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Sabin Dahal

# BIM Based Design of Hydropower in Nepal

## Lower Piluwa Small Hydropower Project

Metropolia University of Applied Sciences

Bachelor of Engineering

Sustainable Building Engineering

Bachelor's Thesis

29 November 2019

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Title	BIM Based Design of Hydropower in Nepal Lower Piluwa Small Hydropower Project
Number of Pages	31 pages + 3 appendices
Date	29 November 2019
Degree	Bachelor of Engineering
Degree Programme	Civil Engineering
Professional Major	Sustainable Building Engineering
Instructors	Sunil Suwal, Senior Lecturer
<p>The purpose of this thesis was to design a sustainable hydropower project in Nepal using BIM technology and the benefits that users can get from the BIM-based project. The thesis included a case study of a Lower Piluwa Small Hydropower Project. A comparison was made between the amount of concrete used in the powerhouse with the traditional and the BIM-based method, and the results were shown based on a model made in Tekla structures. The model was compared it with the original documents of the project. The result showed that BIM-based quantity take-off and cost estimation gave an accurate estimation of concrete use in the building and allowed for the calculation of the number of bags of cement, fine aggregates, number of bricks, and coarse aggregate. Then calculations gave the exact information about the budget needed for the project.</p> <p>For the case study of this thesis, phone and skype interviews were carried out, and the data related to the project were added. This might be a test project for the hydropower projects in Nepal, but the results clearly show that the use of new technology will help in every aspect of the construction industry.</p>	
Keywords	BIM, sustainability, Nepal, hydropower, environment, economy

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## List of Abbreviations

AEC	Architecture Engineering and Construction
BIM	Building Information modelling
CAD	Computer-Aided Design
EIA	Environmental Impact Assessment
HPP	Hydropower Project
INPS	Integrated Nepal Power System
KW	Kilowatt
MW	Megawatt
NPR	Nepalese Rupees, Currency of Nepal
PPA	Power Purchase Agreement
SHP	Small Hydropower Project
VDC	Village Development Community

## **Acknowledgement**

I would like to thank Mr. Sunil Suwal, chairperson of Nepal BIM Forum and a senior lecturer at Helsinki Metropolia University of Applied Sciences for his help and guidance while doing research for this thesis. His suggestions and advice were vital for me to complete my thesis. I would like to express my special thanks to Taija Salminen for helping me with the editing of the thesis.

Similarly, I would also like to thank Mr. Mahesh Karki, Secretary of Nepal BIM Forum for his help and suggestions while writing this thesis.

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29 November 2019

## Glossary of Terms

<b>Terms</b>	<b>Definition</b>
Design discharge	Volume of water required to run the turbines at full capacity.
Generator	A device that converts mechanical energy into electric power.
Headworks	Civil engineering term for diverting water into a canal.
Headpond	An artificial pond or lake for the storage of water.
Horizontal Shaft	Term used for the placement of turbines in 180 degrees in a powerhouse in order to rotate a generator.
Intake	Structure which allows water to move from the reservoir and delivered to the penstock.
Penstock	Pipes which are used to ensure uniform flow of water from the intake to the turbines.
Powerhouse	Building which has turbines and generator to produce electricity.
Switchyard	A place from where the electricity is transmitted to the grid.
Tailrace	Discharge of water from the powerhouse after generating electricity.
Turbine	Engine in a powerhouse that rotates the with the force of water.

## **Assumptions**

All the calculations in this thesis are in Nepalese currency and the foreign exchange rate of Euro to Nepalese rupees is shown below in the approximate figure.

1 Euro=125 Nepalese Rupees NPR. approximately

## 1 Introduction

The traditional methods used in hydropower construction in Nepal impact the economy of the country substantially. Hydropower construction is a very long project and completing it on time is a challenging task. The projects have had to pay hefty penalties to the government, which directly affects all people involved in the project, as well as the users later on. This thesis aims to study the possibilities of BIM to support the projects so that they are completed on time, as well as help the project for cost optimization.

If hydropower projects are completed on time and on a low budget, it is a benefit for the users or clients. The use of advanced technology in a project leads to lower human errors, maximizes the efficiency, and saves costs through better estimation of logistics and materials. Information sharing and retrieval, while working help to understand the project in detail, which is possible through the 3D visualization of BIM. This gives a new dimension for the construction of a project. Execution of a project using advanced BIM tools is easier than ever. If the modern construction tools are used in the right way, then the construction of hydropower in Nepal takes a new way to a bright future, paving the way of good fortune for all the Nepalese.

In this thesis, the main objective is to design hydropower projects using BIM-based technology so that the construction of hydropower projects become easier and faster. The literature review is done in order to know the current status of hydropower projects in Nepal and technologies used during and before the construction of hydropower projects. Furthermore, the technologies used in the currently developed countries are also analyzed. Comparison between the existing project and steps that can be made to improve the operation and maintenance is also carried out during this thesis process. Interview with many professionals who are currently in the hydropower sector was very fruitful for writing this thesis. The readers are going to know the current status of hydropower projects in Nepal and steps to minimize the problems and use of right technologies before the construction of a hydropower project.

## 2 Hydropower and Sustainability in Nepal

Due to the favorable topography and many perennial rivers, Nepal has a tremendous potential of hydropower. There are three significant basins in Nepal's river system



known as, Koshi, Gandaki, and Karnali-Mahakali and four smaller basins, kamala, Bagmati, Rapti and Babai. All these rivers drain in one of the major river systems in South East Asia known as the Ganges located in India. Despite having 83.000 MW hydropower potential in Nepal, only 40.000 MW to 45.000 MW is possible because of the economic situation of the country. [1.]

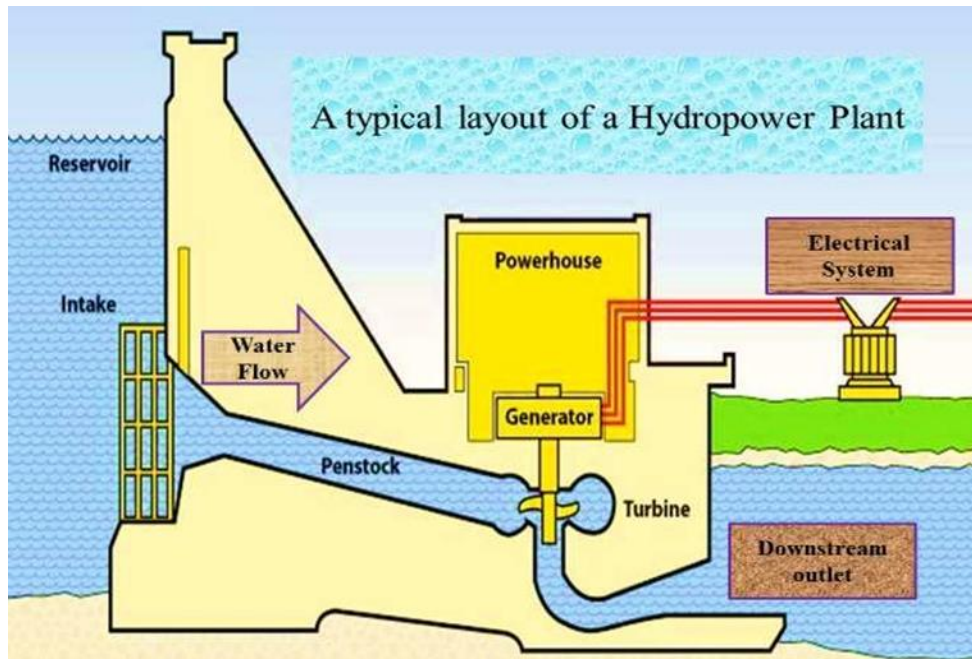


Figure 1. A typical layout of a Hydropower Plant [2].

Figure 1 shows the basic principle of a hydropower plant. The main parts of a hydropower plant includes powerhouse, generator, turbine, penstock pipe, intake, reservoir, tailrace and transmission system. [2.]

The first hydroelectric plant of Nepal was installed in 1911 at Pharping, about 20 km south-west of Kathmandu, generating 500 KW of power to electrify the capital city Kathmandu. After the installation of Pharping hydroelectric plant for the first time in Nepal, it took nearly 25 years for the installation of another hydropower at Sundarijal, with an installed capacity of 640KW. [3.]

The government formulated Hydropower Development Policy in 1992 and, then, legislated the Electricity Act in 1993 and Regulation in 1994 to attract local and foreign entrepreneurs to invest in the hydropower sector of Nepal, together with other important acts and regulations. Hydropower project development was opened to private investors by issuing licenses to conduct feasibility studies. When the Hydropower Development

Policy of 1992 came into force, the sole producer, supplier and distributor of electricity, Nepal Electricity Authority (NEA), entered into a power purchase agreement with the license holders. [4.]

The current electricity generation in Nepal is 765MW of which hydropower is the main contributor, contributing 702 MW. The peak demand for electricity grew by 7.7% and 9% in 2012 and 2013 respectively. In dry season, the generation of electricity is reduced by 80 MW and it is compensated by importing electricity from India and diesel-fired power plants. The power demand in Nepal is expected to increase by 8.6 % per annum for a decade or so. Hence, new power projects are needed to fulfil the increasing demand. The newer projects that will be built are expected to be more efficient than the projects carried out through the traditional methods. [5.]

BIM-based hydropower projects are very few in the world right now. Because of the numerous benefits of BIM modelling in the Architecture, Engineering, and Construction (AEC) industry, hydropower projects are also following the trend. BIM is an entirely new concept in Nepal. The implementation of BIM is widely advertised in developed countries, but the term is still a myth to the Nepalese AEC industry. Nepalese engineers are still adopting the traditional 2D drawing methods for projects. This thesis aims to be a primary tool for the implementation of BIM in Nepal. Despite the major potential that BIM poses, the Nepalese construction industry is scared to use practically. Some reasons can be lack of education regarding BIM and its implementation, using BIM with beginners might delay the project and hence might have to pay a compensation fee and the owners, contractors and investors are still unaware of innovations in the construction industry. [6.]

Although hydropower is the most environmentally friendly renewable energy source there are still things that can help to reduce carbon emissions to the environment. A sustainable hydropower project is a project with minimal effects on the surrounding environment during construction. Sustainability in hydropower projects can be achieved by using environmentally friendly building materials for the construction of dams, powerhouses, houses for staff. Even though the contribution of a single building is small, in the built environment, in the long run and with numerous hydropower projects beginning soon, the impact on the built environment will be a major one.

According to the Oxford Dictionary, the word sustainable means “Conserving an ecological balance by avoiding depletion of natural resources [7].” Sustainable construction

is a process which includes fulfilling the demand of a growing population in such a way that the environment and its surrounding are taken into consideration. Nepal is an underdeveloped country where many construction processes are done with traditional materials and by avoiding the building code which may arise various problems. [8.]

The target of sustainable construction can be achieved if actions are taken immediately. People should be aware of sustainable construction and know how it can be achieved. The government and the private sector should act actively to achieve the target. Some of the possible ways to act might be the development of rules and regulations, depicting and promoting sustainability in the construction sector and founding a governing legal sustainable construction consortium, as well as promoting educational activities in engineering curriculums.

The materials used on the construction site also help in sustainable development. Low carbon dioxide and carbon monoxide emissions should be an essential priority in the construction sector. Green construction materials such as bamboo, timber Crete, mycelium, wood, recycled plastics should be used as much as possible. The process of making bricks emits a lot of carbon dioxide and carbon monoxide gases in the atmosphere, so these materials should be replaced with green construction materials.

Nepal is a tiny landlocked country bordered by India in the South, east, and west while China in the north. Nepal is an underdeveloped country; however, the construction sector is booming right now, especially hydropower construction is growing. Urbanization and industrialization are increasing rapidly. This is the right time to think about the future and develop the country in such a way that everything is taken into consideration. [9.]

