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3D Modelling, Design and Safety Management in High Rise Building using Bim

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Abstract*: *In this works 3D modeling, design and safety management of high rise building using building information modeling (BIM) technology is carried out.. Initially a AutoCAD plan with all its salient features is developed following byelaws of high rise building. Then the 3D modeling and rendering of high rise building is done in the Revit architecture of the 2D plan which is imported from the AutoCAD. The analysis and design of high rise building is carried out using ETabs software. Apart from the structural design Mechanical, Electrical and Plumbing (MEP) services design is carried out using BIM technology . The layout of fire safety system is specified efficiently with use of BIM in co-ordination with MEP services. The application of BIM based design process resulted in considerable time reduction in compression with traditional design process and the holistic design of the high rise building is carried out with the compatibility of different softwares.

Keywords* : *High Rise Building; Bim; Mep; Fire Safety.

I. INTRODUCTION

Plan and 3d model with great elevation, detailed diagrams, and V-ray rendering are all provided by the Revit Architecture software. Building information modeling (BIM) provides information on project design, its various views, scope, numbers, and phases when you need it. Every project In Revit the model will include 2D, 3D, and section views. elevations with detailing and schedules. Revit Architecture gathers data on each structural element's material, its realistic visualization, and its design, such as thickness and height, and in the schedule, it will provide a number of data points such as cost, family type, number of bricks, number of doors, number of windows, and so on, across all other representations of the project. We can have all of these 2D, 3D, and sectional views, as well as elevation and detailed drawings, in one full sheet in Revit. The goal of structural design is to achieve a reasonable likelihood that the structure will fulfill the purpose for which it was intended and will safely resist the forces acting on it during its useful life.

Temperature swings, foundation settlements, and other factors should all be taken into account. The working stress technique, ultimate load method, and limit state approach are all utilized in the design of reinforced concrete buildings. For slabs, beams, columns, and stairwells, the selected approach is the limit state method. The limit state technique requires the structure to be built to withstand all loads likely to act on it over its life while also meeting serviceability standards such as deflection and cracking limits.

II. BUILDING INFORMATION MODELING (BIM):

"A digital representation of a building's physical and functional features that is shared/used by all stakeholders to minimize waste and enhance efficiency," according to BIM. As such, it acts as a common knowledge repository for information about a facility, providing a solid foundation for choices made throughout its life cycle. A fundamental assumption of BIM is cooperation among multiple stakeholders at various stages of a facility's life cycle to input, remove, update, or alter information in the BIM process to support and represent each stakeholder's function. BIM stands for Building Information Modeling, which is a shared digital representation based on open standards for interoperability. When BIM is utilized throughout the building process, however, it ensures that transportation is smooth. With a high level of detail BIM model, managers can access vital information about every nook and cranny of a facility. Building information modeling, or BIM, is an intelligent digital representation or model-based method for planning, designing, building, managing logistics, and carrying out operations and maintenance processes. It allows the builder to display the building according to its physical and functional features and provides a high level of information integration for the construction process.

III. LITERATURE REVIEW

- Rakesh Reddy E, and Kailash kumar S, (2019) studied on Design And Modeling Of G+5 Commercial Building By Autodesk Revit Architecture".

They concluded,

The project gives the realistic modeling of building and accurate families ranging from furniture to lighting fixtures, as well as import existing models from other software's like Auto CAD etc.

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- Sayyed Feroz Sikandar, et al. (2019) studied on Analysis and Design of Multistory Building Using ETABS 2017.They concluded,
  Analysis and design of building having G+10 storey's by using the ETABS software.
- Miss. Irin Ann Isac, Dr. Anoop C K (2019) studied on "Analysis Of Building Information Modelling And Scope Of BIM In India". They concluded,

BIM Digitalises the life of a building or a group of buildings to deliver optimised solutions in every phase from its conception to demolition.

a. Objectives

Following are the objectives of the project work:

1. To develop a 2D plan of high rise building (G+13) using BIM concept.
2. 3D Modeling and detailing of high rise building in REVIT software.
3. High-rise building analysis and design in ETABS software.
4. Structural detailing of high rise building.
5. Mechanical Electrical and Plumbing (MEP) 3D modeling by using BIM concept from the criteria of safety management.

b. Scope Of The Work

1. Modeling of high rise building with high graphical and good aesthetical visuals of rendered models which includes exterior as well as interior families consisting of various furniture and residential appliances, sighting the compatibility of both AutoCAD and Revit software the models are imported from AutoCAD software to later work upon in Revit.
2. By using ETABS software Analysis and Design of (G+13) High rise building, components of a building structure like beams, columns, stair, and foundation is designed according to the standard specifications.
3. The building services MEP and for safety management fire layout id designed using BIM.

IV. METHODOLOGY

I. SOFTWARES USED:

a. AUTOCAD
b. REVIT
c. ETABS

A. CONCEPTUAL PLANNING:

- Planning& designing of high rise building using Auto CAD.
- Auto CAD permits to draw 2D drawings such as plans, elevations and sections, can place doors, windows, ventilators and can place structural elements like walls, beams, columns, and slab.

B. 3D MODELING:

- For each structural element, the Revit Architecture will provide a plan view, 3D model with great elevation, detailed diagrams, and schedules.
- Every project in the Revit model will offer us with 2D, 3D, section views, elevations with details and schedules, as well as quantities..

