Implementing 5D BIM Process in Pre-construction Stage of Waste Water Treatment Plant

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Abstract - *Waste water treatment plant projects are complex in nature and consists of many different components which work together to treat the waste water. Even though conventional process can also be used for the construction, the risk of errors still persists leading to delay in project delivery and cost overrun. The growing urbanization has led to demand of high efficiency treatment facilities which are complex and enormous. Thus, traditional methods are slowly becoming obsolete. In order to make the construction process faster, safer, cheaper, and more accurate, Building Information Modelling (BIM) is believed to lead the project with greater efficiency through incremental collaboration. BIM provides a new process for working which uses information technology to make the construction process more accurate. New tools were developed which can execute the same work that are done by conventional method but with more accuracy. This thesis mostly concentrates on the time and cost aspects of the construction project by implementing Building Information Modeling in the pre-construction phase and determine the benefits and limitations of implementing this method through the agency of case study. Further, it will provide a methodology to create a 5-Dimensional simulation model by linking construction schedule with the 3-Dimensional model prepared with the help of Autodesk Revit 2020 of a Waste Water Treatment plant with the help of Autodesk Navisworks 2020. Time is considered to be the fourth Dimension and cost is considered as 5th dimension.*

Key Words: Modelling, schedule, treatment, simulation, quantity, collaboration

1.INTRODUCTION

The architecture, engineering, and construction (AEC) has been trying to discover new techniques to optimize project cost, increase productivity and improve quality, and deliver the project in time. Building Information Modeling (BIM) provides tools and platform to achieve this goal. BIM uses the virtual environment to simulate the construction process. BIM is a process whose workflow is predefined. The main step towards BIM is the 3D modeling. Creating 3D model helps to understand the 2D drawings more easily and precisely. Any errors in the 2D drawings get rectified and filtered out through the initial process of 3D modelling. This 3D model gives us and the client a confidence and richness about the data. After the schematic modelling of the project, the model is made more precise by

removing clashes and many designing errors. This 3D model becomes the main source of data after reaching a certain Level of Detailing (LOD), through which you can extract the required information in the format that is desirable. Thus, BIM process gives an information reach model before the construction has even started. Thus, BIM helps plan and schedule the flow of funding required for the construction as well as inventory requirement

The same 3D model can be used as a reference during the construction stage for assistance and also in post-construction stage for facility management of the project. A BIM model consists of accurate geometry, spatial relationships, geographical information, quantity take off, property of the element to be constructed, cost estimation, material inventories & detailed scheduling of construction project. The model can also simulate entire building lifecycle. BIM uses virtual simulation as a preconstruction designing method. With BIM technology, a precise virtual model of a structure, known as a building information model is created in digital format though BIM supporting software. It consists of exact data needed for supporting the designing, material procurement, custom fabrications. The same model can be used after the execution of project for operation and maintenance phase.

A building information model characterizes the geometry, spatial relationships, geographic information, quantities and properties of building elements, cost estimates, material inventories, and project schedule. Enter lifecycle of the building can be illustrated with the help of BIM modeling. As a result, extraction of quantities, material properties become easier and quicker. Scopes of work can be easily isolated and defined. All the Construction documents such as 2D drawings, purchase information, submittal processes, and other specifications can be easily interrelated. BIM is a virtual simulation of the entire construction process as well as the facility management of the complete project. It allows all design team members (owners, architects, engineers, contractors, subcontractors, and suppliers) to collaborate on a single work sharing platform. As the model is being created, team members are constantly refining and adjusting their portions according to project specifications and design changes to ensure the model is as accurate as possible before the project physically breaks ground. BIM is not just a three-dimensional model but a process which can also help define workflow and project delivery process. BIM represents a new paradigm within AEC, one that encourages integration

of the roles of all stakeholders on a project BIM also supports the concept of integrated project delivery, which is a project delivery approach that integrate people, systems, and business structures and practices into a collaborative process to reduce waste and optimize efficiency through all phases of the project life cycle. The main motto of BIM process is to promote collaboration and resolve all the issues by keeping the process transparent to all the participants.

