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Planning, Analysis and Building Information Modelling (BIM) of G+20 Residential Tower

Vishal Uttam Misal[1], Harsh Bhavesh Diwani[2*], Tanishq Ravindra Rane[3], Saish Shamkant Kadam[4], Ashish Shashikumar[5]

[1]*Assistant Professor, Department of Civil Engineering, A. P. Shah Institute of Technology, Thane, India*
[2,3,4,5]*Bachelor of Engineering, Department of Civil Engineering, A. P. Shah Institute of Technology, Thane, India*

***Abstract*: Building information modelling is an advanced technology which is nowadays becoming popular in India due its extensive utility in designing, analysis, planning, etc. The G+20 Residential Building is based out in Mumbai region in the state of Maharashtra, India. The study is aimed at creating an intelligent model through planning, analysis, scheduling and estimation using BIM based softwares. This software addresses project complexity and helps in managing the diverse demands and requirements of designers and contractors. This paper brings out detailed 3D smart model, its complete design report, complete scheduling and approximate estimation. Tall structures have continued to climb higher and higher facing strange loading effects and very high loading values due to dominating lateral loads. The design criteria for tall buildings are strength, serviceability, stability and human comfort. Thus, the effects of lateral loads like wind loads, earthquake forces are attaining increasing importance and almost every designer is faced with the problem of providing adequate strength and stability against lateral loads. Designing using Softwares like Etabs and Revit reduces a lot of time in design work. Details of each and every member can be obtained using Revit. Accuracy is improved by using software. Primavera P6 is an integrated Project Portfolio Management solution consisting of role specific tools to satisfy each team member's needs, responsibilities and skills. This project presents a multi-storeyed residential building is analyzed using ETABS considering all the external forces. This project is designed as per INDIAN CODES i.e IS 456:2000. This project also deals with Primavera P6 which is an EPPM software that includes project management, scheduling and estimation. In the last few years, the construction industry has witnessed a spurt in the use of more advanced software and tools, thanks to the rapid technological advancements, and one of them is the emergence of the Building Information Model (BIM). With the help of advancement in AR and VR technologies we will be able to visually represent our building more effectively using Gamma AR and Enscape.**

***Keywords*: BIM, AutoCad, Revit, Etabs, Naviswork, Gamma AR, Enscape.**

1. Introduction

BIM is a process for combining information and technology to create a digital intelligent model of a project that integrates data from many sources and evolves in parallel with the real project across its timeline, including design, construction, and in-use operational information more economically, and with less environmental impact.

BIM (Building Information Modeling is software that allows for a realistic digital representation of a building to be created for owners, architects, rcc consultants and contractors to collaborate on all aspects of building design. Building Information Modeling (BIM) is one of the most promising developments in the architecture, engineering, and construction (AEC) industries. Although the concepts, approaches, and methodologies that we now identify as BIM can be dated back nearly thirty years, it is first now that BIM is beginning to change the way we plan, design, and construct buildings and other infrastructure.

In order to compete in the ever-growing competent market, it is very important for a Civil Engineer to save time as a sequel to this, an attempt is made to plan and analyze a Multistoried building by using multiple softwares. Structural analysis and design is used to produce a structure capable of resisting all applied loads without failure during its intended life. Prior to the analysis and design of any structure, necessary information regarding supporting soil has to be collected by means of geotechnical investigation. Structural engineers are facing the challenges of striving for the most efficient and economical design with accuracy in solution while ensuring that the final design of a building must be serviceable for its intended function over its design lifetime. Nowadays various software packages are available in the market for analyzing and designing practically all types of structures viz. RISA, STAADPRO, ETABS, STRUDL, MIDAS, SAP and RAM etc.

Primavera P6 gives better quality of construction management process and easily understanding results. The planning process for building construction with some alternative schemes such as execution schedule, activities relationship, resource allocation, etc. has been attempted to examine the consequence of overall implementation in terms of scope and time to the project. Effective time planning is very important in determining the success of any project, poor planning and controlling of projects will cause delays. To overcome this time running problem analysis can be done by using the primavera p6 software.

