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Comparison between Top-Down Construction Method and Bottom-Up Construction Method: Case Study

Kavya Prince[1], Theertha S.L[2], Sujithmon S.[3], Joseph Zacheriah[4], Ajesh K Kottuppillil[5]

[1,2,3,4]UG Scholar, Department of Civil Engineering, SAINTGITS College of Engineering, Kerala, India
[5]Assistant Professor, Department of Civil Engineering, SAINTGITS College of Engineering, Kerala, India

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Abstract - The construction of a building involves various processes such as site selection, survey, soil testing, locating ground water table, excavation of soil, structural design, material availability, feasibility etc. There is different methodology used for building construction. According to infrastructural requirements and limited space constraints buildings with more basement floors are constructed now a days. Top-Down construction method can be adopted in such cases. Bottom-up method is the convectional construction method where substructure and superstructure floors are constructed sequentially from the bottom of substructure to the top of superstructure. Top-down construction method, is a method which builds the permanent structure member of basement along with the excavation from top to bottom and the substructure and superstructure can be constructed subsequently. In this case study all the construction process involved in the construction of a building is analyzed based on an ongoing bottom-up construction project and comparing its implementation (phase of work) and time of execution of the work in both Top-down construction method and bottom-up construction method using PRIMAVERA software.

***Key Words*: Bottom-up construction, Top-down construction, Time of execution , Primavera software**

1. INTRODUCTION

The construction of a building involves various processes such as site selection, survey, architectural and structural design. The art of creating the structure which was a shelter in the primitive stages, employed modern techniques to make the structure satisfy the practical needs as well as to meet the aesthetical requirements. Due to the economic pressure and due to the industrial developments and due the needs of infrastructure developments, may new methods and material of construction be developed.

Conventionally, buildings with underground basements are built by bottom-up method where sub-structure and super-structure floors are constructed sequentially from the bottom of the sub-structure or lowest level of basement to the top of the super-structure. Though this conventional method, also called as bottom-up method, is simple in both design and construction, it is not feasible for the mega projects with limited construction time or with site constraints.

Top-down construction method as the name implies, is a construction method, which builds the permanent structure members of the basement along with the excavation from the top to the bottom. In this case the basement floors are constructed as the excavation progresses. Top-down construction method which provides the significant saving of the overall construction time has been adopted for some major projects where time factor is of primary importance. The sequence construction begins with retaining wall installation and then load-bearing elements that will carry the future super-structure. The ongoing bottom-up construction in G+4 structure is conceptually converting to Top-down construction method structure and then comparing these two-construction methods in this project.

1.1 Bottom-up Construction Method

Bottom-Up construction method is the conventional construction method, which were used for both building with basement floors and normal buildings. In this method the base of the structure is constructed and subsequently moves up to the surface. When compared with top-down construction method bottom-up method is simple in both construction and design.

1.2 TOP-down Construction method

Top-down construction method as the name implies, is a construction method which builds the permanent structure members of the basement along with the excavation from the top to the bottom. Top-down method is mainly used for two types of urban structures, namely tall buildings with basements and underground structures such as car parks, underpasses and metro stations. In this case the basement floors are constructed as the excavation progresses. The Top-down method has been used for deep excavation projects where tieback installation is not feasible and soil movements have to be minimized. This construction method which provides the significant saving of the overall construction time, is showing increasing adoption for major projects where time factor is of primary importance. The sequence construction begins with flexible retaining wall installation and then load-bearing elements that will carry the future super-structure. With increasing basement levels, excavation method have become more complicated, leading to Top-down techniques which allowed for simultaneous construction of the basement and superstructure. The typical

construction sequence of top-down construction is as follows:

- Construct the embedded retaining wall (usually a diaphragm wall).
- Construct piles. Place the steel columns where the piles are constructed.
- Proceed to the first stage of excavation.
- Cast the floor slab of first basement level with the opening to allow machines to be lowered to excavate level below and for excavation material to be removed.
- Proceed to the second stage of excavation; cast the floor slab of the second basement level.
- Repeat the same procedure until the desired depth is reached.
- Construct the foundation slab. Complete the basement.
- Keep constructing the superstructure until it gets finished.