Sustainability is an unfamiliar term in the context of an underdeveloped country like Nepal. The focus is given to the development of the cities with modern high-rise shopping malls and wide roads, but the impact they have on the environment is not taken into consideration. Infrastructure development is prioritized, neglecting the environment. This leads to air pollution, climate change, and many natural disasters. Sustainability has to be considered not only in the construction phase but also in the design of projects and along all the way. Now the country is progressing rapidly, and it is the right time to act. There are many plans and goals set for achieving the target of sustainability, but so far only on paper. [10.]

### 3 Building Information Modelling

Building Information Modelling (BIM) seems to have been one of the best innovations in the AEC industries. BIM technology helps to turn virtual models into digital construction with pinpoint accuracy. They seem to be replacing the traditional 2-D document-based methods and processes that have been used widely in the construction industry for years and are very hard to replace. It could be claimed that the use of technology in the construction industry is belated when comparing to other sectors. [11.]

BIM is a smart model-based process which helps to connect all the engineers, owners and users. So, that the workflow in any project is uninterrupted. A model with physical characteristics of a building is created by designer. The main role of BIM is to coordinate among all the members and give an outline of a task that they have to perform in different phases and allows flexibility to choose the option in the model. BIM also ensures that relationships between the different component in the model are also unchanged. This allows all the views, elevation and section in the model to update automatically. [11.]

In addition to these features, BIM directs the users from the model to construction phase in ease. BIM provides insight into the constructability of a design, improving the efficiency and effectiveness of the construction phase and also providing a better understanding of the building's future operation and maintenance. Owners can use BIM for predictive maintenance, asset tracking, and facilities management, and future renovation or deconstruction projects. After working with BIM, the risk of the project is reduced, the scheduling of the project is improved, cost savings and better project outcomes are achieved. The power of BIM is growing with cloud-connected technologies that let project teams design and work together in novel ways. Driven by global trends, the AEC industry is in a time of transformation. Businesses that want to win more work, deliver projects more efficiently and design better buildings need a robust solution, and that solution is BIM. The most well-known BIM software solutions are Autodesk Revit, Autodesk BIM 360, Archicad, Autodesk, Navisworks, Vector works Architect. [11.]

## 4 History of BIM

BIM was known as Building Description System (BDS) before and it was named by Eastman in 1970s. The name came up when Eastman was working with computer-based data modelling software. Many modelling software were developed in the 1980s and one of them is CAD. There were three types of CAD software, Automated drafting (AutoCAD), 3-D modellers known as Form Z and ArchiCAD at the beginning of the CAD software development phase. After the development of these computer programs building technology got a new dimension of modelling. The life cycle of BIM also added the team that takes part in processes like owners, planners, programmers, designers, architects, engineers, contractors fabricators, and facility managers. [12.]



Figure 2. A Brief History of BIM

Figure 2 gives an idea about the evolution of engineering drawings in a fifty-year period. This figure also shows that it did not take a long time to jump from hand draft to BIM.

## 5 Benefits of BIM

Adopting BIM in any industry is fruitful. It shortens the life cycle of projects, reduces the money needed for paperwork; there can be huge savings on material costs as shown in figure 3 and 4. BIM also increases productivity among labourers.

## Lower costs

# 33%

reduction in the initial cost of construction and the whole life cost of built assets

## Faster delivery

# 50%

reduction in overall time, from inception to completion, for newbuild and refurbished assets

## Lower emissions

# 50%

reduction in greenhouse gas emissions in the built environment

## Improvements in exports

# 50%

reduction in the trade gap between total exports and total imports for construction products and materials

Figure 3. Benefits of BIM in construction sector [13]

BIM is a bridge for the architects, surveyors, engineers to deliver virtual information through communication. With the help of BIM, the project is understood clearly by everyone involved. The design team, the main contractor, subcontractors, owner and operator, can all be notified about other modifications in drawings or any changes in the project. This allows the project to run smoothly without any delay. With the virtual visualization of the project, the workers working will have precise knowledge about what they should do and what they should not do. Problems can be identified earlier, and the project will have enough time to solve the problem. Furthermore, the project will run continuously. Traditionally communication between all parties was a big task, and there was a lot of loss of information. A small problem in a hydropower project is a big concern for the parties involved and can cause major costs for a nation. If the problems are solved beforehand, construction can run smoothly, and a chance of exceeding the budget is low. [14.]



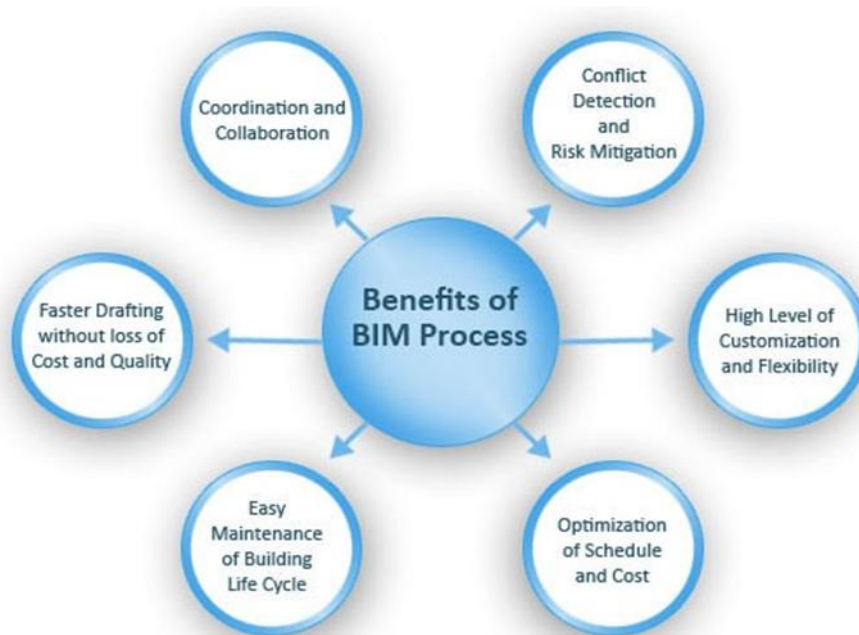


Figure 4. Benefits of BIM process. [15.]

The figure shows that BIM has many benefits and some of them are coordination and collaboration, conflict detection and risk mitigation, high level of customization and flexibility, optimization of schedule and cost, easy maintenance of building life cycle, faster drafting without loss of cost and quality.

### 5.1 Coordination and Collaboration

During the design and construction phase of a project, coordination and collaboration between different parties play a vital role in understanding the project. The coordination of a project can be done with the help of a project model that ensures that all team members have all information. Field conflicts can be reduced significantly, which eventually results in huge economic savings for a project. The visualization of the construction leads to fewer errors and reduces construction costs. The construction time of the project shortens when there are no conflicts between different parties and profits everyone involved. [16.]

Collaboration is an integral part of a project. A small misunderstanding or wrong information can lead to the collapse of a project. Coordination and collaboration between parties help to achieve the goal, and BIM is an integral tool to allow this connection. Collaboration in the construction industry has a history of struggling because of differ-

ent parties involved, but if the construction industry adopts BIM, it is going to benefit greatly in the future. Collaboration is one of the benefits of BIM, and it helps to bring the design team, contractors, manufacturers, and installers together working in cooperation. This means that designs, issues, priorities, and construction methods are agreed about in the initial stages. Collaboration in a project reduces time delays, saves costs and increases on-site productivity. [16.]

## 5.2 Performance-based Building

BIM aids in the analysis of a project in different phases. In the planning phases, BIM supports in-site analysis to determine the location of the project. During site analysis, BIM endorses that the site meets the required criteria according to the project requirements. Site analysis may also decrease costs of utility demand and demolition and minimize the risk of hazardous material. [17.]

In the design phase, BIM assists to determine the energy used in the building by obtaining the information automatically from the BIM model, which saves time effort and costs. Furthermore, BIM contributes to the calculation of the energy consumption in the building and the achievement of energy-efficient buildings that meet the energy-related requirements. If a building does not meet the required standard, the changes can be made quickly and cheaply. It is easier to get building performance efficiency using BIM optimization. During the operation phase, BIM also helps to guarantee that the building operates as specified in the design and according to sustainable standards. The possible analysis which can be done to get sustainable buildings using BIM are site analysis, structural analysis, lighting analysis and energy analysis. [17.]

## 5.3 Clash Detection

The clash detection feature of BIM identify clashes in the model with the help of the software. Clash detection can be used in many 3D models. Clash detection is an indispensable component for designers, architects, builders, engineers, and contractors for finding the specific clashes in the structures. There are mainly three types of clashes, hard clash, soft clash and workflow or 4D clash.



A hard clash is best described as two objects intersecting each other. This type of clashes are difficult to fix if they are missed in the design process. It also costs a lot of money to fix them in the construction phase. [18.] A soft clash occurs when objects try to breach the space allowed for the model. This issue can be solved after entering the correct date and time for the objects. A workflow or 4D clash detection notifies about the clashes related to time delivery and scheduling to engineers or contractors. [18.]

Flag	Number	Type	Status	Priority	Date Modified	Object ID	Assembly ID	Object Name
1	Clash				9/23/2019 1:08 AM	2951349, 2952145	2951363, 2952163	SLAB: ISOLATED FOOTING
2	Clash				9/23/2019 1:08 AM	2948778, 2951349	2948793, 2951363	Floor SLAB: SLAB
3	Clash				9/23/2019 1:08 AM	2946603, 2951349	2946621, 2951363	SLAB (2)
4	Clash				9/23/2019 1:08 AM	2947351, 2950444	2947362, 2950457	SLAB (2)
5	Clash				9/23/2019 1:08 AM	2948221, 2950400	2948246, 2950413	SLAB (2)
6	Clash				9/23/2019 1:08 AM	2948732, 2950400	2948747, 2950413	SLAB (2)
7	Clash				9/23/2019 1:08 AM	2946603, 2948221	2946621, 2948246	SLAB (2)
8	Clash				9/23/2019 1:08 AM	2948732, 2948221	2948747, 2948246	SLAB (2)
9	Clash				9/23/2019 1:08 AM	2956659, 2946694	2956677, 2946705	ISOLATED FOOTING: SLAB
10	Clash				9/23/2019 1:08 AM	2956656, 2946694	2956614, 2946705	ISOLATED FOOTING: SLAB
11	Clash				9/23/2019 1:08 AM	2956407, 2946652	2956425, 2946667	ISOLATED FOOTING: SLAB
12	Clash				9/23/2019 1:08 AM	2956659, 2946603	2956677, 2946621	ISOLATED FOOTING: SLAB
13	Clash				9/23/2019 1:08 AM	2891115, 2919064	2890142, 2919100	TOP CHORD: PANEL
14	Clash				9/23/2019 1:08 AM	2890635, 2919064	2890142, 2919100	TOP CHORD: PANEL
15	Clash				9/23/2019 1:08 AM	2916946, 2918955	2916962, 2918971	PANEL (2)
16	Clash				9/23/2019 1:08 AM	2916817, 2918826	2916833, 2918842	PANEL (2)
17	Clash				9/23/2019 1:08 AM	2872059, 2918697	2871566, 2918713	TOP CHORD: PANEL
18	Clash				9/23/2019 1:08 AM	2872539, 2918697	2871566, 2918713	TOP CHORD: PANEL
19	Clash				9/23/2019 1:08 AM	2918688, 2918697	2918704, 2918713	PANEL (2)
20	Clash				9/23/2019 1:08 AM	2918559, 2918568	2918575, 2918584	PANEL (2)
21	Clash				9/23/2019 1:08 AM	2916430, 2918439	2916446, 2918455	PANEL (2)
22	Clash				9/23/2019 1:08 AM	2916301, 2918310	2916317, 2918326	PANEL (2)
23	Clash				9/23/2019 1:08 AM	2916172, 2918181	2916188, 2918197	PANEL (2)
24	Clash				9/23/2019 1:08 AM	2916043, 2918052	2916059, 2918068	PANEL (2)
25	Clash				9/23/2019 1:08 AM	2915914, 2917923	2915930, 2917939	PANEL (2)
26	Clash				9/23/2019 1:08 AM	2603758, 2890635	2603767, 2890142	Corbel: TOP CHORD
27	Clash				9/23/2019 1:08 AM	2603658, 2890126	2603676, 2890142	Corbel: BOTTOM CHORD
28	Clash				9/23/2019 1:08 AM	2603758, 2890126	2603767, 2890142	Corbel: BOTTOM CHORD
29	Clash				9/23/2019 1:08 AM	2603816, 2872059	2603834, 2871566	Corbel: TOP CHORD
30	Clash				9/23/2019 1:08 AM	2603816, 2871550	2603834, 2871566	Corbel: BOTTOM CHORD
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33	Clash				9/23/2019 1:08 AM	2602922, 2852970	2602940, 2852986	Corbel: BOTTOM CHORD
34	Clash				9/23/2019 1:08 AM	2602922, 2852970	2602940, 2852986	Corbel: BOTTOM CHORD
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36	Clash				9/23/2019 1:08 AM	2602952, 2758957	2602970, 2758999	Corbel: BOTTOM CHORD
37	Clash				9/23/2019 1:08 AM	2602402, 2758957	2602420, 2758999	CORBEL: BOTTOM CHORD

Figure 5. Clash check for a model in a project

#### 5.4 Quantity Take-off and Cost Estimating

During the design phase, many types of estimates of a project can be done, ranging from approximate values to precise values, both in the early stages, and when the design is complete. The cost estimation of a project can be made before the final design phase, which ensures that the project does not exceed its budget. If any problems arise in the early design phase, contractors and engineers will have enough time to look for alternatives. This leads to better collaboration between different parties, and as a result, high-quality construction is possible within the cost estimation. [19.]