Building information modeling is an advanced technology that is nowadays becoming popular in India due to its extensive utility in designing, analysis, planning, etc. The study is aimed

*Corresponding author: harshdiwani17@gmail.com

at creating an intelligent model through planning, analysis, estimation, and simulation using BIM-based software. These softwares addresses project complexity and helps in managing the diverse demands and requirements of designers and contractors. This paper brings out a detailed 3D smart model, its complete report, complete scheduling and estimation along with simulation if any in the project.

Augmented Reality and Virtual Reality, a state of the art technology for superimposing information onto the real world, has recently started to have an effect on our everyday lives. AR and VR technology-based applications are becoming more mature and versatile then before. Using these technologies errors are minimized and Quality management is enhanced. AR combines Real and Computer-based scenes and images to deliver an enhanced view of the world. On the other hand, VR is based on a computer-generated simulation of a 3D image or environment that can be interacted with in an apparently real or physical manner.

Scope:

The scope of this project is to introduce multiple software and reduce the complexity and increase the efficiency with the introduction of Building Information Modeling.

Objectives:

- To create a plan layout of the Residential (G+20) building using Autocad.
- To analyze the Residential Building using Etabs.
- To create a basic schedule of the building using Primavera P6.
- To perform BIM using Revit and Naviswork (3D, 4D & 5D).
- Application of Augmented Reality and Virtual Reality in BIM.

2. Methodology

A. *Planning layout of G+20 residential tower*

- Plinth area - 8500sqft
- Total Area – 170000sqft
- It's a G+20 Residential Building with 15 flats on one floor (including 1bhks & 2bhks).

Fig. 1. Layout

B. *Structural analysis using ETABS*

Fig. 2 and 3 shows the plan view and 3D view of a structural member. Specifications of the structure are gives as below:

Table 1
Specifications of the structure

Height of Building	60m
Type of Structure	Residential Building
Soil type	Medium soft
Floor to floor Height	3m
Response reduction factor	5
Seismic zone	Zone III

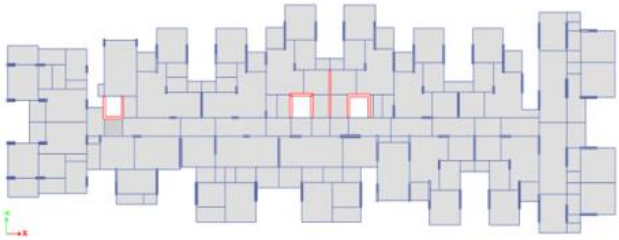

Fig. 2. Plan view

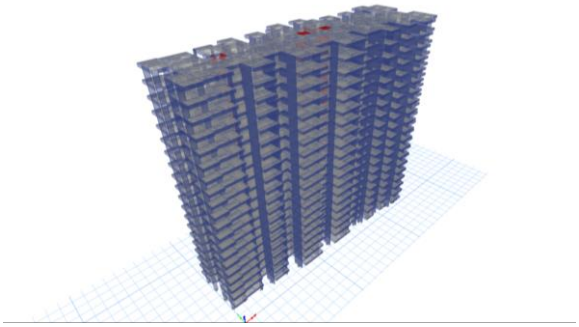

Fig. 3. 3D view

1) Properties

Size of beam:

- Beam(150X600)
- Beam (230X600)
- H Beam (230X125)

Size of Column:

1. Col (230X700)
2. Col (230X900)
3. Col (230X1200)
4. Col (230X1000)
5. Col (230X1650)
6. Col (230X1800)
7. Col (230X2100)
8. Col (230X2400)
9. Col (230X2600)
10. Col (230X2700)
11. Col (300X100)
12. Col (300X700)
13. Col(300X900)
14. Col(300X1200)
15. Col(300X1800)
16. Col(300X2110)
17. Col(300X1650)
18. Col(300X2600)
19. Col(300X2700)
20. Col (350X700)
21. Col (350X900)
22. Col (350X1000)
23. Col (350X1200)
24. Col (400X1000)

Slab Thickness: S1 – 175mm
Steel Grade: HYSD 500
Concrete Grade: M30, M35, M40, M45
Shear Wall: 6" and 9"

2) Defining of loads

The loads in ETABS are defined as using static load cases command in define menu. In the Load Cases Dead load of wall (230mm thick) 17 KN/m, live load of 2 KN/m^2 and floor finish of 1 KN/m^2 was defined.

