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Comparative Analysis of Estimating and Costing Between Beam Supported Structure and Flat Plate Structure for a Resedential Building

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Abstract—Dhaka has experienced an extremely rapid growth in population. This vast population is putting serious pressure on housing facilities. As a result, significant numbers of buildings are being constructed in Dhaka city. Different real estate companies are investing a huge amount of money in the construction industry.

This research work presents a comparative study on the basis of cost of two six storied building structure having beam supported floor system and another is flat plate floor system. Two buildings were provided with same shape, size and loadings. As standard amenities and modern facilities, passenger lift, stairs, ramps were provided. The buildings considered are with same floor area. Conventional Finite component package was used to perform 3D linear elastic study for the building frame. After 3D analysis, the structural members of the building were designed by USD method. The cost per unit area for finishing items will remain same for all cases. After that, the volume of concrete and steel are estimated and finally, their cost are determined. After performing estimation, cost analyses and comparison, the study concluded that beam – column structure is more economical. Flat plate structure method can be used with conditions and care should be taken in design, quality of materials should be ensured and design specifications should be followed perfectly.

Keywords—Beam supported structure, flat plate structure,estimation of cost.

I. Introduction

Over the history of building structures, the changes in technology have been tremendous. Part of this comes from the daily strategies of human living. In recent year, the trend is the construction of mixed-uses structures as limited natural resources, the expenses, time and stresses of commuting draw people back into the city center. As a result, urban center include now mostly structures with a storefront next to the street, offices in the stories immediately above and finally in the upper levels, apartment for city dwellers. But these types of building are difficult to arrange to take total advantages of structural and mechanical systems. Offices need large open spaces with large loads from mechanical and electrical systems. The living quarters, with their intimate spaces, need closer column spacing and have fewer vents, weirs required meeting needs of comfort. Shallow floor-to-floor heights in the apartment areas are possible since they can be accommodated by a flat plate slab design. Offices need grid or pan systems covered by drop ceilings to allow HVAC and electrical systems to be delivered to desired locations within each square. Hence, according to the need of rentable spaces, owner desires, aesthetics, cost, safety and comfort, architects and engineers are now facing the challenges of structural design to accommodate people's total daily life in one single structure. As outcome, six storied structures are now being constructed with different types of concrete floor systems.

The choice of type of slab for a particular floor depends on many factors. Economy of construction is obviously an important consideration, but this is a qualitative argument until specific cases are discussed and is a geographical variable. The design loads, required spans, serviceability requirements and strength requirements are all important. As cost is a major concern in all projects, so it is necessary to design and construct quality apartment buildings at low costs. So the comparison is necessary to select the most efficient one Considering these points of view, the choice between a beam slab and flat plate slab floor systems becomes usually a matter of great confusion to users.

Based on the above considerations, this study focuses on the analysis of two structures having beamed supported structures and another one flat plate structures and finally presents a comparative analysis of estimating and costing. This will give a comparative picture about the advantages and disadvantages, suitability and feasibility, particularly in terms of economy so as to enable someone to choose the suitable option.

II. Objective of the Study

The objective of the study were

- To develop models of structure with beam supported slab and a structure with flat plate slab for analysis and design by finite element method using software ETABS.
- To compare the concrete and steel requirement of the two types of building.
- To compare the total cost between the two types of building.

III. Methology of the Study

Step 1: Two types of six storied building structure having beam supported floor system and another is flat plate floor system had been considered. Two buildings were provided with same shape, size and loadings. As standard amenities and modern facilities, passenger lift, stairs, ramps were provided.

Step 2: Based code on design/specification of ACI/BNBC, material properties (compressive strength of concrete, yield stress of steel, unit weight of concrete, soil, brick etc.) and loadings (standard dead loads, live loads, floor finish etc.) were selected. Wind and earthquake loads were also considered.

Step 3: We have done cost analysis of column, grade beam, floor beam and slab of beam supported structure and column, grade beam and slab of flat plate structure. We have analyzed costing to compare the column, grade beam and slab of beam supported structure and flat plate structure. As the result, this can help someone in terms of economy to choose the suitable option.