In the early design phase, it is necessary to get a parametric cost estimate, or the areas, and volume of space or perimeter lengths. The spaces can be the number of parking spaces and floors for the parking garage. One of the features of BIM is DProfiler

modelling and with the help of DProfiler quantities and cost estimation is possible as can be seen in figure 6. [19.]

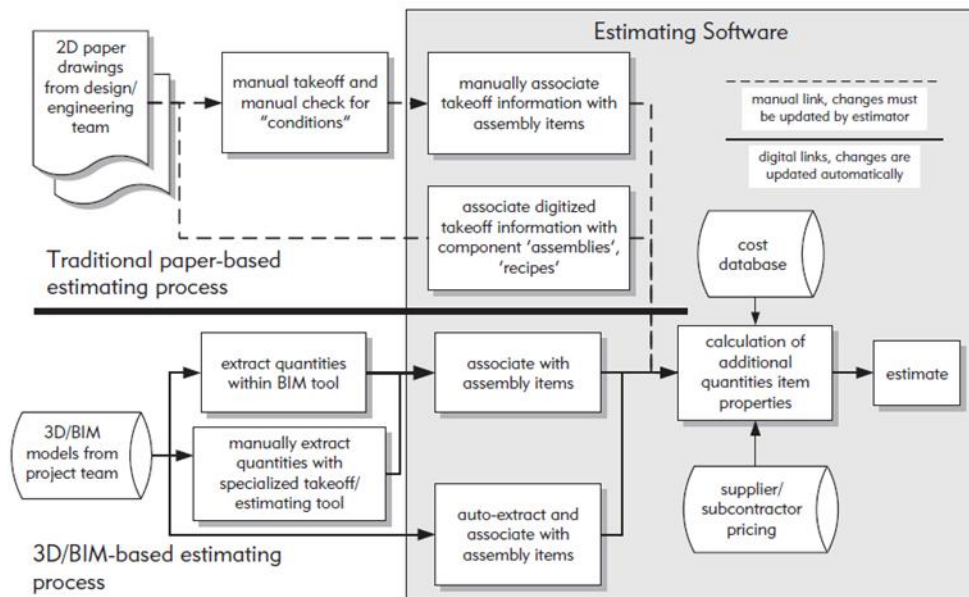


Figure 6. Conceptual diagram of a BIM quantity takeoff and estimating process. [20.]

Figure 6 shows the idea of how BIM will help any project for the quantity take-off and cost estimation process. [20.]

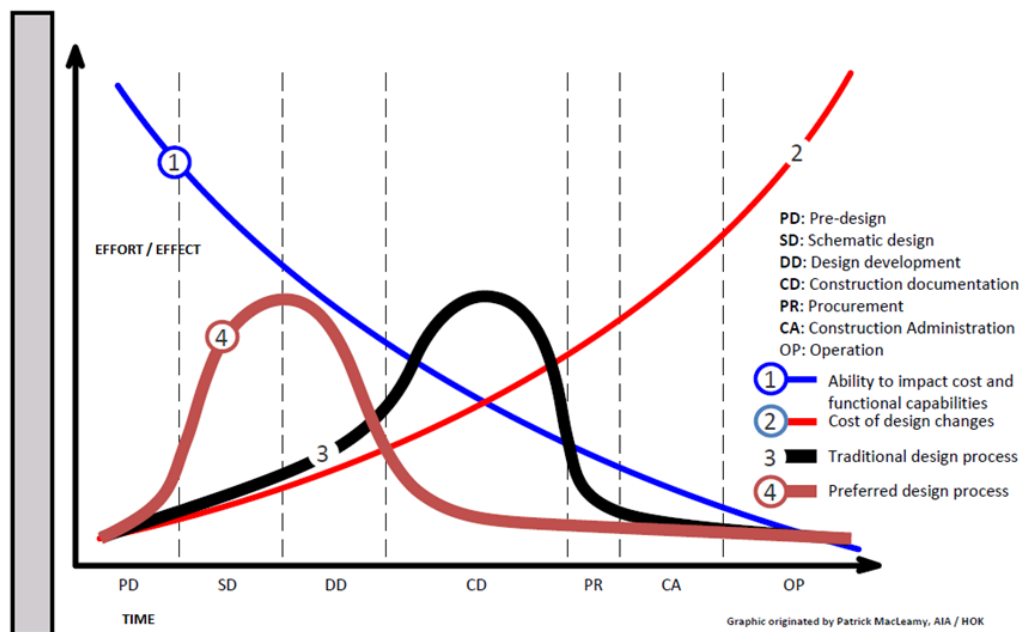


Figure 7. Macleamy curve. [21.]

According to the Macleamy curve in figure 7, in the traditional design process a designer designs the model, but the focus is given to documentation. The documentation includes the necessary construction documents required for a project, such as details and sections. Curve 1 and 2 in figure 7 explain the impact in cost and functional capabilities in different phases of construction. For example, the graph shows if any changes are needed in the design phase while working on construction documentation, what impact it is going to have for the project, and how much it is going to affect cost-wise. A BIM-based design process explains the benefits of using BIM in a construction project. In the preferred design process, all the construction documentation is automated, and if any changes are needed in the design phase, the impact they have on the project is reduced. Furthermore, it does not cost a lot to make changes in the design phase. BIM process assists all the parties involved in a project to work together, and in return, have fewer problems. Fewer problems in a project mean more savings for the project, which eventually benefits the clients.

## 6 BIM in Hydropower

BIM has become even more common in the design, construction, and management of the construction field, and recently BIM has attracted some attention from the hydropower sector. There are some examples of hydropower projects that have adopted BIM. Some examples are construction of Guanyinyan Hydropower Station on Jinsha River, China, Smisto Hydropower Project, Norway and Keselstraße Hydroelectric Power Station, Kempten, Germany. [22.]

The construction of a hydropower project is complicated engineering which includes many people and their hard work to complete the project. The construction of hydropower projects covers a large area and a very tight construction schedule. The construction of a powerhouse alone includes a great amount of concrete casting and very hectic working procedures. To manage everything is a very challenging task for the people involved. The use of BIM technology in hydropower has improved productivity and shortened the design cycle. The method of visualization in BIM has been appreciated everywhere in the construction sector, and the hydropower industry cannot stand isolated without using BIM. The amount of data loss between the owners and supervisors working on the site has significantly reduced. The quality and design of any project that uses BIM are beyond comparison as many things like energy calculation, site orientation, structural analysis are done with the help of BIM as shown in figure 8. [22.]



Figure 8. 3D BIM construction system [23]

Figure 8 shows that BIM helps in integration, networking and visualization which makes the project to go smoothly. [23.]

BIM 360 enables the transmission of engineering data smoothly, effectively, and accurately. Traditionally the changes in design are done by sending documents by fax or over the internet, and by informing other members of the project in the construction site by phone and email. This is a long process of communication, especially on the construction site, where every minute counts. This type of communication may also lead to misunderstanding the drawings, which may negatively impact the project. With the help of BIM, all participants of a project can immediately see the changes in the drawings and visualize the drawings on a whole new level. This helps the project to run smoothly without any delays and maintains the quality of the construction. [24.]

With the help of a photorealistic real-time 3D simulation effect, designers and construction operators can also completely comprehend the structure and game plan of a hydropower station. This allows for the arrangement of a better construction progress and procedures that guarantee high quality and efficiency in the construction of a hydro-power station. Users can turn, glance around, zoom and, section, measure, and query the properties of the BIM models. These features can be an alternative for paper drawings, which lack the capacity of full display and can be utilized to quickly search for the required engineering information if the drawings are not clear. [24.]

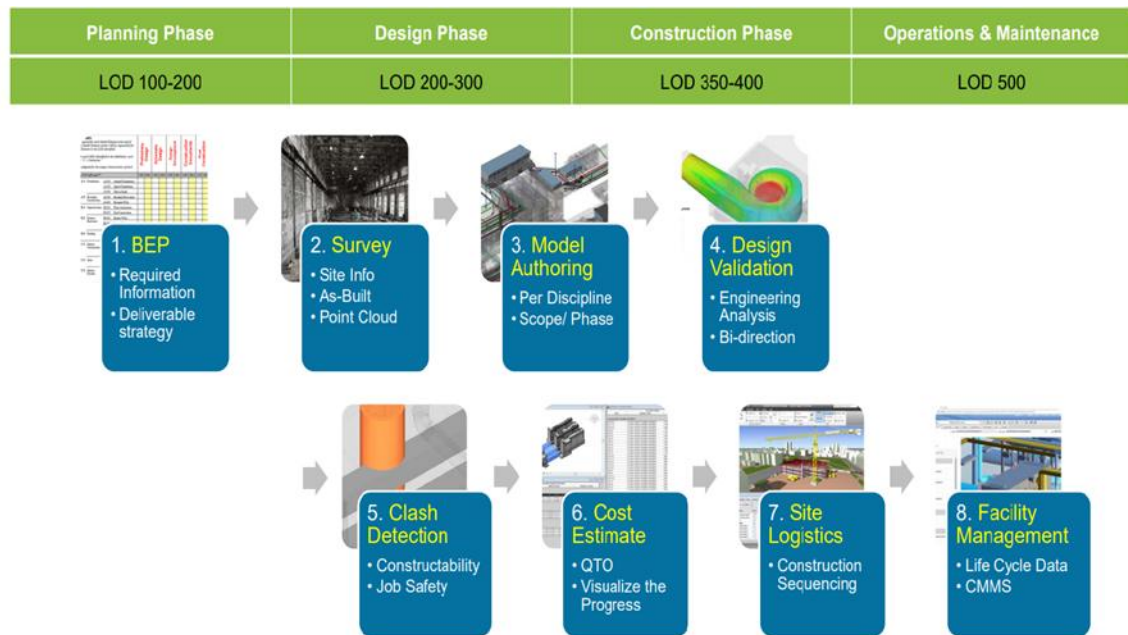


Figure 9. BIM integrated project delivery system. [25.]

Figure 9 explains in details about the delivery system in a BIM-based project in different phases. Using BIM and cloud technology, projects which could take up to eight months can be reduced to just three months. A hydropower project in China called HYdroBIM-Yangfanggou was able to reduce the amount of required concrete by one million cubic meters, and the amount of excavation by 1.5 million cubic meters. The cost savings in the project reached roughly \$300 million due to the use of BIM. This is possible thanks to the quantity take-off and cost estimation features of BIM. This clearly shows how much a hydropower project can benefit from BIM implementation. Furthermore, any possible clashes during the construction of a hydropower project are analyzed beforehand, and all possible solutions can be gathered before the construction begins. This has had a major time and cost-saving in the project, and eventually, users are the ones who will benefit the most. Figure 9 shows how BIM can be helpful during the different stages of construction. [26.]