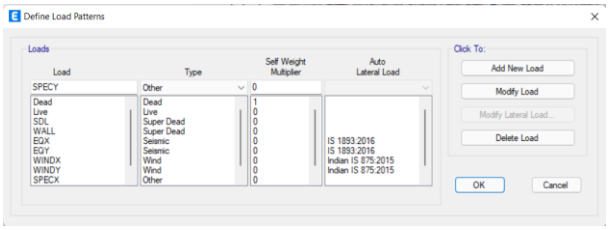

Fig. 4. Load patterns

After modelling of the structure properly and assigning the loads, analysis was performed and errors were rectified.

a. Wind & Earthquake Analysis:

i. Storey Displacement:

As per IS: 456-2000 The lateral sway at the top of the building shall not exceed H/500 for transient wind loads, where H is total height of the building.

The total Height of our building is 60m.

H/500 = 60000/500=120mm.

From fig. the maximum storey displacement is 43.15mm. Hence the displacement is within the limit and therefore the structure is safe.

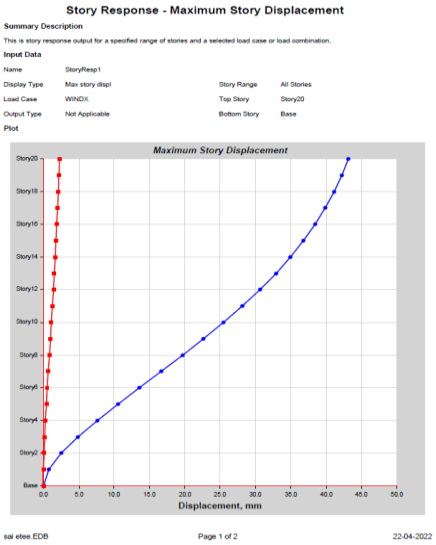

Fig. 5. Storey displacement (Wind X)

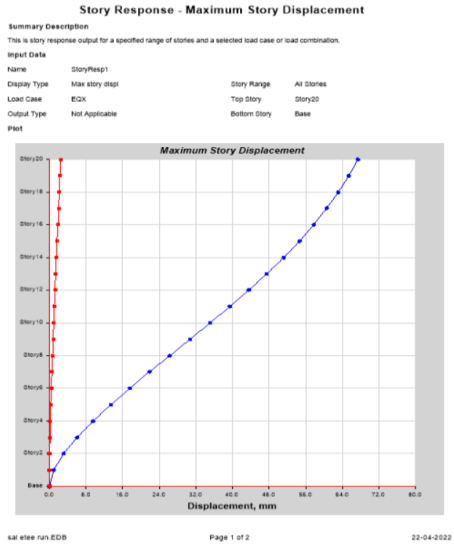

Fig. 6. Storey displacement (EQ X)

i. Storey Drift:

Storey drift is the lateral displacement of a floor relative to the floor below, and the storey drift ratio is the storey drift divided by the storey height.

As per IS Code:

The storey drift in any storey due to the minimum specified design lateral force, with partial load factor of 1.0. shall not exceed 0.004 times the storey height.

Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	m			
Story20	60	Top	0.000325	0.000028
Story19	57	Top	0.000362	0.00003
Story18	54	Top	0.000413	0.000032
Story17	51	Top	0.000474	0.000034
Story16	48	Top	0.000541	0.000036
Story15	45	Top	0.000613	0.000039
Story14	42	Top	0.000685	0.000042
Story13	39	Top	0.000757	0.000044
Story12	36	Top	0.000825	0.000047
Story11	33	Top	0.00089	0.000048
Story10	30	Top	0.000945	0.000049
Story9	27	Top	0.000973	0.00005
Story8	24	Top	0.001004	0.000049
Story7	21	Top	0.001021	0.000048
Story6	18	Top	0.001018	0.000045
Story5	15	Top	0.000986	0.000041
Story4	12	Top	0.000913	0.000036
Story3	9	Top	0.000786	0.000028
Story2	6	Top	0.000579	0.000019
Story1	3	Top	0.000248	0.000006
Base	0	Top	0	0