Design and construction principles for the top-down method primarily call for two major structural elements. Columns with sufficient capacity must be pre-founded in bored piles or diaphragm wall panels to sustain the construction load and to utilize as part of the bracing system.

2. Case Study

An ongoing bottom-up construction of a G+4 residential apartment at Trivandrum, Kerala is taken for comparison study. It is a rectangular plot surrounded with buildings, the main constraints of the site are limited space for parking and others activities and water table level. Considering these constraints the ongoing construction is theoretically converting into top-down construction method and comparing the activities and time of construction.

Fig 1. G+4 residential Building

In our project the above ongoing bottom-up construction of the residential building is theoretically converting into top-down construction procedure as follows:

• The building is considered to have ground level and three levels subsequently above it; with two levels of underground level/basement level with the first initial basement level To be residential apartments while the second basement level below it to have parking facilities.
• Gravity walls/retaining walls have to be installed into ground first. Then intermediate piles are driven into the ground as per requirement. Then the soil is excavated upto a limited height.
• After that the ground floor slab is cast first acting as a both ground floor slab and roof slab for the basement floor. The ground slab is done along with installing support mechanisms (anchors) to the basement from retaining walls.
• The slabs have access voids at suitable distances through which the excavation is continued downwards for the second level of excavation or the first basement floor level.
• Along with these simultaneously the floors above the ground level is constructed after the construction of first level of basement floor with roof slab.
• After achieving the depth of one level of basement, the steel stanchion columns are reinforced by reinforcing bars and are made as permanent columns for the basement floor and similarly the diaphragm walls are also reinforced with increased thickness to become permanent part of the structure
• This sequential process continuous until the two levels below the ground is cast and made, followed by the construction of three floors above ground level; hence in the end the intermediate piles cast into ground act as a permanent load carrying pillars.

3. Scheduling the Activities

The construction activities from ancient age have a typical stage of commencement during the execution phase i.e. the first activity starts from the foundation of the structure. The conventional method of construction of structures is based on Bottom-Up method in which the sub-structure and super-structure floors are constructed sequentially from the bottom of the sub-structure or lowest level of basement to the top of the super-structure. This method is suitable for small scale works, as there is rapid change in patterns of use of land available like use of underground basements for parking, underground metro stations the volume of works at the foundation level of the structures has increased to manifolds The top-down method is an another construction method that can be used for structures with basement floor and having space and other constraints.

Here the all the activities in a construction project management such as project duration, resources, labor etc., are scheduling using primavera in both the above construction methods with respect to our project site (residential building (G+4)).

- Bottom-up Construction Schedule

  Using primavera all the activities such as project duration, resources, labor, cost etc. for the proposed residential apartment with G+4 in bottom-up construction is scheduled. The residential building project is situated in Trivandrum, Kerala. The residential building is 926.112square feet with G+4 structure without providing required parking facilities. Construction schedule is as shown in the Table.

