

Comparative Cost Study for A residential Building Using Different Types of Floor System

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Abstract

Cost estimation is a key part for any project planning. It's the process of predicting the quantity, cost, and price of the resources required for any project. The differences in construction methods between different forms of slabs result into variation in the cost of the slabs for any building project. Thus, this study aims at assessing the variation in construction cost among various construction methods available for four different types of floor slab systems. A 3D structural model had been analyzed and designed under a statically gravity loads by using computer software (ETABS v.16). In this study; a 3D model had been designed with different slab systems, solid, ribbed (one & two way), and flat plate slab. After that, quantity survey and cost estimate were done for each system, and a bill of quantity was constructed for each of them. Finally, the most economical system is selected; it is The Flat Plate Slab System.

Keywords: Flat plate, Solid slab, Ribbed slab, Cost estimation, Structural Quantities, Bill of Quantity (BOQ).

I. INTRODUCTION & RELATED WORK

Designing and constructing buildings date back to the existence of man on earth, and over the years, various design and construction methods have evolved. These evolutions have led to modern designs and construction methods of various elements of a building; such as floors, wall, ceilings and roofs [1]. Reinforced concrete structures make up of a set of elements that interact together as a one unit to carry the dead loads and live loads placed on the structure safely.

Most reinforced concrete structures are subdivided into slabs and beams, which are subjected primarily to flexure (bending moment) and Shear forces, and columns, which are subjected to axial compression under gravity load and to bending moment and shear force in case of dynamic load. A slab is a structural element and has little thickness comparing to its cross section. [2]

Reinforced concrete slab is a widely used structural element. It provides an economical and versatile method of supporting gravity loads. In addition, the slab also forms integral part of structural frames to resist lateral loads.

These slabs combined with other elements (beams, drop panels or column capitals, etc.) are known as roofing system [3]. There

are different types of reinforced concrete slab depending on various criteria such as ribbed slab, flat slab, solid slab, continuous slab, simply supported slab etc.

In general, structural floors/roofs account for the substantial cost of a building in a normal situation. Therefore, any savings achieved in floor/roof considerably reduce the cost of the building [4].

Cost is one of the main constraints of a construction project. Competition in today's construction industry and the importance of cost control are increasing. Accurate estimation of costs in a construction project is one of the major factors for project managers.

Several attempts have been made by researchers to compare the cost among different types of floor systems Zekirija and Isak conducted a comparative study between waffle and solid slab systems. They concluded that the benefits of using a waffle slab system over the solid slab system are significant in the sense of achieving a lighter and economical structure [5]. Besides, Reddy found that the residential building constructed from solid slab requires lesser quantity of material (steel and concrete) by 5.512% than structure constructed from rib slab [6].

Another study has been developed by MATLAB for optimum design of reinforced concrete slabs (Sahab et al.) [7]. Two types of reinforced concrete slabs, simply supported one-way slab and cantilever slab, have been designed. Cost reduction of 18.92% and 6.78% are observed for reinforced cantilever and one-way slab, according to literature.

Elemental cost estimation is one of the methods of approximate estimation which gives a simple and a quick quantification of buildings but it requires significant expertise and judgment in pricing. This method analyzes the cost of the project depending on the element [8].

II. METHOD

There are different types of economical floor systems (slabs) for reinforced concrete buildings that nearly satisfy all loading and span conditions. Selecting economical floor systems which can withstand design requirements is discussed. This paper study and examines the elemental cost comparing different types of floor system for residential building in Nablus as a case study. The floor systems used in this study include: solid slab,

flat plate slab, one-way ribbed slab, and two-way ribbed slabs.

II.I Dataset

The residential building considered for this study is a typical building similar to a number of buildings constructed in various cities in Palestine.

It is located in Salfit City in Palestine. The building was constructed in 2017 consisting of two floors; ground floor and one top floor with an area equal to 385 m², and a staircase with an area equal to 14.3 m². Figure 1 shows the columns layout for the residential building.