Fig. 7. Storey drift (Wind X)

Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	m			
Story20	60	Top	0.000708	0.000045
Story19	57	Top	0.000751	0.000046
Story18	54	Top	0.00084	0.000047
Story17	51	Top	0.000942	0.000049
Story16	48	Top	0.001046	0.00005
Story15	45	Top	0.001146	0.000052
Story14	42	Top	0.001238	0.000052
Story13	39	Top	0.001319	0.000052
Story12	36	Top	0.001386	0.000051
Story11	33	Top	0.001439	0.00005
Story10	30	Top	0.001473	0.000047
Story9	27	Top	0.001465	0.000044
Story8	24	Top	0.001459	0.000042
Story7	21	Top	0.001436	0.000038
Story6	18	Top	0.001387	0.000035
Story5	15	Top	0.001305	0.00003
Story4	12	Top	0.001179	0.000025
Story3	9	Top	0.000993	0.000019
Story2	6	Top	0.000711	0.000013
Story1	3	Top	0.000304	0.000005
Base	0	Top	0	0

Fig. 8. Storey drift (EQ X)

ii. Storey Shear:

It is the lateral force acting on a storey due to the forces such as seismic and wind force. It is calculated for each storey, changes from minimum at the top to maximum at the bottom of the building.

As the storey number decreases the base shear value for WX & WY increases.

Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	m		kN	kN
Story20	60	Top	-60.586	0
		Bottom	-60.586	0
Story19	57	Top	-181.0761	0
		Bottom	-181.0761	0
Story18	54	Top	-300.5459	0
		Bottom	-300.5459	0
Story17	51	Top	-418.9558	0
		Bottom	-418.9558	0
Story16	48	Top	-535.8051	0
		Bottom	-535.8051	0
Story15	45	Top	-650.7793	0
		Bottom	-650.7793	0
Story14	42	Top	-763.8884	0
		Bottom	-763.8884	0
Story13	39	Top	-875.1474	5.315E-07
		Bottom	-875.1474	5.315E-07
Story12	36	Top	-984.5717	9.749E-07
		Bottom	-984.5717	9.749E-07
Story11	33	Top	-1092.1765	1.12E-06
		Bottom	-1092.1765	1.12E-06
Story10	30	Top	-1197.7784	1.599E-06
		Bottom	-1197.7784	1.599E-06
Story9	27	Top	-1300.6082	1.608E-06
		Bottom	-1300.6082	1.608E-06
Story8	24	Top	-1400.5071	1.608E-06
		Bottom	-1400.5071	1.608E-06
Story7	21	Top	-1497.4337	1.609E-06
		Bottom	-1497.4337	1.609E-06
Story6	18	Top	-1590.4666	1.613E-06
		Bottom	-1590.4666	1.613E-06
Story5	15	Top	-1678.7116	1.615E-06
		Bottom	-1678.7116	1.615E-06
Story4	12	Top	-1760.912	1.616E-06
		Bottom	-1760.912	1.616E-06
Story3	9	Top	-1839.1937	1.616E-06
		Bottom	-1839.1937	1.616E-06
Story2	6	Top	-1917.1685	1.616E-06
		Bottom	-1917.1685	1.616E-06
Story1	3	Top	-1995.1432	1.616E-06
		Bottom	-1995.1432	1.616E-06
Base	0	Top	0	0
		Bottom	0	0

Fig. 9. Storey shear (Wind X)

Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	m		kN	kN
Story20	60	Top	-272.1167	-6.566E-07
		Bottom	-263.9142	-0.6193
Story19	57	Top	-553.2527	-0.4864
		Bottom	-553.2527	-0.4864
Story18	54	Top	-836.8006	-2.039E-06
		Bottom	-832.4761	-6.5753
Story17	51	Top	-1040.7708	-12.5575
		Bottom	-1040.7708	-12.5575
Story16	48	Top	-1238.5507	-12.2073
		Bottom	-1238.5507	-12.2073
Story15	45	Top	-1415.5695	-10.9497
		Bottom	-1415.5695	-10.9497
Story14	42	Top	-1570.6891	-9.2612
		Bottom	-1570.6891	-9.2612
Story13	39	Top	-1701.9801	-7.809
		Bottom	-1701.9801	-7.809
Story12	36	Top	-1813.1504	-6.6079
		Bottom	-1813.1504	-6.6079
Story11	33	Top	-1912.4369	-5.4216
		Bottom	-1912.4369	-5.4216
Story10	30	Top	-2005.1387	-3.6399
		Bottom	-2005.1387	-3.6399
Story9	27	Top	-2072.9004	-3.6164
		Bottom	-2072.9004	-3.6164
Story8	24	Top	-2126.8407	-3.4579
		Bottom	-2126.8407	-3.4579
Story7	21	Top	-2168.5693	-3.2293
		Bottom	-2168.5693	-3.2293
Story6	18	Top	-2199.331	-3.0059
		Bottom	-2199.331	-3.0059
Story5	15	Top	-2221.248	-2.7889
		Bottom	-2221.248	-2.7889
Story4	12	Top	-2236.4183	-2.6122
		Bottom	-2236.4183	-2.6122
Story3	9	Top	-2246.9437	-2.4005
		Bottom	-2246.9437	-2.4005
Story2	6	Top	-2254.7611	-2.6551
		Bottom	-2254.7611	-2.6551
Story1	3	Top	-2260.3191	-0.0004
		Bottom	-2260.3191	-0.0004
Base	0	Top	0	0
		Bottom	0	0

Fig. 10. Storey shear (EQ X)

1) 3D modelling using REVIT 2019

Revit is a building information modelling (BIM) software that helps constructions companies, structural engineers, architects and mechanical, engineering and plumbing (MEP) service providers manage designing, 3D visualization, analysis and other construction operations. Revit includes communication management tools, which lets teams share files, simultaneously work on projects and add notes or annotations on designs in a shared workspace to facilitate collaboration across multiple departments. Features include process design and documentation, 2D sheets import/export, construction coordination, fabrication management and more. Additionally, engineers can generate a variety of model-based designs such as elevations, floor plans and 3D views.