➢ REVIT means Revised instantly which includes

a) Revit architecture
b) Revit structure
c) Revit MEP (Mechanical Electrical Plumbing)

C. ANALYSIS AND DESIGN:

- Analysis of the proposed plan in ETABS with different load combination.
- Modeling of the high rise building with structural details.
- Structural design of high rise building.

Building bye laws and regulation

The building bye laws oversee the following rules and regulation of building features:

1. Setback or building line.
2. Floor area ratio (FAR) or Total built-up area.
3. Open space requirement all over the building.
4. Plan showing internal dimensions of rooms, kitchen, living etc.
5. Cross sectional details showing heights of building and floor height.
6. Lightening and ventilation of rooms.
7. Structural details and design.

Floor area ratio

As per the NBC code-2016 for clear understanding, the built up area v/s plot area is follow:

Table 1

Sl /no	Plot area	Max allowable built-up area
1.	<200sqm	60%with 2storied structure.
2.	From 200-500sqm.	50% of the plot area.
3.	From 500-1000sqm.	40% of the plot area.
4.	Above 1000sqm.	33.33% of the plot area.

While preparing the plan the following bye laws are used:

- The maximum allowable built up area is 33% for the area 1000sqm and above.(NBC 2016).
- For building height of 45- to- 50m the setback in all direction should be 13m.
  (as per NBC 2016 table 2 of part 3)
- The minimum no of staircase and lifts for high rise building is 2.(NBC part 4).
- The width of staircase varies from 1m to 2m for high rise building. (NBC part 4).

PLAN OF THE BUILDING

The plan of the residential building (G+13), used for the current project work ,is developed using autocad and is shown in fig 1. The salient features of the proposed building are shown below:

TOTAL AREA = 2856SQM
➢ TOTAL BUILT UP AREA = 559SQM
➢ AREA OF 2BHK BLOCK = 140SQM

- FLOOR HEIGHT = 3.5M
- NO OF BLOCKS IN EACH FLOOR = 4
- TOTAL NO. OF FLOORS =13
- NO OF STAIRCASE =2
- NO OF ELEVATORS = 2
- COMMON CORRIDOR =1

The schedule of openings of doors, windows and ventilators are shown in table 2 below:

SCHEDULE OF OPENINGS

Table 2

1.	Doors, M.D	1.2 X 2.1M
2.	D	1 X 2.1M
3.	D1	0.75 X 2M
4.	Windows, W	1.2 X 1.2M
5.	KW	1.2 X 0.9M
6.	V	0.6 X 0.6M

CREATING PLANS IN AUTOCAD

The typical floor plan, column centre line diagram and plan showing column-beam layout are shown in fig.2,3&4 respectively:

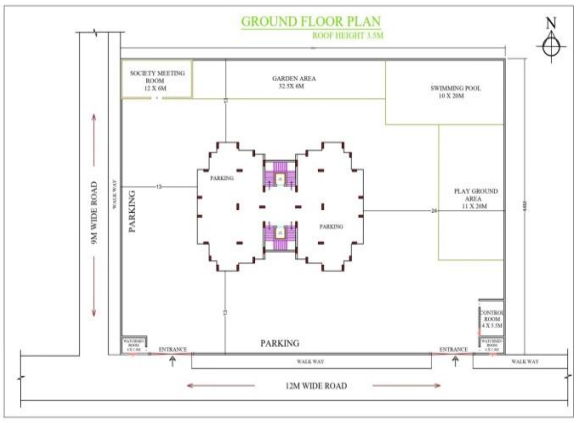

Fig1, Ground Floor Plan of Residential Building.

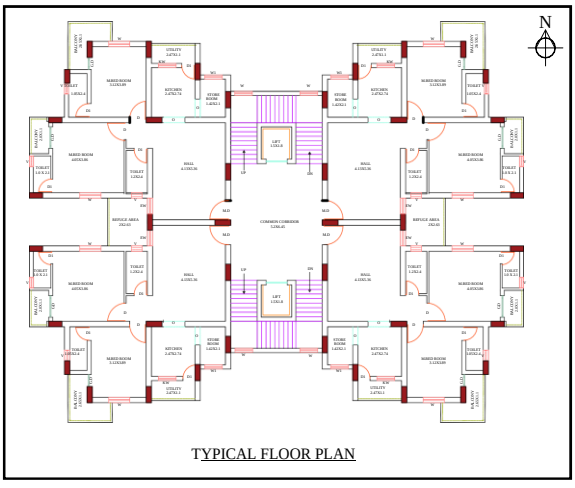

Fig2, Typical Floor Plan of Residential Building.

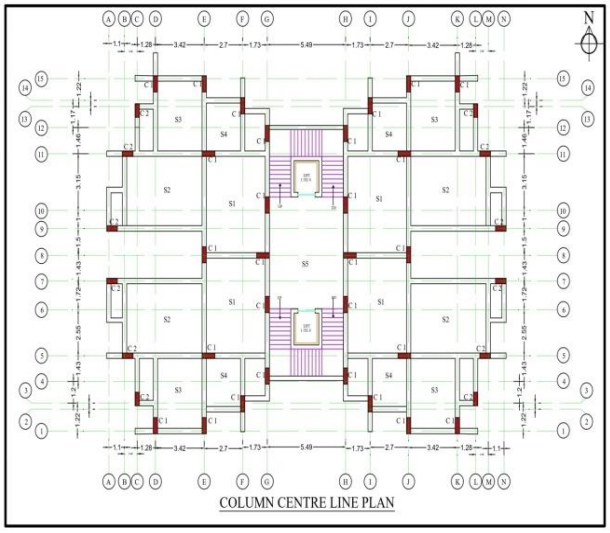

Fig3, Column Centre Line Plan.