Description
➢ Ultimate Strength Design (USD)
➢ American Concrete Institute (ACI) Building design code, ACI 318-99 ➢ Bangladesh National Building Code (BNBC) ➢ Uniform Building Code (UBC), 1994
➢ Beam supported structure: Six (6) storied having 12X14; 12X18; 12X24; (inch) columns size. ➢ Flat plate structure: 14X20; 14X28; 24X30 (inch) column size. ➢ Both of Structure having 60 Grade reinforcement. ➢ Both of Structure having 3.5 Grade concrete.
➢ Framed structure. ➢ Residential.
➢ Dead load = 147.5 psf ➢ Live load = 40 psf ➢ Considering wind load & earthquake load
➢ Slab type = Flat plate structure & Beam supported structure ➢ Beam type = Rectangular ➢ Column type = Tide
➢ Reinforcing bars, f_y = 60 ksi ➢ Concrete compressive strength, f'_c = 3.5 ksi ➢ Normal density concrete having = 150 psf

IV. ANALYTICAL STUDY

The building geometries are as following:

*a) Beam Supported Structure:*All the floors have 19 columns. All the slabs of the structure are beam supported. Story height is 10 ft. column and beam size is different.

*b) Flat plate structure:*All the floors have 19 columns. All the slabs are directly supported on column (flat plate structure). Column size is different.

c) The load considered (with factor):

Self weight of slab = 62.5 psf, Partition wall = 60 psf
Floor finish = 25 psf, Dead load = 147.5 psf, Total Dead load, D.L = 206.5 psf ,Live load = 40 psf, Live load, L.L = 68 psf.

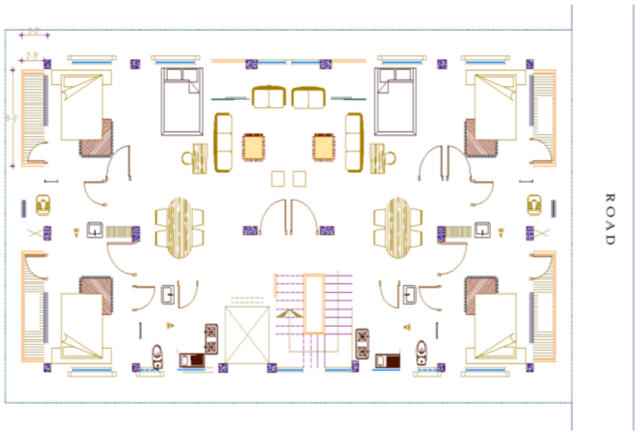

Fig1: Building Plan

V. DESIGN OF STRUCTURE

After analyzing the two types of structures, we got the required value to pursue the design process. We did slab flexural design, beam flexural and shear design and column main steel calculation and tie bar design using USD method .Getting the result of design we found out the costing of the two types of buildings.

VI. COST ANALYSIS

The buildings are analyzed for the best condition which can be constructed economically. We use the good materials. We use BSRM steel in 60 grades which steel rate is 65 Tk. per kg as market price in December 2013. Cement use is Shah Cement and it's market price is 450 Tk. per bag in December 2013. Stone chips used in column and it's market price is 135 Tk. per cft in December 2013 and brick chips used in beam & slab and it's market price is 85 Tk. per cft. Sylhet sand is used all structure work and it's market price is 35 Tk. in December 2013.

A. *Cost Estimation:*

1) Estimate of Floor Beam:

a) Beam supported structure:

1	**2**	**3**	**4**	**5**	**6**	**7=3*5*6**	**8**	**9=7*8**
Name of beam	Bar description	No.of beam	Size of bar (mm)	Nos of bar	Length of bar	Total length of bar(ft)	Bar weight = kg/ft	Total weight kg
FB1	Main bar	4	16	4	18'-4"	293.2	0.5	140.8
	Ext .top	4	16	2	8'-7"	68.6	0.5	32.9
	Ext. bottom	4	16	1	5'-2"	20.6	0.5	9.9
	Stirrups	4	10	28	4'-2"	467.0	0.2	224.2
FB2	Main bar	2	16	4	14'-3"	114	0.5	54.7
	Ext .top	2	16	1	7'-2"	14.3	0.5	6.9
	Stirrups	2	10	24	3'-10"	183.8	0.2	34.9
	Main bar	2	16	4	14'-0"	112	0.5	53.8
	Ext .top	2	16	1	7'-6"	15	0.5	7.2
	Stirrups	2	10	23	3'-10"	176.1	0.2	33.5
FB3	Main bar	2	16	4	11'-8'	93.3	0.5	44.8
	Ext .top	2	16	1	3'-5"	6.8	0.5	3.3
	Stirrups	2	10	18	3'-10"	137.8	0.2	26.2
	Main bar	2	16	4	18'-4"	146.6	0.5	70.1
	Ext .top	2	16	1	4'-3½"	8.5	0.5	4.1
	Stirrups	2	10	28	3'-10"	214.4	0.2	40.7
FB4	Main bar	5	16	4	14'-3"	285	0.5	136.8
	Ext .top	5	16	1	7'-2"	35.8	0.5	17.2
	Stirrups	5	10	24	4'-10"	579.6	0.2	110.1

