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COST COMPARISON OF A SEWAGE TREATMENT PLANT UNIT BY CONVENTIONAL METHOD AND BIM APPROACH

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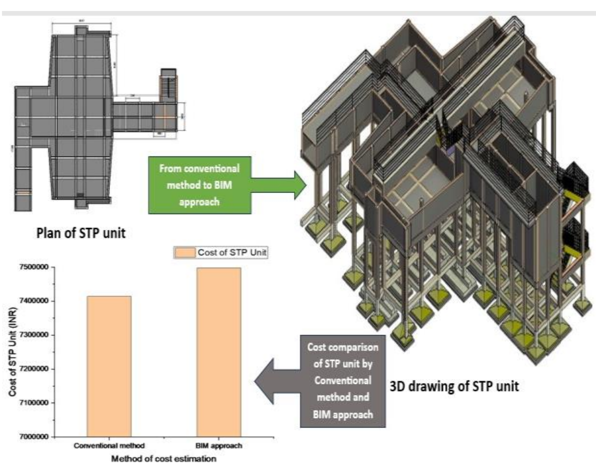
Graphical abstract



Abstract

The large-scale sewage treatment plant (STP) projects are considered as complex infrastructure projects when compared to residential and commercial building projects. These complex projects need to have accurate estimation because cost estimate helps in tendering stage, pre construction stage and during the construction stage. This study compares the costs of a unit in an STP by using BIM software versus the conventional method. For BIM approach, to create a three-dimensional model of the STP unit using 2D floor plan, Revit software is used. Schedules of quantities are then produced under the schedule option in the software to calculate the cost of construction components. The result is, the percentage difference of quantities between the conventional method and BIM approach in excavation, PCC, footing, column, beam, slab, RCC wall, plaster, exterior paint, interior paint, railing, and steel is 0.41%, 0.39%, -0.15%, -0.03%, 0.33%, -0.05%, 0.38%, -2.37%, -2.47%, -2.10%, 0% and -3.48% respectively. The total estimated cost of STP unit by conventional method is Rs 74,13,845/- and Rs 74,97,461/- by BIM software respectively. The BIM-Assisted Detailed Estimating (BADE) tool's visualization and aggregation features in BIM significantly outperform the conventional method for the detailed estimate. BIM cost estimate is 1.12% more as compared to conventional method.

Keywords: sewage treatment plant, manual quantity estimation, Building Information Modelling (BIM), BIM- quantity estimation, Cost estimation.

1.0 INTRODUCTION

The cost estimation is the initial step in every construction project since it helps determine the project's feasibility, control of costs, and bidding processes. The two forms of cost estimating are preliminary cost estimation and detailed cost estimation. Based on engineering news record (ENR) indexes rates, rough cost estimates may be used to rapidly estimate the approximate cost of a work [1]. They also allow the competent authority to consider the financial elements of the plan when granting administrative approval for the design [2]. A comprehensive cost estimation, on the other hand, offers all the details on the quantities, rates, and costs of each item required to provide technical sanction, solicit bids, and effectively finish a project [3].

Floor plans, elevations, cross sections, and other relevant materials are manually measured as part of the traditional quantity takeoff process when using the manual approach. Because it depends on human interpretation, this strategy is particularly prone to mistakes [4]. Additionally, whether they are made by hand or with the aid of CAD tools, 2D-based documents are just as prone to mistakes [5]. Incorrect inputs and interpretations are highly prevalent since it is very challenging to comprehend complicated circumstances, especially connections between different architectural parts (such as a cross section of the connection between a beam, a column, a wall, and a slab) [6,7]. A manual procedure is used to create additional 2D papers from which new 2D documents are designed. Further complicating the manual development of 2D documentation is the collaboration of multiple project professionals while avoiding conflicts between distinct components [8].

Technologies of many kinds have been developed to help estimators complete their task more faster and accurately using the most contemporary Building Information Modelling (BIM) software including colour markers, digitizers, and two-dimensional (2D) on-screen takeoffs included in this list of tools [8]. An alternative to the conventional data model approach uses 3D visualization and quantity data from models created using BIM, allowing estimators to make their own domain-specific judgments on the design attributes. This strategy is known as a Detailed Estimate with BIM Assistance [5]. BIM tools have addressed the serious drawbacks of 2D drawings, which lack the detailed 3D information needed by estimators to identify important cost-sensitive design elements [9]. On the basis of 3D digital technology, BIM enables the visual depiction of a broad variety of technical information sets. BIM integrates geometrical properties, functional specifications, and item performance information in addition to the project's construction schedule and process control data [10]. Leading CAD software suppliers like Autodesk® have integrated bill of material (BOM) functions into their BIM systems to help with construction estimating and procurement. In order to manage building information throughout the project, Building Information Modeling (BIM) is often used in pre-construction stage of projects for estimating cost benefit analysis of projects [11]. Eventually quantity take-off and cost estimation are gaining attraction in BIM. Table 1 shows the details of publications where BIM is specifically used for quantity estimation of different infrastructure facilities.

To the best of author's knowledge limited research is available on implementing BIM for public infrastructure facilities like sewage treatment plant (STP). The possible reason might be STP's are considered as a complex infrastructure facility requiring knowledge of multidisciplinary areas [12]. According to Kamal and Bahgat, 2021 [4], stakeholders of the project find it difficult to understand all the project's components. The water and wastewater treatment infrastructure business frequently utilizes two-dimensional drawings to communicate the design information to the site. When utilizing conventional 2D layout, wastewater treatment project construction management is quite challenging and tedious As the degree of urban water pollution rises, cleanup becomes time-consuming and exceedingly challenging [13]. Sustainable development goal 6.3.1 necessitates that countries should develop an efficient wastewater treatment plant network for treating the wastewater before discharging it to the environment [14]. The wastewater generated and wastewater treated in India in the year 2020 is 72,638 MLD and 36,668 MLD respectively. This wastewater is being treated by the 1631 numbers of STP's whereas new 162 STP's have been proposed to increase the wastewater treatment capacity (www.cpcb.nic.in). The demand for new STP's in future must be met using sustainable construction techniques efficaciously [10]. In order to help project stakeholders obtain the essential information and make decisions during the project's planning, design, building, and operation phases, a digitally produced model of such complex infrastructure facilities is necessary [15].

Table 1 Quantity estimation using BIM for infrastructure facilities.

No.	Reference	Infrastructure facility	Material quantity estimation by BIM
1	[6]	Multi-storeyed residential and commercial building	Provides quantity estimation of major elements of multi storied building.
2	[16]	Road and Bridges	BIM provided quantity estimation for excavation and laying works of the road project.
3	[17]	Interior components of building	Provides quantity estimation of interior components of building
4	[5]	College building	Provides quantity estimation of major elements of the building using BIM and conventional method.
5	[18]	Residential building	Provides quantity estimation of walls and floors of a residential building.
6	[7]	Warehouse building	Provides quantity estimation of hollow core slab panels and ducting pipes of a ware house building.
7	[19]	Rebar project	Provides quantity estimation of reinforcement provided for infrastructure.

