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Structural BIM Application

Implementaion of Tekla Structures in Nepal

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The objective of this bachelor's thesis was to study the implementation strategy for Building Information Modeling (BIM) in Nepal and the possibilities of BIM implementation for Nepal. The major aspects, in the context of construction in Nepal were considered for BIM implementation. Similarly, the study also elaborated the features and advantages of Tekla Structures.

To understand the methods in implementation, a literature review was carried out. The purpose of the thesis was focused on two approaches of implementation: educational and commercial approaches to guide individuals to promote BIM implementation. The study of two major projects was done to understand the benefits of Tekla structures and BIM implementation. The implementation methods mentioned in the thesis shows merits and suitable process in the Nepalese context.

This thesis could be used as a suggestion for the preliminary process of BIM implementation in Nepal. In addition, the construction industry in Nepal could benefit with the guidelines of the implementation process.

Keywords	BIM, Structural BIM, Tekla Structures, implementation

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Prashant Pradhan
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Contents

Acronyms

E-BPS	Electronic- Building Permit System
BIM	Building Information Modeling
BOQ	Bill of Quantities
LOD	Level of Development
ROI	Return on Investment
AEC	Architecture, Engineering and Construction
MEP	Mechanical, Electrical and Plumbing
GC	General Contractors
A&D	Analysis and Design
IFC	Industry Foundation Classes
RFI	Request for Information
SRN	Strategic Road Network
AIA	American Institute of Architects
GDP	Gross Domestic Product

1 Introduction

Architecture, Engineering and Construction (AEC) industry has been continuously struggling and facing declining productivity compared to other industries. Competitiveness has been at its least rate and the industry has been facing challenges to fulfil and overcome clients' expectations. There are numerous advancements in technology to overcome the loss in the construction industry and aid in steady rise of productivity. (Azhar 2011.)

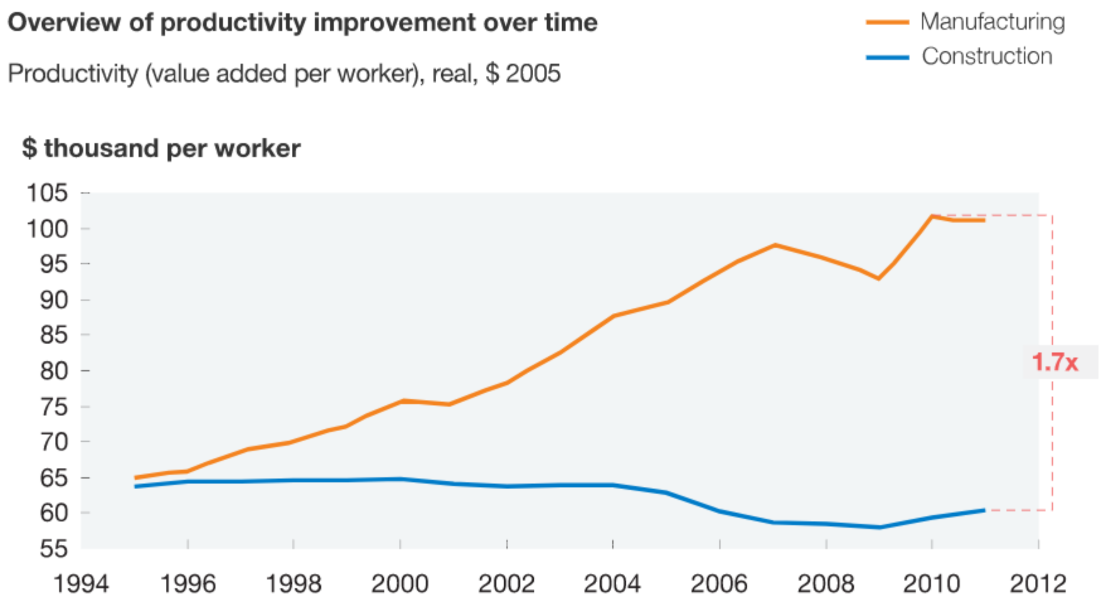

Figure 1. Productivity curve comparison of manufacturing and construction (Changali 2018.)