APPARTMENT BUILDING G+4_td

#	Activity ID	Activity Name	Original Duration	Start	Finish	Budgeted Total Cost
1	**APPARTMENT BUILDING G+4_td**		300.75d	01-Jun-19 A	20-May-20	133,034,941.16
2	**Diaphram Wall Construction**		24.00d	01-Jun-19 A	01-Jul-19 A	962,500.00
3	A1000	Earthwork excavation	4.00d	01-Jun-19 A	06-Jun-19 A	27,500.00
4	A1010	Reinforced Cement concrete - R.C.C (with reinforceme	20.00d	07-Jun-19 A	01-Jul-19 A	935,000.00
5	**Pile foundation**		44.00d	01-Jul-19 A	22-Aug-19 A	5,220,000.00
6	A1020	Drilling of holes at 20m depth for pile foundation	24.00d	01-Jul-19 A	29-Jul-19 A	2,160,000.00
7	A1030	Reinforced Cement concrete - R.C.C (with reinforceme	20.00d	29-Jul-19 A	22-Aug-19 A	3,060,000.00
8	**BASEMENT FLOOR**		18.00d	22-Aug-19	12-Sep-19 A	1,035,000.00
9	**TIE BEAM**		8.00d	22-Aug-19	31-Aug-19 A	459,000.00
10	A1040	Reinforced Cement concrete - R.C.C (with reinforceme	8.00d	22-Aug-19	31-Aug-19 A	459,000.00
11	**COLUMNS**		8.00d	31-Aug-19	10-Sep-19 A	408,000.00
12	A1050	Reinforced Cement concrete - R.C.C (with reinforceme	8.00d	31-Aug-19	10-Sep-19 A	408,000.00
13	**Plain Cement concrete**		2.00d	10-Sep-19	12-Sep-19 A	168,000.00
14	A1060	PCC	2.00d	10-Sep-19	12-Sep-19 A	168,000.00
15	**GROUNDFLOOR**		22.00d	12-Sep-19	08-Oct-19 A	1,189,499.70
16	**TIE BEAM**		8.00d	12-Sep-19	21-Sep-19 A	459,000.00
17	A1070	Reinforced Cement concrete - R.C.C (with reinforceme	8.00d	12-Sep-19	21-Sep-19 A	459,000.00
18	**COLUMNS**		8.00d	21-Sep-19	01-Oct-19 A	408,000.00
19	A1080	Reinforced Cement concrete - R.C.C (with reinforceme	8.00d	21-Sep-19	01-Oct-19 A	408,000.00
20	**Brick work- Solid cement block 6"**		6.00d	01-Oct-19 A	08-Oct-19 A	322,499.70
21	A1090	GROUND FLOOR	6.00d	01-Oct-19 A	08-Oct-19 A	322,499.70
22	**Plastering**		30.00d	08-Oct-19 A	12-Nov-19 A	1,050,772.16
23	A1100	BASEMENT FLOOR	15.00d	08-Oct-19 A	25-Oct-19 A	430,089.80
24	A1110	GROUND FLOOR	15.00d	25-Oct-19 A	12-Nov-19 A	620,682.36
25	**Wood work for joinery(teakwood)**		25.00d	12-Nov-19	11-Dec-19 A	1,600,000.00
26	A1120	GROUND FLOOR	25.00d	12-Nov-19	11-Dec-19 A	1,600,000.00
27	**Earth filling**		2.00d	11-Dec-19	13-Dec-19 A	108,000.00
28	A1130	Earth filling	2.00d	11-Dec-19	13-Dec-19 A	108,000.00
29	**Supplying,paving and polishing with tiles**		10.00d	13-Dec-19	25-Dec-19 A	247,000.00
30	A1140	GROUND FLOOR	10.00d	13-Dec-19	25-Dec-19 A	247,000.00
31	**White washing and colour washing**		12.00d	25-Dec-19	08-Jan-20 A	384,792.40
32	A1150	BASEMENT FLOOR	6.00d	25-Dec-19	01-Jan-20 A	157,350.00
33	A1160	GROUND FLOOR	6.00d	01-Jan-20 A	08-Jan-20 A	227,442.40
34	**Supplying and fitting 30mm thick solid pvc door**		2.00d	08-Jan-20 A	10-Jan-20 A	35,000.00
35	A1170	BASEMENT FLOOR	1.00d	08-Jan-20 A	09-Jan-20 A	15,000.00
36	A1180	GROUND FLOOR	1.00d	09-Jan-20 A	10-Jan-20 A	20,000.00
37	**Electrification & plumbing**		20.00d	10-Jan-20 A	03-Feb-20 A	1,500,000.00