According to [20], the attention of BIM in sewage treatment plants is lacking and BIM can be applied in design and construction management phase of sewage treatment projects. Wang et al., 2016 [20], discussed the significance of visualization of complex structures in the sewage treatment plant and the monitoring of construction progress through visual simulation by using BIM application. Further Kussumardianadewi, 2020 [21], discussed the influential factors due to which construction of wastewater treatment plants are delayed by an average of 20% and suggested implementation of BIM for wastewater treatment plants. Li et al., 2021 [15], discussed the significance of using BIM in construction, operation and maintenance of wastewater treatment plants where BIM played an important role in productivity increase, cost minimization and reduced construction time. Previous studies conducted on application of BIM for wastewater treatment plants focused on optimizing construction process, visualization of the complex structure and collaborative utilization of datasets on BIM platform by project stake holders.

The cost comparison of the selected STP unit using the traditional methodology and the approach based on BIM is the objective of this study. A three-dimensional model is created in Revit for cost evaluation using the BIM methodology. The construction specifications taken into consideration for estimation include excavation, PCC, footing, column, beam, slab, wall, plastering, exterior and interior painting, railing and reinforcement steel. To the best of author's knowledge there is no study which provides details on estimation of STP by BIM approach considering all the above construction specifications taken into consideration. The STP selected for case study in this work is in pre-construction stage and located in India. Therefore, only a part/unit of STP is considered for study purpose. The significance of this study is to provide economic advantage of using BIM in STP pre-construction stage.

2.0 METHODOLOGY

In this section the description of the sewage treatment plant (STP) is given and the method adopted for quantity estimation of STP unit by manual and BIM method is discussed.

2.1 Description of Sewage Treatment Plant

The sewage treatment plant (STP) chosen for the cost comparison study is designed for 63 million litres per day (MLD) capacity. As shown in Figure 1, the units included in the 63 MLD capacity STP plant are inlet chamber (1), screen chamber (manual and mechanical) (1), grit chamber (manual and mechanical) (2), distribution chamber (2), sequencing batch reactor basin (3), chlorine contact tank (4), chlorinator cum tonner house (5), sludge sump (6), sludge pump house (7), centrifugal house (8) and administrative block and PLC control room (9).

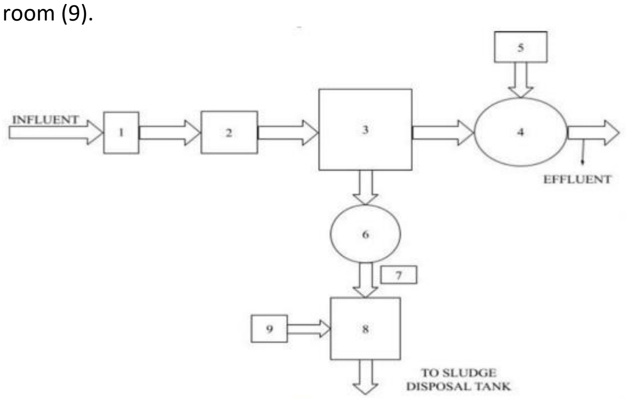


Figure 1 Flow chart of sewage treatment plant.

Inlet chamber, manual and mechanical screen chamber, mechanical and manual grit chamber, and distribution chamber of the STP were chosen for the cost comparison. Working drawings, layout plans, elevations and sectional drawings of the structure were collected for this cost estimation study.

2.2 Items and construction specifications of STP unit

Before building begins on every project, specific types and category of materials are determined. The finalization of the specification is important so that the quality of the work is maintained and the planning of the project. Also, the rate analyses of the items are done based on materials and the specification of the project. The construction specifications are provided in Table 2.

Table 2 Specifications required for selected unit of the 63 MLD capacity STP.

No.	Item	Unit	Construction specification
1	Excavation	m^3	Up to 1.524 m.
2	Plain cement concrete (P.C.C)	m^3	Grade of concrete M15. Thickness 100mm.
3	Footing	m^3	Isolated and Combined footings. Grade of concrete is M30
4	Column	m^3	Grade of concrete is M30
5	Beam	m^3	Grade of concrete is M30
6	Slab	m^3	Grade of concrete is M30
8	Wall	m^3	Grade of concrete is M30
9	Plaster	m^2	20 mm thick. Cement mortar 1:5
10	Paint	m^2	Acrylic water proof paints for exterior surface above ground level. Whitewash for internal walls
11	Steel	kg	TMT bar of Fe415.
12	Railing	RM	Made up of Galvanized Iron (GI)

2.3 Detailed estimate by conventional method.

An accurate estimate called an accurate assessment comprises calculating the prices and amounts for each work item. The dimensions of the length, breadth, and height of each item of the STP unit are precisely retrieved from the image, their amounts are calculated, and billing and abstracting is finished. The detailed estimate has 2 stages-

(1) Specifications for measuring and calculating quantity.

(2) A brief description of the projected cost.

The quantities of the various items like foundation concrete, brickwork in foundation, plinth, RCC components, wall, plaster, paint and railing can be estimated by the following 2 methods;

a. Centre line method: This method entails measuring the length of a building's walls along the centre lines, then multiplying that figure by the breadth and depth of each component to get the whole amount at once. The centre line length of each segment of a wall should be determined independently for each part in the construction. When a partition or veranda wall joins a main wall, the partition or veranda wall's centre line length must be halved by the width of the main wall layer. The quantity of such joints is first assessed in order to establish the centre line length. This method can provide estimates more quickly and with equal accuracy as the other methods. This strategy cannot be said to be superior to others because the centre line length changes at each layer, with the exception of an asymmetrical wall, which is not frequent.

b. Long and short wall or out to out and in to in method: In this system, longer walls (or often those facing one way) are regarded as long walls, while those facing the other direction are regarded as short walls. The amount is calculated by multiplying the lengths of the long and short walls individually by the width and height of the corresponding layer. Centre to centre lengths is calculated in order to estimate the long and short wall lengths. After doubling the wall's width at either end from its centre to its centre length, the length of a long wall from outside to inside may then be computed. In order to calculate the length of a short wall, the half-breadth of the wall at each end is subtracted from the wall's centre to centre measurement.

For estimating the steel quantity, the bar-bending schedule is prepared to know the exact quantity of the steel and to provide the exact comparison. The cutting length of each item such as footing, column, beam, slab, and RCC wall are calculated. The weight of steel is calculated by the cutting length of steel of the items. The formula used is as per equation (1) as given by [19].

$$L = [W \times 162.28] / D^2 \quad (1)$$

where, W is the weight (kg) of the steel, D is the diameter (mm) of steel bars and L is the length (m) of the steel bars.

