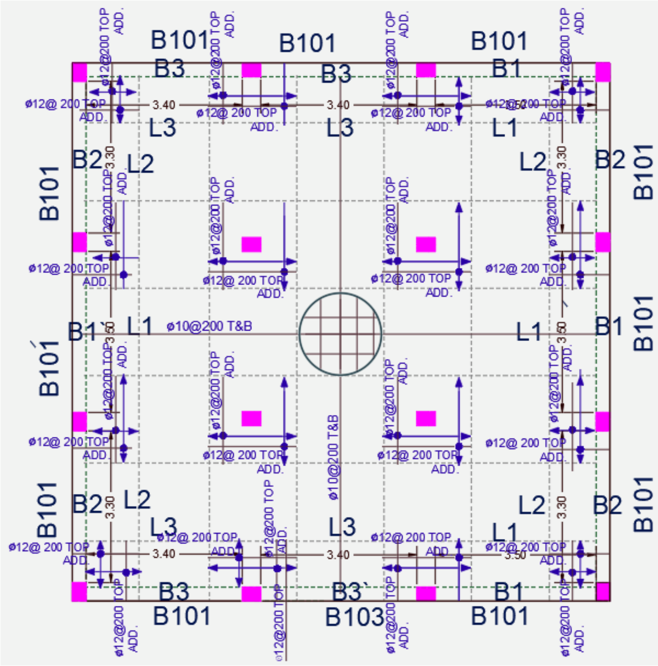


Figure 5. A structural plan for the apartment's roof

5.2 Tunnel System

The second system is the Tunnel system, which was applied to (Zone B). This system is not considered very common compared to the first system, but it is a new system locally and has begun to be used to construct multi-storey buildings. It is considered one of the site casting systems, meaning that all construction stages take place inside the site, and Regarding the design, the structural design of the plans was carried out and the entire structural system was changed compared to the reality of the situation (the first case), from the structural system of columns and beams to the system of reinforced concrete walls and ceilings, based on the original plans in terms of dimensions and heights of the floors (Figures 6, 7).