The construction of a hydropower project is a major impact on the built environment. For any project to be feasible the impact it has on the environment should be lowered and the historical monuments, wildlife, and vegetation should not be harmed in any way, but be preserved. In the traditional method of construction, it takes a lot of time and effort to analyze the impact of a project on the built environment, but with the help of BIM environment, impact assessment is done easily. In Nepal, every hydropower project needs to follow the Environmental Impact Assessment (EIA) guidelines and

should meet the minimum requirements. EIA is defined as “assessment of the environmental effects of those public and private projects which are likely to have significant effects on the environment”. [27.] During the construction of a project, the environment is affected directly or indirectly. To analyse the impact and procedures to minimize the impact on the environment, environmental impact assessment is carried out. Environmental attributes during the construction and operation of a hydropower project are listed below:

- Impact identification during the construction phase
- Construction phase activity potential environmental impact
- Impact on air environment
- Impact on noise environment
- Impact on the water environment
- Impacts on flora and fauna
- Rehabilitation and resettlement aspects. [28.]

There are numerous benefits of BIM during the EIA process of a hydropower project. BIM helps the project to achieve a sustainable design. The use of BIM during an EIA process aids to the position of the building as well as aids in the design of a powerhouse lighting system, the BIM process plays a vital role in the positioning of the building and saving energy. The site analysis can avoid any world heritage site or protected habitat, and the surrounding environment is taken care of. During the EIA process of a project, BIM reduces waste production and carbon emissions by avoiding unnecessary excavation. [29.]

## **7 Lower Piluwa Khola Small Hydropower Project**

The 1 MW Lower Piluwa Khola Small Hydropower Project (SHPP) has been in operation since 17 July 2011 [30]. It would be a long process to study the whole Lower Piluwa Khola SHPP. Therefore, this thesis only aims at modelling the powerhouse of the Lower Piluwa Khola SHPP in Tekla structures and comparing the bill of quantity of the construction of the powerhouse to one made with the traditional method.

The Lower Piluwa Small Hydropower Project, located in the Sankhuwasava District of the Koshi Zone, is a cascade type project. The headworks of the project is located closed to the outlet of the existing Piluwa Project at Chainpur VDC ward number 1. The



project has an installed capacity of 990 kilowatts, and it uses the tailrace water of the Piluwakhola Project with a design discharge of  $3\frac{1}{2}$  cumecs and net head of 34.8 m. The annual energy generation capacity of Lower Piluwa SHPP is 6.842 GWh. The power generated from this project will be connected to NEA 33 KV Tirtire Sub-station at Mamling VDC ward no. 1 of Sankhuwasava District. [31.]

The Lower Piluwa SHPP is 61 kilometers away from Basantapur, Terathum and 71 kilometers from Hile Bazaar, Dhankuta. The government of Nepal, Department of Road is constructing a fair weather motorable road between Basantapur-Chainpur-Khandbari 92 kilometers. This road has already reached Ghatte Bazar of Baneswar VDC. An access road 1.2 kilometers will be constructed up to the powerhouse site during the construction. [31.]

There is a 33 KV transmission line constructed with a planning of rural electrification of the districts of Therathum, Dhankuta, Sankhuwasava and Bhojpur. The switching station sub-station of the distribution network is located at Tirtire, Mamling VDC, which is very near the construction site which shall be used for interconnection and power evacuation. [31.]

Lower Piluwa SHPP will occupy around 24.928,26 m<sup>2</sup> of land. In terms of ownership, 5,080.74 m<sup>2</sup> constitute public land and the rest 19,840.86 m<sup>2</sup> private agricultural lands. Local construction materials like sand, boulders, and aggregates are easily available at the project site. The electricity line is available at the site now, and a telephone connection is obtained from the nearest telecommunication office from Chainpur Bazar. There is no displacement of people at the project site, and the environmental impact due to the construction of the project is minimal.

The design discharge for the power generation is taken as 3.50 m<sup>3</sup>/sec. The project will run on its full capacity for about six months. Power generation will be lower in the dry months. The plant factor of this project is 78.89 % based on the net sellable energy. The elevation of the water level at the headpond and tailrace level at the powerhouse is located at 534.50 m and 496.40 m respectively, from the mean sea level. The gross head of the project is 38.10 m. A 1,182.00 m long mild steel pipe is used in the project. The discharge from the intake structure passes to the powerhouse through a headrace and penstock pipe with a thickness varying from 8 to 10 mm. Two units of the horizontal shaft, Francis turbine of 550-kilowatt capacity will be installed at the powerhouse. There will be governors and control panels in the powerhouse with an outdoor

switchyard near the powerhouse. The power generated by this project will be sold to the NEA. The price of the power generated by the independent power producers (IPP) is fixed as NPR. 3.90 per kilo-watthour or the wet months (eight months) and NPR. 5.52 per kilowatt-hour for the dry months (December, January, February, and March) by NEA. [31.]

The total cost of the project is NPR. 145 million. A total of 70 per cent loan and 30 per cent equity are arranged for the project. Promoter's equity and share collection are the sources of funds for this project. The bank loan will be repaid within nine years (eight years plus a two-year construction period). The interest rate of the bank loan is considered as 8.0 per cent for 10 Years and 0.50 % for loan management and arrangement fee. [31.]

For the economic analysis, the life of the project is considered as 25 years. The financial analysis has indicated the following investment-friendly positive parameters:

- Internal rate of return is 13%
- Benefit ratio is 1.43 at a discount rate 8.0%
- Net present value is NPR. 31.071 million
- Unit energy cost is NPR 2.58
- Specific project cost is NPR 2.44.251,00 per KW
- The simple payback period is 7.40 years. [31.]

During the construction period, the project will minimize the cutting of the soil, rocks, and a mild steel pipe is be used for conveyance. There are no permanent settlements near the project alignment. The project will plant trees to maintain greenery in the project site. There are no active landslide zones at the project site. The environmental impact of the project is minimum. With the construction of this project, the hilly districts of the Eastern Development Regions will obtain an uninterrupted power supply, which will help the socio-economic development of the region. At present, the Eastern Development Region has a shortage of power at peak times and relies on either from Katiaya Power-house India or Multi-fuel plant from Duhabi at the deficit on the National Grid. [31.]

The first feasibility study of the Lower Piluwa Small Hydropower Project was undertaken by Rambeni Hydropower Development Company Pvt. Ltd. in 2002. The PPA stage and the power purchase agreement with the Nepal Electricity Authority was revisited



and conclusions were made based on different technical clarification and amendments. After an agreement and power purchase agreement(PPA), the developers have agreed with m/s Clean Energy Consultants (p) Ltd about a major detailed design and most of the technical input in the project. The scope of the services includes detailed planning, construction detailing and help on preparation of documents required for various purposes during the implementation of the project. The detailed survey work was carried out by the project staff in October-November 2007. The current detailed project report is prepared as teamwork with project personnel for outlining the outcomes of thorough study and planning for the construction arrangement of the project. The basic result shall be used for planning and the tendering process. The construction detailing shall be carried out before the contractor's mobilization. This is an important step for planning and fixing the project components, scrutinizing options and alternatives available at the project. The following details are included in the project description:

- Civil works components which are concluded for the construction
- Hydro-mechanical components design and detailed estimates
- Electromechanical components and details
- Transmission line components requirement and details. [31.]

The main objective of this thesis is to outline the differences between a BIM-based hydropower project and a traditional 2-D based hydropower project.

## 8 Project Description

### 8.1 Location

The project site is in Chainpur and Baneshwor VDC of Sankhuwasava District, Koshi Zone. The project site lies between 87018'12" to 87019'35" longitude and 27015' 00" and 27016' 45" latitude. Khandbari, the district headquarter, is about 30 kilometers from the project site. Chainpur, the next big market in the district, is four kilometers away from the project site. The project will utilize the tailrace water of Piluwakhola Small Hydropower Project 3000 KW, which is already completed. The powerhouse of the Piluwakhola Small Hydropower Project is in ward no. 1 of Chainpur VDC. The tailrace water will be trapped and conveyed by a mild steel pipe to a powerhouse which shall be located on the right bank of Piluwakhola of Baneshwor VDC Ward No. 5. [31.]

## 8.2 Powerhouse and Tailrace

The surface powerhouse is located on the right bank of the Piluwakhola. It contains two Horizontal Francis turbine units directly coupled with generators with an installed capacity of 550 KW. The dimensions of the powerhouse are 22.80 m x 10.40 m x 6.44 m. The space of the powerhouse is designed to have two generating units, a repair bay, a control, and an office room. There will be an overhead travelling crane of 10 ton capacity in the powerhouse. [31.]

The water from the turbine will discharge through the tailrace canal. The size of the tailrace canal will be 1.82 m x 2.00 m. The length of the tailrace canal is 17.00 m. It will be constructed of reinforced cement concrete and stone masonry 1:4 cement mortar. The thickness of the bottom slab will be 30 cm, and the thickness of the sidewall will be 30 cm. Sufficient protection works shall be provided at the outlet of the tailrace to protect from the high flood. [31.]

## 8.3 BIM Modelling of Powerhouse

The modelling of the powerhouse in this thesis is done with Tekla structures. For the modelling of the powerhouse, a new reference model, a drawing file from AutoCAD, is added to the Tekla structures.

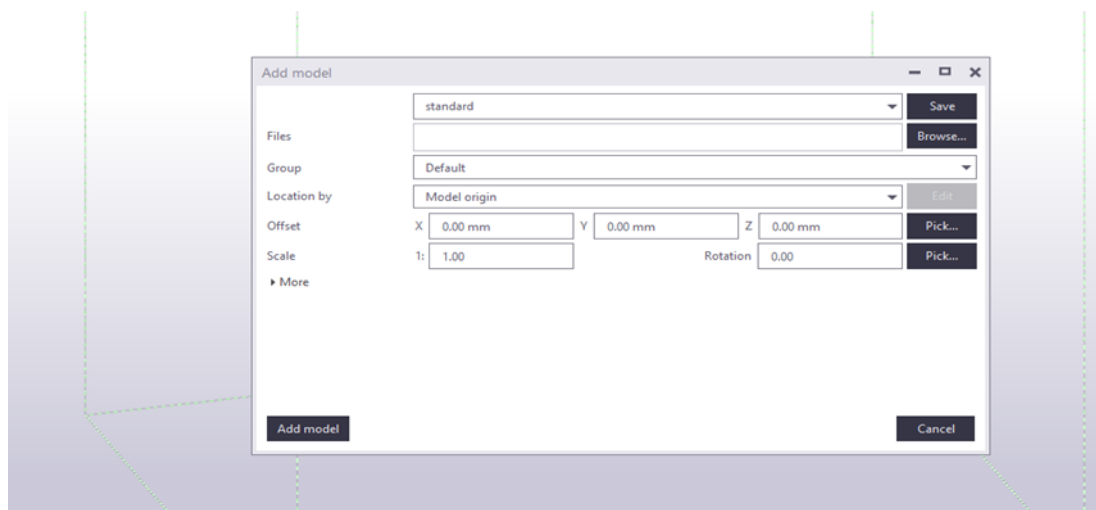


Figure 10. A new reference model is added by clicking on browse

The reference model was inserted with the browse function. Then, a foundation of concrete material C20/25 was added. The total number for the foundations for the powerhouse is ten. To create the foundation of the powerhouse in the software, a grid was created by measuring the distance between the footings and the elevation.