Various factors are responsible for the lower productivity in the construction industry. Poor organization leads to inefficiency in decision making and the processes exceeds time. Increasing involvement of large number of small and medium enterprises (SMEs) and the lack of communication among contractors, subcontractors and owners involved in the project leads to frequent delays in project completion. This not only results in miscommunication between project stake-holders but also results in a pile up of unsolved issues. Hence, the poor organization of the project leads to a delay in the project's completion, and cost overruns. The industry mostly works with traditional document-based approaches of designing and managing construction projects. Developed countries are rapidly implementing model-based approaches, commonly known as Building Information Modeling (BIM), to tackle the issues faced by the industry. The implementation of BIM in AEC projects shows positive promises towards increasing construction productivity, saves time and money as well as provides products with better quality and customer satisfaction. (Changali 2018.)

Tekla Structures is a structural designing software of Tekla. The designs are accurate and detailed information required for building modeling. There are numerous advantages of Tekla Structures including modeling of materials, feasible information flow and collaboration with other BIM oriented software. The detail explanation and features of Tekla Structures are discussed in chapter 3. (Trimble 2018.)

The construction industry in Nepal contributes around 10 percent to the Gross Domestic Product (GDP) every year. After the agricultural sector, construction industry provides employment to the people in Nepal. The estimated number of one million people are employed in the construction industry. Therefore, it can be assured that the construction industry is the most important sector having a positive impact in the improvement of the country’s budget. (Baral 2009.)

This thesis deals with the selection of best BIM implementation methodology applied by many countries in Europe and the USA. The implementation methods applicable in the Nepalese context are explained thoroughly in chapter 4. Moreover, this thesis tries to explain the importance of Tekla Structures as Structural BIM implementation. The advantages of Tekla Structures software over the BIM oriented software were studied.

2 Building Information Modeling (BIM)

According to Autodesk overview “BIM is an intelligent 3D model-based process that gives architecture, engineering, and construction professionals the insight and tools to more efficiency plan, design, construct and manage buildings and infrastructure.” (Trimble 2018.)

Building Information Modeling (BIM) is currently implemented as a process to model the information that is crucial for our built environment. It is seen as an information repository which can be used as a source for better design and planning of construction projects

(Rokooei, 2015). Buildings have certain limitations of life span with the option of demolition at the end of the life span. This leads to the production of enormous amounts of waste which has a direct impact on the sustainability of the construction. As the European Commission European Commission (2016.) stated, about 30% of all waste generated in all European Union countries are the remains of construction and demolition waste. These waste materials like concrete, bricks, gypsum, woods, glasses, metals, plastics, solvents, asbestos and excavated soil can be recycled. Excessive waste generation has a diverse impact in sustainability. In order to make the world sustainable, waste should be minimized, buildings should be designed as reversible structures, including the disassembly and reuse of the building elements and materials. (EC 2016.)

According to previous research done at University of Twente, Faculty of Engineering Technology, the Netherlands, it has been suggested that Building Information Modeling (BIM) helps in additional gathering, synthesizing and interpreting of information needed about the building structure. Syed (2016) suggests that BIM implementation helps in maximizing the following facts of productivity rates given in table 1.

Table 1. Productivity rate of different facts in construction (Syed 2016.)

Facts	Rate
Sound multi party communication	75%
Design Phase error minimization	57%
Project time minimization	37%
Reduction of reworks and costs	65%

Some uses of BIM during the phases of construction are presented in Figure 2. It can be said that BIM is a platform for designers, engineers, structural engineers implement model-based tools and applications to enhance their work. One of the benefits BIM is an automated process of 2D documentation, allowing designers to focus more towards the possible design solutions for better products. There is a model-based approach and a common data environment (CDE) for active collaboration between the project participants in BIM. The possibilities of visualizing designs in 3D help every stake-holder to easily visualize and understand the project. With the features mentioned above, BIM delivers result in the desired output with minimum errors, mistakes and this interpretation, this making clients and customers happier. In other words, BIM provides better value for the project participants and increases customer satisfaction. (Syed 2016.)