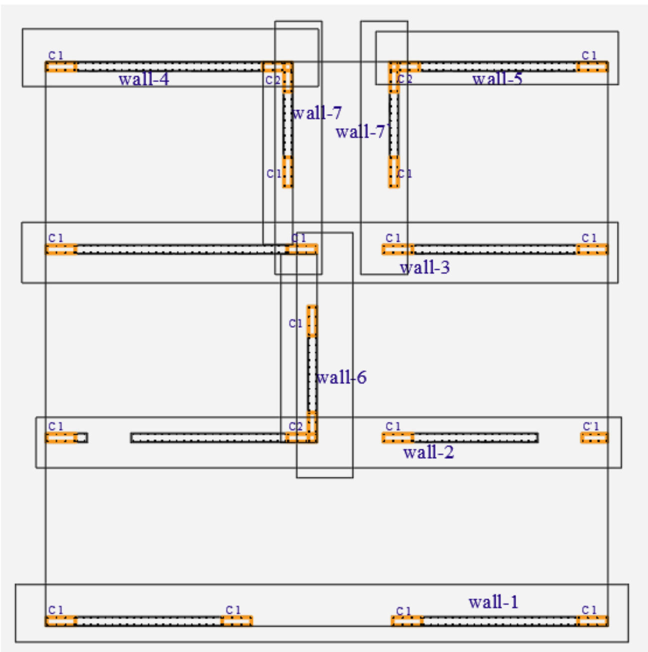


Figure 6. A plan showing the structural design of walls

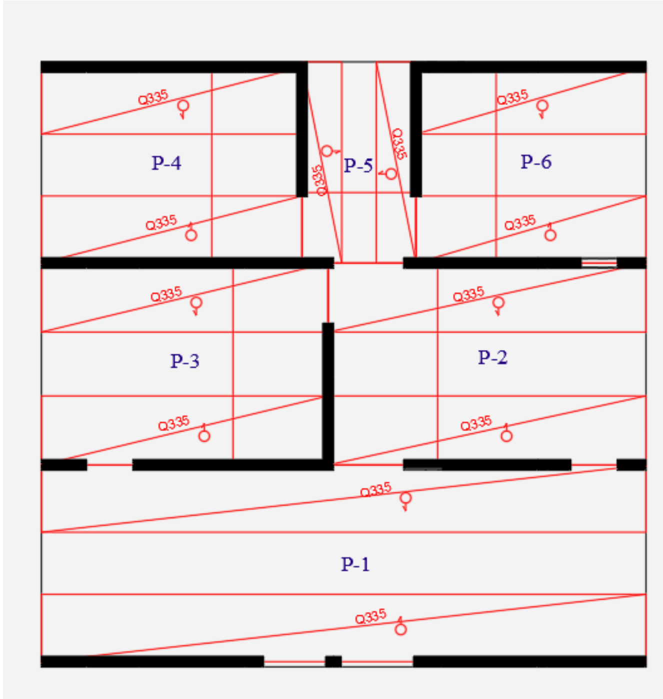


Figure 7. A plan showing the structural design of roof

5.3 Precast system

The prefabricated building system, which was applied to (Zone C), is the third proposed system, which is considered one of the well-known systems locally. There are various projects in Mosul and Iraq in general implemented using the prefabricated construction method. With regard to the design of the prefabricated building system, the buildings have been redesigned to be compatible with this system, as the main dimensions of the reality of the situation (the first case) were relied upon and changes were made in the dimensions to suit the proposed construction method, as this method depends on the modular dimensions, which are based on (60 cm) (Figure 8), so the basic dimensions of the plans were increased to suit the model. The dimensions of the original apartment were 11.7 x 11.7 m, but my design of the apartment for the precast system became 12 x 12 m.

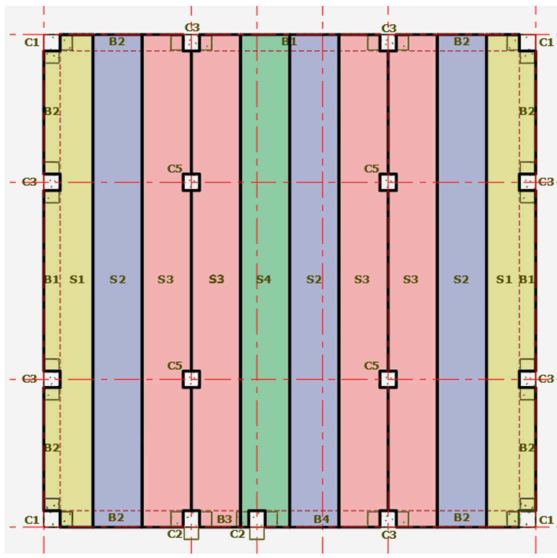


Figure 8. A construction plan for the apartment with a precast system

5.4 The proposed system is the integration of the precast system and the in situ casting Mixed System

The Mixed System was applied to (Zone D). In this system, the first system was mixed, which is the traditional construction (on-site pouring of concrete) to implement the columns and stair area, and the third system is the prefabricated construction system (pre-casting of concrete) to implement the beams and roofs, as the structural designs shown were adopted. in the previous parts.

6. GATHER INFORMATION

A number of field visits were made to different sites of engineering projects and a visit to a consulting company in the city of Mosul for being one of the most important companies in the province. Some interviews were conducted with experts and specialists from the implementing engineers and consulting engineers in the companies in the provinces of Dohuk and Baghdad, where the experts were selected. On the basis of their great experience in the field of project implementation, the interviews were conducted in order to obtain preliminary information that will help in completing the next part of the practical study and to be able to make a comparison between the different construction systems. The information obtained included:

(1) Execution times for the construction stages of residential building structures in detail, which differ from one system to another, as the on-site casting systems consist of (the reinforcing stage, the mold installation stage, and the concrete pouring stage). As for the precast concrete system, the implementation times for the construction stages of the structure included installation inside the site exclusively and for the different elements (columns, beams, ceilings and stairs), each of which has a different installation time.

(2) Costs of establishing structures (exclusively labor costs).

7. PRACTICAL APPLICATION

After collecting the information required to begin the practical study and making a comparison between construction systems in terms of time and cost, and despite the differences in factors affecting the measurement of project performance as mentioned previously, this study relied on the factors (time, cost, quality), and in this study the aspect was neutralized. Quality, as this factor is supposed to be present in all systems within the test, and the steps followed in implementation that were obtained through interviews are applied in practical life and also cannot be measured through a specific program. For these reasons, the quality aspect was neutralized and the focus was on the impact of the construction system on both time and cost (Figure 9). Calculations related to time and cost were performed as shown in the following paragraphs.

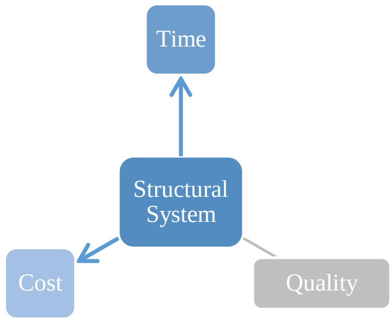
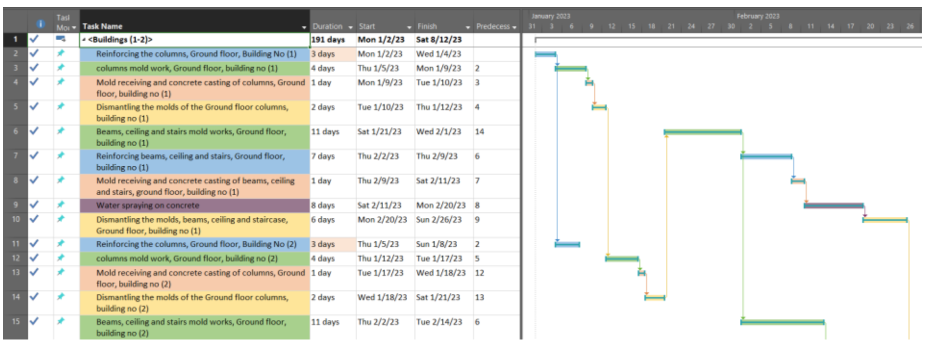