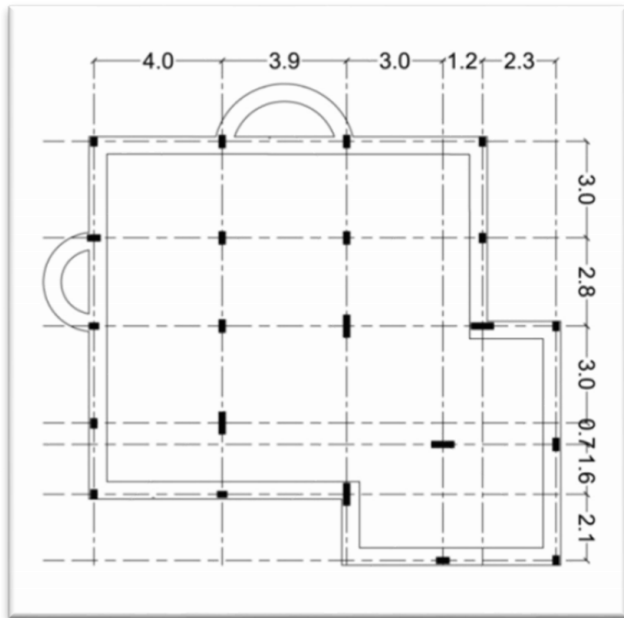


Fig. 1. Columns layout for the building (in meters)

II.II MODELLING, ANALYSIS AND DESIGN ASSUMPTION

II.II.I Structural Material Properties

The properties of the concrete and steel used in this research paper shown in table 1

Table 1. Material Properties

Modulus of Elasticity of concrete, E_c	23×10^3 MPa
Compressive strength of concrete, f_c	24 MPa
Modulus of Elasticity of steel, E_s	200 GPa
Yield Strength	420 MPa

II.II.II Details of the model

There are four types of floor system considered in this study. These are solid slab (SSS), flat plate (FPS), one-way ribbed slab (OWRS), and two-way ribbed slab (TWRS). The structural elements and types of loading for different types of floor

system are shown in table 2

Table 2. Description of different floor system

Type of structure	Residential building
Flat Plat Slab System	
Thickness of slab	200 mm
Size of edge beams	300 mm × 200 mm 450 mm × 200 mm
Size of columns	700 mm × 200 mm 400 mm × 200 mm 300 mm × 200 mm
Size of footing	1.4 m × 1.4 m × 0.35 m 1.6 m × 1.6 m × 0.35 m 1.85 m × 1.85 m × 0.35 m
Solid Slab System	
Thickness of slab	150 mm
Size of drop beams	300 mm × 300 mm
Size of columns	550 mm × 200 mm 400 mm × 200 mm 300 mm × 200 mm
Size of footing	1.4 m × 1.4 m × 0.35 m 1.6 m × 1.6 m × 0.35 m 1.85 m × 1.85 m × 0.35 m
Two Way Ribbed Slab System	
Thickness of slab	250 mm
Width of the web	120 mm
Flange Width	520 mm
Block Dimensions	40 cm × 25 cm × 17cm
Size of hidden beams	450 mm × 250 mm 300 mm × 250 mm
Size of columns	550 mm × 200 mm 400 mm × 200 mm 250 mm × 200 mm
Size of footing	1.2m × 1.2 m × 0.3 m 1.5 m × 1.5 m × 0.35 m 1.8 m × 1.8 m × 0.4 m
One Way Ribbed Slab System	
Thickness of slab	300 mm
Width of the web	120 mm
Flange Width	520 mm
Block Dimensions	40 cm × 25 cm × 17cm
Size of hidden beams	700 mm × 300 mm 400 mm × 300 mm
Size of columns	550 mm × 200 mm 400 mm × 200 mm 250 mm × 200 mm
Size of footing	1.3m × 1.3 m × 0.35 m 1.55 m × 1.55 m × 0.35 m 1.75 m × 1.75 m × 0.4 m

II.II.III Analysis

Structural model will be analyzed and designed under a statically gravity load by using computer software (ETABS v.16). The structural elements will be designed as reinforced concrete members according to strength and serviceability criteria as specified in ACI 318-11.

In this study, a 3D model will be analyzed and designed with different slab systems, flat plate, ribbed (one & two way) and solid slab as shown in figures 2,3,4,5 respectively. The soil in the site area is mainly rocky where footings will be laid on natural excavated ground, where the bearing capacity of the soil based on the nature of the soil in the site is 280 KN/m^2 .