The BIM process has been very successfully implemented in the residential, commercial and transport projects and there are many studies that prove that BIM process is better than the conventional method of construction. Therefore, in order to make the study unique, we define the steps and procedure to implement 4D BIM process for the construction of a waste water treatment plant.

A detailed methodology will be explained in this dissertation as to create a 4D model and various other information that can be extracted from the model. This methodology comprises of four main steps to prepare a 4D model. Firstly, a 3D model is prepared in Autodesk Revit 2020, secondly a construction schedule is prepared in Microsoft Project 2016 and finally a 4D model is generated in Autodesk Navisworks 2020. With the help of currently available modeling and scheduling tools a 4D model is prepared. This study provides methodology for creating a 5D model which act as a platform for future projects.

1.1 Aim & Objective

The aim of the study is to create a 3D model and link it with time schedule with the help of software supporting BIM platform and obtain a information rich 4-dimensional model. To define the steps for creating 4D BIM model and obstacles faced during the entire process.

The objectives are as follows:

1. Defining difference between BIM process & conventional process
2. Study BIM flow process for proper collaboration between all participants.
3. Software training for 5D BIM modeling
4. Validate construction schedule

1.2 METHODOLOGY

Software training is the initial step towards creating 5D BIM model. It requires three software learning

1) 3D Modeling software: Many software are available in the market, but Autodesk Revit will be our preference since it is most widely accepted in many organizations.
2) Scheduling: Microsoft Project will be used for planning & scheduling. It has an easy and understandable interface
3) Data Combining software: For 5D modeling, the schedule & 3D model needs to be linked with the

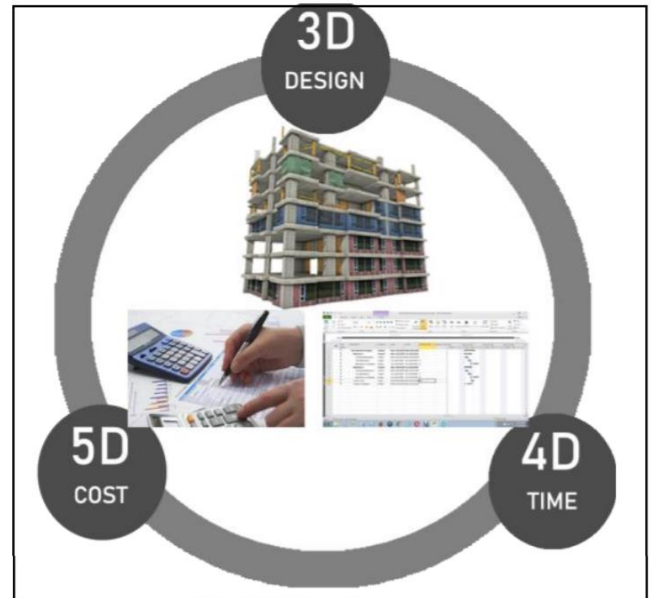help of Autodesk Navisworks Manage 2020. This tool also helps in clashes detection and report generation

Fig 1. 5D BIM process

2. LITERATURE REVIEW

The AEC industry is gradually understanding the benefits that BIM process can offer and accepting it to implement in their organization. Using technology to solve coordination issues and extracting information in desired format is what BIM process offers. The BIM concept was initially introduced in 60s. This concept or idea lead to the foundation stones for developing new software that could be used as a tool to implement BIM process.