Figure 9. The impact of the structural structure on (time, cost, and quality)

7.1 Time calculations

In this part, the Microsoft Project program and the Excel program were relied upon in order to perform calculations related to the total time for project implementation, where information about the implementation times was entered to reach the total time spent in days and hours. The duration of the project start was determined by default from the date 1/1/2023 either the number of working hours varies from one system to another depending on the type of system used in addition to the system of the company that was communicated with, where 8 working hours were specified for all the proposed systems except for the Tunnel system, where the number of working hours is 12 hours, and the weekly holidays were Friday. Only, and annual holidays are 8 days only.

The construction times for residential building structures across the four parts of the site were calculated. The first part was executed using the in-situ casting method, employing a structural system of flat ceilings. The process involved setting up wooden templates, placing reinforcing steel, and pouring concrete for each of the columns, beams, ceilings, and stairs. Cumulative calculations were conducted to determine the total time required to establish this initial system (Figures 10, 11). The final results were determined for 14 residential buildings, and the same method was adopted for the other three systems.



	Task Name	Duration	Start	Finish	Predecessors
1	<Buildings (1-2)>	191 days	Mon 1/2/23	Sat 8/12/23	
2	Reinforcing the columns, Ground floor, Building No (1)	3 days	Mon 1/2/23	Wed 1/4/23	
3	columns mold work, Ground floor, building no (1)	4 days	Thu 1/5/23	Mon 1/9/23	2
4	Mold receiving and concrete casting of columns, Ground floor, building no (1)	1 day	Mon 1/9/23	Tue 1/10/23	3
5	Dismantling the molds of the Ground floor columns, building no (1)	2 days	Tue 1/10/23	Thu 1/12/23	4
6	Beams, ceiling and stairs mold works, Ground floor, building no (1)	11 days	Sat 1/21/23	Wed 2/1/23	14
7	Reinforcing beams, ceiling and stairs, Ground floor, building no (1)	7 days	Thu 2/2/23	Thu 2/9/23	6
8	Mold receiving and concrete casting of beams, ceiling and stairs, ground floor, building no (1)	1 day	Thu 2/9/23	Sat 2/11/23	7
9	Water spraying on concrete	8 days	Sat 2/11/23	Mon 2/20/23	8
10	Dismantling the molds, beams, ceiling and staircase, Ground floor, building no (1)	6 days	Mon 2/20/23	Sun 2/26/23	9
11	Reinforcing the columns, Ground floor, Building No (2)	3 days	Thu 1/5/23	Sun 1/8/23	2
12	columns mold work, Ground floor, building no (2)	4 days	Thu 1/12/23	Tue 1/17/23	5
13	Mold receiving and concrete casting of columns, Ground floor, building no (2)	1 day	Tue 1/17/23	Wed 1/18/23	12
14	Dismantling the molds of the Ground floor columns, building no (2)	2 days	Wed 1/18/23	Sat 1/21/23	13
15	Beams, ceiling and stairs mold works, Ground floor, building no (2)	11 days	Thu 2/2/23	Tue 2/14/23	6

Figure 10. A detailed part of the actual time calculations for the construction of the first system - Skeleton Frame (Flat roofs)
Source: Researcher