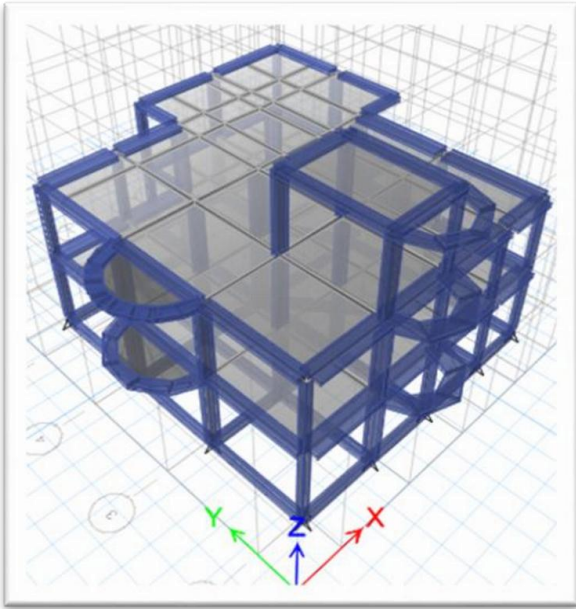


Fig. 2. 3D view for Flat Plat slab model

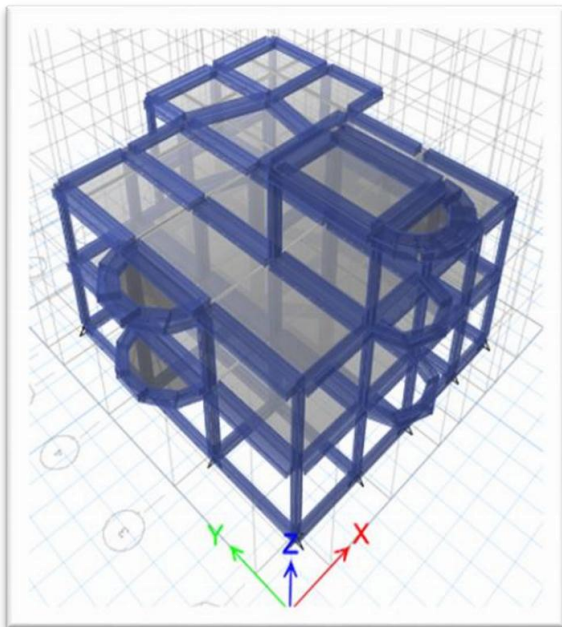


Fig. 3. 3D view for One- Way Ribbed slab model

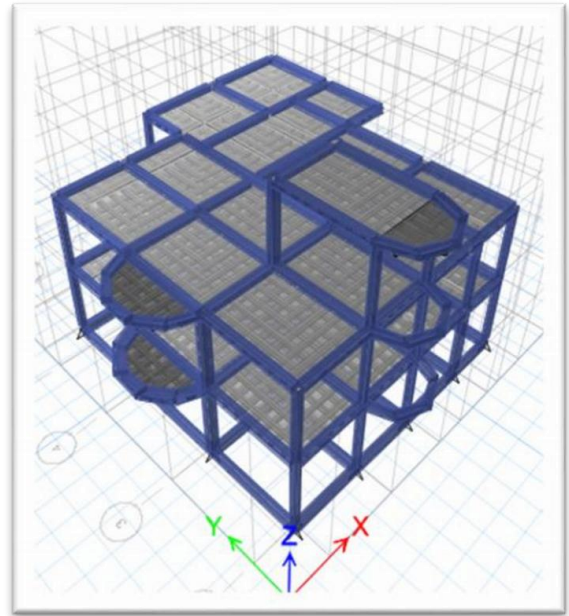


Fig. 4. 3D view for Two Way Ribbed slab model

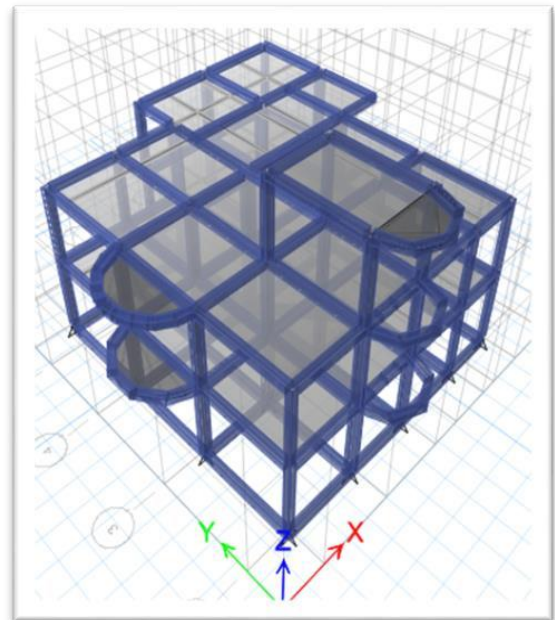


Fig. 5 3D view for Solid slab model

IV. RESULT

IV.I Structural Quantities

This part includes quantity surveying work which is required to estimate the quantities of various required materials and the labor involved for satisfactory completion of the construction project. Tables 3 to 6 present the quantities for each element of the building with different floor system.