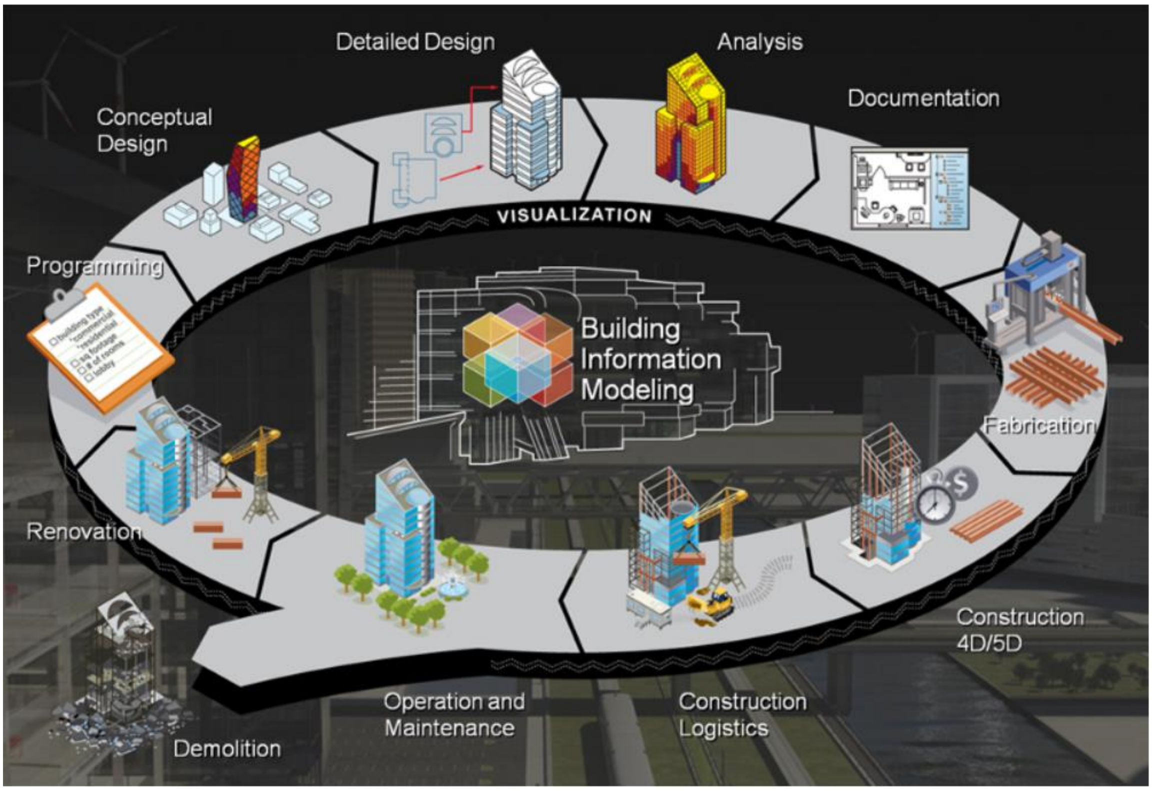

Figure 2. Digital concept of BIM (Kekhia 2015.)

The idea of Building Information Modeling (BIM) is illustrated in figure 2. As shown in the figure, BIM is a modeling platform of all the different information of the building including conceptual design, detailed design, analysis, documentation, fabrication, construction, logistics, maintenance, demolition, renovation and programming. (Kehia 2015.)