As per McGraw Hill Smart market Report (2014), which consisted of survey data collection of 727 contractors from 10 different countries, stated that the BIM adoption will escalate by 50 percent. All contractors reported 60 percent positive Return on Investment. Sixty percent of the surveyed contractors believed that implementing 3-dimensional BIM implementation will definitely have constructive impact. According to Autodesk, many organizations have began accepting BIM methodology, whereas Indian organizations have still not incorporated BIM process completely and unlocked its full potential.
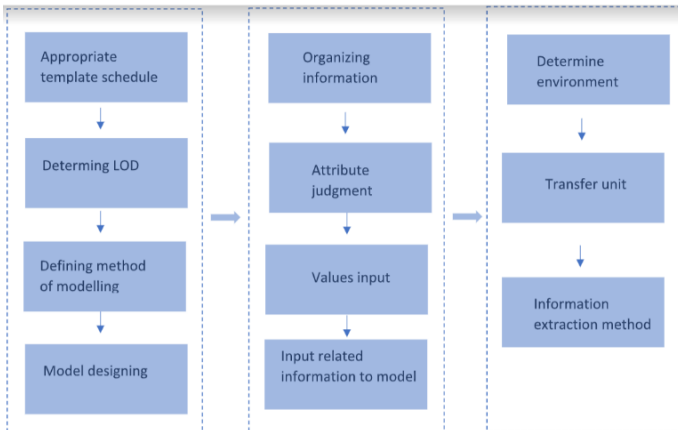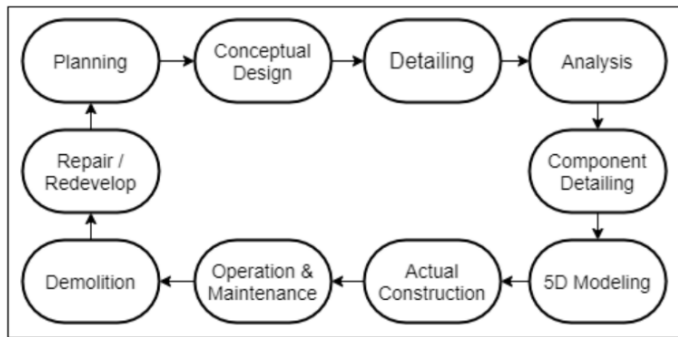
Fig 2. Information Processing in BIM

Fig 3. Flow of Information Processing in BIM

3. Three-Dimensional Modeling

1st Step:

The most initial step is template selection. Autodesk Revit provides standard templates which consists of different settings in them. These settings are customizable as per the participants needs. There are basically three participants i.e., Architect, Structural Designer and Mechanical-Electrical-Plumbing (MEP) consultants. These three participants create 3D model of their own. Since the elements created and the views of the models are different, the templates used by all the participants also tend to be different, for instance, the Revit consists of family of walls, but the shear walls in the structural model needs to be differentiated with brick walls in architectural model. They both belong to the wall family in Revit, but their properties and texture are different. Thus, template provides you with settings according to different consultants.

2nd Step:

After loading the desired template, we define the elevations that are required for the model. Elevations are nothing but floor levels. Each elevation represents a floor level and viewing a particular elevation shows floor view.

3rd Step:

Importing or linking CAD drawing to the respective floor elevation level. Using the 2D CAD as reference, you can start drafting the model. Every participant has its flow of drafting

defined. For structural modeling, vertical members are modelled first, then the beams and floors at the end.

4th Step:

Detailing should also be provided parallel to drafting. For example, a beam drafted must consist of beam number, concrete grade, steel grade, type of beam, etc., as per client's requirement.

5th Step:

Define the format in which the client requires quantity schedules. Any changes made in the model gets immediately reflected in the quantity schedule.

As the design reviewing stage consists of Schematic, Detailed Design and Good for Construction stage, so does the 3D model. As the model reach GFC stage, the model becomes ready to extract 2D sheets and quantities.

4. 5D BIM Methodology principle

In order to make a 5-dimensional model, 3D model is linked with the schedule. The schedule consists of a resource sheet where the rates of material and labour are defined. Tasks or activities and the number of resources required for that particular activity is defined in schedule. The material requirement can be easily extracted from the 3D model. When the schedule is completely defined, it is then linked with the 3D model with the help of BIM supporting software, in this case Autodesk Navisworks Manage. This process also helps scrutinize the schedule.

Therefore, 5D BIM process can give you data such as the material quantity requirement, labour requirement for a particular task as well as the amount of funds required in the future. It helps compare the actual construction progress with the planned schedule. This method assists in identifying the reason behind the delays. It helps the stakeholders to control the flow of information and keep themselves updated.

Another advantage of 5D BIM process Is to consider different material for simulation and determine which material used will cost optimum and consume less time to construct. For instance, plywood and mivan form work, both can be used for RCC casting. 5D BIM process creates a simulation which helps you predetermine the optimum option between them.