Table 3. Quantities estimation of FPS

Type of member	Concrete Volume (m ³)	Steel Bar (ton)	Formwork (m ³)	No. of Blocks
Footing	29.17	0.83	1.73	-
Column neck	2.28	0.58	1.01	-
Columns	14.42	2.48	6.55	-
Floor Slab	81.40	6.97	20.69	-
Drop beams	0	2.44	0	-
Total	127.27	13.3	29.98	

Table 6. Quantities estimation of OWRS

Type of member	Concrete Volume (m ³)	Steel Bar (ton)	Formwork (m ³)	No. of Blocks
Footing	27.05	0.81	1.67	-
Column neck	2.11	0.56	0.96	-
Columns	13.30	2.22	6.20	-
Floor Slab	84.77	6.42	20.69	1923.60
Drop beams	0	5.03	0	-
Total	127.23	15.04	29.52	1923.60

Table 4. Quantities estimation of SSS

Type of member	Concrete Volume (m ³)	Steel Bar (ton)	Formwork (m ³)	No. of Blocks
Footing	28.56	0.83	1.72	-
Column neck	2.07	0.51	0.95	-
Columns	13.11	2.18	6.15	-
Floor Slab	61.05	6.21	20.69	-
Drop beams	14.06	3.63	3.64	-
Total	118.85	13.36	33.15	-

Table 5. Quantities estimation of TWRS

Type of member	Concrete Volume (m ³)	Steel Bar (ton)	Formwork (m ³)	No. of Blocks
Footing	24.7	0.75	1.53	-
Column neck	2.06	0.42	0.99	-
Columns	12.79	2.24	5.95	-
Floor Slab	70.59	7.13	20.69	2236.24
Drop beams	0	4.72	0	-
Total	110.14	15.26	29.16	

IV.II Cost Estimation

Cost estimation in construction projects is an important factor for decision making in all the project phases. The cost estimating for construction project starts in the planning phase or in feasibility study to determine the required financial requirements. Then in the construction phase, the actual cost is estimated and compared with the planned cost to assess the variation cost. The successful estimating process essentially depends upon estimator's experience, and acquaintance with achieving an accurate cost assessment; which shouldn't be different a lot from the actual cost.

The results of cost estimation are summarized in table 7 to 10. For each floor system and regarding the cost of materials and labor of the floor slab system, the results show that the use of flat plate system saves 31.40 % in comparison with solid slab system, 18.27% in comparison with two way ribbed slab system, and 17.99% in comparison with one way ribbed slab system.

In addition, the results show that the use of flat plate system compared to other types of slab systems reduces the total cost of construction as shown in figure 6