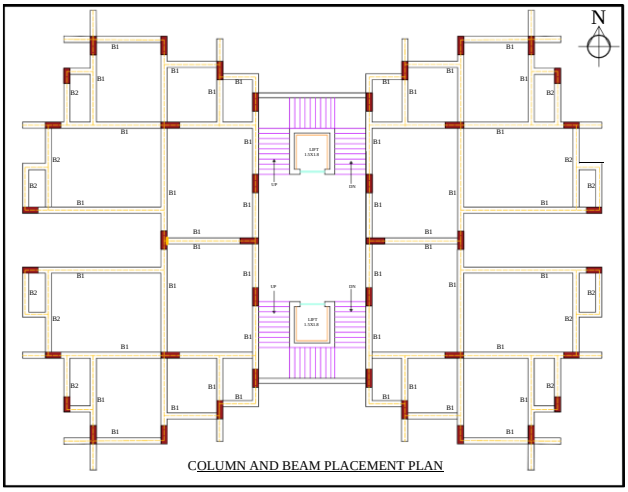

Fig4, Column Beam Placement Plan

Architectural 3D Modeling

Steps involved in completing the 3d modeling of a building:

1. Creating a Project
2. Name and Save the Project File
3. Zoom To a View
4. Rename Levels
5. Components
6. Creating walls
7. Adding doors
8. Adding window
9. Adding a roof
10. Adding a Ceiling
11. Adding a Floor
12. Adding stairs and railings
13. Adding Material
14. Placing a Component

V. CREATING 3D MODELS IN REVIT

3d rendered floor plan of high rise building in Revit as shown in fig 5&6 below:

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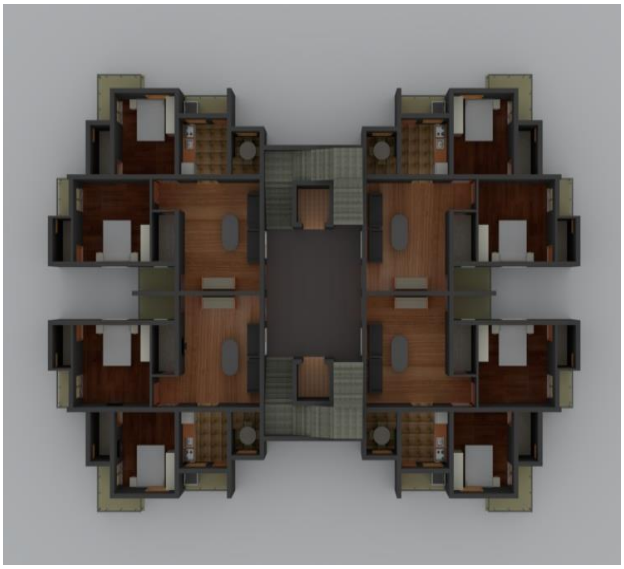

Fig 5, Architectural 3D floor plan of building.

Fig 6, Architectural 3D floor plan of building.

3D elevation of building showing east side elevation rendering in Revit software Using v ray application, is shown in fig, 7.

Fig 7,3D East elevation of Building.

3D elevation of building showing south side elevation rendering in Revit software using v ray application, is shown in fig.8.

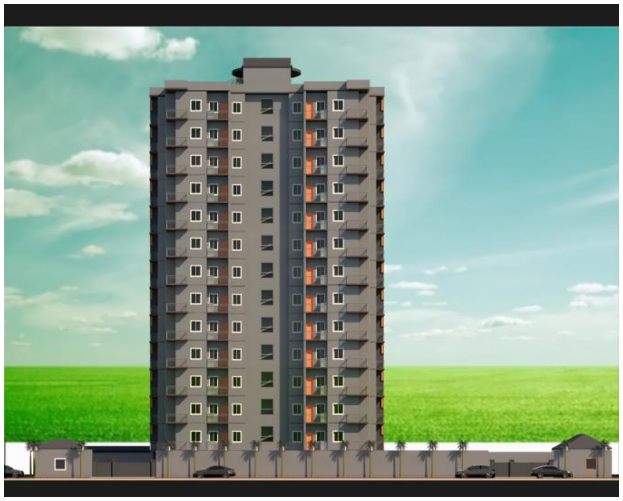

Fig 8, 3D front elevation of Building.

3D elevation of building showing west side elevation rendering in Revit software Using v ray application is shown in fig.9.

Fig 9, 3D West Elevation of Building.

3D terrace elevation of building providing helipad over the head room roof slab rendering in Revit software using v ray application, is shown in fig.10.

Fig 10, Architectural top view of Building in Revit.

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VI. ANALYSIS AND DESIGN

A. Structural Planning:

After completing the architectural plan, the structural plan of the residential high rise building is done which involves Position and orientation of beams and columns.