2.4 Detailed estimate by BIM approach

The BIM based approached for the estimation of the STP unit, is explained in the methodology Figure 2. Data analysis must be performed in according to the construction drawings before the establishment of the BIM database and drawings. The Work Breakdown Structure (WBS) is used to break down the cases into individual components and with various information provided according to the various features. After examining the 2D construction drawings, the 3D models are built in Revit Architecture utilizing the various components. The identified building materials and elements are added in form of properties in Revit software. Next the quantities for each item are obtained. Rates are put into the software, and the software calculates the abstract of the entire price and the bill of items.

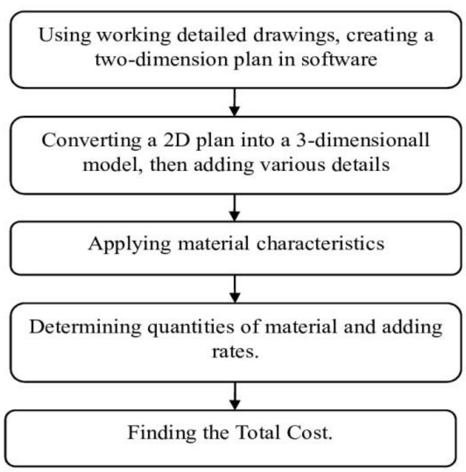


Figure 2 Flow chart for quantity estimation of STP unit by BIM approach

After studying the literature review, some of the important concept and procedures were identified and adapted for creating the STP unit 3-D model in Revit. The 3-D model created in the BIM should contain a complete database of the STP unit. This database should have the size, number, and other information of all components of the STP unit. Since STP's have a large quantity of shaped structures, the BIM software having a dimension tool helps in creating complex objects. This complex structure should be broken in simple structure parts to form a parametric models and finally combine them as a whole [10].

2.5 Construction Materials And Labour Rates

Knowing labour and material rates is crucial for proper assessment. Also, rates for tools, equipment, and plants. These rates are offered in State Schedule of Rates (SSR) or District Schedule Rate (DSR). The prices vary from location to location. As the STP is to be constructed in Maharashtra state so the States Scheduled of Rates of the Govt. of Maharashtra is used which is published by the Public Works Department. All of Maharashtra's districts are subject to the rates listed in the published schedule. The rates for items used in all districts are taken into account while creating the schedule of rates. In according with the construction specification/description, rates of the individual items are adopted from the SSR 2022-23.

3.0 RESULTS AND DISCUSSION

In the BIM method, data analysis and modeling are the steps for the establishment of the BIM database and drawings. The construction drawings are studied for the data analysis. After analyzing the 2D drawing, the model is prepared in the Revit Architecture.

Cost estimation of selected STP unit having inlet chamber, manual and mechanical screen chamber, mechanical and manual grit chamber, and distribution chamber was computed by conventional method and BIM approach. In the conventional method, for each item listed in Table 2, the measurement sheet is prepared which included the columns of description, numbers, length, width, height, deduction, quantity, and unit. The total quantity estimated by the conventional method of the items for selected STP unit are mentioned in Table 3.

Table 3 Quantity estimation of STP unit by conventional method and BIM approach.

No.	Item	Unit Cost	Conventional method	BIM approach
1	Excavation	258	434.26m^3	432.4979m^3
2	PCC	6359	28.49m^3	28.3791 m^3
3	Footing	7471	64.21 m^3	64.3039 m^3
4	Column	14150	47.65m^3	47.662 m^3
5	Beam	12635	76.72 m^3	76.4704 m^3
6	Slab	14299	64.68m^3	64.7134 m^3
7	Wall	15750	65.66m^3	65.4100 m^3
8	Plaster	375	1774.20 m^2	1816.799 m^2
9	Exterior Paint	261	1296.49	1328.968
10	Interior Paint	12	477.7	487.8302
11	Railing	917	184.28 m	184.285 m
12	Steel	61	30490 kg	31571 kg

As shown in Figure 3 the selected unit of the STP has inlet chamber (1), a manual fine screen channel (2), a mechanical fine screen channel (3), two mechanical grit units (4), a manual grit unit (5) and distribution chamber (6). The wastewater enters through the inlet chamber and goes through the fine screen (either mechanical or manual) then the grit chamber (either mechanical or manual) and then through the distribution chamber to SBR basin. The manual screen chamber and manual grit chamber are provided as standby unit to be used when the operation and maintenance of the mechanical screen chamber and mechanical grit chamber is to be done. Since the flow of wastewater is under gravity, it is important to provide level difference at each treatment unit. The screen chamber floor level was 0.1m and 0.15 m higher than the floor of grit chamber and distribution chamber respectively. The grit chamber purpose is to remove grit from the wastewater. This STP has manual and mechanical grit chamber. In manual grit chamber the grit is removed manually. The settled grit in mechanical grit chamber is removed from the grit chamber by collecting the grit in hopper provided to the mechanical grit chamber. The level difference between the floor of grit chamber and hopper where grit gets collected is 0.7m. The mechanical grit chamber is trapezoidal in plan with the area reducing towards the outer side of the tank. This trapezoidal shape is necessary to provide a uniform inlet and outlet velocity of wastewater in the mechanical grit chamber. Incorporating all the minute details, the 3D model of the STP unit is prepared and the quantities estimated by the BIM approach are provided in Table 3.