Virtual Visuals:

Sharing design information in 2-dimensional format leads to many design errors. These errors can be easily identified when the structure is constructed virtually with the help of software. The modelling process itself identifies many errors in designing an provide correct information.

Clash Detection:

Every consultant participating in the construction of the project needs to create its 3D model. Later on, these models are linked with each other to create a single central model.

Clashing between these models is identified and corrected through collaborative platform created by BIM. This process leads to determining clashed before the commencement of actual construction, thus saving time and money.

Schedule Management

5D BIM model helps clients keep track of the construction w.r.t defined schedule. It helps identify the reason for delay. Many times, the on-field situation differ from the planned assumptions. Thus, BIM also guide the on-site engineers to get a better idea of the structure and work out a solution accordingly.

5. BIM IMPLEMENTATION-CASE STUDY

There are many examples of successful BIM implementation on residential and commercial projects, but many few studies about industrial and facilitative project. Hence, this research aims on implementing BIM process on a wastewater treatment plant (WWTP). The BIM implementation will be done from structural consultants' perspective. The model will be incorporated with all the structural components. This research will give an idea about the process as well as the difficulties faced in its implementation. Since the modelling will be done from structural designer's perspective, the detailed design drawings of Wastewater Treatment Plant are to be acquired and thoroughly studied. This 2D CAD drawings will guide us in defining the elevations, components and views.

Water treatment Plant Components & workflow

The WWTP is equipped for domestic water treatment. The components of wastewater treatment plant are as follows:

1. Grit screening chamber
2. Equalization Tank
3. Anoxic Tank
4. Aerobic Tank
5. Treated Water Tank
6. Membrane Tank
7. Pump rooms
8. Sludge Disposal tank

1. Grit screening chamber – Coarse particles from effluent is removed by passing the water through a bar screen of specific gap. It is a physical method of treatment

2. Equalization Tank – The effluent is allowed to drop in these tanks. The water flows out of the tank at a slow rate, so that the fine particles in them settle down at the bottom and treated water can move forward to the next treatment.

3. Anoxic Tank – Anoxic tank creates an environment where the bacteria responsible for decomposition breaks down nitrates for oxygen requirement. It helps decompose the sludge> The main goal of this treatment is to reduce nitrogen level to a permitted level.

4. Aerobic Tank – Now the oxygen is mechanically induced into the wastewater via blower and mixed with activated sludge for effective decomposition of waste mixed in water.

5. Treated Water Tank – The water from the aerobic tank is now sent to treated water tank, where chemicals are mixed to kill harmful bacteria in water before releasing it into natural water sources.

6. Sludge Disposal Tank - This is where the unnecessary sludge is collected and pumped out

This research method consists of two types of studies

1. Literature study
2. Case study

Literature study consists of reviewing many research papers related to BIM implementation in construction process. This study gave us an idea about success rate of BIM implemented in other countries, the costing of implementation, software required for BIM implementation, situation of Indian AEC industry regarding the acceptance of BIM process, problems faced in BIM implementation and the views of consultants regarding BIM process implementation in construction of a facility, such as waste water treatment plant.