B. DESIGN INPUTS TO ETABS

Sectional Properties
COLUMN
Grade of Concrete : M35
Grade of Steel : HYSD 415
Weight per Unit Volume : 25KN/CU.M
Size of Column 1 (C1) : 300 X 900MM
Column 2 (C2) : 300 X 750MM
BEAM
Grade of Concrete : M35
Grade of Steel : HYSD 415
Weight per Unit Volume : 25KN/CU.M
Size of BEAM 1 (B1) : 300 X 900MM
BEAM 2 (B2) : 300 X 750MM

C. Load Pattern:

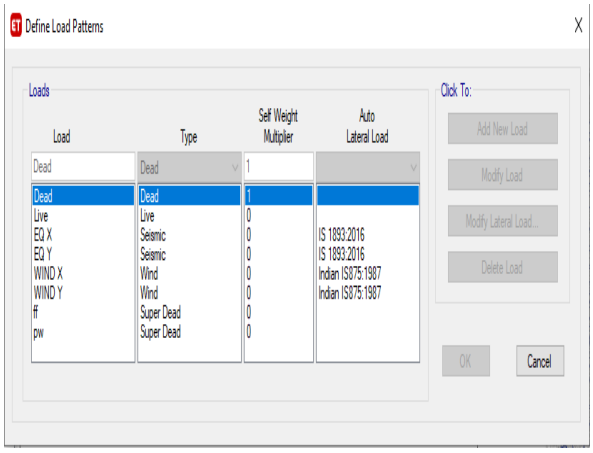
Codes used for design:

- IS 456-2000 code of practice for plain and reinforced concrete design.
- IS 875 part 1,2 and 3 for dead load, live load and wind load respectively.
- IS 1893-2016 for earthquake load.

D. Defining loads patterns

Reinforced concrete and prestressed concrete structures are generally designed as per Limit state method, the following load combinations are taken:

1. 1.5 (D.L +L. L)
2. 1.2(D. L + L. L±EX)
3. 1.2(D. L + L. L±EY)
4. 1.5(D. L ± EX)
5. 1.5(D. L±EY)
6. 0.9D. L±1.5EX
7. 0.9D. L±1.5EY



The live load for Hall, Kitchen, Bathroom and Toilet is taken as 2kN/m^2 For Staircase, corridors and balconies as 3kN/m^2 For parking area and electrical equipment room live load as 5kN/m^2

E. MODELLING IN ETABS

Imported floor plan centre line diagram from auto-CAD is shown in fig.11.

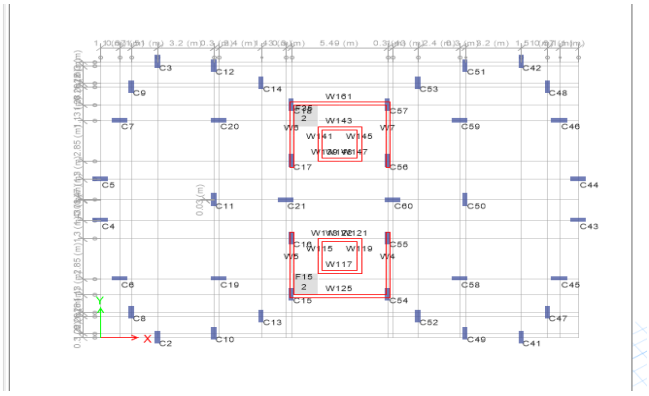


Fig11, centre line plan.

Details of 3D shell components of the building is shown in fig.12.

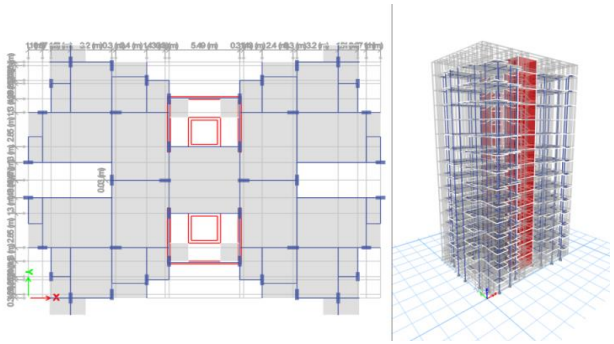


Fig 12, 3D Shell Component of High Rise Building.

- 2D & 3D MODEL OF FRAME SECTION IS SHOWN IN FIG.13.

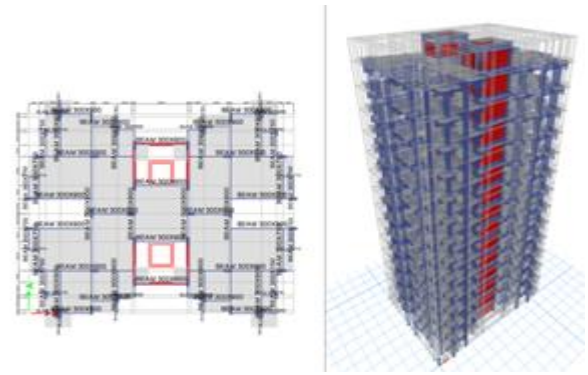


Fig13, 2D & 3D model of frame section.

- FIG.14 SHOWS THE LOAD ASSIGNED TO THE MODEL, THE ANALYZED 3D MODEL IS SHOWN IN FIG.15.