FB5	Main bar Stirrups	1 1	16 10	4 163	103'-0" 3'-10"	412.0 624.2	0.5 0.2	197.8 118.6
							Total	1368.5

Table1: Bar schedule of beam

Total 6 floors:

Reinforcement = 1368.56*6 = 8211.36 kg

Name of beam	Length of beam(L)	Width of beam (B)	Depth of beam (H)	Nos of beam	Total volume = L*B*H cft
FB1	17'-0"	1'-0"	1'-3"	4	90.44
FB2	14'-1"	0'-10"	1'-3"	2	29.22
FB3	17'-0"	0'-10"	1'-3"	2	35.28
FB4	14'-7"	1'-0"	1'-6"	5	109.35
FB5	11'-3"	0'-10"	1'-3"	4	46.68
FB5	10'-5"	0'-10"	1'-3"	2	21.62
FB5	14'-3"	0'-10"	1'-3"	2	29.57
FB5	8'-6"	0'-10"	1'-3"	2	17.64
FB5	16'-2"	1'-0"	1'-3"	1	16.77
FB1	14'-3"	1'-3"	1'-3"	2	35.63
FB3	11'-3"	1'-3"	1'-3"	2	23.34
				Total =	455.54

Table.2: Casting of floor beam

Total volume = 455.54 cft
Ratio: 1:2:4
Wet volume: 455.54*1.5 = 683.31 cft
Cement = 683.31/7 = 97.62/1.25 = 78.09 ~ 78 bag.
Sand = 97.62*2 = 195.24 cft.
Brick chips = 97.62*4 = 390.48 cft.

Total 6 floors:

Cement = 78*6 = 468 bag
Sand = 195.24*6 = 1171.44 cft
Brick chips = 390.48*6 = 2342.88 cft

2) Estimation of Grade Beam:

a) Beam Supported structure:

1	2	3	4	5	6	7=3*5*6	8	9=7*8
Name of beam	Bar description	Nose of beam	Size of bar (mm)	No of bar	Length of bar	Total length of bar(ft)	Bar weight = kg/ft	Total weight kg
Short Beam	Main bar Stirrups	6 6	16 10	4 62	32'-2" 4'-4"	772.1 268.5	0.5 0.2	370.6 51
Long Beam	Main bar Stirrups	3 3	16 10	4 119	61'-3" 3'-10"	245.1 455.1	0.5 0.2	117.6 87.0
							Total	626.5

Table3:Bar schedule of beam

Name of beam	Length of beam(L)	Width of beam (B)	Depth of beam (H)	Nos of beam	Total volume = L*B*H cft
GB1	17'-0"	1'-0"	1'-6"	6	153
GB2	14'-1"	1'-0"	1'-6"	7	148
GB3	11'-3'	1'-0"	1'-3"	6	85
GB3	10'-5"	1'-0"	1'-3"	2	26
GB3	10'-10"	1'-0"	1'-3"	1	14
GB4	8'-6"	1'-0"	0'-10"	1	7
GB4	6'-4"	1'-0"	0'-10"	1	6
GB2	14'-3"	1'-0"	1'-6"	4	86
				Total =	525

Table4:Casting of Grade beam

Total volume = 525 cft
Ratio: 1:2:4.
Wet volume = 525*1.5 = 787.5cft
Cement = 787.5/7 = 112.5/1.25 cft = 90 bag
Sand = 112.5*2 = 225 cft
Brick chips = 112.5*4 = 450 cft

b) Flat Plate Structure:

1	2	3	4	5	6	7=3*5*6	8	9=7*8
Name of beam	Bar description	No of beam	Size of bar (mm)	Nos of bar	Length of bar	Total length of bar(ft)	Bar weight = kg/ft	Total weight kg
Short Beam	Main bar Stirrups	6 6	16 10	4 62	32'-2" 4'-4"	772.1 268.5	0.5 0.2	370.6 51.0
Long Beam	Main bar Stirrups	3 3	16 10	4 119	61'-3" 3'-10"	245.1 455.1	0.5 0.2	117.6 87.0
							Total	626.5

Table5:Bar schedule of beam

Name of beam	Length of beam(L)	Width of beam (B)	Depth of beam (H)	Nos of beam	Total volume = L*B*H cft
GB1	17'-0"	1'-0"	1'-6"	6	153
GB2	14'-1"	1'-0"	1'-6"	7	148
GB3	11'-3'	1'-0"	1'-3"	6	85
GB3	10'-5"	1'-0"	1'-3"	2	26
GB3	10'-10"	1'-0"	1'-3"	1	14
GB4	8'-6"	1'-0"	0'-10"	1	7
GB4	6'-4"	1'-0"	0'-10"	1	6
GB2	14'-3"	1'-0"	1'-6"	4	86
				Total =	525

Table6: Casting of Grade beam

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Total volume = 525 cft
Ratio: 1:2:4.
Wet volume = 525*1.5 = 787.5cft
Cement = 787.5/7 = 112.5/1.25 cft = 90 bag
Sand = 112.5*2 = 225 cft
Brick chips = 112.5*4 = 450 cft

3) Estimation of Column:

a) Beam Supported structure:

1	2	3	4	5
Name of column	Bar description	Nose of column	Size of bar(mm)	Nose of bar
C1,C7,C14, C19	Main rod stirrups	4 4	16mm 10mm	6 65
C2,C3,C4, C5,C6,C8, C13,C15, C16,C17, C18	Main rod stirrups	11 11	16mm 10mm	8 65
C10,C11, C12	Main rod stirrups	3 3	16mm 10mm	10 65
C9	Main rod Main rod stirrups	1 1 1	20mm 16mm 10mm	10 8 65

Table7 (a): Bar schedule of column (1st half0

6	7=3*5*6	8	9=7*8
Length of bar	Total length of bar(ft)	Bar weight = kg/ft	Total weight kg
84'-7" 4'-2"	2030 1084	0.48 0.19	974.4 205.96
84'-7" 4'-2"	7444 2982	0.48 0.19	3573.12 566.58
84'-7" 4'-2"	2538 813.15	0.48 0.19	1218.24 154.50
42'-3.5" 42'-3.5" 4'-2"	423 339 271.05	0.75 0.48 0.19	317.25 162.72 51.50
		Total	7224.27

Table7(b): Bar schedule of column (2nd Half)

Name of column	Length of column (L)	Width of column (B)	Depth of column (H)	Nos of colum n	Total volume = L*B*H cft
C1,C7,C14,C19 C2,C3,C4,C5,C6,C8,C9,C13,C15,C16,C17,C18 C10,C11,C12	1'-0" 1'-0" 1'-0"	1'-2" 1'-6" 2'-0"	68'-6" 68'-6" 68'-6"	4 12 3	321 1233 411
				Total	1965

Table.8:Casting of Column

Total volume = 1965 cft
Ratio: 1:1.5:3.
Wet volume = 1965*1.5 = 2947.5 cft
Cement = 2947.5/5.5 = 535.9/1.25 cft = 429 bag
Sand = 535.9*1.5 = 804 cft
Brick chips = 535.9*3 = 1608 cft

b) Flat Plate structure:

1	2	3	4	5
Name of column	Bar description	Nose of column	Size of bar(mm)	Nose of bar
C1,C2, C6,C7, C14,C15, C16,C17, C18,C19	Main rod stirrups	10 10	20mm 10mm	14 66
C3,C4,C5, C9,C10, C11,C12	Main rod stirrups	7 7	25mm 10mm	12 57
C8,C13	Main rod stirrups	2 2	16mm 10mm	10 79

Table 9(a) :Bar schedule of column (1st half)