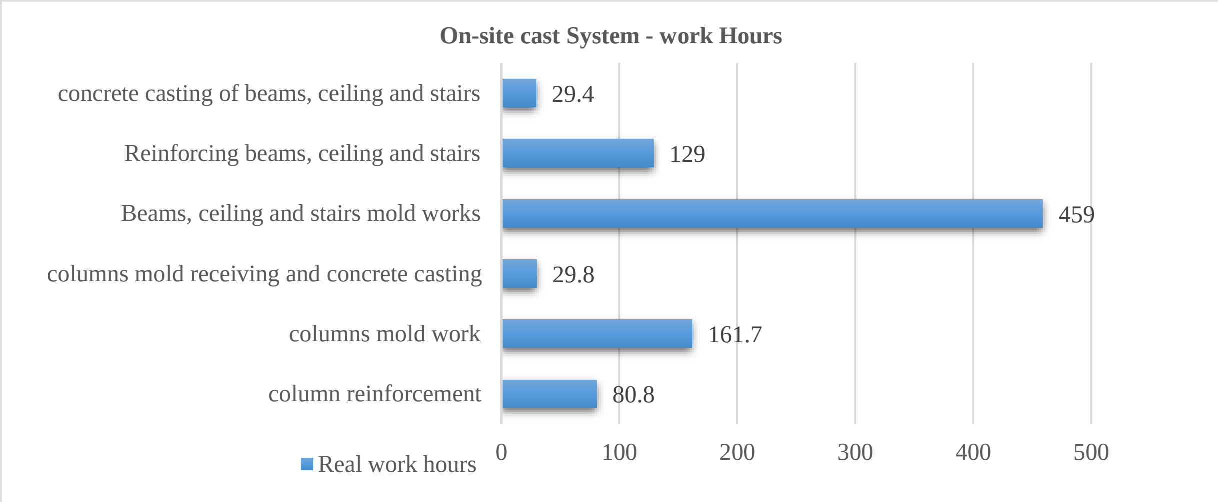


Figure 11. The number of hours to construct one building - the first system - Skeleton Frame (flat roofs)
Source: Researcher

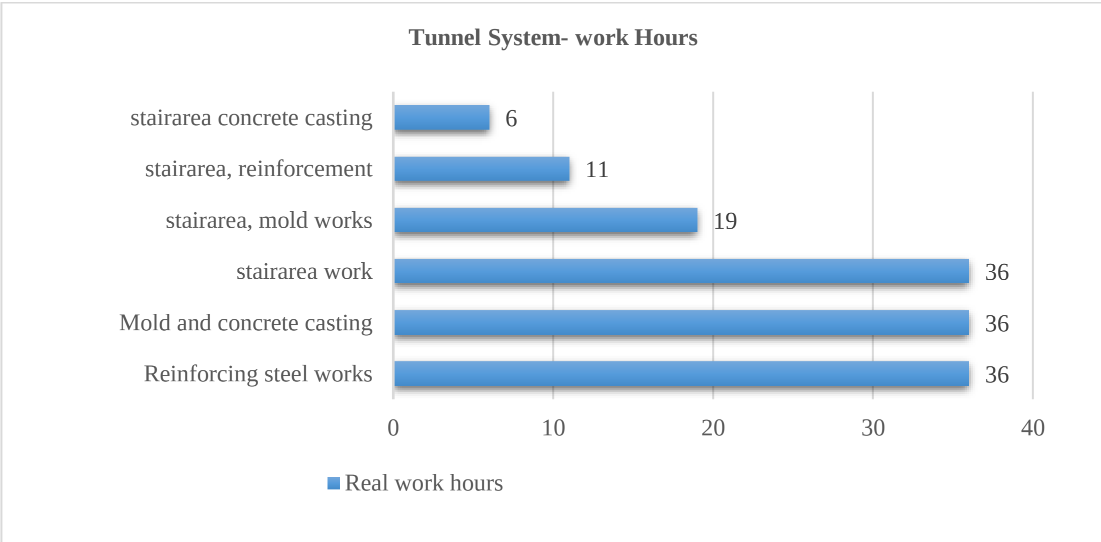


Figure 12. The number of hours to construct one building - the second system
Source: Researcher

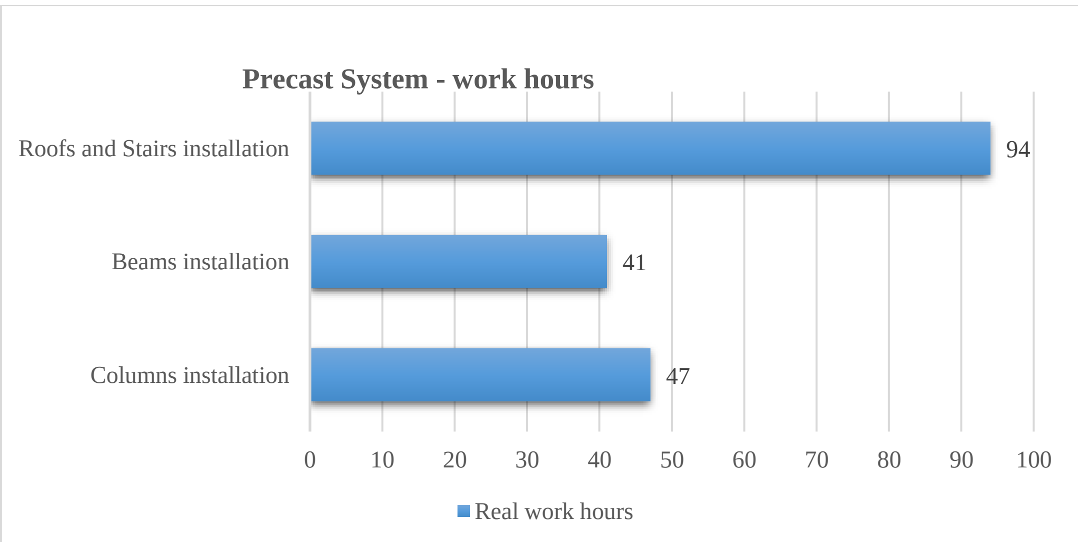


Figure 13. The number of hours to construct one building - the third system
Source: Researcher