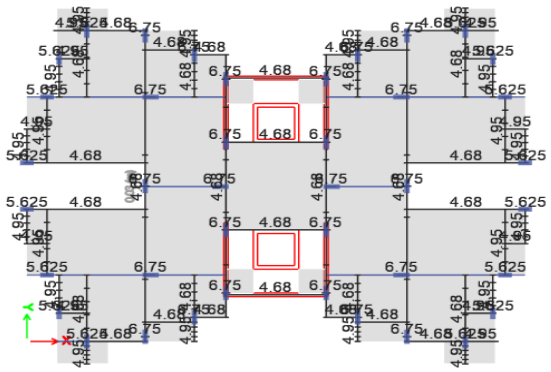


FIG 14, LOAD ASSIGNED TO THE MODEL.

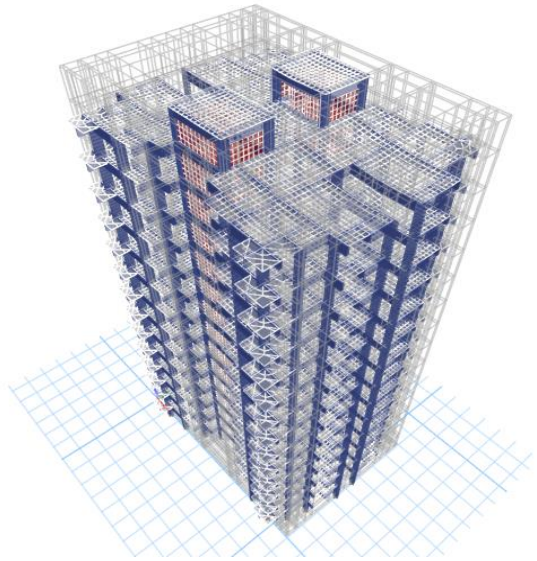


Fig 15 .Analyzed 3D model.

2D & 3D views of Bending moment and shear force diagrams are shown in fig.16. Bending moment and shear force diagram for two typical beam elements are shown in fig.17 & 18.

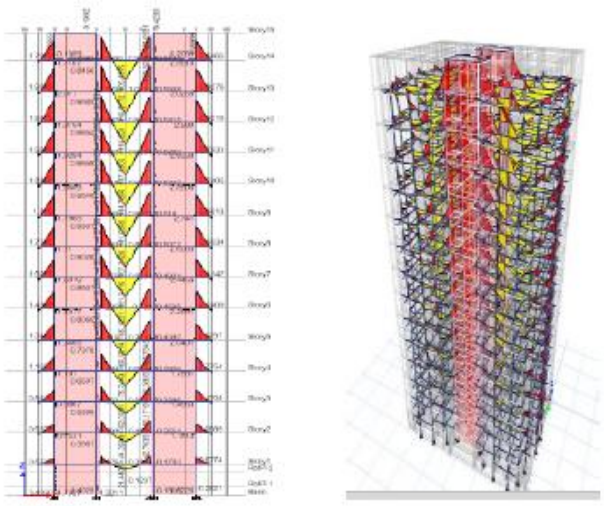


Fig 16, Bending Moment and Shear Force Diagram For The Building Frame.

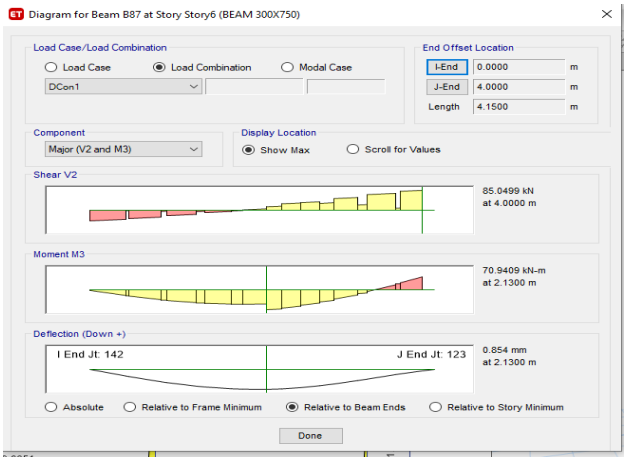


Fig 17, Shear force and bending moment values of beam (1).

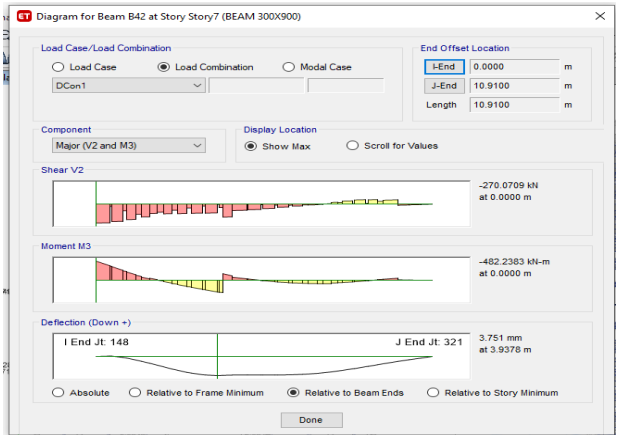


Fig 18, Shear force and bending moment values of beam (2).