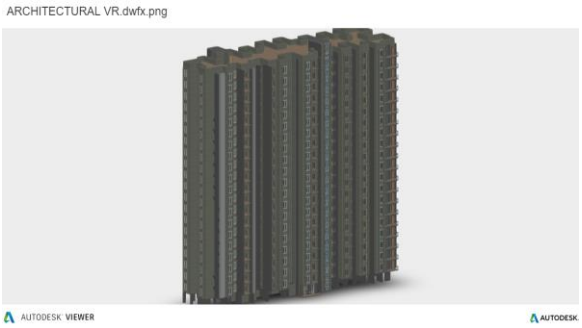

Fig. 11. 3D model

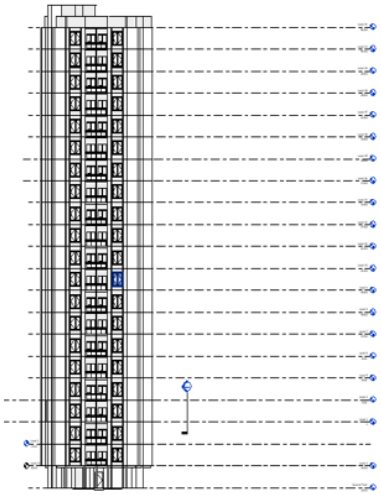

Figure No. 12 Levels in Elevation view

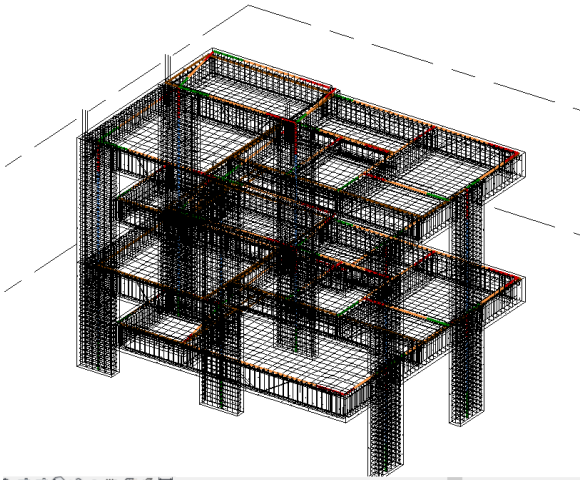

Fig. 13. Reinforcement detailing of a room

2) Estimation

Estimating is the technique of calculating or computing the various quantities and the expected Expenditure to be incurred on a particular work or project. While preparing an estimate, it is not possible to work out in detail in case of petty items. Items which are other than civil engineering such items are called lump sum items or simply L.S. items. During the construction of a project considerable number of skilled supervisors, work assistance, watch men etc., are employed on temporary basis. The salaries of these persons are drawn from the L.S. amount allotted towards the work charged establishment. The following are the methods used for preparation of approximate estimates.

a) Plinth area method
b) Cubical contents methods
c) Unit base method

a) Plinth area method:

The cost of construction is determined by multiplying plinth area with plinth area rate. The area is obtained by multiplying length and breadth (outer dimensions of building).

APPROXIMATE ESTIMATION

PLINTH AREA 8500 SQ.FT

TYPE	RATE	UNIT	FLOORS
Cost of Superstructure	₹ 7,000.00	per SQ.FT	for 1- 5 Floors
	₹ 8,000.00	per SQ.FT	for 6- 10 Floors
	₹ 9,000.00	per SQ.FT	for 11- 15 Floors
	₹ 10,000.00	per SQ.FT	for 16- 20 Floors

Fig. 14. Approximate rates

FLOORS	COST			
1	₹ 5,95,00,000.00		COST OF SUPERSTRUCTURE	₹ 1,44,50,00,000.00
2	₹ 5,95,00,000.00		COST OF SUB-STRUCTURE @ 10%	₹ 14,45,00,000.00
3	₹ 5,95,00,000.00		TOTAL COST	₹ 1,58,95,00,000.00
4	₹ 5,95,00,000.00			
5	₹ 5,95,00,000.00		SERVICE CHARGES	
6	₹ 6,80,00,000.00	1	WATER CHARGES @ 5% OF TOTAL COST	₹ 7,94,75,000.00
7	₹ 6,80,00,000.00	2	SANITARY CHARGES @ 5% OF TOTAL COST	₹ 7,94,75,000.00
8	₹ 6,80,00,000.00	3	ELECTRIFICATION CHARGES @ 9% OF TOTAL COST	₹ 14,30,55,000.00
9	₹ 6,80,00,000.00	4	ARCHITECTURAL CHARGES @ 1% OF TOTAL COST	₹ 1,58,95,000.00
10	₹ 6,80,00,000.00	5	MISC. CHARGES @ 5% OF TOTAL COST	₹ 7,94,75,000.00
11	₹ 7,65,00,000.00			₹ 39,73,75,000.00
12	₹ 7,65,00,000.00			
13	₹ 7,65,00,000.00		OVERALL COST	₹ 1,98,68,75,000.00
14	₹ 7,65,00,000.00			
15	₹ 7,65,00,000.00		ADDITIONAL COST	
16	₹ 8,50,00,000.00	1	CONTIGENCIES @ 5% OF OVERALL COST	₹ 9,93,43,750.00
17	₹ 8,50,00,000.00	2	WCE AND T&P @ 10% OF OVERALL COST	₹ 19,86,87,500.00
18	₹ 8,50,00,000.00			₹ 29,80,31,250.00
19	₹ 8,50,00,000.00			
20	₹ 8,50,00,000.00		GRAND TOTAL	₹ 2,29,00,00,000.00
	₹ 1,44,50,00,000.00			

Fig. 15. Calculations

3) Planning and scheduling

Project planning is the process of identifying all the activities necessary to successfully complete the project. Project scheduling is the process of determining the sequential order of the planned activities, assigning realistic durations to each activity, and determining the start and finish dates for each activity. Thus, project planning is a prerequisite to project scheduling because there is no way to determine the sequence or start and finish dates of activities until they are identified. However, the terms of project planning and scheduling are often used synonymously because planning and scheduling are performed interactively.