38		A1190	Electrification & plumbing	20.00d	10-Jan-20 A	03-Feb-20 A	1,500,000.00
39	**Unforeseen item if any**			5.00d	03-Feb-20	08-Feb-20 A	29,309.20
40		A1200	Unforeseen item	5.00d	03-Feb-20	08-Feb-20 A	29,309.20
41	**Reinforced Cement concrete work**			60.00d	12-Sep-19	21-Nov-19 A	2,388,112.00
42		A1210	FIRST FLOOR	20.00d	12-Sep-19	05-Oct-19 A	19,550.00
43		A1220	SECOND FLOOR	20.00d	05-Oct-19 A	29-Oct-19 A	1,101,667.00
44		A1230	THIRD FLOOR	20.00d	29-Oct-19 A	21-Nov-19 A	1,266,895.00
45	**Brick work- Solid cement block 6"**			24.00d	21-Nov-19	19-Dec-19 A	1,767,109.00
46		A1240	FIRST FLOOR	8.00d	21-Nov-19	30-Nov-19 A	508,875.00
47		A1250	SECOND FLOOR	8.00d	30-Nov-19	10-Dec-19 A	585,221.00
48		A1260	THIRD FLOOR	8.00d	10-Dec-19	19-Dec-19 A	673,013.00
49	**Supplying and fitting 30mm thick solid pvc door**			3.00d	19-Dec-19	23-Dec-19 A	200,000.00
50		A1270	FIRST FLOOR	1.00d	19-Dec-19	20-Dec-19 A	20,000.00
51		A1280	SECOND FLOOR	1.00d	20-Dec-19	21-Dec-19 A	20,000.00
52		A1290	THIRD FLOOR	1.00d	21-Dec-19	23-Dec-19 A	160,000.00
53	**Electrification &plumbing**			20.00d	23-Dec-19	15-Jan-20 A	25,045,224.00
54		A1300	Electrification & Plumbing	20.00d	23-Dec-19	15-Jan-20 A	25,045,224.00
55	**Plastering-work**			15.00d	15-Jan-20 A	01-Feb-20 A	17,242,280.00
56		A1310	FIRST FLOOR	5.00d	15-Jan-20 A	21-Jan-20 A	4,965,440.00
57		A1320	SECOND FLOOR	5.00d	21-Jan-20 A	27-Jan-20 A	5,712,360.00
58		A1330	THIRD FLOOR	5.00d	27-Jan-20 A	01-Feb-20 A	6,564,480.00
59	**Wood work for joinery (teak wood)**			15.00d	01-Feb-20	06-Mar-20	49,230,528.00
60		A1340	FIRST FLOOR	5.00d	01-Feb-20	07-Feb-20 A	14,177,200.00
61		A1350	SECOND FLOOR	5.00d	07-Feb-20	05-Mar-20	16,304,048.00
62		A1360	THIRD FLOOR	5.00d	13-Feb-20	06-Mar-20	18,749,280.00
63	**White and colourwashing**			18.00d	19-Feb-20	23-Mar-20	6,207,150.70
64		A1370	FIRST FLOOR	6.00d	19-Feb-20	10-Mar-20	1,786,743.98
65		A1380	SECOND FLOOR	6.00d	26-Feb-20	16-Mar-20	2,055,292.66
66		A1390	THIRD FLOOR	6.00d	04-Mar-20	23-Mar-20	2,365,114.07
67	**Supplying,paving and polishing with tiles**			15.00d	23-Mar-20	09-Apr-20	10,548,112.00
68		A1400	FIRST FLOOR	5.00d	23-Mar-20	28-Mar-20	3,037,840.00
69		A1410	SECOND FLOOR	5.00d	28-Mar-20	03-Apr-20	3,493,008.00
70		A1420	THIRD FLOOR	5.00d	03-Apr-20	09-Apr-20	4,017,264.00
71	**LIFT**			20.00d	09-Apr-20	02-May-20	6,400,000.00
72		A1430	LIFT	20.00d	09-Apr-20	02-May-20	6,400,000.00
73	**Unforeseen item**			15.00d	02-May-20	20-May-20	644,552.00
74		A1440	Unforeseen item	15.00d	02-May-20	20-May-20	644,552.00

Table 1: Activity scheduling using Primavera software (Bottom-up construction)

- Top-down Construction Schedule

The ongoing conventional construction of the proposed project is theoretically converting into top-down construction method and erecting all the constraints in the project. The proposed project is with ground floor and four floors residential apartment without required parking facilities and space constraints. These proposed structures is converting to a structure with two basement floor and G+2 structure providing parking facilities and one floor below the ground floor. The scheduling of all the activities using primavera in the top-down technique is shown in the table below.