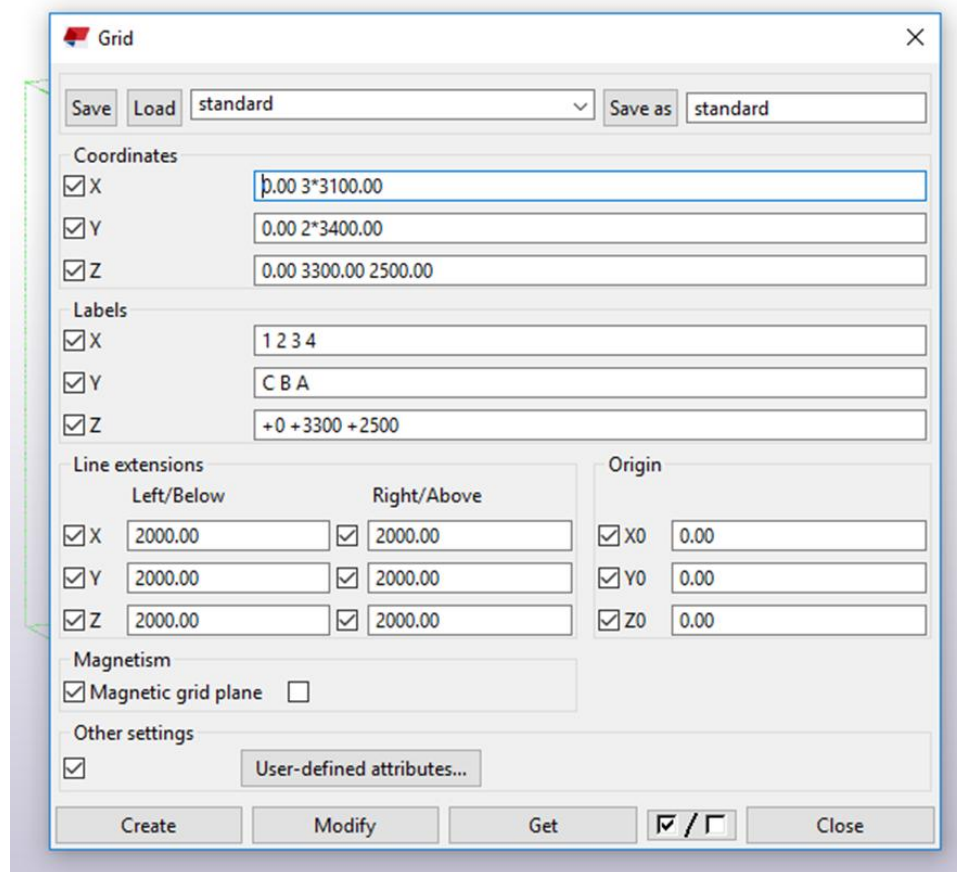


Figure 11. Creating a grid for modelling

Next, a column of concrete C20/25 with the dimensions of width 400 mm height 400 mm and length of 3,300 mm was placed on top of the foundation. Beams (400\*200 mm, length 2,900mm) were added on top of columns. On the second floor, differently shaped columns, modified according to the reference drawings, were added.

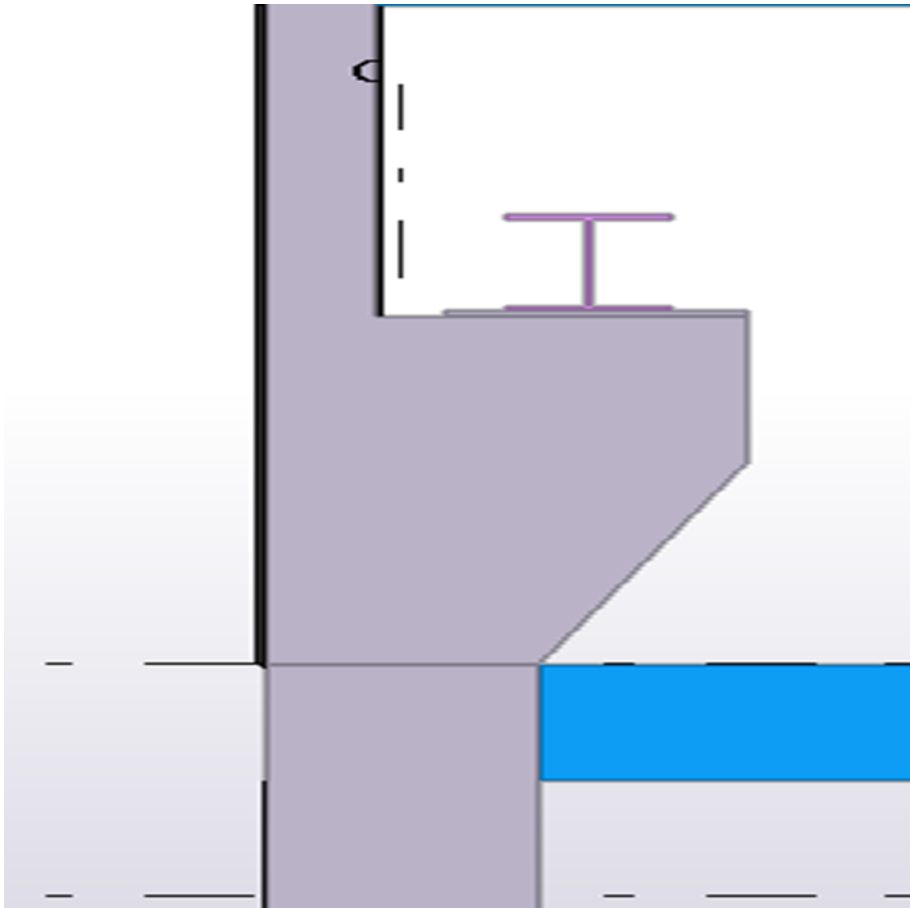


Figure 12. Corbel on the second floor

Corbels were added on the second floor, and beams were copied from the first floor to the second floor using a copy tool. The corbels on the second floor are designed so that an overhead crane can travel to install heavy equipment like a generator, turbines, pipes, panel board, power transformer. A steel beam is placed on the corbel for the travelling of the overhead crane. Beams in the column were added, and a roof truss was placed on top of the columns. The dimensions of the roof truss were modified in the Tekla simulation according to the dimensions in the reference drawing.



Figure 13. Adding truss on top of columns for the roof

After adding of truss on top of the columns, roofing sheets were added. After adding the roofing sheets, the tailrace canal for the water discharged from the turbine was drawn. The length of the tailrace canal is 17 meters. After the tailrace canal, the horizontal slab was placed on the first floor, and after that, a horizontal steel beam was placed on both sides of the column of the second floor for the travelling of an overhead crane. A brick wall is also added.

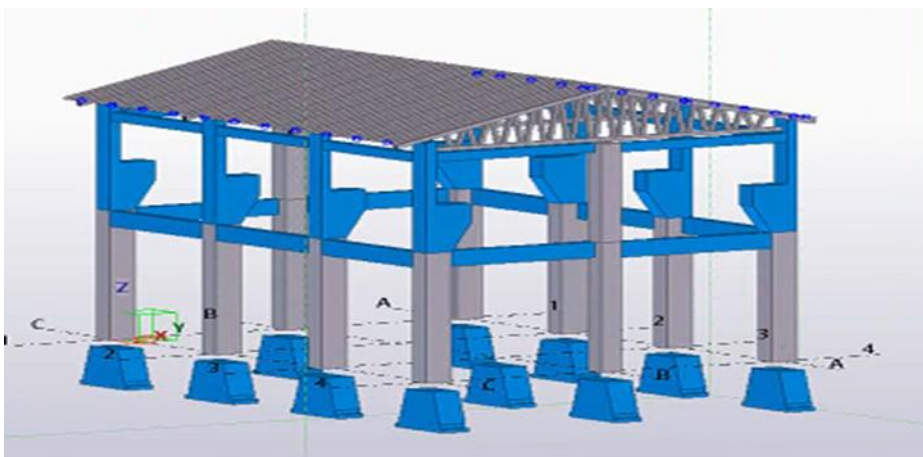


Figure 14. The 3d view of the powerhouse after adding truss and roof sheets

As shown in figure 15 below, ArchiCAD was used to add the walls, doors and windows to the powerhouse.

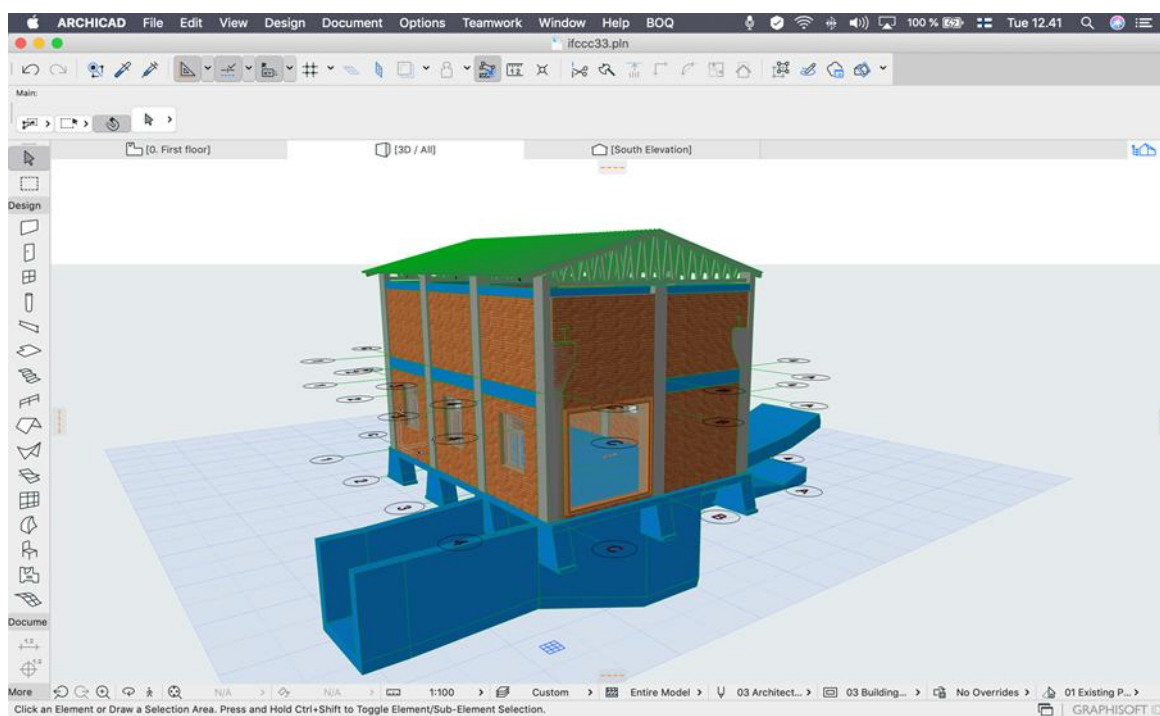


Figure 15. The 3D view of the powerhouse with the tailrace canal

The 3D model of the powerhouse is easily accessible to all the parties involved in the project, and, if needed, any changes can be made easily. During the modelling of the powerhouse, energy consumption in the building, lighting inside the building and thermal comfort of the building can be calculated and adjusted in the design if needed changes in design will be much easier and will cost significantly less than with the traditional method. During the construction of Lower Piluwa SHPP, there were problems with the communication between the site and head offices, which led to delays in the project. These problems can easily be resolved with the help of BIM. Not only the engineers but other people who do not understand any 2D drawings can easily get the idea of the model with the help of a 3D visualization. The workers who cannot understand the drawings can get a clear picture of the building. Hence, any confusion or mistake can be minimized. In this model, various clash checks have been performed and shown (see figure 5). A clash check helps the designer to correct their mistakes in advanced and saves time and effort in the future for other, bigger issues. A quantity take-off and cost estimation for the model is shown below in chapter 8.5. The result shows the difference in the amount of concrete used in the traditional method and in a BIM-based method. The model also shows that errors done in with a traditional method can be omitted.