- The longitudinal reinforcement of columns and beams values are shown in fig.19,

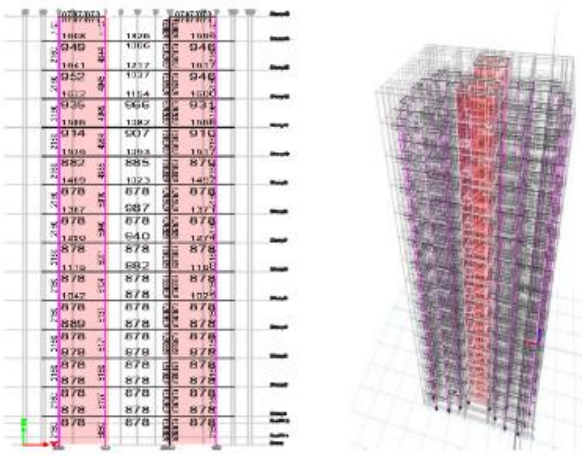


Fig 19, 3D model of structure after designed.

DETAILS OF COLUMN, BEAM, SLAB, FOOTING AND STAIRCASE

Typical design details of column and beam are shown in Table 3 & 4 respectively.

Table 3. Design details of Column C1 & C2

SCHEDULE OF COLUMNS		
PARTICULARS	SIZES	
COLUMN 1 (C1)	300 x 900MM	C/S OF COLUMN (C1)
COLUMN 2 (C2)	300 x 750MM	C/S OF COLUMN (C2)

Table 4. Design details of beam B1 & B2.

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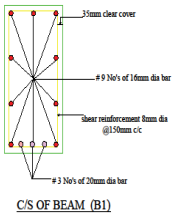
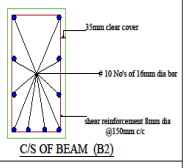
SCHEDULE OF BEAM		
PARTICULARS	SIZES	
BEAM 1 (B1)	300 x 900MM	 C/S OF BEAM (B1)
BEAM 2 (B2)	300 x 750MM	 C/S OF BEAM (B2)
		20MM DIA OF BAR 16MM DIA OF BAR 16MM DIA OF BAR

- SLAB DESIGN IS CARRIED OUT USING ETABS SOFTWARE.

Fig.20, Shows Typical Slab reinforcement details:

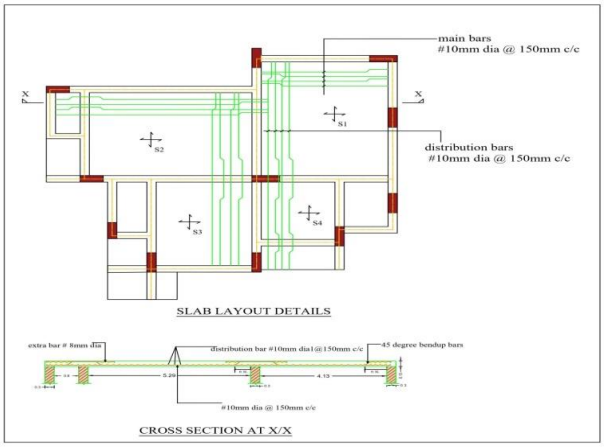


Fig.20, Slab Layout details.

- FIG.21, SHOWS THE TYPICAL COLUMN AND FOOTING REINFORCEMENT DETAILS:

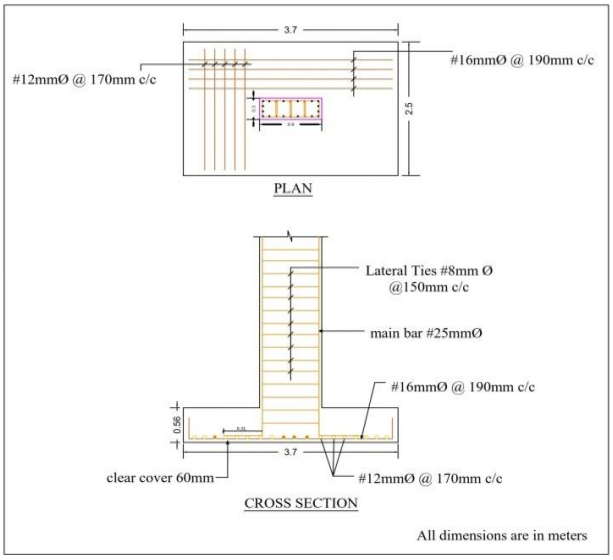


Fig.21, Column and Footing Details.

- Fig.22 Shows the typical Staircase reinforcement details:

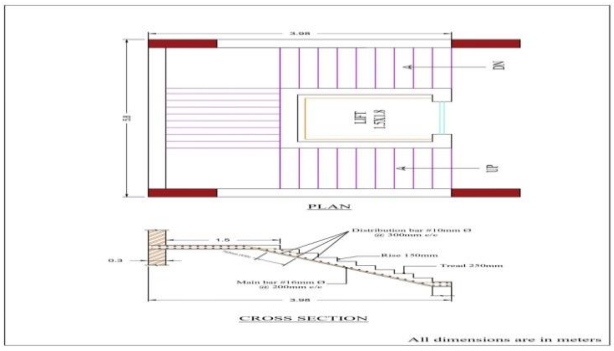


Fig.22, Staircase Details.

MECHANICAL, ELECTRICAL AND PLUBING (MEP)

These are the three key parts of a building project that comprise design, construction, and setup, operation, and maintenance. MEP Engineering is an important element of any construction project.

Planning, decision-making, correct documentation, performance- and cost-estimation, building, and operating/maintaining the resulting facilities all need mechanical, electrical, and plumbing (MEP) design.