For case study, a Waste Water Treatment Plant is considered. The initial data required for the case study such as 2D drawings, concrete grade, reinforcement detailing was collected from structural designer. The planning and scheduling is done by referring to many different schedules. The next step was to install and setup all the software required. 3D modelling, Scheduling and simulation require three different BIM supporting software. The data collected from structural designer provides detailed information to create a precise 3-Dimensional Model. Then comes the scheduling part, where tasks are defined. Each task is assigned a duration, resources required and the date of commencement and finish. The task can be a Finish-to-finish, Finish-to-start, Start-to Start. Finish-to-Finish.
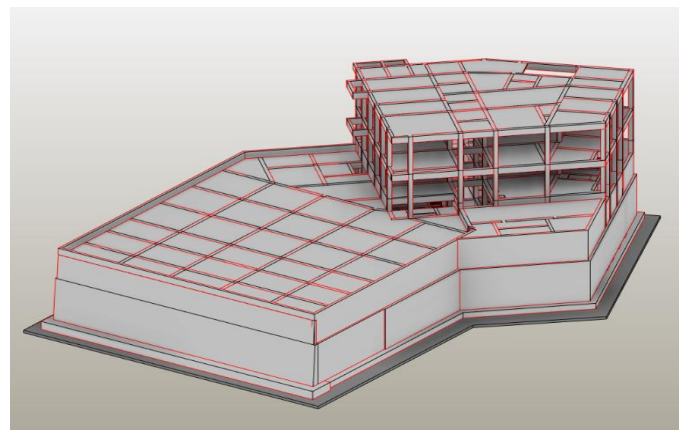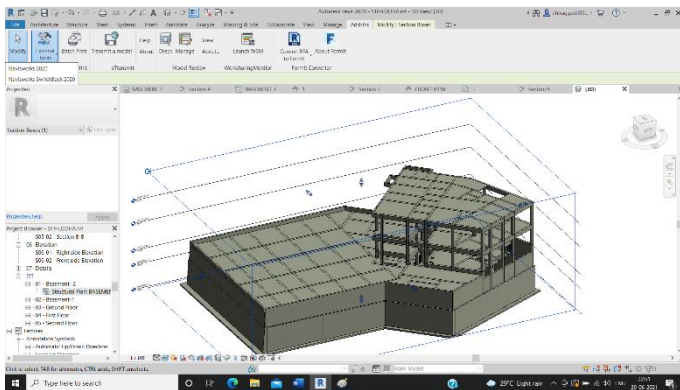

Fig.4 3D Model

Fig. 5 3D View

The BIM supporting software selected are as follows:

Name	Use
Autodesk Revit 2020	3-Dimensional Modelling
Microsoft Project 2016	Planning & scheduling of the construction process
Autodesk Navisworks Manage 2020	Linking schedule with model, creating simulation, detecting clashes

Table 1. Software used

3D model

In order to start BIM process, 3D model needs to be made first as it becomes the central source of information. During initial stage of modeling, all the required families need to modified as per the project needs. For instance, if there are beams with different sizes, then they need to be defined. If there is a component in the model which is not of standard type, then in such case Revit provides you with two options, either model it in place or create a new family with properly defined constraints. When modeling, simultaneously define the concrete grade of the components, grade of steel or type of steel member. Additional parameters can also be defined as per client's requirement.

Time Schedule

The scheduling process requires actual site knowledge. This helps define the task in a right sequence. The total duration for the RCC construction of Waste Water Treatment Plant was 191 days i.e., approximately 7 months.

SITE PREPARATION AND MOBILIZATION	20 days	Mon 02-03-20	Fri 27-03-20	6
SUBSTRUCTURE	76 days	Fri 27-03-20	Fri 10-07-20	16SS+2 days
STP BASMENT LVL-2	27 days	Mon 13-07-20	Tue 18-08-20	25
STP BASMENT LVL-1	43 days	Tue 04-08-20	Thu 01-10-20	34SS
STP GROUND FLOOR LVL	31 days	Wed 16-09-20	Wed 28-10-20	48
STP FIRST FLOOR	17 days	Fri 09-10-20	Mon 02-11-20	
STP SECOND FLOOR	17 days	Wed 28-10-20	Thu 19-11-20	
FINISHING WORK	58 days	Tue 25-08-20	Thu 12-11-20	47
PROJECT CLOSE-OUT	50 days	Tue 15-09-20	Mon 23-11-20	82

Fig.6 Schedule

After defining the schedule, the resources that are required for the construction are listed out and a resource sheet is created in Microsoft Project. This resource sheet consists of resource name. the unit in which the resource is purchased.

Quantity Estimation

The quantity of material required can be easily imported from Revit in desired arrangement. The quantity schedule is mostly imported in txt format and then opened in excel or any other application. The quantity obtained is then added in the summary sheet of each task in the schedule. This gives us an idea about the resource consumption of each task. The labour resource requirement information was obtained by many surveys and interviewing contractors. Summary sheet of each task is defined. After final checkup, the schedule is confirmed and the total resources required is known.