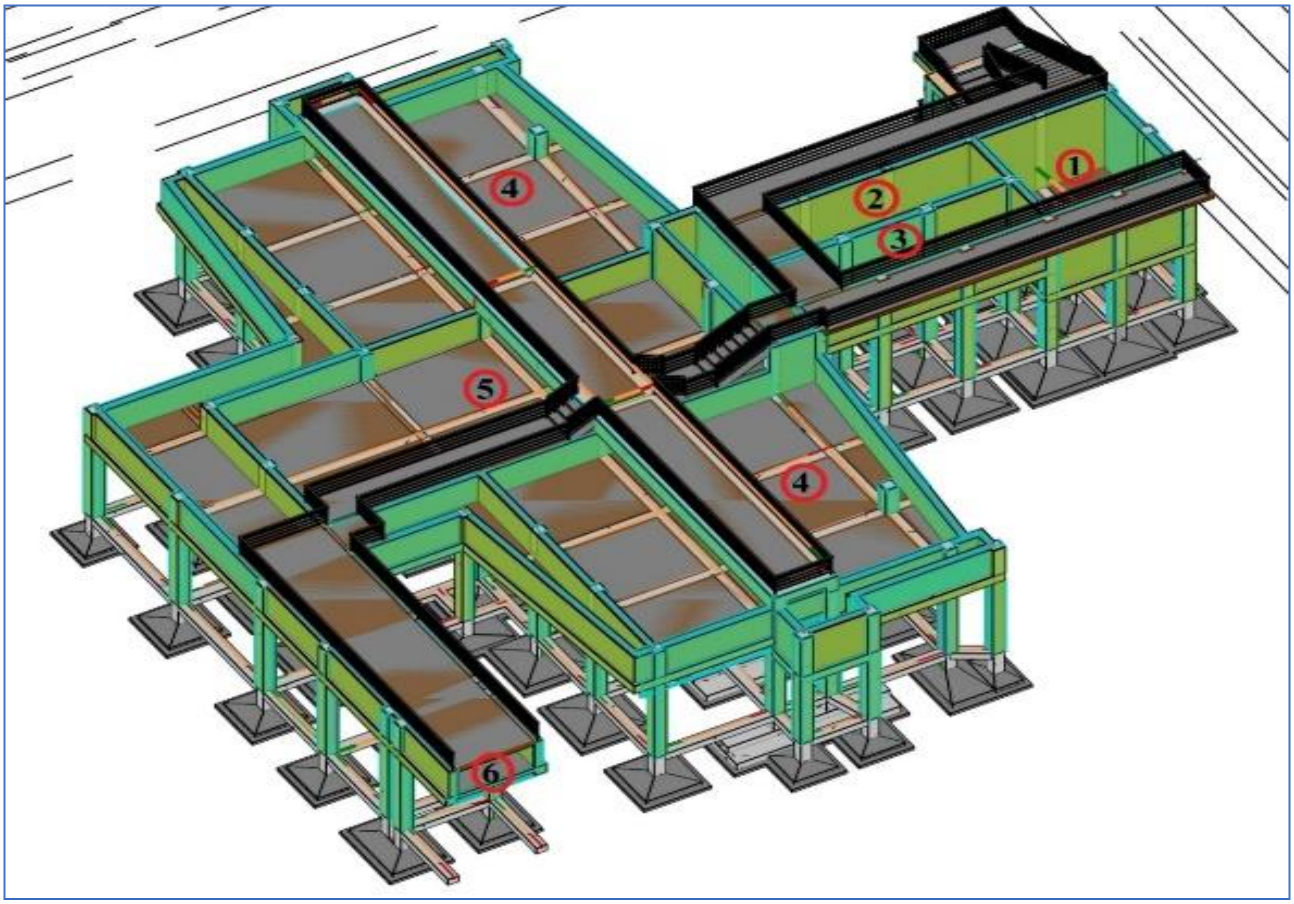


Figure 3 3-D diagram of STP unit showing 1) Inlet chamber, 2) manual screen chamber, 3) mechanical screen chamber, 4) mechanical grit chamber, 5) manual grit chamber and 6) distribution chamber.

3.1 Quantity Comparison By Conventional Method And BIM Approach

3.1.1 Excavation Quantity Comparison By Conventional Method And BIM Approach

The excavation depth is 1.524m below the ground level. According to the footing/ excavation sizes, there are 15 different types.

The difference in the quantity of excavation by conventional method and BIM approach is 1.7621m³. Here, the conventional method quantity is 0.41 % more than BIM approach, which is small in comparison with the total quantity of excavation. This difference is expected to be due to the difference in digits considered after decimals [22]. In conventional method the quantities are considered up to 2 decimals where as in the BIM approach the quantities are up to 6 decimal points.

3.1.2 Plain Cement Concrete (P.C.C) Quantity Comparison By Conventional Method And BIM Approach

The grade of P.C.C is M15. The thickness of P.C.C is 100 mm and offset from the footing is 150 mm as shown in Figure 4. According to the footing/excavation sizes, there are 15 different types. In P.C.C quantity, the conventional method quantity has greater value than BIM by 0.1109 m³. Hence, the BIM tool has 0.39% less quantity than conventional method. The two values have very small variation, the BIM quantity seems to be more accurate as the quantity generated is from the 3D model data [17].

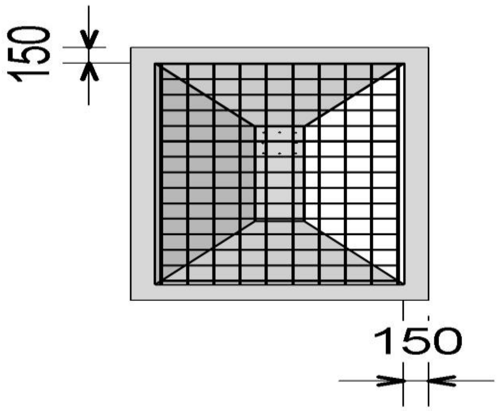


Figure 4 150 mm PCC offset from sides of isolated footing

3.1.3 Footing Quantity Comparison By Conventional Method And BIM Approach

Figure 5 shows the isolated and combined footings of the STP unit. The total numbers of footings are 75 which have 12 number of combined footings and 63 numbers of isolated footings. The classification of footing is done according to the footing sizes & types, therefore there are 15 types. The difference in quantity estimation of footing by conventional method and BIM approach is -0.0939 m³ and the percentage difference is -0.15%.

The quantity of the conventional and BIM is almost the same. The reasons for slight difference in quantities estimation is because of the footing area been calculated less by 0.0939 m^3 by the conventional method for footings encircled in Figure 5 and difference in digits considered after decimals [23].

3.1.4 Column Quantity Comparison By Conventional Method And Bim Approach

The Grade Of Concrete Is M30. All Columns Have The Same Size Of 300 Mm X 300 Mm. Total 77 Columns Are Present In The Stp Unit. For Comparison Of Column With Conventional And Bim Tool, The Classification Is Done On The Basis Of The Height Of Column. As Studied From The 2d Drawings Columns Had Different Heights. Columns Provided For Inlet Chamber Were At Reduced Level (R.L) 422.30 M, Whereas Columns Provided At Screen Chamber, Grit Chamber And Distribution Chamber Were At R.L 426.3 M As Shown In Figure 6.

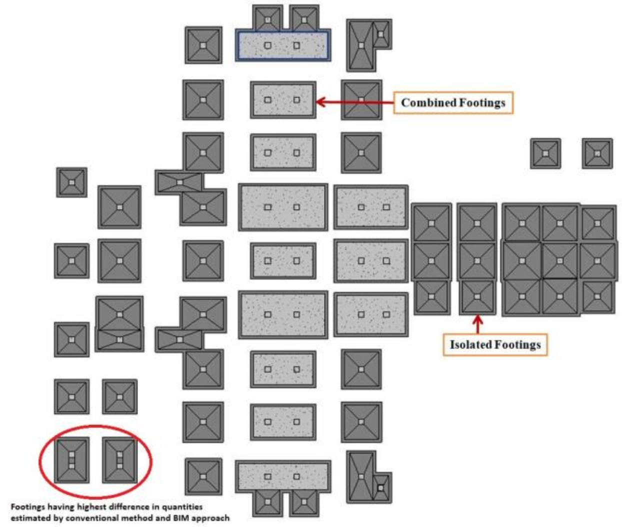


Figure 5 Isolated and combined footings of the STP unit.