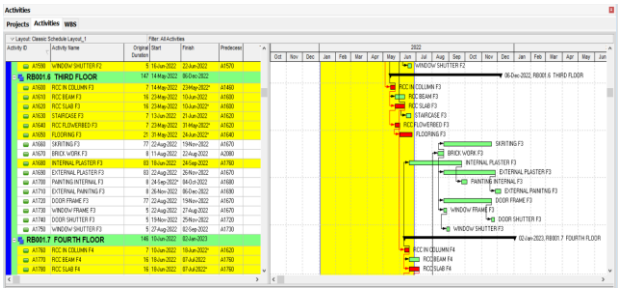

Fig. 16. Scheduling with Gantt chart

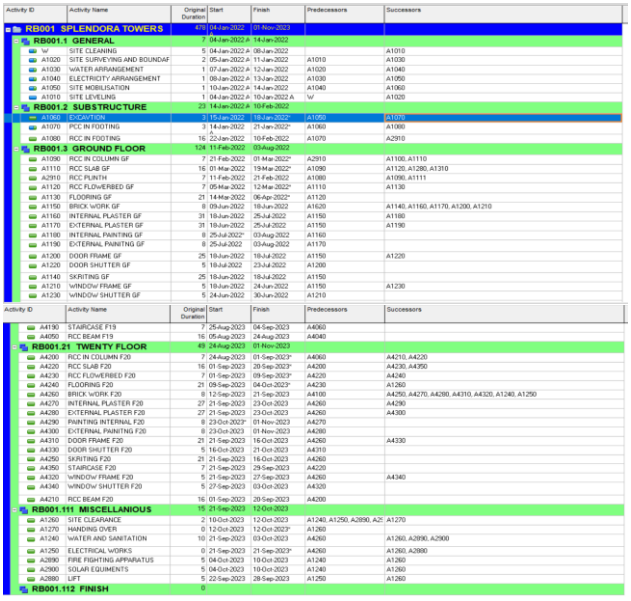

Fig. 17. Scheduling

4) 4D & 5D integration using Navisworks 2019

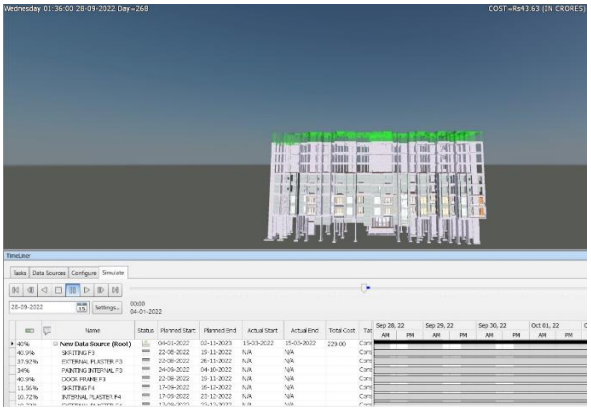

Fig. 18. 4D & 5D analysis

4D & 5D integration or visualization refers to the intelligent linking of individual 3D components or assemblies with time- or schedule-related and cost- related information. The use of the term 5D is intended to refer to the fifth dimension i.e. 5D is 3D plus 4D schedule (time) and cost. Time-related information for a particular element might include information on lead time, how long it takes to install/construct, the time needed to become operational/harden/cure, the sequence in which components should be installed, and dependencies on other areas of the project. Cost related information for a particular project that

include cost of superstructure, cost of substructure, service charges and the contingencies etc.

5) Augmented & Virtual Reality

i. Augmented Reality

AR merges the real and the virtual into a single immersive environment. AR uses a mobile smartphone or an AR headset to visualize 3D images onto a person's physical environment as they walk through a space.

ii. GAMMA AR

GAMMA AR provides an augmented reality-based construction management software that assists construction site managers and craftsman by intuitively overlaying 3D BIM Models accurately on the site, resulting in reduced errors, as well as speedy and unambiguous communication and progress monitoring, ultimately saving time and money. The application uses the data contained in Building Information Models (BIM) to overlay the worksite using augmented reality using mobile devices.