#### 8.4 Current Cost Estimation of Concrete in Powerhouse

The current cost estimation methods used in Nepal are traditional in other words manual methods. Traditional cost estimation includes a process where all the dimensions of all elements in a project are measured in 2D drawings in AutoCAD. After measuring the dimensions, all the data are transferred to MS Excel for further calculation. The cost estimation done with this process is time consuming, inaccurate, manual, and requires manpower, and errors occurred due to human mistakes. The cost estimation method includes the following items materials and labour, quoted items, contingencies, statutory fees, holding charges and overheads and profit. The total cost estimation of the powerhouse for this project in the traditional method is NPR 9,311,311.95. [31.]

Table 1. Table 1: Concrete work estimation of Powerhouse traditional method

<b>Concrete work 1:2:4</b>	Unit	No.	Length(m)	Breath(m)	Height(m)	Area(m2)	Quantity(m3)
Top Beam	m3	10	4,1	0,2	0,25		2,05
Middle Beam	m3	10	4,1	0,3	0,4		4,92
Isolated Footings	m3	10	1,5	1,5	0,35		7,875
Floor Slab	m3	1	7,3	9,96	0,15		10,9062
Column	m3	12	0,5	0,4	3,3		7,92
Corbel	m3	8		0,4		0,18	0,576
Total							34,25

The table 1 shows the concrete work done during the construction of the powerhouse and the volume of concrete used for different components of the powerhouse.

#### 8.5 BIM-based Cost Estimation of Concrete in Powerhouse

BIM-based cost estimation is a modern method for cost estimation of a project. Cost estimation with this method is more accurate than the traditional method. The mistakes

that are made by humans are significantly minimized. Any changes to the model will automatically update the data, which makes it easier for the calculation, and time consumed is reduced. [32.]

Table 2. Quantity take-off using Tekla Structures

<b>Concrete work 1:2:4</b>	Unit	No.	Length	Breath	Height	Area	Quantity
Top Beam	m3	10	2,7	0,2	0,25		1,24
Middle Beam	m3	10	2,7	0,2	0,4		2,16
Isolated Footings	m3	10	0,5	1,4	0,35		7
Floor Slab	m3	1	38			0,18	6,84
Column	m3	12	3,8	0,4	0,4		7,2
Corbel	m3	8				0,18	4
<b>Total</b>							<b>28,54</b>

BIM-based cost estimation of the concrete used in the elements in the powerhouse isare calculated with organizer in Tekla Structures.The details are shown in the appendix 3 page 1,2 and 3.

## 9 Results and Findings

After analyzing the quantity estimation made with both traditional method and the BIM-based method, a significant difference was found.The estimation was only done for the concrete work of a powerhouse and the results were surprising,the results would have immense difference, if the design of all the structures in a hydropower was designed using BIM-based method.The amount of concrete needed in the project was 28.54 cubic meters using Tekla Structures and with the traditional method, the amount of concrete used was 34.25 cubic meters.



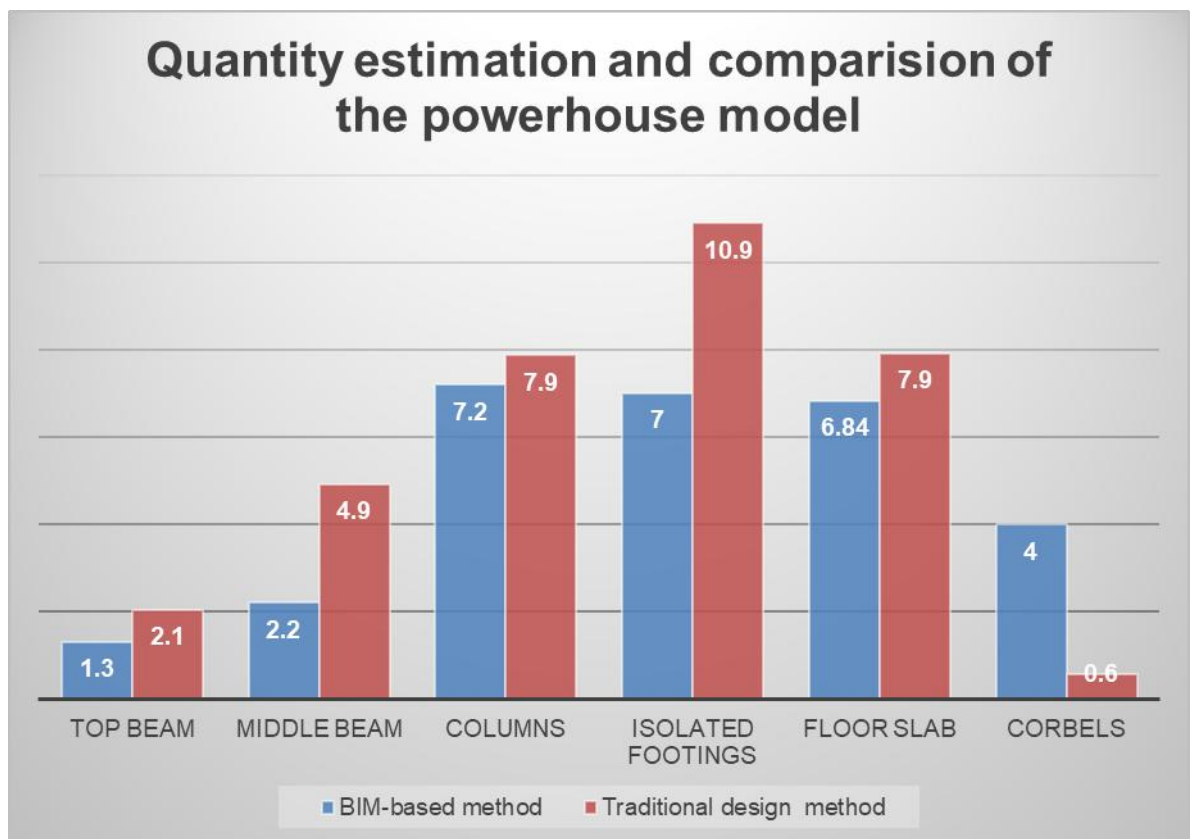


Figure 16. A bar graph showing the differences between BIM-based method and the traditional design method

There is a difference of 5.71 cubic meters of concrete. It is a considerable amount when considering the impact that it is going to have in terms of budget for the whole project. This is just a small part of the project and it already shows how big a role BIM-based cost estimation and quantity take off play in terms of finance in the project. If the whole project is designed in a BIM-based way, there is going to be massive savings, and it eventually benefits for the user and the country.

After this calculation of cement, the amount of sand and aggregate can be calculated easily. Calculating the cement, sand, and aggregate for C20 concrete is performed as shown below.

C stands for compression and concrete of grade C20 means that the compression resistance of the concrete is 20 N/mm<sup>2</sup> per square millimeter in 28 days. C20 is 1:2:4 where 1 part is cement 2 parts sand and 4 parts coarse aggregate.

*Finding the materials used in C20 = 1: 2: 4 concrete*

Calculating the material for 1 cubic meter.

We know that,

*Dry volume = wet volume \* 2 times wet volume of concrete*

*Sum of ratio for C20 = 1 + 2 + 4 = 7*

Now changing one cubic meter volume to dry volume

The formula for finding dry volume is,

*Dry volume = wet volume \* 2*

*= 1 \* 2 = 2 cubic meter*

Calculating the volume of cement,

*Cement volume = 1/7 \* 2 = 0.285m<sup>3</sup>*

*Volume of cement in Kg = 0.285 \* 1440*

*= 411kg where 1440kg/m<sup>3</sup> is Density of cement*

*Number of cement bags = 411/50*

*= 8 numbers of a bag, where 50 kg is the weight of one bag*

Calculating the volume of sand,

$$\text{Sand volume} = 2/7 * 2 = 0.57\text{m}^3$$

Next the volume of coarse aggregate is calculated,

$$\text{Coarse aggregate} = 4/7 * 2 = 1.142\text{m}^3$$

The calculations shown above help in any project to calculate the exact amount of materials needed. After knowing the accurate amount, the chances of materials being unused is significantly reduced.[33.]

## 10 Conclusion

The thesis has outlined just the basic design of one of the hydropower projects and though it does not reflect all the parts of hydropower project, at least this thesis has tried to show the advantages of BIM applied in the design of a powerhouse in hydro-power project. The result shows that there are tremendous benefits from using BIM just for the powerhouse. Therefore, it can be imagined how big the benefits for the project would be if BIM were applied throughout the project. As Nepal is crippled with the shortage of power and poor economy, hydropower is one of the most appropriate solutions to solve several problems in the country. Fulfilling the domestic energy demands is one of them. In the long run, when the economy of the country gets a boost, this will create a pavement to a better future for Nepal and help in the overall economic development of the country. Most of the projects have right to apply for funding, and a lower cost and faster construction of a project will eventually help everyone involved directly or indirectly.

The study of Lower Piluwa SHPP showed that there are some things that BIM is still lacking in the hydropower sector. BIM objects are limited in number for a hydropower project. Therefore, if companies responsible for BIM objects can be involved, it would be much easier for hydropower projects.

Furthermore, during the design phase the nomenclature of different elements in the project should be the same and everyone should understand it. If an element has several names, the designers and engineers will have difficulty to understand the document, which in turn will have a negative impact on the project. During the case study of this thesis, the accuracy of the quantity estimation is high and cost calculation is more accurate with the traditional based method.

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## Drawings of Powerhouse

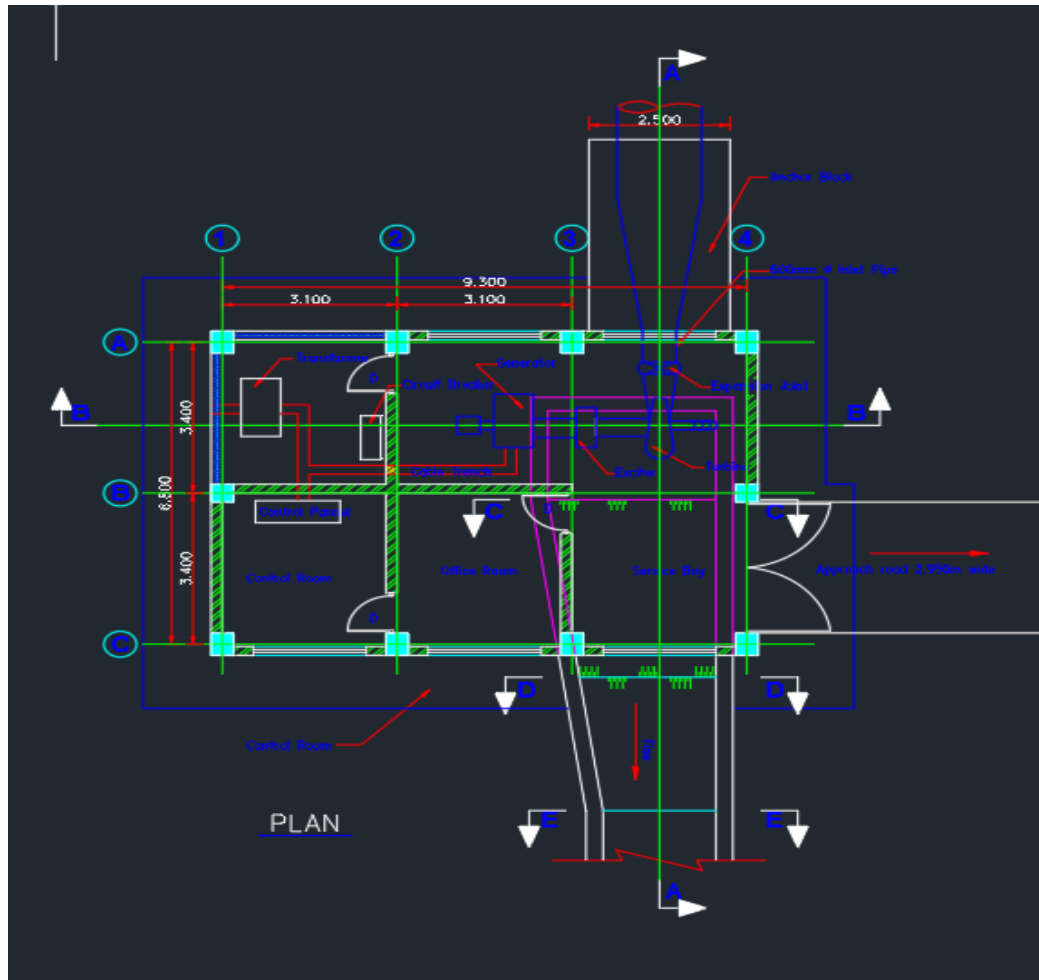


Figure 1. Floor plan of the powerhouse.