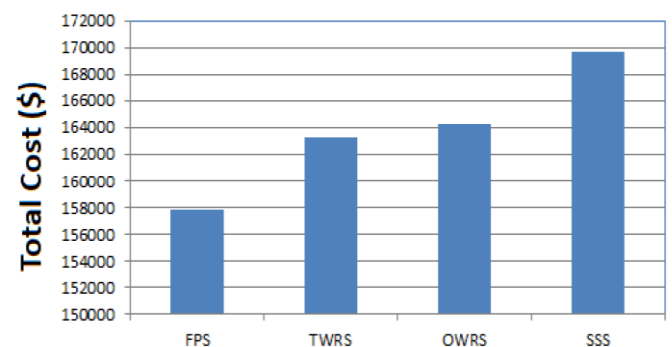


Fig. 6 The total cost of construction for each type

Table 7. Cost Estimation for Flat Plate System

<i>Item</i>	<i>Description</i>	<i>Quantity</i>		<i>Unit Price</i>		<i>Total Price(\$)</i>
		<i>Value</i>	<i>Unit</i>	<i>Value</i>	<i>Unit</i>	
1	<i>Excavation for Footing</i>	329.70	CM	16.04	\$/CM	5288.78
2	<i>Footing</i>	21.66	CM	203.13	\$/CM	4399.86
3	<i>Column Neck</i>	2.28	CM	516.31	\$/CM	1177.18
4	<i>Tie Beams</i>	14.06	CM	303.28	\$/CM	4264.16
5	<i>Ground Slab</i>	19.58	CM	147.08	\$/CM	2879.90
6	<i>Columns</i>	14.42	CM	433.10	\$/CM	6245.31
7	<i>Floors Slab</i>	379.30	SM	58.61	\$/SM	22229.82
8	<i>Drop beams</i>	2.44	Ton	992.58	\$/Ton	2421.89
9	<i>Stairs</i>	6.82	CM	198.49	\$/CM	1353.72
10	<i>Sloping Screed</i>	5.41	CM	102.42	\$/CM	554.11
11	<i>Plastering Floors</i>	1612.96	SM	7.14	\$/SM	11516.53
12	<i>Painting Floors</i>	1571.95	SM	3.64	\$/SM	5724.10
13	<i>Tiles</i>	515.82	SM	28.41	\$/SM	14652.02
14	<i>Blocks</i>	113.00	Box	105.87	\$/Box	11963.80
15	<i>Stone</i>	693.24	SM	60	\$/SM	41594.4
16	<i>Beam</i>	6.72	CM	457.08	\$/CM	3071.57
17	<i>Doors</i>	41.75	SM	159.66	\$/SM	6665.90
18	<i>Windows</i>	68.02	SM	95.20	\$/SM	6475.50
19	<i>Staircase rail</i>	15.17	SM	47.60	\$/SM	722.09
20	<i>Staircase Tile</i>	26.88	SM	45.22	\$/SM	1215.51
21	<i>Window Stone</i>	51.44	SM	47.60	\$/SM	2448.54
22	<i>Granite Stone</i>	8.00	SM	119.00	\$/SM	952.00
Total Cost						157816.7

Table 8. Cost Estimation for Solid Slab System

<i>Item</i>	<i>Description</i>	<i>Quantity</i>		<i>Unit Price</i>		<i>Total Price (\$)</i>
		<i>Value</i>	<i>Unit</i>	<i>Value</i>	<i>Unit</i>	
1	<i>Excavation for Footing</i>	326.63	CM	15.97	\$/CM	5216.26
2	<i>Footing</i>	21.15	CM	204.32	\$/CM	4322.07
3	<i>Column Neck</i>	2.07	CM	507.50	\$/CM	1052.61
4	<i>Tie Beams</i>	14.06	CM	303.28	\$/CM	4264.16
5	<i>Ground Slab</i>	19.58	CM	147.08	\$/CM	2879.90
6	<i>Columns</i>	13.11	CM	429.20	\$/CM	5628.12
7	<i>Floors Slab</i>	379.30	SM	85.43	\$/SM	32403.64
8	<i>Drop beams</i>	3.44	Ton	1466.71	\$/Ton	5040.56
9	<i>Stairs</i>	6.82	CM	198.49	\$/CM	1353.72
10	<i>Sloping Screed</i>	5.41	CM	102.42	\$/CM	554.11
11	<i>Plastering Floors</i>	1612.96	SM	7.14	\$/SM	11516.53
12	<i>Painting Floors</i>	1571.95	SM	3.64	\$/SM	5724.10
13	<i>Tiles</i>	515.82	SM	28.41	\$/SM	14652.02
14	<i>Blocks</i>	113.00	Box	105.87	\$/Box	11963.80
15	<i>Stone</i>	693.24	SM	60	\$/SM	41594.4
16	<i>Beam</i>	6.72	CM	457.08	\$/CM	3071.57
17	<i>Doors</i>	41.75	SM	159.66	\$/SM	6665.90
18	<i>Windows</i>	68.02	SM	95.20	\$/SM	6475.50
19	<i>Staircase rail</i>	15.17	SM	47.60	\$/SM	722.09
20	<i>Staircase Tile</i>	26.88	SM	45.22	\$/SM	1215.51
21	<i>Window Stone</i>	51.44	SM	47.60	\$/SM	2448.54
22	<i>Granite Stone</i>	8.00	SM	119.00	\$/SM	952.00
Total Cost						169717.1