APPARTMENT BUILDING G+4					
Activity ID	Activity Name	Original Duration	Start	Finish	Budgeted Total Cost
APPARTMENT BUILDING G+4		359d	01-Jun-2019 A	27-Jul-2020	Rs28,715,514.66
Earthwork excavation in ordinary soil		4d	01-Jun-2019 A	06-Jun-2019 A	Rs56,000.00
A1000	Earthwork excavation	4d	01-Jun-2019 A	06-Jun-2019 A	Rs56,000.00
Plain cement concrete work		10d	07-Jun-2019 A	19-Jun-2019 A	Rs310,000.00
A1010	GROUND FLOOR	10d	07-Jun-2019 A	19-Jun-2019 A	Rs310,000.00
Earth filling & foundation		24d	01-Jul-2019 A	27-Jul-2019 A	Rs108,576.00
A1020	GROUND FLOOR	24d	01-Jul-2019 A	27-Jul-2019 A	Rs108,576.00
Reinforced Cement concrete work		105d	29-Jul-2019 A	28-Nov-2019 A	Rs6,657,564.00
A1030	GROUND FLOOR	25d	29-Jul-2019 A	27-Aug-2019 A	Rs1,666,000.00
A1040	FIRST FLOOR	20d	28-Aug-2019 A	19-Sep-2019 A	Rs957,950.00
A1050	SECOND FLOOR	20d	20-Sep-2019 A	12-Oct-2019 A	Rs1,101,666.00
A1060	THIRD FLOOR	20d	14-Oct-2019 A	05-Nov-2019 A	Rs1,266,900.00
A1070	FORTH FLOOR& STAIR ROOM	20d	06-Nov-2019 A	28-Nov-2019 A	Rs1,665,048.00
Brick work- Solid cement block 6"		40d	29-Nov-2019 A	14-Jan-2020 A	Rs2,955,402.01
A1080	GROUND FLOOR	8d	29-Nov-2019 A	07-Dec-2019 A	Rs322,500.00
A1090	FIRST FLOOR	8d	09-Dec-2019 A	17-Dec-2019 A	Rs508,874.00
A1100	SECOND FLOOR	8d	18-Dec-2019 A	26-Dec-2019 A	Rs585,220.00
A1110	THIRD FLOOR	8d	27-Dec-2019 A	04-Jan-2020 A	Rs673,020.00
A1120	FORTH FLOOR& STAIR ROOM	8d	06-Jan-2020 A	14-Jan-2020 A	Rs865,788.00
Supplying and fitting 30mm thick solid pvc door		3d	15-Jan-2020 A	17-Jan-2020 A	Rs95,000.00
A1130	GROUND FLOOR	1d	15-Jan-2020 A	15-Jan-2020 A	Rs15,000.00
A1140	FIRST FLOOR	1d	15-Jan-2020 A	15-Jan-2020 A	Rs20,000.00
A1150	SECOND FLOOR	1d	16-Jan-2020 A	16-Jan-2020 A	Rs20,000.00
A1160	THIRD FLOOR	1d	16-Jan-2020 A	16-Jan-2020 A	Rs20,000.00
A1170	FORTH FLOOR& STAIR ROOM	1d	17-Jan-2020 A	17-Jan-2020 A	Rs20,000.00
Electrification &plumbing		20d	18-Jan-2020 A	10-Feb-2020 A	Rs3,130,653.00
A1180	Electrification & Plumbing	20d	18-Jan-2020 A	10-Feb-2020 A	Rs3,130,653.00
Plastering		29d	11-Feb-2020 A	14-Mar-2020	Rs3,565,445.00
A1190	GROUND FLOOR	5d	11-Feb-2020 A	15-Feb-2020 A	Rs430,090.00
A1200	FIRST FLOOR	5d	17-Feb-2020 A	21-Feb-2020 A	Rs620,680.00