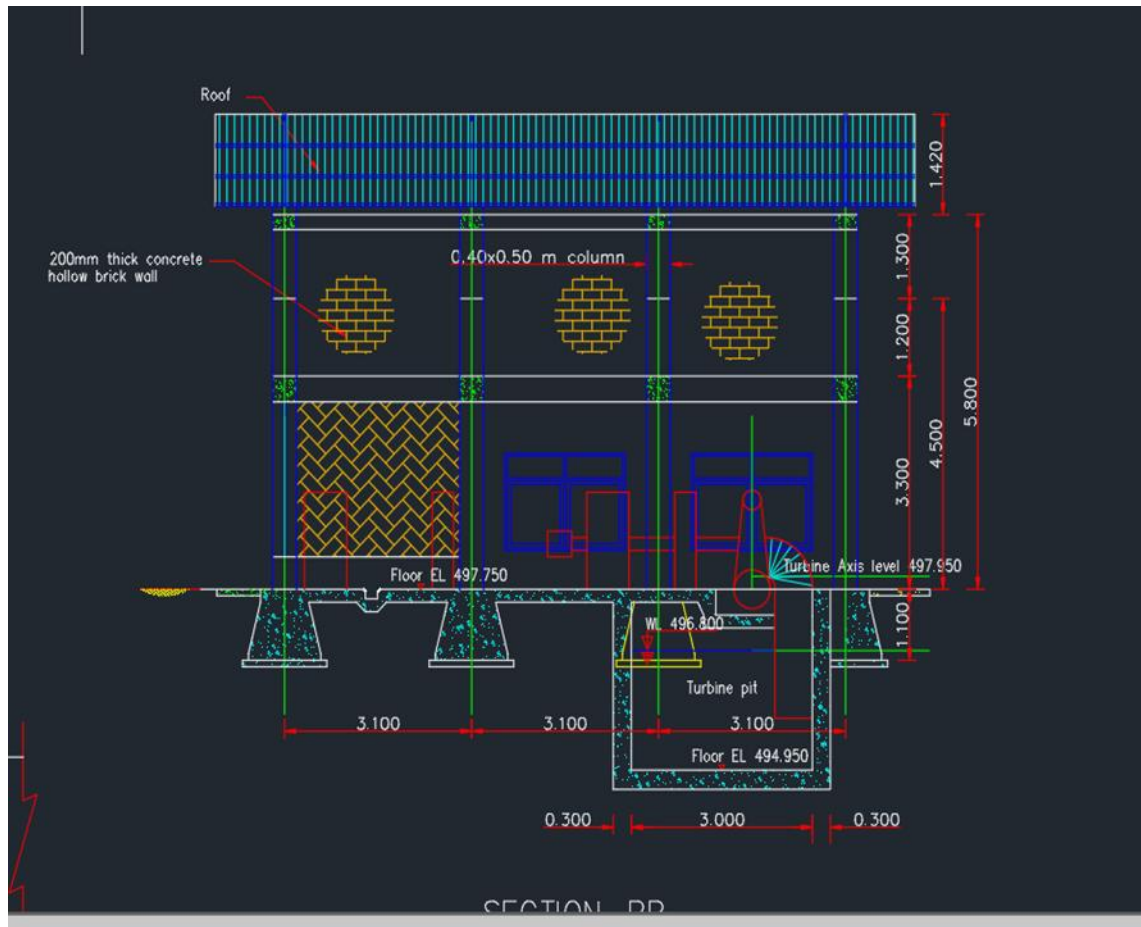


Figure 2. Section-BB of the powerhouse.

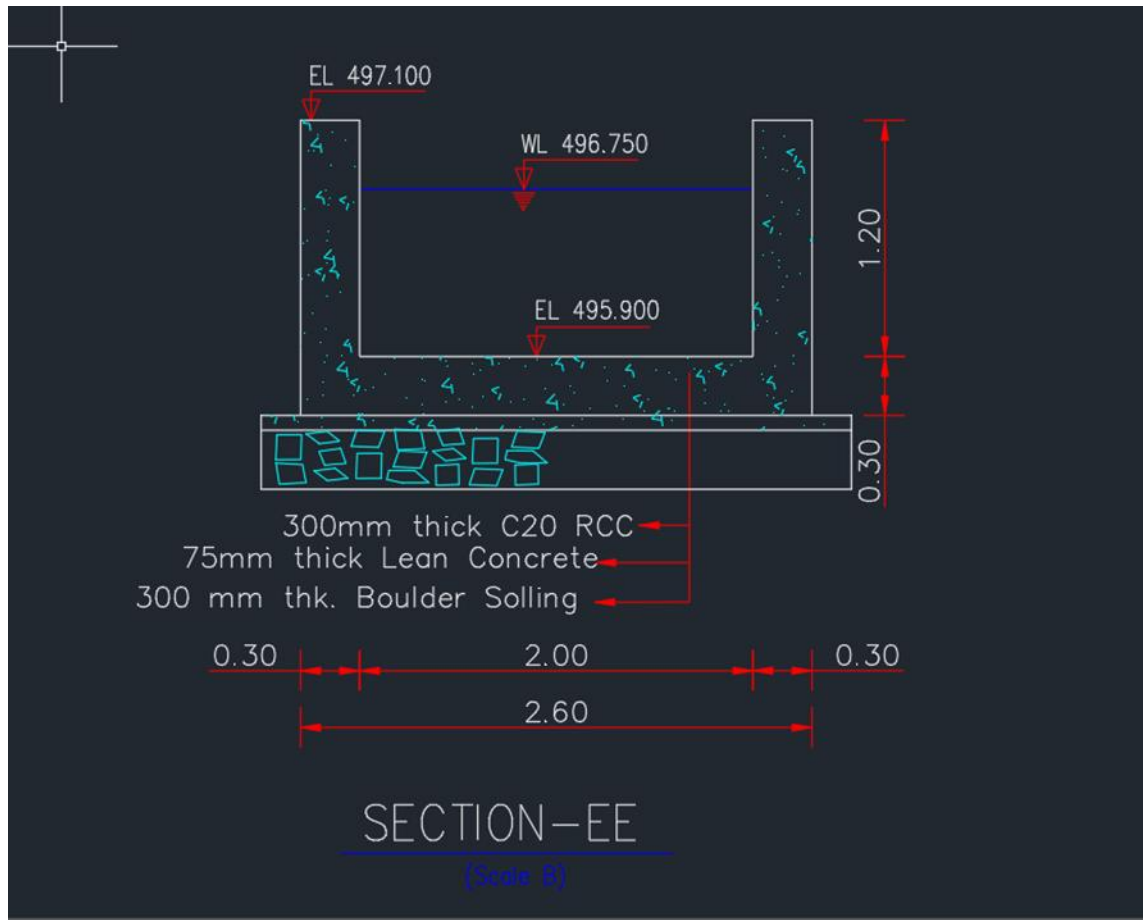


Figure 3. Section-EE of the powerhouse.

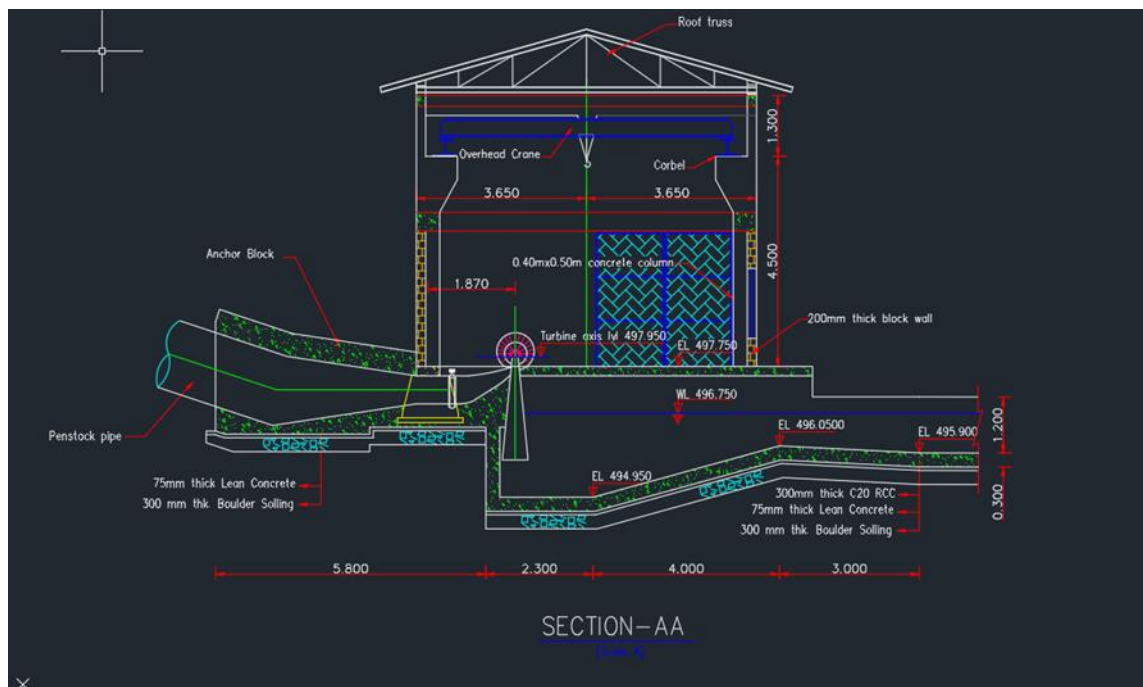


Figure 4. Section-AA of the powerhouse.

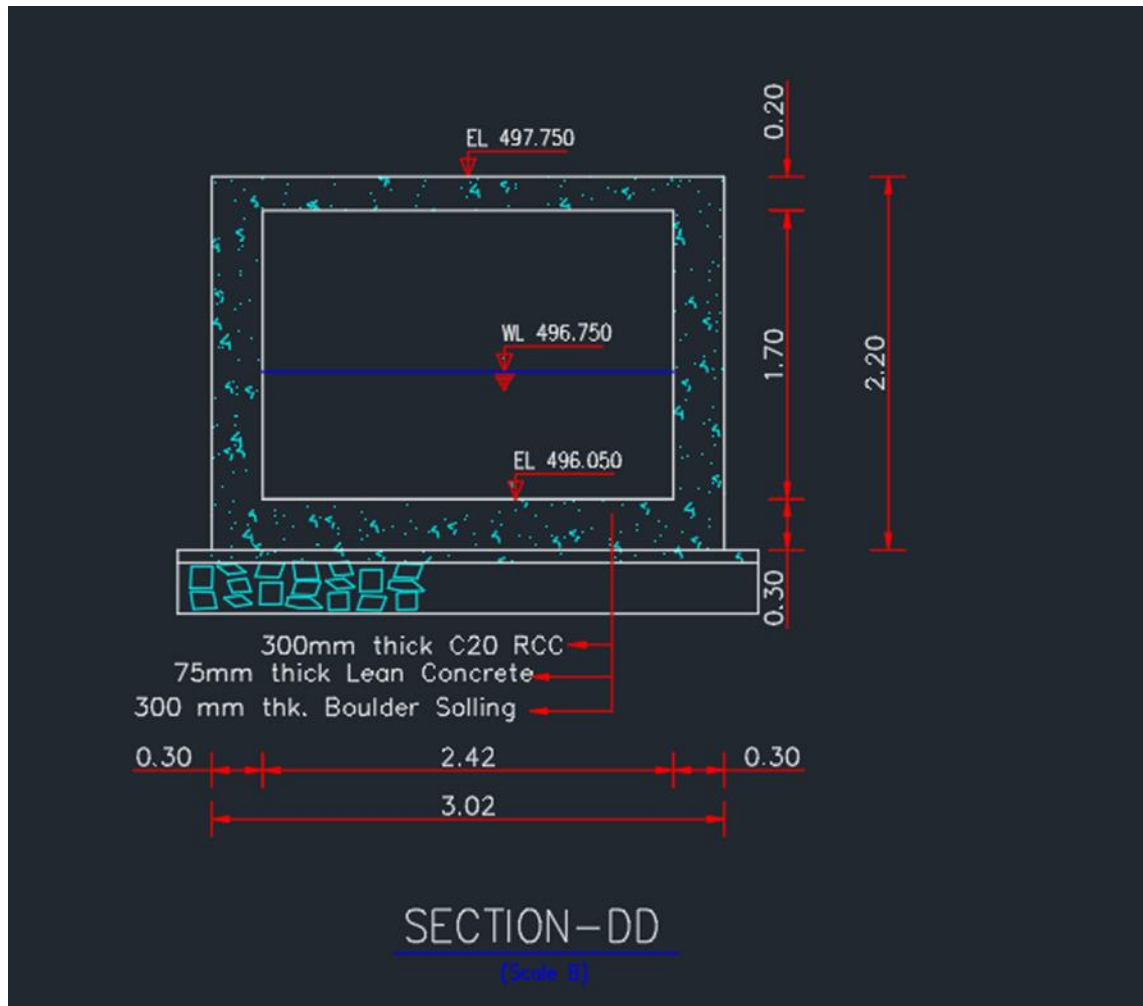


Figure 5. Section-DD of the powerhouse.