2.1 Structural BIM

The emergence of powerful and practical BIM tools for structural analysis, design and detailing has resulted in a quick adoption of BIM in structural engineering (Kaner, et al., 2008). Architect models are generally focused on space, mass and textures whereas structural design is focused on structural components. Multi-material (steel, concrete, timber, masonry, etc.) consists of analysis and design (A&D) information for report and drawing production. It promotes structural design and detailing process for engineers, detailers and fabricators. There are various benefits of BIM for structural disciplines. Archistar (2018) mentions the following: improved productivity, superior project insights, improved collaboration and constant information access. (Archistar 2018)

Information exchange between different project stakeholders and their tools are important for smooth workflow and effective processes. In present context, IFC (industry foundation classes) is an ISO certified standard data exchange format for sharing information. Structural analysis plays an important role in structural engineering design. These analyses are often carried out multiple times in different scenario; Results thus generated are needed to be updated frequently. For example, a beam design with different support system requires structural calculation and analyses at different phases of design. Information generated during the analysis are important as they base for the structural design parameter. With different scenario, the design of the beam might be impacted, and thus prior analysis results would be important for further calculation. In BIM applications, these types of model elements normally are provided as with a unique GUIDs (Globally Unique Identifications) to track element background of analytical and physical model. Multi-material solutions to make BIM transparent can be acquired with IFC. Structural BIM software is object-oriented programming prototype where instances of structural members are assembled for the creation of building structure. It aims to internally coordinate with results from analysis and design software. A well-built structural BIM model is only as useful as the models it is linked to and coordinated with. (Robinson 2007.)

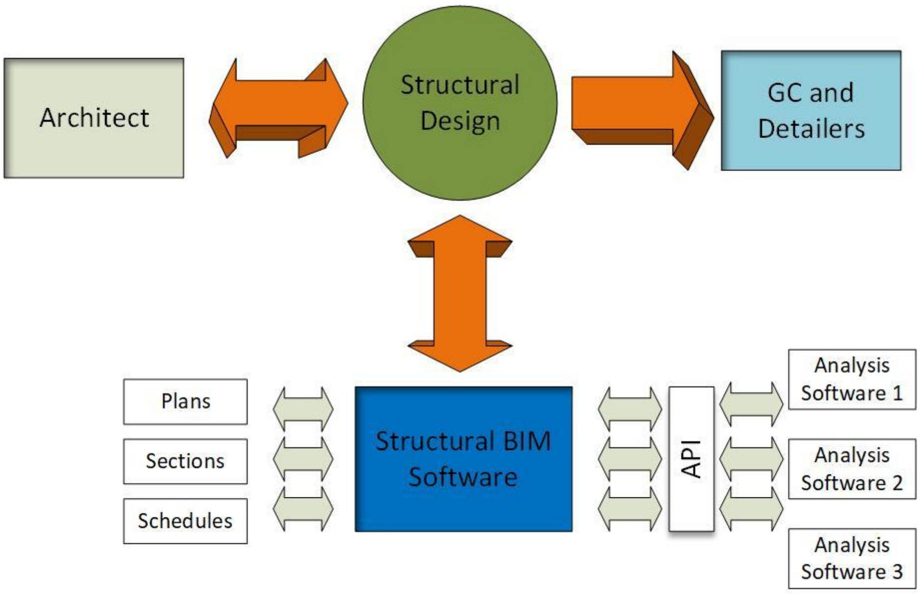

Figure 3. Workflow of structural BIM (Robinson 2007.)

Figure 3 above shows the workflow of structural design and possible outcomes of using structural BIM application. The starting point of any structural design relies with the architectural information. Based on architectural design, a structural engineer develops his structural design so that the proposed facility can be constructed. The structural design model also provides the key information to the general contractors and detailers. Structural BIM applications can produce 2D drawings like plans, sections and schedules required for different trades and activities. Structural model information furthermore can be shared through different APIs (Application Programming Interface) to perform different types of analysis like structural analysis, earthquake simulation and so on. These most of the information exchange process are bi directional and support the results and changes for better design output. Thus, BIM plays a vital role for collaboration, information exchange and reduces coordination time to result a better building. (Robinson 2007.)

2.2 Open BIM

Open BIM is a platform for interdisciplinary collaboration of collaborative design, realization and operation of buildings based on standards and workflows. Open BIM was executed by various companies, including GRAPHISOFT and Tekla working together to promote the concept of Open BIM within the AEC industry. Open BIM allows a transparent and open workflow between project members allowing them to participate regardless of the software used in the project. Open BIM also provides data from the data dictionary to avoid errors and a multiple input of same data. (buildingSmart International 2018.)