Final quantities

Structural Framings (Beams) – 373.97 cumec

FLOOR LVL	VOLUME (CUMEC)
BASEMENT 1	80.30
BASEMENT 2	166.73
00 GF	61.81
1ST FLOOR	65.14
GRAND TOTAL	**373.97**

Table 1. Beams QTO

Footing Quantity – 520.46 cumec

FLOOR LVL	VOLUME (CUMEC)
BASEMENT 1	530.46
GRAND TOTAL	**530.46**

Table 2. Footing QTO

Structural Column Quantity – 183.39 cumec

FLOOR LVL	VOLUME (CUMEC)
BASEMENT 1	69.54
BASEMENT 2	56.53
00 GF	26.22
1ST FLOOR	30.13
GRAND TOTAL	**182.42**

Table 3. Column QTO

Slab Quantity – 866.53 cumec

FLOOR LVL	VOLUME (CUMEC)
BASEMENT 1	289.70
BASEMENT 2	54.29
00 GF	292.62
1ST FLOOR	160.27
GRAND TOTAL	**866.53**

Table 4. Floor QTO

Retaining Wall Quantity – 1147.53 cumec

BASE OFFSET	VOLUME (CUMEC)
BASEMENT 1	1147.53
GRAND TOTAL	1147.53

Table 5. Walls QTO

Reinforcement Quantity – 332054.85 kg

Total Quantities

Activity	Quantity
Excavation	17194.74 cumec
Concrete	3177.56 cumec
Reinforcement	332054.85 kg

Table 6. Total Quantity

Total Estimated cost for the construction of structural framing components = **Rs.4,40,90,942 /-**
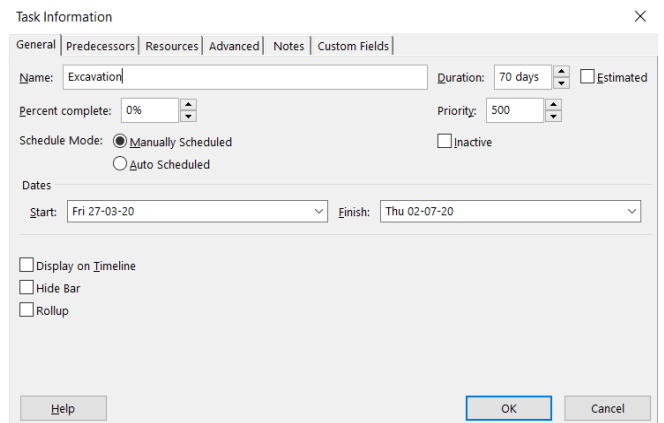

Fig.6 Resource Sheet

Fig.7 Task Summary

5. 5D Simulation of Waste Water Treatment Plant

5-dimensional simulation model requires linking of time schedule with the 3D model. This is where Navisworks Manage comes into play. But first the 3D model needs to be saved in nwc. Format which can be opened in Navisworks. After opening the nwc file in Navisworks, you can visualize the same model. Saving the same model will convert it into nwd format. The next step would be to import the schedule into navisworks. Navisworks can directly import Microsoft Project files, Primavera files and csv files. After importing, the schedule can be seen in the task list of timeliner tool. Then you select each component of the model through selection tree or by clicking the element and attach it to its respective task. Each component should get attached to the schedule in order to get a complete 5D simulation.

The Navisworks tool not only helps create simulations, but also helps in detecting clashes in the model
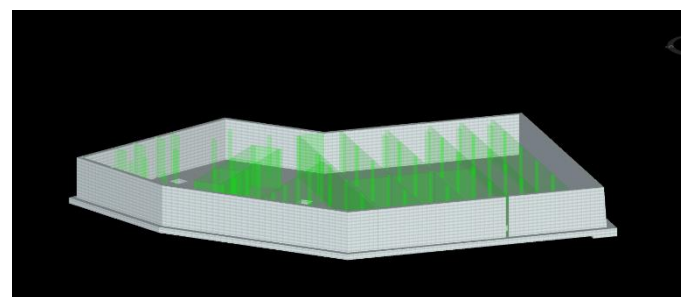