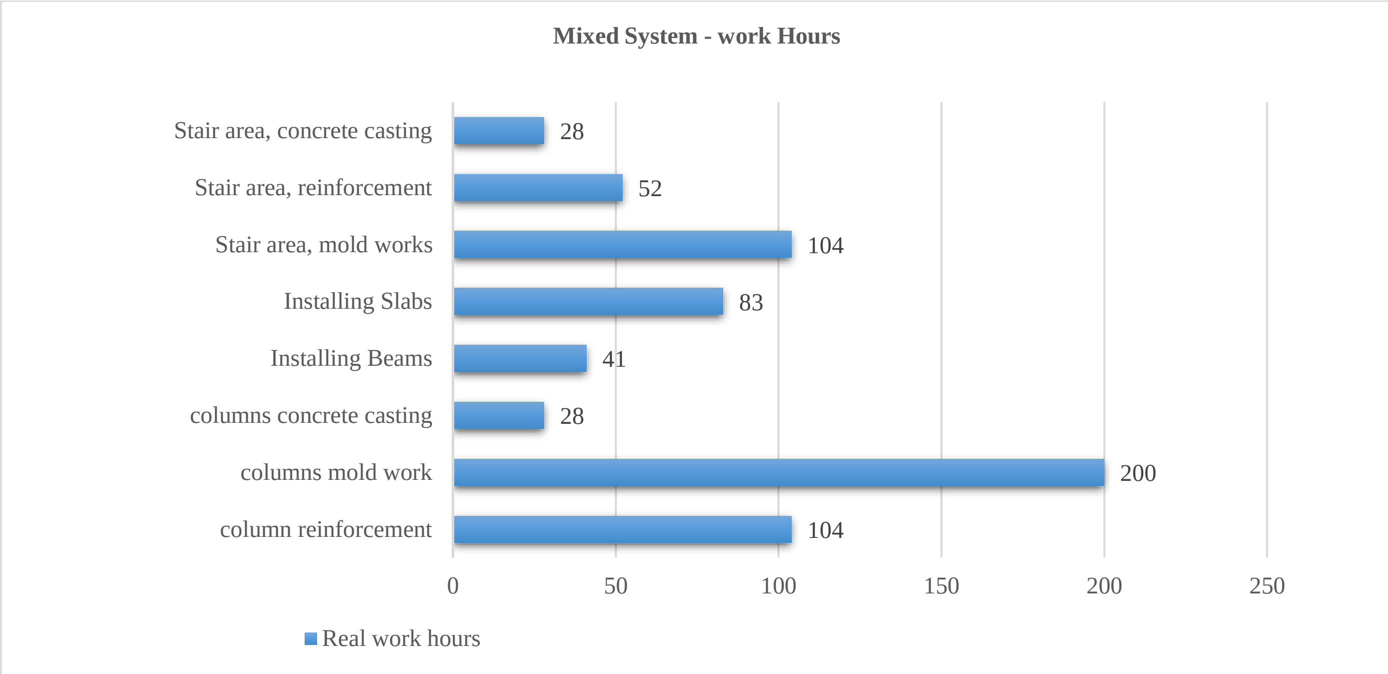


Figure 14. The number of hours to construct one building - the fourth system – Mixed System
Source: Researcher

The Tunnel system, where the construction of the apartment structures was adopted on the Tunnel system. As for the central area (the staircase area), the traditional system was adopted with wooden templates in the construction process (Figure 12), and the prefabricated building system was adopted as the entire structure (apartments and the staircase area) from pre-cuts. Manufacture, and only the calculations were based on the installation time at the site, given that the elements are ready and transported from the factory without addressing the time spent in constructing the pieces inside the factory (Figure 13). The other is pre-cast, where the columns and the middle area (the staircase area) including ceilings, beams, and the staircase element were identified using the site casting system. As for each of the beams and ceilings of the apartments specifically, they were constructed by installing the precast elements (Figure 14).

7.2 Time calculations

After conducting the total calculations for the construction time of the residential building structures, the completion percentages were calculated for the first 100 hours of work, through the Excel program, where the serial paragraphs were entered from the Microsoft Project program, and the overlapping paragraphs were calculated for some systems, and the final percentages of completion were calculated and are presented in the following tables: Table 1 for the On-site cast System, Table 2 for the Tunnel System, Table 3 for the Precast System, and Table 4 for the Mixed System.