6	7=3*5*6	8	9=7*8
Length of bar	Total length of bar(ft)	Bar weight = kg/ft	Total weight kg
84'-7" 10'-2"	11841.2 6712.2	0.75 0.19	8880.9 1275.32
84'-7" 54'-1"	7104.72 6420.48	1.17 0.19	8312.52 1219.89
84'-7" 8'-10"	1691.6 1395.14	0.48 0.19	812 265
		Total	20765.63

Table 9(b) :Bar schedule of column (2nd half)

Name of column	Length of column (L)	Width of column (B)	Depth of column (H)	Nos of column	Total volume = L*B*H cft
C1,C2,C6,C7,C14,C15,C16,C17,C18,C19	1’-2”	2’-4”	69’-0”	10	1881
C3,C4,C5,C9,C10,C11,C12	2’-0”	2’-6”	69’-0”	7	2415
C8,C13	1’-2”	1’-8”	69’-0”	2	270
				Total =	4566

Table 10: Casting of Column

Total volume = 4566 cft
Ratio: 1:1.5:3.
Wet volume = 4566*1.5 = 6849 cft
Cement = 6849/5.5 = 1245.27/1.25 cft = 996 bag
Sand = 1245.27*1.5 = 1868 cft
Brick chips = 1245.27*3 = 3735.81 cft

4) Estimation of slab:

a) Beam supported structure:

1	2	3	4	5	6=4*5	7	9=7*6
Bar direction	Bar description	Size of bar(mm)	Nose of bar	Length of bar	Total length of bar (rft)	Bar weight = kg/ft	Total weight kg
long	Straight bar	10	30	58’-3”	3495	-	-
	Crank bar	10	30	60’-1”	1802	-	-
	Ext. top	10	58*2	3’-3 ½”	391	-	-
	Ext. top	10	58*2	6’-3”	725	-	-
	Ext. top	10	32*2	5’-8 ½”	364	-	-
	Ext. top	10	26	7’-10 ½”	205	-	-
	(-)Straight bar	10	27	10’-9”	291	-	-
	Straight bar	10	60	30’-10”	1850	-	-
	Crank bar	10	59	32’-8”	1928	-	-
	Ext. top	10	60	7’-8”	461	-	-
	Ext. top	10	60*2	7’-6”	900	-	-
	(-)Straight bar	10	32	13’-7”	435	-	-
	(-) Ext. top	10	16	22’-8”	363	-	-
				Total =	13210	0.19	2510

Table 11: Bar schedule of slab

Total 6 Slabs:
Reinforcement = 2510*6 = 15060 kg

Estimation casting of slab:
30’-1”*59’-06”*0’-5” = 752 cft
Total volume = 752 cft
Ratio: 1:2:4.
Wet volume = 752*1.5 = 1128cft
Cement = 1128/7 = 161.14/1.25 cft = 128 bag
Sand = 161.14*2 = 322.28 cft
Brick chips = 161.14*4 = 644.56 cft

Total 6 slabs:
Cement = 128*6 = 768 bag
Sand = 322.28*6 = 1933.68 cft
Brick chips = 644.56*6 = 3867.36 cft

b) Flat plate structure:

1	2	3	4	5	6=4*5	7	9=7*6
Bar direction	Bar description	Size of bar(mm)	Nose of bar	Length of bar	Total length of bar(rft)	Bar weight = kg/ft	Total weight kg
long	Top bar	12	55	37’-11”	2085.6	-	-
	Bottom bar	12	55	37’-11”	2085.6	-	-
	Ext. top	12	54	7’-6”	405	-	-
	Ext. top	12	54*2	7’-6”	810	-	-
	Ext. top	12	9	3’-4”	-30	-	-
	Straight bar	12	10*2	13’-7”	-271.6	-	-
Short direction	Top bar	12	29	59’-6”	1725.5	-	-
	Bottom bar	12	29	59’-6”	1725.5	-	-
	Ext. top	12	28*2	2’-8”	150	-	-
	Ext. top	12	13*2*2	5’-3”	273	-	-
	Ext. top	12	15*4	6’-3”	375	-	-
	Ext. top	12	15*4	5’-8”	340	-	-
	Top & bottom	12	13*2	10’-10”	-281.58		
				Total =	10558.38	0.27	2850

Table 12: Bar schedule of slab

Total 6 Slabs:

Reinforcement = 6*2850 kg = 17100 kg.