Mechanical, electrical, and plumbing (MEP) systems are critical components of building services and can serve a variety of purposes. The usage of Revit MEP software in current times is beneficial in the design of MEP for buildings. Mechanical, electrical, and plumbing (MEP) work encompasses all aspects of a building's mechanical, electrical, and plumbing systems. Mechanical includes HVAC, electrical includes fire alarm, lighting, cabling, elevators, and plumbing includes everything from drain lines, soil lines, valves, and water tanks to W.C. repair. Architectural and civil construction gives a building its shape, structure, and beauty, but MEP, or mechanical, electrical, and plumbing, brings life to it by delivering services. MEP is a bundle of mechanical and electrical services for a variety of structures ranging from residential to commercial, such as processing plants, retail malls, and housing compounds, including skyscrapers.

Mechanical Works for the Building Project as Per NBC 2016.

Coordination of Mechanical System:

Figure.23 shows the heating, ventilation, and air conditioning (HVAC) equipment and distribution for the present project, including air handling units (AHU), variable air volume (VAV), ducting, and air terminals.

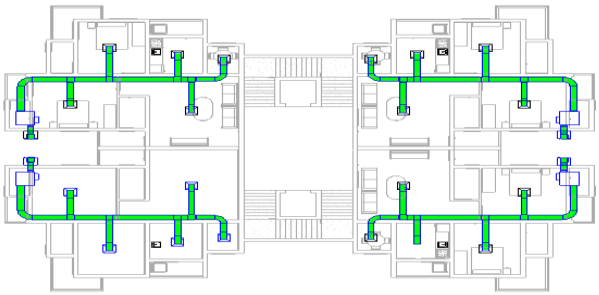


Fig.23, HVAC layout system plan.

Mechanical workers handle the majority of the work in MEP because of the HVAC or air conditioning system, which includes piping for cold and hot water, duct fabrication, thermal/cold insulation, and the installation of equipment such as chillers, air handling units, diffusers, and so on. Figure. 24 shows a 3D design of the HVAC layout system for the present project's of high-rise structure.

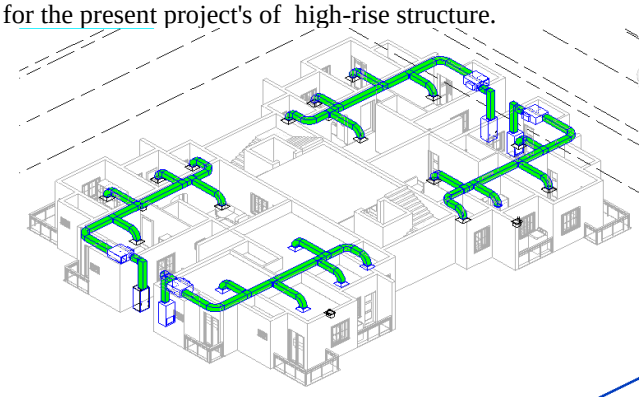


Fig24, 3D plan of HVAC layout system

Electrical Works for the Building Project as Per NBC 2016.

Coordination of Electrical System:

The electrical system include, Panel boards, switchboards, elevators, transformer , cable trays, conduits, conduits fittings etc, for the building of the project work in shown in fig.25.

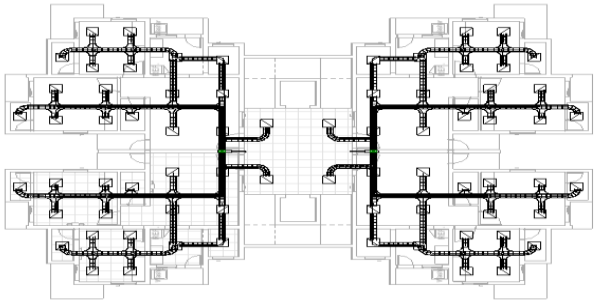


Fig25, Electrical layout system plan

- The typical 3D plan layout of electrical system is shown in fig.26.

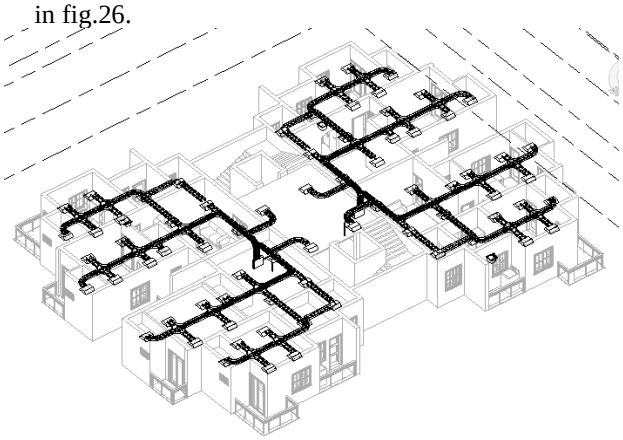


Fig26, 3D Plan of Electrical Layout System.

Plumbing Works for the Building Project as Per NBC 2016

Coordination of Plumbing System:

The system includes, water supply and sanitary arrangement. as shown below fig.27. For the building of the project work. Typical 3D plumbing layout is shown in fig.28.

Fig.29. shows a typical sectional elevation of a common toilet.