APPARTMENT BUILDING G+4					
Activity ID	Activity Name	Original Duration	Start	Finish	Budgeted Total Cost
A1210	SECOND FLOOR	5d	22-Feb-2020 A	06-Mar-2020	Rs714,045.00
A1220	THIRD FLOOR	5d	28-Feb-2020 A	09-Mar-2020	Rs820,560.00
A1230	FORTH FLOOR& STAIR ROOM	5d	09-Mar-2020	14-Mar-2020	Rs980,070.00
Wood work for joinery (teak wood)		25d	14-Mar-2020	13-Apr-2020	Rs6,987,236.00
A1240	GROUND FLOOR	5d	14-Mar-2020	20-Mar-2020	Rs230,000.00
A1250	FIRST FLOOR	5d	20-Mar-2020	26-Mar-2020	Rs1,772,150.00
A1260	SECOND FLOOR	5d	26-Mar-2020	01-Apr-2020	Rs2,038,006.00
A1270	THIRD FLOOR	5d	01-Apr-2020	07-Apr-2020	Rs2,343,660.00
A1280	FORTH FLOOR& STAIR ROOM	5d	07-Apr-2020	13-Apr-2020	Rs603,420.00
White washing and colour washing		29d	13-Apr-2020	16-May-2020	Rs1,261,974.05

A1290	GROUND FLOOR	5d	13-Apr-2020	18-Apr-2020	Rs146,550.00
A1300	FIRST FLOOR	6d	18-Apr-2020	25-Apr-2020	Rs223,343.03
A1310	SECOND FLOOR	6d	25-Apr-2020	02-May-2020	Rs256,908.92
A1320	THIRD FLOOR	6d	02-May-2020	09-May-2020	Rs295,639.05
A1330	FORTH FLOOR& STAIR ROOM	6d	09-May-2020	16-May-2020	Rs339,533.05
Supplying,paving and polishing with tiles		26d	16-May-2020	16-Jun-2020	Rs2,143,112.60
A1340	GROUND FLOOR	6d	16-May-2020	23-May-2020	Rs247,002.60
A1350	FIRST FLOOR	5d	23-May-2020	29-May-2020	Rs379,730.00
A1360	SECOND FLOOR	5d	29-May-2020	04-Jun-2020	Rs436,626.00
A1370	THIRD FLOOR	5d	04-Jun-2020	10-Jun-2020	Rs502,158.00
A1380	FORTH FLOOR& STAIR ROOM	5d	10-Jun-2020	16-Jun-2020	Rs577,596.00
LIFT		20d	16-Jun-2020	09-Jul-2020	Rs800,000.00
A1390	LIFT	20d	16-Jun-2020	09-Jul-2020	Rs800,000.00
Unforeseen item if any		15d	09-Jul-2020	27-Jul-2020	Rs644,552.00
A1400	Unforeseen item	15d	09-Jul-2020	27-Jul-2020	Rs644,552.00

Table 2: Activity scheduling using Primavera software (Top-down construction)

4. Construction Schedule Comparison

After scheduling all the activities such as project duration, resources and cost in both top-down and bottom-up construction technique the scheduled data is compared and analyzed with respect to execution time.

	Bottom-up method	Top-down method
Execution time (days)	359	300

Table 3: Comparison table

The comparative study of both the schedules concludes that the project duration can be reduced by adopting top-down method.

5. CONCLUSION

The time saving is one of the important factor while considering the construction of a building and by using the top-down construction method the execution time can be considerably reduced whether it is an infrastructural work or residential works. In this case study the project duration for the five floor residential apartment is 359 days in bottom-up construction method and 300 days in top-down construction method. Here the time over runs can be reduced by 15% while using top-down construction method. For gigantic projects the time over runs can be reduced more. One of the advantage of this technique is that underground areas are utilized to a better extend reducing the number of podium floors that are generally provided in buildings for parking without affecting the construction schedule. The another benefit this construction method is that height of the superstructure can be reduced by providing number of basement floors and thus the height restriction rules like restricted zones near airport, tower or other areas of strategic importance cannot be affected.

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BIOGRAPHIES

Kavya Prince
Department of Civil Engineering
Saintgits College of Engineering

Theertha S.L
Department of Civil Engineering
Saintgits College of Engineering

Sujithmon S
Department of Civil Engineering
Saintgits College of Engineering

Joseph Zacheriah
Department of Civil Engineering
Saintgits College of Engineering

Er. Ajesh K Kottuppillil
Assistant Professor
Department of Civil Engineering
Saintgits College of Engineering