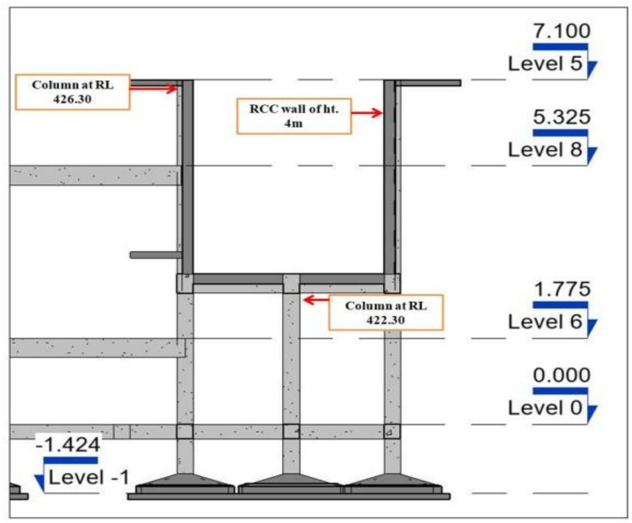


Figure 6 Column R.L's at inlet chamber and screen chamber of the STP unit

The total difference in column quantity by conventional method and BIM approach is -0.012m³ where the conventional method estimated lesser quantity than the BIM approach and the percentage difference is -0.03%. This difference is expected to be due to the difference in digits considered after decimals [24]. In conventional method the quantities are considered up to 2 decimals where as in the BIM approach the quantities are up to 4 decimal points.

3.1.5 Beam comparison by conventional method and BIM approach

The grade of concrete is M30. The sizes of beam are 300mm x 300mm, 300mm x 400mm and 300mm x 750mm. For the comparison of beams by conventional and BIM method, the classification is done on beam at ground level, first floor level and second floor level. The total number of beams is 222 out of which brace beams are 126, first floor level beams are 87 and second floor level beams are 9. The quantity estimated by conventional method for brace beams, first floor beams and second floor beams are 25.89m^3, 39.46m^3 and 11.36m^3 respectively. The quantity estimated by BIM approach for brace beams, first floor beams and second floor beams are 25.6109m^3, 39.4613m^3 and 11.3982m^3 respectively. The conventional method quantity is more than BIM quantity by 0.2496m³ and percentage difference calculated is 0.33%. The difference in quantities is because of the difference in digits considered after decimals [24]. In conventional method the quantities are considered up to 2 decimals where as in the BIM approach the quantities are up to 4 decimal points.

3.1.6 Slab Quantity Comparison By Conventional Method And BIM Approach

The grade of concrete is M30. The thickness of slab is 200mm and 125mm. The classification is done of slab having different thickness. The total number of slabs are 73 out of them 65 numbers of slab have 200mm thickness and 8 numbers of slab have 125 mm thickness. The slab of 200mm thickness and 125mm thickness has the total variation in quantity of -0.0334m³. Here, the BIM tool quantity is more by 0.05% than the conventional method which is a very small difference [6]

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3.1.7 Reinforced Cement Concrete (R.C.C) Wall Quantity Comparison By Conventional Method And BIM Approach

The grade of concrete is M30 and thickness of wall is 200mm. The walls were made up of R.C.C were having different heights. So, for the comparison between conventional method & BIM approach, the wall of different height is compared. The R.C.C. wall height was 4 m at the inlet chamber whereas the R.C.C. wall height at screen chamber, grit chamber and distribution chamber were having a height of 2.4m, 1.4m and 1.1m respectively. The BIM quantity is less than conventional method by 0.25m³. Therefore, the percentage difference is 0.38%. The difference in quantities is because of the difference in digits considered after decimals [23]. In conventional method the quantities are considered up to 2 decimals where as in the BIM approach the quantities are up to 4 decimal points.

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3.1.8 Plastering and Painting Quantity Comparison By Conventional Method And BIM Approach

The plaster and paint quantity includes the exterior surface quantity which covers the area of the exterior wall surface, columns, and exterior beam surface. The interior surface includes the area of the interior walls and the ceiling quantity include the slab plaster. The BIM quantity has more value than conventional method by 42.5985m^2 for plastering. So, the BIM tool generates 2.37% more quantity with respect to conventional method for plastering. The more difference seen is for exterior plaster surface quantity which is 45.6985m^2. It is evaluated that, surface areas at the junction (as shown in Figure 7) or near the level difference (as shown in Figure 8) might have remained or could not be visualized during calculation of the quantities by conventional method [9]. For exterior paint the quantity estimated by BIM tool has more value than conventional method by 32.4783 m^2. So, the BIM tool generates 2.47% more quantity with respect to conventional method for plastering. For interior paint the quantity estimated by BIM tool has more value than conventional method by 10.1302 m^2. So, the BIM tool generates 2.10% more quantity with respect to conventional method for plastering. Using the BIM tool the 3D model helps for visualization and so the finishing layers can be added easily in the model which provides the accurate quantity of finishing work. The steps given by Khosakitchalert et al 2020 [18], are followed in modeling the plaster and paint of the STP unit. This creates a specific layers of plaster and paint in the model and so, this plaster and paint layers get align to each layer automatically in the model.

This help to eliminate the overlap of the quantity of plaster and paint through BIM and also helps to measure the quantity from the outside of the plaster and paint layers. Therefore, these help in creating an accurate and efficient quantity of plaster and paint. So, the quantity provide by Revit is more accurate and precise.

3.1.9 Railing Quantity Comparison By Conventional Method And BIM Approach

The railings are provided at staircase and ceiling and the railing quantity is measured in running metre (R.M). The staircase and ceiling railing quantities are 184.28m and 184.2850m by conventional method and BIM approach. The conventional method and BIM approach provides same quantity of railing.

3.1.10 Steel Quantity Comparison By Conventional Method And BIM Approach

Steel amount is an important factor in any construction project because the cost of steel is high in all projects when compared to other items. The sewage treatment plant has the complex design of reinforcement due to heavy load values and complex plan. So, the quantity of steel estimating is imported and there is need for accurate and easy method.