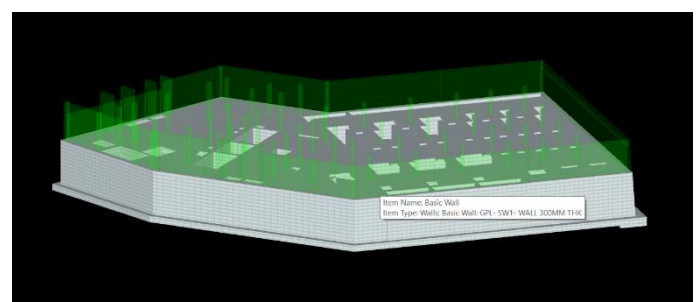Fig. 8   5D Simulation Model - Day 156

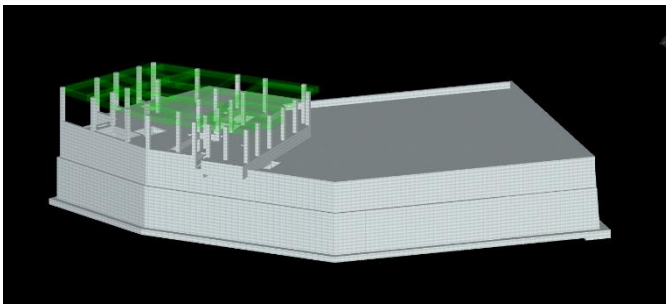Fig.9   5D Simulation Model - Day 203
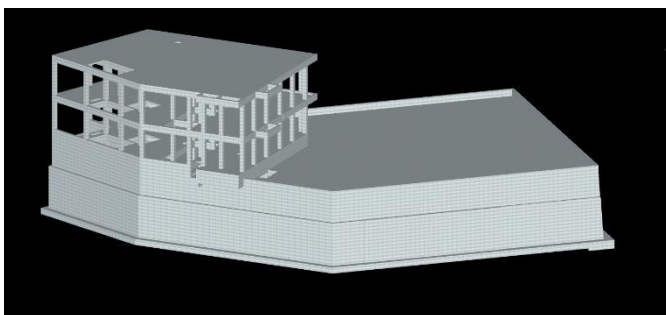
Fig 10. 5D Simulation Model - Day 233

Fig 11. 5D Simulation Model - Day 264

6. BENEFITS, LIMITATIONS, OBSTACLES AND PROBLEMS OF BIM PROCESS

3-Dimensional model definitely provides with better level of understanding compared to 2D CAD drawings. BIM tools also guide the clashing in 3-dimension. Hence, showing an issue rather than explaining saves time, better understanding of issue and also determine to which participant this issue is concerned. It helps communicate the information regarding the project to all the participants, control the flow of information and maintain a positive collaborative environment. Transition of design from schematic to Good for construction stage is smooth. BIM process resolves most of the designing issues in preconstruction stage, which in turn saves time, money and wastage of environment. BIM process is very beneficial to the organization, but it is a costly affair. The AEC suitable software are expensive, the configuration of the machines required is high and time required for training is also more. This method can be successfully implemented if all the participants involved in the project are equipped with BIM supporting tools.

7. RESULTS:

It was detected that BIM process has potential to benefit the organization in all scenarios and implementation will lead to successful execution of projects. Three BIM supporting software were learned. Importing quantity schedules was convenient. Editing views to obtain suitable structural 2D drawings. Training and understanding Autodesk Revit consumed most of the time as compared to other software.

8. CONCLUSIONS

BIM process promises to change the Indian construction industry with the help of information technology by making activities more efficient and give refined information. Large sized organizations which work on massive and complex project should definitely implement BIM process. A facility project such as Waste Water Treatment Plants are complex in nature and designs from all the participants needs to be compared and studied properly. With the help of BIM supporting tools, the complexity of the project can be resolved step-by-step. For instance, Mechanical-Electrical-Plumbing (MEP) team plays a major role in the construction of WWTP. Collaborating with structural designer can give both the consultants a better understanding of each other's perspective and then together come to a solution for resolving issue. From literature study, it was discovered that the AEC industry from those countries whose government has also accepted and implemented BIM has successfully implemented BIM methodology in their organization. For instance, the UK government is making it mandatory to use BIM process for organization. They are even bringing existing construction to BIM process. They have created approval workflow on BIM platform. This will help them store the data securely and retrieve it whenever needed.

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