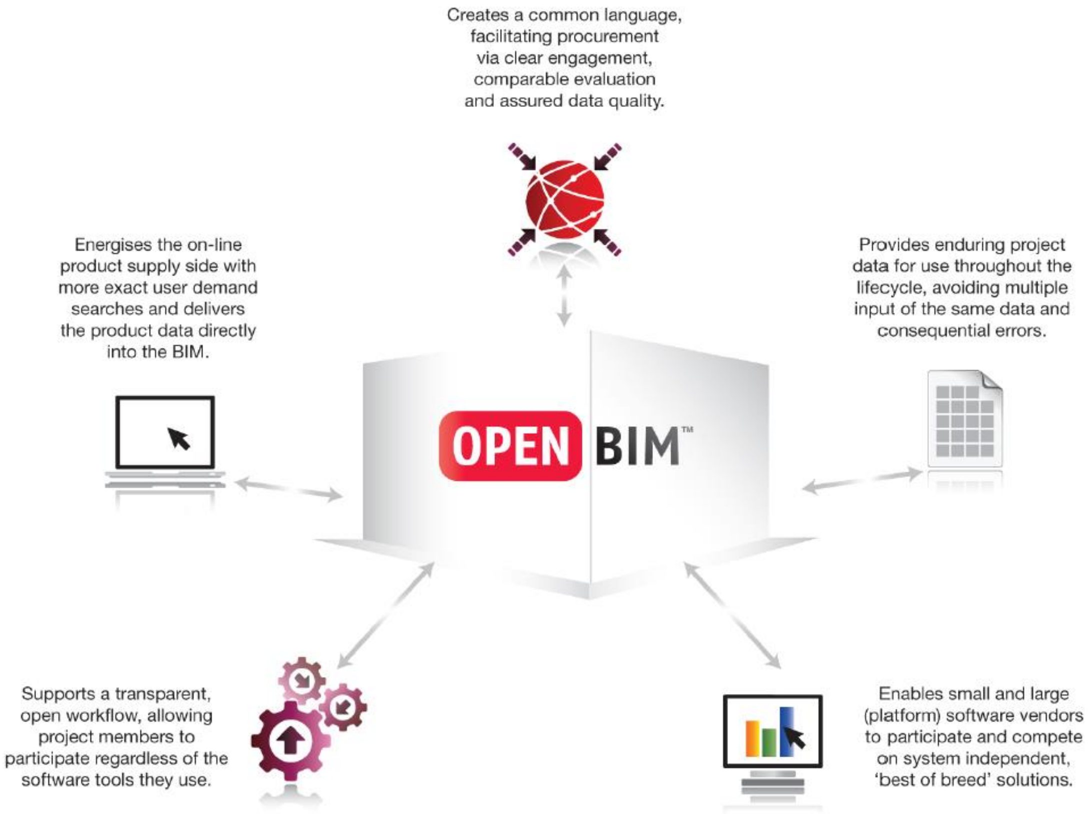

Figure 4. Benefits of Open BIM (Luis 2015.)

All building objects are shared in an open format known as IFC. The IFC data dictionary allows all the parties involved in a project to work efficiently. This is an attempt of Open BIM to alter the direction of the construction productivity curve which has been going down for few decades. Building Smart is an international organization that promotes and develops BIM so that it can act as a single platform of data dictionary to clients, designers, consultants, architects and contractors involved in a project. This data dictionary standardizes entities, properties and classification. It allows different BIM software to understand the building model, tools and IFC products. (buildingSmart 2016.)

3 Importance of Tekla Structures as Structural BIM application

Tekla Structures is a structural BIM application for structural engineering design, modeling, fabrication and detailing (Firoz, June 2012). Tekla Structures has been utilized efficiently in various projects from large to small as well as from simple to complex. It has intelligent tools to design complex structures with ease. Tekla Structures is very important when detailing steel and concrete structures. It enables engineers and designers to create analytical and physical structure models for design. Tekla structures support the import and export of IFC files, enabling collaboration and data exchange between different disciplines in one project. Various visualization possibilities with simple clicks makes it easier to navigate and reference the models of other disciplines. (Firoz 2012.)