The TMT bars of different sizes are used in the unit. The structure design sheets are studied and the accurate quantity is found out. The main bar length, distribution bar length, stirrups bars are calculated as per formula. For the conventional method, the steel quantity is calculated by preparing the bar bending schedule. In which the cutting length of each section are calculated. The steel quantity is calculated in Kilogram (kg). The steel quantity by the conventional method and BIM tool is 30490 and 31571 kg respectively. The steel quantity difference between conventional method and BIM approach is -1081 kg and the percentage difference is -3.48%. The quantities estimated for 8mm, 10mm, 12mm and 16 mm bars by BIM method are 15834kg, 4046kg, 6514kg and 5177kg respectively and by conventional method are 15117kg, 3950kg, 6329kg and 5094kg respectively. The 8mm bars are having more difference of 4.63% while 16mm bars are having difference of 1.62% by conventional method.

The 8mm diameter bar has a greater quantity as compared to the different size of bars as reinforcement in the selected STP unit. 8 mm bars have been used in footing, columns, beam, slab, walls and staircase of the selected STP unit as distribution steel and majorly stirrups. The stirrups are having 135^o hooks (as shown in Figure 9) and distribution bars have 90^o hook (as shown in Figure 10). Due to these different shapes of reinforcement the estimation of reinforcement becomes tedious and prone to mistakes when used the conventional method whereas if BIM approach is adopted the errors will be minimized [25,26].

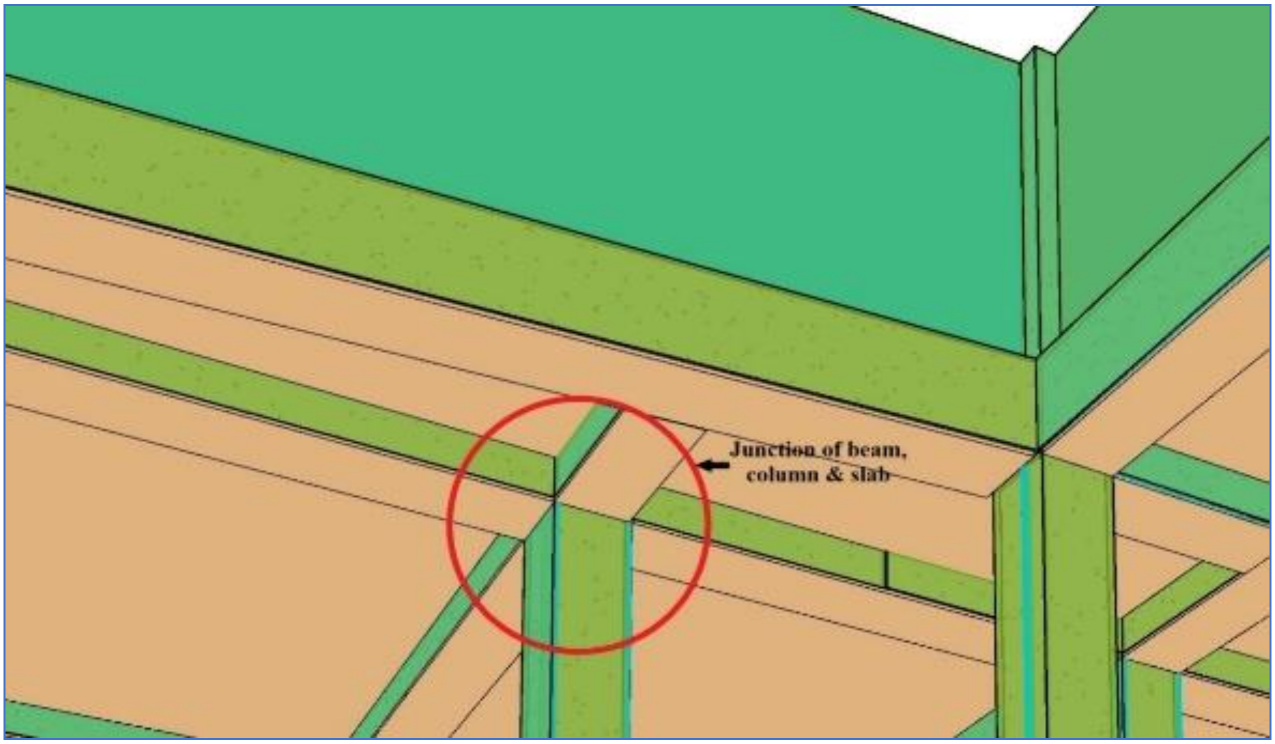

Figure 7 Three-dimensional views of the BIM model showing junction of beam column and slab.

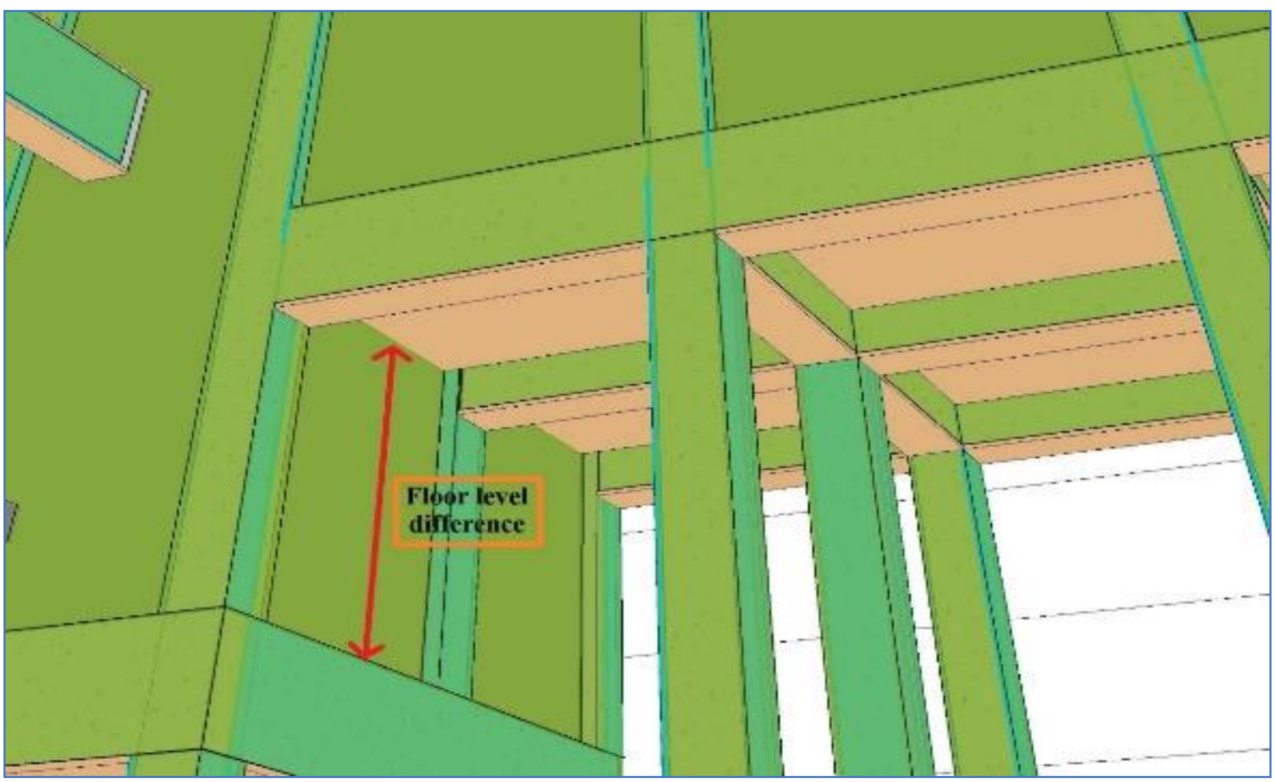

Figure 8 Three-dimensional views of the BIM model showing floor level difference at inlet chamber and screen chamber.