Table 1. The details of the completion percentage calculations for the first 100 hours - the first system - Skeleton Frame (flat roofs)

1- On Site Cast System							
No	**Task Name**	**Duration / Day**	**Work Hours in Day**	**Total Work Hours**	**Completion Amount**	**Total / Time**	**Final Completion Percentage / 100 Hour**
1	**Reinforcing the columns, Ground floor, building No (1)**	3	8	24	3.921	9912	0.242
2	**Columns mold work, Ground floor, building No (1)**	4+1	8	40	256.428	9912	0.404
3	**Mold receiving and concrete casting of columns, Ground floor, building No (1)**	1	8	8	21.811	9912	0.081
4	**Dismantling the molds of the Ground floor columns, building No (1)**	2	8	16	256.428	9912	0.161
5	**Reinforcing the columns, Ground floor, building No (2)**	3+1	8	32	4.049	9912	0.323
6	**Columns mold work, Ground floor, building No (2)**	1.5	8	12	99.374	9912	0.121
				100			1.170

Source: Researcher

Table 2. The details of the completion percentage calculations for the first 100 hours - the second system - Tunnel System

No	Task Name	Duration / Day	Work Hours in Day	Total Work Hours	Completion Amount	Total / Time	Final Completion Percentage / 100 Hour
			2- Tunnel System				
1	Reinforcing works, part A, Ground floor, building No. (1-2)	1+1	6	6	19.244	648	0.926
2	Mold and concrete casting works, part A, Ground floor, building No. (1-2)	1	4.5	4.5	158.192 436.346	648 648	0.309 0.386
	Reinforcing works, part B, Ground floor, building No. (1-2)	1	6	6	19.244	648	0.926
	Dismantling the mold, part A, ground floor, building No. (1-2)	1	1.5	1.5	436.346	648	0.231
3	Mold and concrete casting works, part B, Ground floor, building No. (1-2)	1	4.5	4.5	158.192 436.346	648 648	0.309 0.386
	Reinforcing works, part A, First floor, building No. (1-2)	1	6	6	19.244	648	0.926
	Dismantling the mold, part B, ground floor, building No. (1-2)	1	1.5	1.5	436.346	648	0.231
4	Mold and concrete casting works, part A, First floor, building No. (1-2)	1	4.5	4.5	158.192 436.346	648 648	0.309 0.386
	Reinforcing works, part B, First floor, building No. (1-2)	1	6	6	19.244	648	0.926
	Dismantling the mold, part A, First floor, building No. (1-2)	1+1	1.5	1.5	436.346	648	0.231
5	Mold and concrete casting works, part B, First floor, building No. (1-2)	1+1	4.5	4.5	158.192 436.346	648 648	0.309 0.386
	Reinforcing works, part A, Second floor, building No. (1-2)	1+1	6	6	19.244	648	0.926
	Dismantling the mold, part B, First floor, building No. (1-2)	1	1.5	1.5	436.346	648	0.231
6	Mold and concrete casting works, part A, Second floor, building No. (1-2)	1	4.5	4.5	158.192 436.346	648 648	0.309 0.386
	Reinforcing works, part B, Second floor, building No. (1-2)	1	6	6	19.244	648	0.926
	Dismantling the mold, part A, Second floor, building No. (1-2)	1	1.5	1.5	436.346	648	0.231
7	Mold and concrete casting works, part B, Second floor, building No. (1-2)	1	4.5	4.5	158.192 436.346	648 648	0.309 0.386
	Reinforcing works, part A, Ground floor, building No. (3-4)	1	6	6	19.009	648	0.926
	Dismantling the mold, part B, Second floor, building No. (1-2)	1	1.5	1.5	436.346	648	0.231
8	Mold works, reinforcing and concrete casting staircase area, ground floor, building No. 1	1	12	12			
	Mold and concrete casting works, part A, Ground floor, building No. (3-4)	1	4.5	4.5	156.330 427.526	648 648	0.309 0.386
	Reinforcing works, part B, Ground floor, building No. (3-4)	1	6	6	19.009	648	0.926
	Mold works, reinforcing and concrete casting staircase area, first floor, building No. 1	1	12	12			
9	Dismantling the mold, part A, ground floor, building No. (3-4)	1	1.5	1.5	427.526	648	0.231
	Mold and concrete casting works, part B, Ground floor, building No. (3-4)	1	4.5	4.5	156.330 427.526	648 648	0.309 0.386
	Reinforcing works, part A, First floor, building No. (3-4)	0.917	6	5.5	19.009	648	0.849
				100			15.432

Source: Researcher

Table 3. The details of the completion percentage calculations for the first 100 hours - the third system - Precast System