Tekla Structures is used in about 80 countries in the world, accomplishing huge projects like Wembley Stadium, Beijing Olympic Stadium, New York's freedom tower and Leadenhall in London. Different departments can do their share of a project and finally combine all the designs and detailing in Tekla Structure with no loss of time. The aim of IFC objects conversion is to make the product of one software accessible in the other one. One of the major benefits of Tekla is that it has an ability to convert IFC reference objects such as beams, braces, slabs, and walls, into native Tekla Structures objects. (AEC Magazine 2008.)

3.1 History of Tekla Structures

The history of Tekla goes back to 1966 when "Teknillinen laskenta Oy" was founded by Reino Heinonen and appointed as Managing Director in March 1st,1966. It was established for the software development and computer programming offices in Finland. Later in 1968, the company's focus was changed to structural engineering and road construction. By 1970, Tekla was able to do major calculations completing task in few hours that would take a week to complete. During the years, programs like plotter software and graphic printing were developed. Another success was the development of X-product family which consists of three main bodies: X-road for road planning, X-power for electricity utilities and X-steel for structural steel engineering. In 2004, Ari Kohonen was appointed as CEO and President of Tekla and structural engineering software called Tekla Structures was launched. By 2010, Tekla Structures sold 18,000 licenses globally in nearly 100 countries. Tekla has offices in many Asian countries including India, Malaysia, Thailand, Singapore which serve as Tekla hub for South East Asia. (Trimble 2013.)

3.2 Features of Tekla Structures

The features of Tekla Structures include tools for detailing of steel, concrete, reinforced concrete, standard design, project manager and viewer. The process of Structural BIM starts with conceptual design to detailing and fabrication. These processes are easily accessible and designed utilizing Tekla Structures. The specific roles of Tekla Structures are design and modeling, analysis, drawing and reports, and concrete detailing. (AEC magazine 2008.)

Design and modeling in Tekla Structures can be developed from 2D drawings, or 3D models, or they can be based on referenced architectural drawings. Furthermore, any types of elements can be drawn in Tekla Structures. The components can be chosen from the UK and European sections of library of industry standards or, cold rolled profiles can also be modelled. The platform is flexible as the user can design the model in both 2D and 3D at the same time. The data is stored in a central database which allows different engineers to work in the same environment without failure and break downs. Analysis of a BIM model is done by exporting structural data from Tekla Structures to an analysis application, for example SAP or Robot, and then imported back for the final check of design changes. Some of the analyses applications have a direct link to Tekla, and if there is no direct link, Tekla Structures supports CIS/2 and IFC standards. Drawings can be created as snapshot of 3D model because the database contains all structural information. Automatic referencing allows the creation of details and sections in the other different views from the original drawings. Drawings can be based on templates with all project information. Similarly, Tekla Structures can generate reports in formats such as HTML,.XLS and .TXT, depending on the model. Concrete detailing in Tekla Structures includes 3D detailing tools for reinforced and pre-caste concrete and steel detailing. It also features many standard objects and automatically details pad, strip footings and beams with each other. (AEC magazine 2008.)

3.3 Major Projects

Many successful building construction projects have been carried out in this decade. The world has changed to be more sustainable and environmentally friendly in the last few years. Sustainability has been a major topic among the engineers and environmentalist, and Tekla Structures has advanced its tools to access BIM in sustainable way. Numerous BIM projects globally by various architectural and construction companies use Tekla Structures. The projects utilizing Tekla Structures are discussed below, in chapters 3.3.1 and 3.3.2.

3.3.1 Integrated BIM Design of Easton Helsinki

Easton Helsinki is a shopping centre located in Itäkeskus, Eastern Helsinki, owned by Kesko Oyj. This major project was carried out by following the parties listed in table 2. (Trimble 2018.)