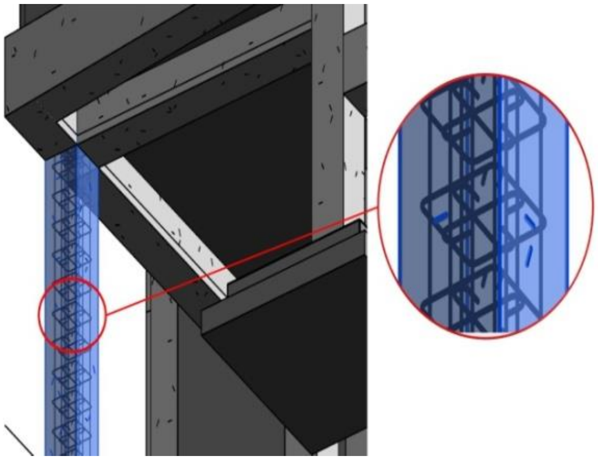

Figure 9 8mm Fe 415 steel reinforcement provided as stirrups in column with 135° hooks.

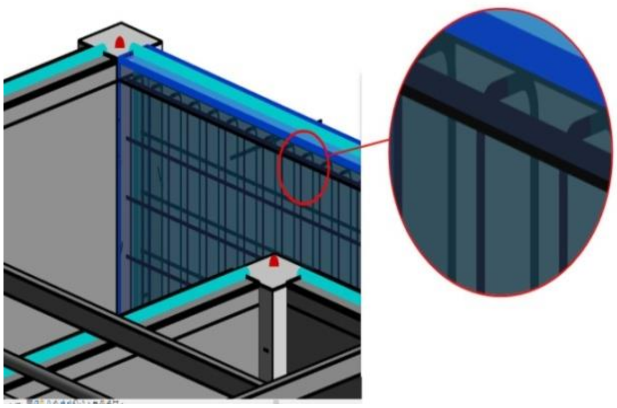

Figure 10 8mm Fe 415 steel reinforcement provided as distribution steel in R.C.C wall with 90° hooks.

For Revit rebar modelling of the STP unit, the guidelines given by [27] is followed. The guidelines given in ACI Detailing Manual SP-66 (2004), include how to deal with rebar forms and limitations, how to show rebar in construction drawings, how to extract data from schedules, and the best practices for positioning and adjusting free-form and shape-driven rebar, area, and route reinforcement. Therefore, these guidelines were helpful for preparing a rebars in project with effective and accurate approach.

3.2 Cost Estimation Of STP Unit By Conventional Method And BIM Approach

When calculating the items, the Bill of Quantities (BOQ) sheet is created. The document includes the amount of items, their unit costs, and the project's overall cost calculated using conventional cost estimating. Figure 11 provides the comparison of cost of each item by conventional method and BIM approach.

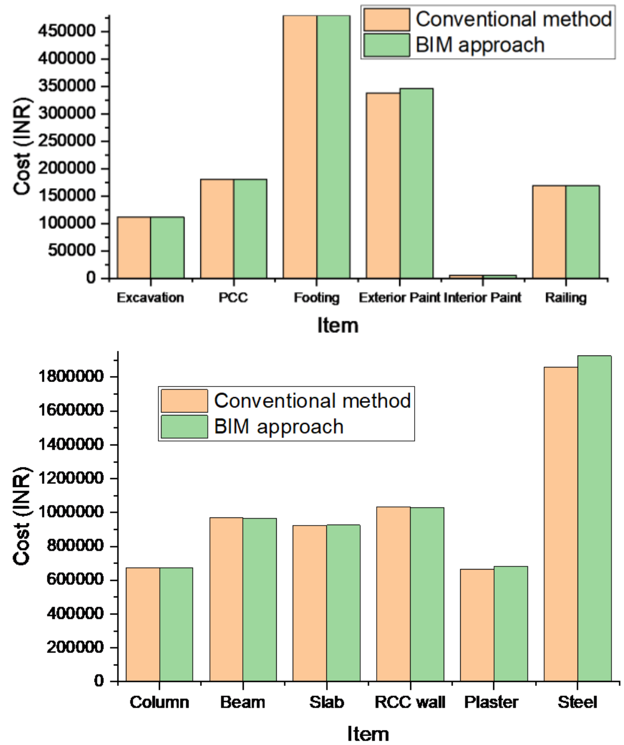

Figure 11 Comparison of cost of items by conventional method and BIM approach.

Table 4 in the appendix provides the total cost of the STP unit by conventional method and BIM approach. Using the conventional cost estimating approach, the project's total projected cost is 74,13,845/- INR. Similar, to conventional BOQ sheet, quantities of items are collected from BIM software while creating a BOQ sheet. BIM software cost estimates the project's overall cost at 74,97,461/- INR. Finding an accurate project cost in pre construction stage is the fundamental goal of cost estimating. The price difference for the STP unit comes to -83,616/- INR or -1.12%. It is found that estimation by BIM software is more accurate due to accuracy in the BIM/Revit software. The percentage that separates the BIM software estimate from the conventional technique in excavation, PCC, footing, column, beam, slab, RCC wall, plaster, exterior paint, interior paint, railing, and steel is 0.41%, 0.39%, -0.15%, -0.03%, 0.33%, -0.05%, 0.38%, -2.37%, -2.47%, -2.10%, 0%, -3.48% respectively. The efficiency of the detailed estimate is significantly impacted by the visualization and aggregation features of the BIM-Assisted Detailed Estimating (BADE) tool [28].

4.0 CONCLUSION

The aim of this study was to estimate the quantity and cost of a unit of a STP by manual method and BIM approach. The results obtained by the conventional method and BIM tool are analyzed. The quantities provided by conventional and BIM tool for the slab, column and railing have almost the same values. The excavation, PCC, beam, RCC wall quantities have a difference of 0.41%, 0.39%, 0.33%, 0.38% and footing quantity has a difference of -0.15%. The BIM-Assisted Detailed Estimate (BADE) tool is a major tool for providing the accurate and greater efficiency. Also, there is chance that conventional method has the errors because of complexity but as the IFC viewer's visualization feature alone, which is a function of the BIM, is sufficient to produce observable gains in both estimating accuracy and efficiency. So, the BIM quantity generated are precise and efficient.