No	Task Name	Duration / Day	Work Hours in Day	Total Work hours	Completion Amount	Total/ Time	Final Completion Percentage / 100 Hour
			3- Precast System				
1	Installing the columns, Ground floor, apartment (1-2), building no.1	1	8	8	34	2688	0.298
2	Installing the columns, Ground floor, apartment (3) and Stair area, building no.1	1	8	8	23	2688	0.298
3	Installing the beams, Ground floor, apartment (1-2), building no.1	1	8	8	27	2688	0.298
4	Installing the beams, Ground floor, apartment (3) and stair area, building no.1	1+1	8	8	22	2688	0.298
5	Installing roofs and stairs, Ground floor, building no.1	4	8	32	472.800	2688	1.190
6	Installing the columns, First floor, apartment (4-5), building no.1	1	8	8	34	2688	0.298
7	Installing the columns, First floor, apartment (6) and Stair area, building no.1	1	8	8	23	2688	0.298
8	Installing the beams, First floor, apartment (4-5), building no.1	1+1	8	8	27	2688	0.298
9	Installing the beams, First floor, apartment (6) and stair area, building no.1	1	8	8	22	2688	0.298
10	Installing roofs and stairs, First floor, building no.1	0.5	8	4	59.100	2688	0.149
				100			3.72

Source: Researcher

Table 4. The details of the completion percentage calculations for the first 100 hours - the fourth system - Mixed System

No	Task Name	Duration / Day	Work Hours in Day	Total Work Hours	Completion Amount	Total / Time	Final Completion Percentage / 100 Hour
			4- Mixed System				
1	Reinforcing the columns, Ground floor, Building no (1)	4+1	8	32	13.419	5136	0.623
2	Columns mold work, Ground floor, building no (1)	6	8	48	188.15	5136	0.935
3	Mold receiving and concrete casting of columns, Ground floor, building no (1)	1+1	8	8	34.36	5136	0.156
4	Dismantling the molds of the Ground floor columns, building no (1)	1.5	8	12	141.11	5136	0.234
5	Reinforcing the columns, Ground floor, Building no (2)	4	8	32	13.419	5136	0.623
				100			1.95

Source: Researcher

8. RESULTS AND DISCUSSION

8.1 Results

Through the practical study, the final results of the implementation time calculations for the four types of systems appear, as the results showed with regard to the first system, which is the in situ casting (flat ceilings), that it will end on 19/1/2027, i.e., an average of 1239 working days, equivalent to 9912 hours. The second system, which is the Tunnel system, will end on 4/3/2023, meaning that it takes 54 working days, which represents 648 working hours, while the third system, which is the precast construction system, will end on 2/7/2024 at a rate of 336 days, which represents 2688 working hours. The last system, which is a Mixed System between the on-site and pre-cast system, the results show that it will end on 4/2/2025 at an average of 642 days, which represents 5136 hours (Table 5).

As for the percentage of completion for the first 100 hours of work, the results showed that the percentages were uneven, as the largest percentage was for the second system, which is the Tunnel System, as it reached 15.432%, compared to the lowest percentage that was for the first system, which is the On-Site Cast System, as it did not exceed 1.7%. While the Precast System, the completion rate reached 3.72%, and the last Mixed System, the completion rate reached 1.95% (Table 6).

Table 5. The details of the days and hours for the establishment of the four systems

Structural System	Total Time / Days	Total Time / hours
On Site Cast System	1.239	9.912
Tunnel System	54	648
Precast System	336	2.688
Mixed System	642	5.136

Source: Researcher

Table 6. Shows the percentage of completion for the first 100 hours to establish the four systems

Structural System	Final Completion Percentage / 100 Hour
On Site Cast System	1.17
Tunnel System	15.432
Precast System	3.72
Mixed System	1.95

Source: Researcher

As for the final costs (labor costs only) for the four systems, the results showed that the first system (in situ casting) amounted to the total cost of all its paragraphs 82,359,837 IQD, while the second system (Tunnel) amounted to the total cost of all its paragraphs 617,798,886 d. The third system (ready building) cost amounted to 243,992,653 IQD, and the last system is the system (precast and in-situ casting), so the cost amounted to 226,340,573 IQD. The labor cost per hour, is shown in Table 7. It should be noted that the costs shown per hour are for a number of workers and not for one worker only.