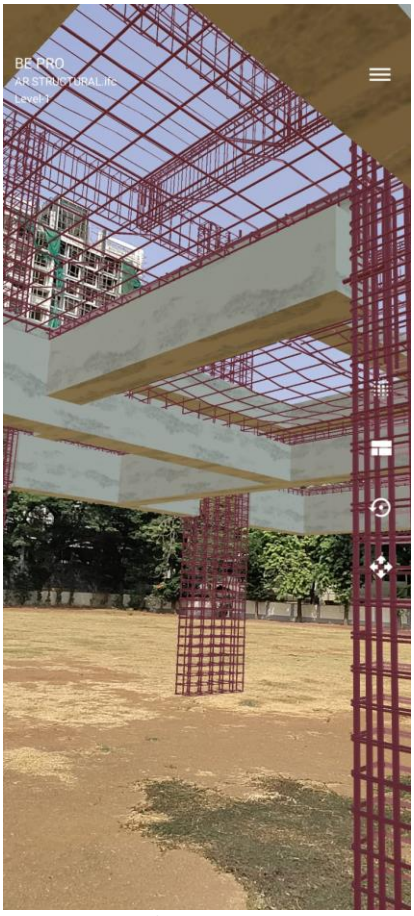

Fig. 19. Reinforcement Detailing in AR

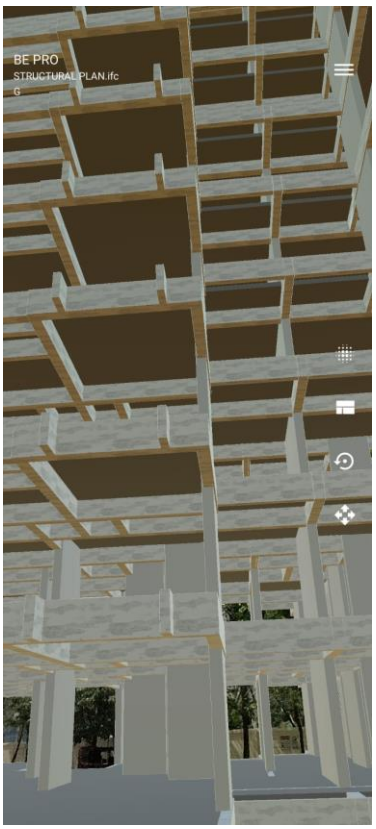

Fig. 20. Structural Model in AR

iii. Virtual Reality

The use of virtual reality in the construction industry gives

management as well as employees a clear, more realistic view of what to expect on the job site. Virtual reality can help ensure the safety of employees, provide a rapid view of what can be changed to improve productivity, and allow management a clear view of designs and construction sites before building begins.

iv. Enscape

Enscape is a real-time 3D rendering tool that focuses on enhanced visualization of BIM models, and it supports such visualization in the VR mode. Enscape is able to convert everything in a Revit file into a VR environment, such as the model itself, including materials and lighting, as well as the site environment and sun settings. It enables us to Geo-Tag the structure.

Fig. 21. Architectural Model in VR

Fig. 22. Structural model in VR

3. Results and Conclusions

- The G+20 structure was analysed using Etabs and all the results such as Storey displacement, Storey shear, Storey drift etc. were found under the maximum permissible limit. Hence the structure is stable.
- An exact 3D digital replica of the building was created using Autodesk Revit 2019.
- Approximate Estimation was done manually using plinth area method.
- The total cost of the project is Rs 229 Cr.
- Planning and Scheduling were done using Primavera P6. Work Breakdown Structure (WBS), Critical Path and Gantt chart were obtained from it.
- The total duration for the construction of the project was found to be 478 days, the project was assumed to be commencing on Jan 4th, 2022 and the estimated completion date of the project was found to be November 1st, 2023.
- The 3D model from Revit with the Schedule and cost made in Primavera were integrated in Navisworks to obtain an accurate 5D model (with 4D simulation) of the project.

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