The plaster, exterior paint and interior paint quantities by the BIM are more by 2.37%, 2.47% and 2.09% respectively, than the conventional method. The function of visualization improves efficiency and accuracy in the detailed estimate using BIM tool whereas, the conventional method can have the omissions or errors during calculations. The reinforcement steel quantity has deviation of -3.48% between conventional method and BIM approach quantity estimation. The cost by the BIM tool is more by 65,941/- INR for steel quantity. Utilization of BIM tool helps to draw a steel model in efficient way and provide a precise quantity. Contrarily, using the bar-bending schedule table in conventional method involves a complicated process that can have human mistake and omissions.

The BADE tool's visualization and aggregation features in BIM significantly outperform the conventional method for the detailed estimate. Therefore, BIM cost estimate shows 1.12% more as compared to conventional method which helps to achieve the accuracy of the project pre construction. One of the major contributions is automatic and accurate elaboration of quantity of the project by creating a 3-D model in BIM. The calculation work can be done automatically in the software by inserting the measurements in the software. Therefore, BIM allows for simplification of many tasks and considerable saving both in terms of time and money. The quantity surveyor's job is considerably altered by BIM-based operations; the number of basic activities declines whiles the need for professional competence increases. A quantity specialist's expertise is still required for evaluating the reliability of the source data and source materials, making sure the take-off was covered, coming up with creative solutions, and analyzing the outcomes. Future scope of research is to implement BIM for life cycle costing analysis of STP's. Integrating BIM with life cycle cost estimation can bring a more sustainable approach towards implementing STP's for wastewater treatment.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

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Appendix

Table 4 Comparison of quantity and cost of STP unit by conventional method and BIM approach.

SN	Item	Unit	Unit Cost	Quantity by Conventional method	Quantity by BIM approach	Difference	Percentage Difference	Cost by Conventional Method (INR)	Cost by BIM approach (INR)	Difference (INR)	Percentage Difference
1	Excavation	cum	258	434.26	432.4979	1.7621	0.41	112039.08	111584.4582	454.6218	0.41
2	PCC	cum	6359	28.49	28.3791	0.1109	0.39	181167.91	180462.6969	705.2131	0.39
3	Footing	cum	7471	64.21	64.3039	-0.0939	-0.15	479712.91	480414.4369	-701.5269	-0.15
4	Column	cum	14150	47.65	47.662	-0.012	-0.03	674247.5	674417.3	-169.8	-0.03
5	Beam	cum	12635	76.72	76.4704	0.2496	0.33	969357.2	966203.504	3153.696	0.33
6	Slab	cum	14299	64.68	64.7134	-0.0334	-0.05	924859.32	925336.9066	-477.5866	-0.05
7	RCC wall	cum	15750	65.66	65.41	0.25	0.38	1034145	1030207.5	3937.5	0.38
8	Plaster	sqm	375	1774.2	1816.7985	-42.5985	-2.37	665325	681299.4375	-15974.4375	-2.37
9	Exterior Paint	sqm	261	1296.49	1328.9683	-32.4783	-2.47	338383.89	346860.7263	-8476.8363	-2.47
10	Interior Paint	sqm	12	477.7	487.8302	-10.1302	-2.10	5732.4	5853.9624	-121.5624	-2.10
11	Railing	m	917	184.28	184.285	-0.005	0.00	168984.76	168989.345	-4.585	0.00
12	Steel	kg	61	30490	31571	-1081	-3.48	1859890	1925831	-65941	-3.48
							Total Cost	7413845.0	7497461	-83616	-1.12

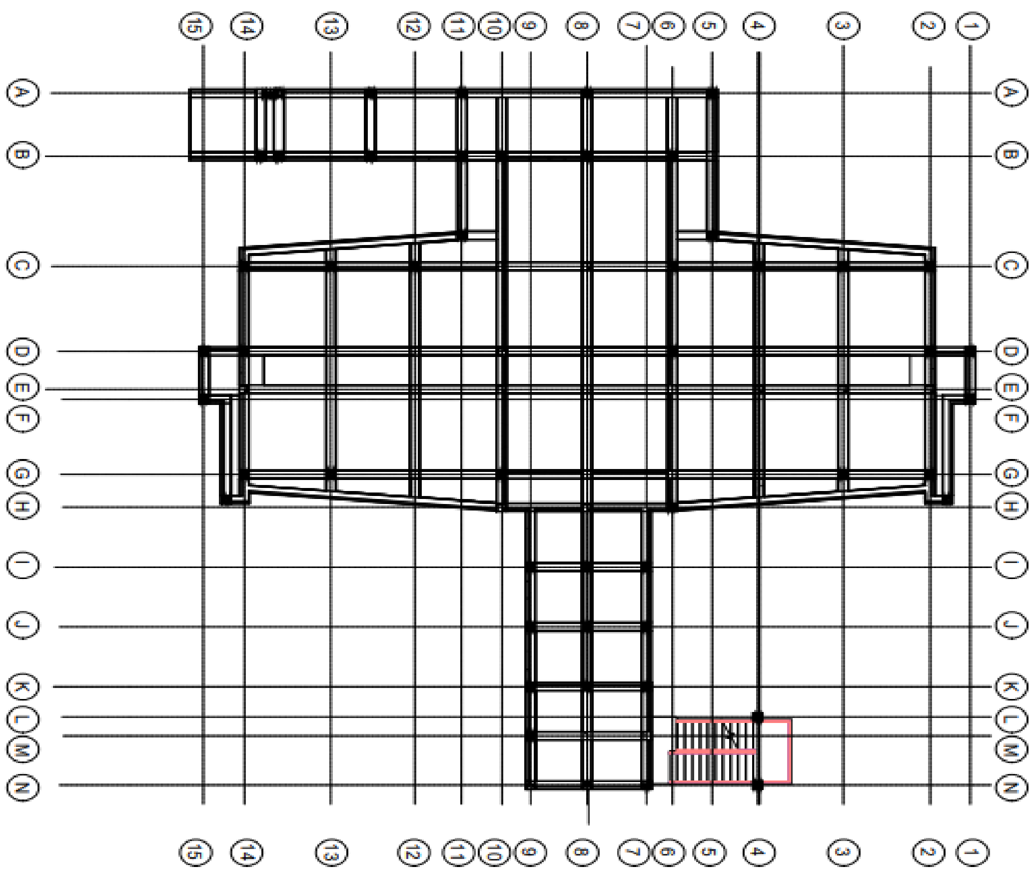

Figure 12 Centre Line Plan of STP unit