Estimation casting of flat plate slab:
30’-1”*59’-06”*0’-8” = 1200 cft
Total volume =1200cft
Ratio: 1:2:4.
Wet volume = 1200*1.5 = 1800cft
Cement = 1800/7 = 257.14/1.25 cft = 206 bag
Sand = 257.14*2 = 514.28cft
Brick chips = 257.14*4 = 1028.56 cft

Total 6 Slabs:

Cement = 206*6 = 1236 bag
Sand = 514.38*6 = 3086.28 cft
Brick chips = 1028.56*6 = 6171.36 cft

B) Cost analysis:

1) Beam supported structure

Column

Reinforcement cost of column = 7224.27*65 Tk. /Kg = 469577.55 Tk.
Cement of column = 429*450 Tk. /bag = 193050.00 Tk.

Sand of column = 804*35 Tk. /cft = 28140.00 Tk.
Stone chips of column = 1608*135 Tk. /cft = 217080.00 Tk.

Grade beam

Reinforcement cost of grade beam = 626.54*65 Tk. /Kg = 40725.10 Tk.
Cement of grade beam = 90*450 Tk. /bag = 40500.00 Tk.
Sand of grade beam = 225*35 Tk. /cft = 7875.00 Tk.
Brick chips of grade beam = 450*85 Tk. /cft = 3825

Floor beam

Reinforcement cost of floor beam = 8211.36*65 Tk. /Kg = 533738.40 Tk.
Cement of floor beam = 468*450 Tk. /bag = 210600.00 Tk.
Sand of floor beam = 1171.44 *35 Tk. /cft = 41000.40 Tk.
Brick chips of floor beam = 2342.88 *85 Tk. /cft = 199144.80 Tk.

Floor slab

Reinforcement cost of floor slab = 15060*65 Tk. /Kg = 978900.00 Tk.
Cement of floor slab = 768*450 Tk. /bag = 345600.00 Tk.
Sand of floor slab = 1933.68 *35 Tk. /cft = 67678.80 Tk.
Brick chips of floor slab = 3867.36 *85 Tk. /cft = 328275.60 Tk.

Total = 3740585.65 Tk.

2) Flat plate structure

Column

Reinforcement cost of column = 20765.63*65 Tk. /Kg = 1349765.95 Tk.
Cement of column = 996*450 Tk. /bag = 448200.00 Tk.
Sand of column = 1868*35 Tk. /cft = 65380.00 Tk.
Stone chips of column = 3735.81 *135 Tk. /cft = 504334.35 Tk.

Grade beam

Reinforcement cost of grade beam = 626.54*65 Tk. /Kg = 40725.10 Tk.
Cement of grade beam = 90*450 Tk. /bag = 40500.00 Tk.
Sand of grade beam = 225*35 Tk. /cft = 7875.00 Tk.
Brick chips of grade beam = 450*85 Tk. /cft = 38250.00 Tk.

Floor slab

Reinforcement cost of floor slab = 17100*65 Tk. /Kg = 1111500.00 Tk.
Cement of floor slab = 1236*450 Tk. /bag = 556200.00 Tk.
Sand of floor slab = 3086.28 *35 Tk. /cft = 108019.80 Tk.
Brick chips of floor slab = 6171.36 *85 Tk. /cft = 524565.60 Tk.

Total = 4795315.80 Tk

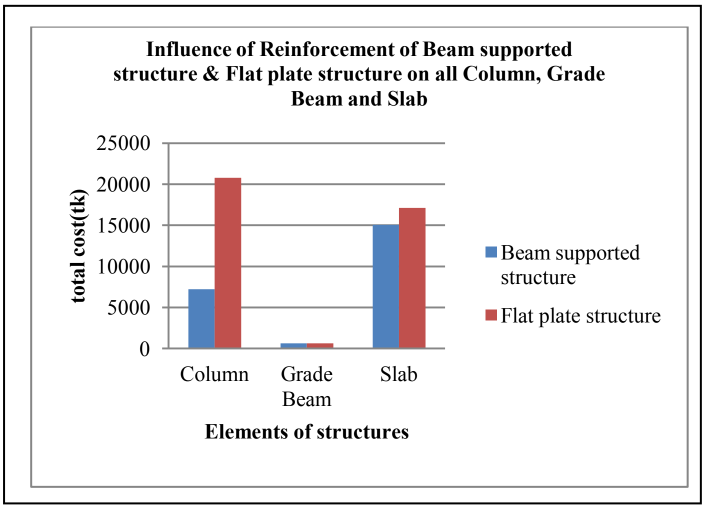

Fig 2: Reinforcement of all floors on Column, Grade beam and Slab of all structures