Table 7. Shows the percentage of completion for the first 100 hours to establish the four systems

Structural System	Total Cost	Cost / 1Hours
On Site Cast System	82.359.837	8.309
Tunnel System	617.798.886	953.393
Precast System	243.992.653	90.771
Mixed System	226.340.573	44.069

Source: Researcher

8.2 Results analysis and discussion

The results shown in the previous section indicated a clear difference in the tested construction systems and the time required for each of them in the project implementation process, with a clear difference in the results of the completion rates for the first 100 hours of project implementation, and there is also a large discrepancy between the time and cost of a single system, as in the (in-situ casting) and (Tunnel) systems, a large discrepancy is observed between the project time and its cost, as the lower cost was for the more time and the greater cost for the less time, meaning that there is an inverse relationship between time and construction cost for both systems, and this analysis also applies to the percentage of completion that reached up to 15% in the first 100 hours for the construction of building structures in the second system (Tunnel), which is a very large percentage compared to the time spent, while the first system, the percentage of completion in the first 100 hours was 1.17%, which is a very small percentage compared to the time spent. While the percentage of achievement for the other two systems ranged between (1.5-4%) (Table 8). As for the time spent in implementation, the (Tunnel) system has achieved the least time at a very high cost. It can be considered as number (1) in terms of time, while the system (In situ casting took more than 15 times the time of the (Tunnel) system and at a relatively low cost, while the third system (precast) represented more than four times the time spent for the (Tunnel) system and at a relatively reasonable cost when compared to the cost of (Tunnel), which applies to the last system (the Mixed System), which is about eight times likelier, from here we notice that the third system (precast) is the closest to the optimal system, but in terms of cost, the first system (in situ casting) is the most optimal because it is the least expensive Considering it also represents the number (1), we note that the second system (Tunnel) represents 7.5 times the first system (in situ casting), and the third system (precast) represents nearly 3 times, while the fourth system (the Mixed System) represents 2.75 times, accordingly, in terms of time, the (precast) system is considered the closest to the optimal system, while in terms of cost, the fourth system (the Mixed System) is the closest to the optimal system. They are excluded from the comparison because they are very far from the optimal system in terms of time and cost, while the other two systems, the third (precast) and the fourth (Mixed System), are closest to the optimal system in terms of time and cost.

Table 8. The ratio of each system to the optimal system (time - cost)

Structural System	Time	Cost
On Site Cast System	15.30	1
Tunnel System	1	7.50
Precast System	4.15	2.96
Mixed System	7.93	2.75

Source: Researcher

The reasons for the differences that we see between the four systems are due to a number of reasons. In terms of time, and as the results showed, the first system is the most time consuming. This is due to the fact that this system is considered one of the systems that takes a long time to construct as a result of the type of molds used in addition to the type of concrete used locally, which it requires that the concrete remain in the formwork for 8 days before it is removed, in addition to the total reliance on manpower in installing the formwork, which takes a long time because the formwork in this system is small pieces of wood compared to the spaces that are created by it, while the system with the least time (Tunnel system). It depends on a different type of formwork, through which walls and ceilings are created simultaneously, and also the type of concrete that hardens quickly and quickly reaches the required strength, which allows the formwork to be removed the next day and begin constructing the next floor, and the other system (prefabricated construction), where the time for this system includes the time for installing the elements, which takes a little time compared to the first system (on-site casting).

In terms of cost, the most expensive system is the Tunnel system. The reason behind this is that this system is characterized by high costs, primarily due to the requirement for skilled labor, which demands significantly higher wages compared to the first system. The first system, on the other hand, requires inexperienced labor and consequently has lower wage costs. The two systems, Tunnel and prefabricated construction, are generally perceived as more expensive than the first system. This perception may be due to the fact that the first system is one of the most commonly used construction systems in the city of Mosul. Therefore, the general costs of this system are low, and also because this system relies primarily on manpower and there is no reliance on devices or equipment.

The results presented in this study will help construction practitioners determine the construction system used in implementing the project, depending on the main goal of the project, whether it is to complete the project in the least time or the lowest cost, as the choice of construction method greatly affects the final time and cost of any project.

9. CONCLUSIONS AND RECOMMENDATIONS

(1) The research hypothesis was verified that the structural system used in the implementation of the project has a major role in reducing and increasing the project implementation time.

(2) It is not possible to directly determine a specific system to be the optimal among the four systems in terms of time and cost, as the optimal system is the one that achieves the duration of the project at the lowest total cost [21] and that, based on the results that have been reached, is not possible because the least expensive system is the most time consuming, and vice versa, the most expensive system is the least time consuming, meaning that there is a large gap between the least time and the least cost.

(3) Given that the first two systems (in situ casting) and the second (Tunnel) were excluded from the comparison because they are very far from the optimal system, as we noted in the previous paragraph, it is likely that the third system (prefabricated construction) is the optimal one in terms of time, and the fourth system (the Mixed System) is the most optimal in terms of cost, and these two systems do not have a significant increase in time and cost compared to the first and second systems.

(4) The choice of the system depends on the circumstances surrounding the projects and their initial conditions. If time is the most important, then it is possible to resort to the (Tunnel) system in the implementation process, but if the cost is the important factor in the project and the budget specified for the project is low, with no specific time in which it is completed. The completion of the project, the (in-situ casting) system is the best for the implementation of the project.

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