Table 9. Cost Estimation for Two Way Ribbed Slab System

Item	Description	Quantity		Unit Price		Total Price (\$)
		Value	Unit	Value	Unit	
1	<i>Excavation for Footing</i>	301.48	CM	16.55	\$/CM	4989.55
2	<i>Footing</i>	18.10	CM	208.35	\$/CM	3771.58
3	<i>Column Neck</i>	2.06	CM	468.88	\$/CM	963.96
4	<i>Tie Beams</i>	14.06	CM	303.66	\$/CM	4268.40
5	<i>Ground Slab</i>	19.58	CM	147.08	\$/CM	2879.90
6	<i>Columns</i>	12.79	CM	437.74	\$/CM	5599.23
7	<i>Floors Slab</i>	379.30	SM	71.71	\$/SM	27200.98
8	<i>Drop beams</i>	4.72	Ton	992.46	\$/Ton	4680.27
9	<i>Stairs</i>	6.82	CM	198.49	\$/CM	1353.72
10	<i>Sloping Screed</i>	5.41	CM	102.42	\$/CM	554.11
11	<i>Plastering Floors</i>	1612.96	SM	7.14	\$/SM	11516.53
12	<i>Painting Floors</i>	1571.95	SM	3.64	\$/SM	5724.10
13	<i>Tiles</i>	515.82	SM	28.41	\$/SM	14652.02
14	<i>Blocks</i>	113.00	Box	105.87	\$/Box	11963.80
15	<i>Stone</i>	693.24	SM	60	\$/SM	41594.4
16	<i>Beam</i>	6.72	CM	457.08	\$/CM	3071.57
17	<i>Doors</i>	41.75	SM	159.66	\$/SM	6665.90
18	<i>Windows</i>	68.02	SM	95.20	\$/SM	6475.50
19	<i>Staircase rail</i>	15.17	SM	47.60	\$/SM	722.09
20	<i>Staircase Tile</i>	26.88	SM	45.22	\$/SM	1215.51
21	<i>Window Stone</i>	51.44	SM	47.60	\$/SM	2448.54
22	<i>Granite Stone</i>	8.00	SM	119.00	\$/SM	952.00
Total Cost						163263.7

Table 10. Cost Estimation for One Way Ribbed Slab System

<i>Item</i>	<i>Description</i>	<i>Quantity</i>		<i>Unit Price</i>		<i>Total Price (\$)</i>
		<i>Value</i>	<i>Unit</i>	<i>Value</i>	<i>Unit</i>	
1	<i>Excavation for Footing</i>	314.70	CM	16.30	\$/CM	5130.45
2	<i>Footing</i>	20.04	CM	205.58	\$/CM	4119.39
3	<i>Column Neck</i>	2.11	CM	525.93	\$/CM	1107.21
4	<i>Tie Beams</i>	14.06	CM	303.28	\$/CM	4264.16
5	<i>Ground Slab</i>	19.58	CM	147.08	\$/CM	2879.90
6	<i>Columns</i>	13.30	CM	429.58	\$/CM	5715.39
7	<i>Floors Slab</i>	379.30	SM	71.47	\$/SM	27109.10
8	<i>Drop beams</i>	5.03	Ton	992.46	\$/Ton	4990.99
9	<i>Stairs</i>	6.82	CM	198.49	\$/CM	1353.72
10	<i>Sloping Screed</i>	5.41	CM	102.42	\$/CM	554.11
11	<i>Plastering Floors</i>	1612.96	SM	7.14	\$/SM	11516.53
12	<i>Painting Floors</i>	1571.95	SM	3.64	\$/SM	5724.10
13	<i>Tiles</i>	515.82	SM	28.41	\$/SM	14652.02
14	<i>Blocks</i>	113.00	Box	105.87	\$/Box	11963.80
15	<i>Stone</i>	693.24	SM	60	\$/SM	41594.4
16	<i>Beam</i>	6.72	CM	457.08	\$/CM	3071.57
17	<i>Doors</i>	41.75	SM	159.66	\$/SM	6665.90
18	<i>Windows</i>	68.02	SM	95.20	\$/SM	6475.50
19	<i>Staircase rail</i>	15.17	SM	47.60	\$/SM	722.09
20	<i>Staircase Tile</i>	26.88	SM	45.22	\$/SM	1215.51
21	<i>Coping</i>	51.44	SM	47.60	\$/SM	2448.54
22	<i>Kitchen marble</i>	8.00	SM	119.00	\$/SM	952.00
Total Cost						164226.4

V. DISCUSSION & CONCLUSION

Based on the cost analysis results obtained from this case study, the following conclusions can be drawn:

- For all system floors, the cost constitutes the major part of the total structural cost of reinforced concrete residential building.
- The cost of floor slab may range from 13 to 16 % of the structure cost in building work. The percentages are
- 13.71% for FPS, 16.56% for SSS, 16.23% for TWSS, and 16.1% for OWSS of the total cost of structure.
- Using flat plate system is more economical than any other systems.
- The flat plate system is economical since it has no beams. So it can reduce the floor height by (10-15) %.
- The Results figure out that using flat plate system reduces the total cost of construction by 7% compared to the solid slab system, 4 % compared to the one way ribbed slab system, and 3.33% compared to the two way ribbed slab system.

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