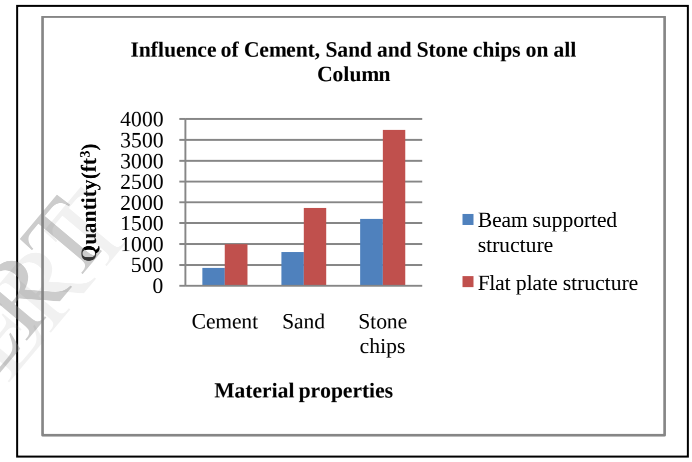

Fig 3: Cement, Sand & Stone chips of all floors on Column of all structures

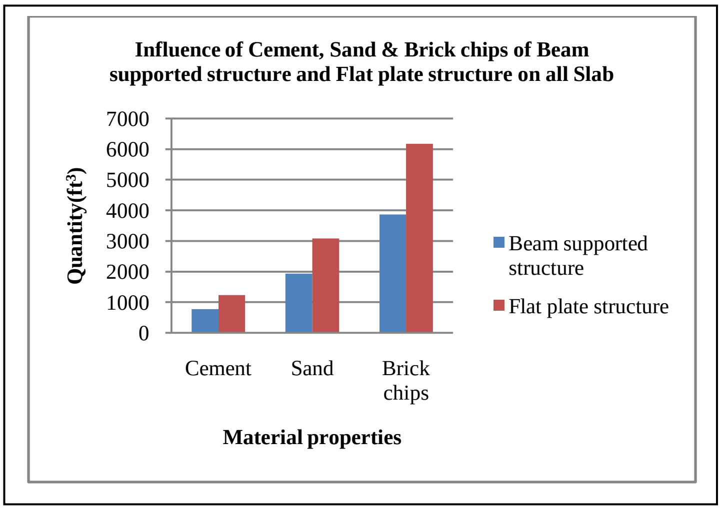

Fig 4: Cement, Sand & Brick chips of all floors on Slab of all structures

VII. SUMMARY OF THE COMPARATIVE STUDY

Finally the total cost is **Total = 4795315.80 Tk.** of Flat plate structure & **Total = 3740585.65 Tk.** of Beam supported structure. It is 28.2% above on flat plate structure than beam supported structure.

VIII. CONCLUSION

After performing analysis of the structures as well as the comparative study of beam supported structure and flat plate structure, we gathered knowledge that:

a) Flat plate slab is thicker and more heavily reinforced than slabs with beams and girders. Almost 24% more reinforcement are used for flat plate structure than beam supported structure.
b) Almost 28% more concrete are used for flat plate structure than beam supported structure.
c) And finally increased the cost of flat plate structure about 28.2% than beam supported structure.
d) So from economic point of view, beam supported structure is more economical than flat plate structure .But from aesthetic point of view, flat plate structure is better.

IX. RECOMMENDATION FOR FUTURE USE

For further study in this field, the following recommendations are put forward:

- For further study estimation of cost of footing, stair, overhead tank and lift core are required.
- Cost analysis for finishing work & upper design are required for better result.
- In the further study, soil test reports nearer projects of that area should have been collected and used in foundation design for the proposed project.
- This research work has been conducted on slab of a six storied residential building but it can be conducted on all the components of the building as well as for other high and low rise buildings.
- For analysis ETABS design software was used, so it may be cheeked by other reliable software's.

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