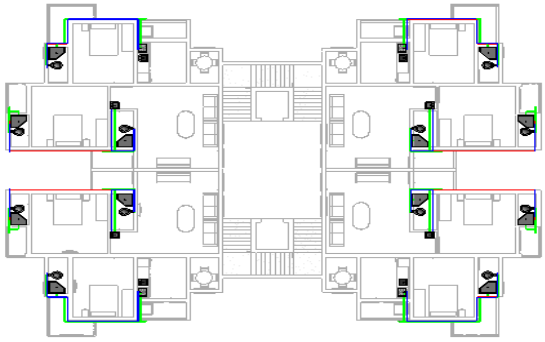
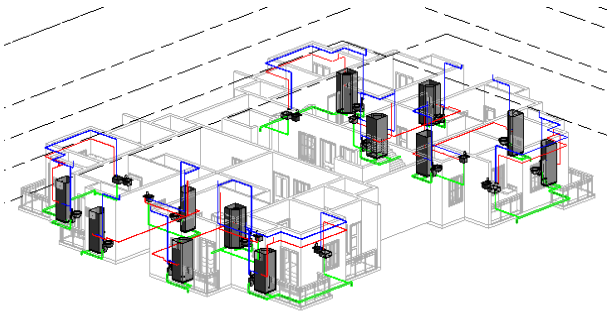


Fig27,Plumbing layout system plan



Fg28, Typical Plumbing Layout System

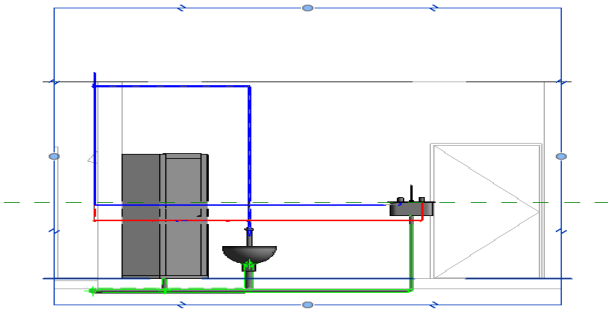


Fig29, Sectional elevation of common toilet.

Safety management system for the building as per NBC Part (4)

Fundamental studies carried out included:

i. Fire prevention.
ii. Life safety.
iii. Fire protection.

I. **Fire prevention:**

Classification of Buildings Based on Occupancy

a) Setback.
b) Height of building.
c) Floor area and layout.
d) Access to road.

II. **Life safety:**

The minimum number of exits necessary in a building should be based purely on the occupant load and the width required per person as relevant to the kind of exit for each occupancies, subject to the maximum travel distance requirement.

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Exit access and exits are in a number of different forms.
Doors, Corridors and passageways, Staircases, Fire Detection and Alarm.

III. **Fire protection:**

Fig 30. Shows fire fighting arrangement system layout for the building schedule for the current project work.

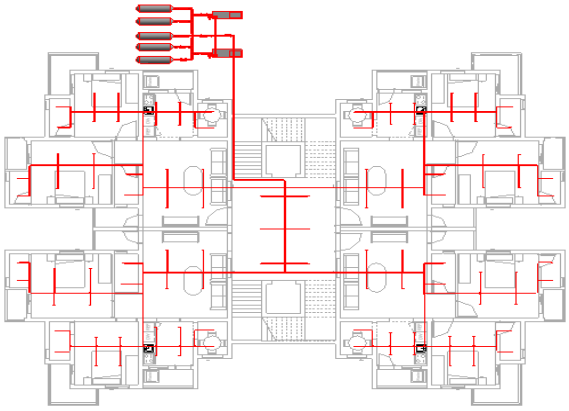

Fig30, Fire fighting arrangement system layout.

➢ Automatic Sprinkler System

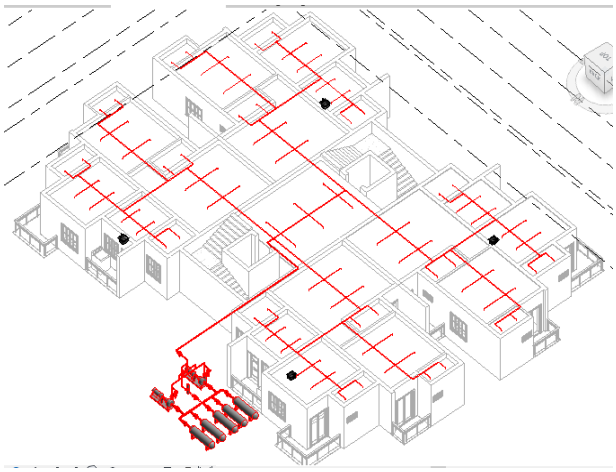

Fig.31, 3D model of fire fighting arrangement system.

VII. CONCLUSIONS:

In the current project the modeling, design and safety management of high rise building is done by integrated use of 3 different software's in a sequential manner, which is BIM based.

Following are the conclusions:

a) The application of BIM based design process shows considerable time reduction in comparison with traditional design process.
b) The AutoCAD 2d drawings stored and transferred to a completely different software for further continuation of work in 3D.
c) 3d modeling which is done in Revit with all its specifications gives much more realistic visual of the building and overall 3d building with various elevation views from different angles. By which the user can reach to any level and also to all parts of the 3D model.
d) 3d model of the building is rendered in the v.ray application to give an improved aesthetical visuals of the 3d model, where in all the components can be viewed clearly.
e) The compatibility of all software's is of greater use.
f) Safety management systems designed can be easily integrated with planning and designing using BIM.

SCOPE FOR FURTHER WORK

Following is the scope for further studies:

- Detailed scheduling and real time data for monitoring the construction work can be generated.

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