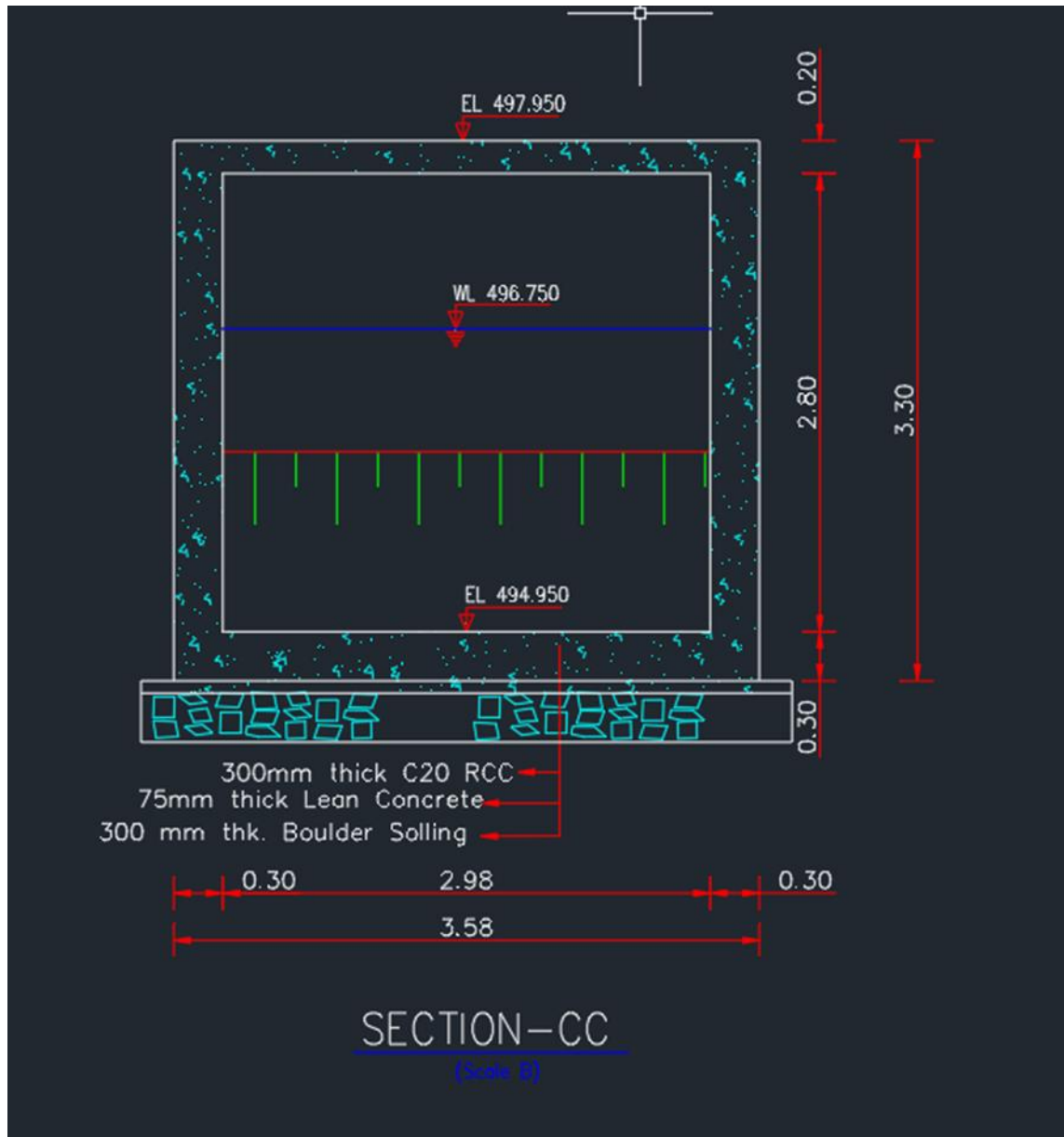


Figure 6. Section-CC of the Powerhouse.

## Pictures of Powerhouse



Figure 1. Roof of the powerhouse.





Figure 2. Turbine and generator operating inside the powerhouse.



Figure 3. Walls, roof and lighting inside the powerhouse.





Figure 4. Transmission of electricity from the powerhouse.



Figure 5. Surrounding of the powerhouse.



## Quantity take-off using Organizer in Tekla Structures


 PO Box 1, Street address 1, 12345 City 1 Tel: 555 1234567, Fax 555 7654321 Email: first.last@company.com												
Project name:		Project number:		Author:								
Project address:		List date:		Revision, date:		List number:						
Design Gr./Name	Content ty	Material type	Material	Profile	Top level / Height / m	Length / m	Width / m	Volume / n	Weight / t	Phase	Section	Floor
Corbel	PART	CONCRETE	C20/25	COLUMN2	6,143	2,843	400	880	0.5	1.202	1	
Corbel	PART	CONCRETE	C20/25	COLUMN2	6,143	2,843	400	880	0.5	1.202	1	
Corbel	PART	CONCRETE	C20/25	COLUMN2	6,143	2,843	400	880	0.5	1.202	1	
Corbel	PART	CONCRETE	C20/25	COLUMN2	6,143	2,843	400	880	0.5	1.202	1	
Corbel	PART	CONCRETE	C20/25	COLUMN2	6,143	2,843	400	880	0.5	1.202	1	
Corbel	PART	CONCRETE	C20/25	COLUMN2	6,143	2,843	400	880	0.5	1.202	1	
Corbel	PART	CONCRETE	C20/25	COLUMN2	6,143	2,843	400	880	0.5	1.202	1	
Corbel	PART	CONCRETE	C20/25	COLUMN2	6,143	2,843	400	880	0.5	1.202	1	
<b>Total</b>							3,200	4	9.613			
<b>All objects in the table:</b>												
<b>8</b>												

Figure 1. Volume of concrete used in the corbel.


 PO Box 1, Street address 1, 12345 City 1 Tel: 555 1234567, Fax 555 7654321 Email: first.last@company.com												
Project name:		Project number:		Author:								
Project address:		List date:		Revision, date:		List number:						
Design Gr./Name	Conte	Material type	Material	Profile	Top level / Height / m	Length / m	Width / m	Volume / n	Weight / t	Phase	Section	Floor
COLUMN	PART	CONCRETE	C20/25	400*400	5,800	400	2,500	400	0.4	0.96	1	
COLUMN	PART	CONCRETE	C20/25	400*400	5,800	400	2,500	400	0.4	0.96	1	
COLUMN	PART	CONCRETE	C20/25	500*400	3,300	500	3,300	400	0.7	1.584	1	
COLUMN	PART	CONCRETE	C20/25	500*400	3,300	500	3,300	400	0.7	1.584	1	
COLUMN	PART	CONCRETE	C20/25	500*400	3,300	500	3,300	400	0.7	1.584	1	
COLUMN	PART	CONCRETE	C20/25	400*400	3,300	400	3,300	400	0.5	1.267	1	
COLUMN	PART	CONCRETE	C20/25	500*400	3,300	500	3,300	400	0.7	1.584	1	
COLUMN	PART	CONCRETE	C20/25	500*400	3,300	500	3,300	400	0.7	1.584	1	
COLUMN	PART	CONCRETE	C20/25	500*400	3,300	500	3,300	400	0.7	1.584	1	
COLUMN	PART	CONCRETE	C20/25	400*400	3,300	400	3,300	400	0.5	1.267	1	
COLUMN	PART	CONCRETE	C20/25	500*400	3,300	500	3,300	400	0.7	1.584	1	
<b>Total</b>							38,000	7.1	17.126			
<b>All objects in the table:</b>												
<b>12</b>												

Figure 2. Volume of concrete used in the column.


 PO Box 1, Street address 1, 12345 City 1 Tel: 555 1234567, Fax: 555 7654321 Email: first.last@company.com													STATUS		
Project name:				Project number:				Revision_date:		Author:					
Project address:				List date:		Revision_date:		List number:							
Design Gr./Name	Content ty	Material type	Material	Profile	Top level / Height / mm	Length / m	Width / m	Volume / m <sup>3</sup>	Weight / t	Phase	Section	Floor			
Floor SLAB	PART	CONCRETE	C20/25	200*7300	0	400	38 000	200	6,84		1				
<b>Total</b>								38 000	6,84						
All objects in the table:															
1															

Figure 3. Volume of concrete used in floor slab.


 PO Box 1, Street address 1, 12345 City 1 Tel: 555 1234567, Fax: 555 7654321 Email: first.last@company.com												
Project name:				Project number:				Revision_date:		Author:		
Project address:				List date:		Revision_date:		List number:				
Design Gr./Name	Content ty	Material type	Material	Profile	Top level / Height / mm	Length / m	Width / m	Volume / m <sup>3</sup>	Weight / t	Phase	Section	Floor
ISOLATED FOOTING	PART	CONCRETE	C20/25	FOUNDATIONPLAN1	-200	1,000	500	1,400	0.5	1.272	1	
ISOLATED FOOTING	PART	CONCRETE	C20/25	FOUNDATIONPLAN1	-200	1,000	500	1,400	0.5	1.272	1	
ISOLATED FOOTING	PART	CONCRETE	C20/25	FOUNDATIONPLAN1	-200	1,000	500	1,400	0.5	1.272	1	
ISOLATED FOOTING	PART	CONCRETE	C20/25	FOUNDATIONPLAN1	-200	1,000	500	1,400	0.5	1.272	1	
ISOLATED FOOTING	PART	CONCRETE	C20/25	FOUNDATIONPLAN1	-200	1,000	500	1,400	0.5	1.272	1	
ISOLATED FOOTING	PART	CONCRETE	C20/25	FOUNDATIONPLAN1	-200	1,000	500	1,400	0.5	1.272	1	
ISOLATED FOOTING	PART	CONCRETE	C20/25	FOUNDATIONPLAN1	-200	1,000	500	1,400	0.5	1.272	1	
ISOLATED FOOTING	PART	CONCRETE	C20/25	FOUNDATIONPLAN1	-200	1,000	500	1,400	0.5	1.272	1	
ISOLATED FOOTING	PART	CONCRETE	C20/25	FOUNDATIONPLAN1	-200	1,000	500	1,400	0.5	1.272	1	
<b>Total</b>								5,000	5.3	12.72		
All objects in the table:												
10												

Figure 4. Volume of concrete used in the isolated footing.