Table 2: Project description of Easton Helsinki

S.N.	BIM participants	Company
1	Architect	Arkkitehtitoimisto Lahdelma & Mahlamäki Oy
2	Project Management	Haahtela-rakennuttaminen Oy
3	Structural Design	Wise Group Finland Oy
4	Steel and precast concrete detailing	Ramboll Finland Oy
5	MEP design	Granlund OY
6	Precast Fabrication	Lujabetoni Oy
7	BIM coordination and construction scheduling	Byggnadsekonomi Oy

Shopping centres are comparatively complex projects, with workflow done in different levels, consisting of design desks of individual end-users to contractors on the project site. All this was possible due to a centralised model. A centralised BIM model means the collaboration of various tasks, such as design, fabrication, installations and environmental conditions together to view the work done in real time in a cloud environment. Consequently, experts from different fields can make changes in their work in real time according to the situation and requirements (Davidson, 2017). According to data, Easton Helsinki has total surface area of 65,700 m^2. For the communication, the BIM collaboration format (BCF) files and cloud-based monitoring is utilized. The IFC models are checked and updated once a week to have fast information flow within the project parties. Real time data transfer is done in the project for the detailing of the building units by structural designers working in Tekla Model Sharing model. Tekla Structures and Vico Schedule Planner was used for the onsite scheduling of the frame by utilizing the element weights and locations. (Davidson 2017.)

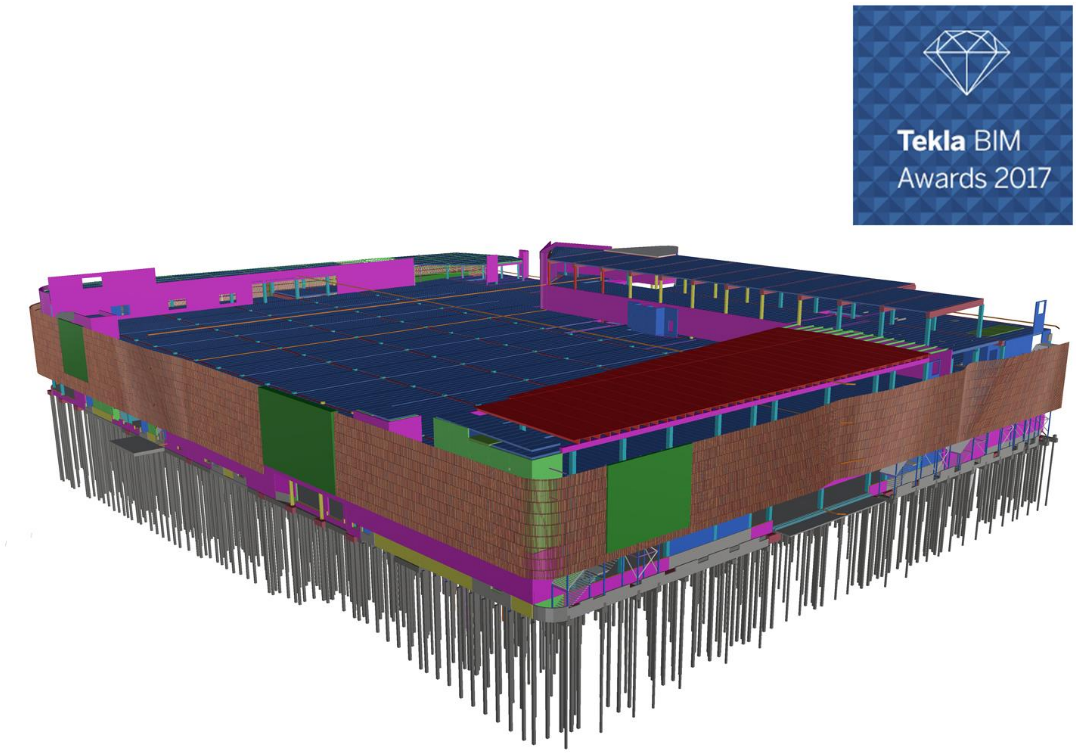

Figure 5. Tekla BIM awards 2017 winning design of Easton Helsinki

Tekla Structures also enabled safe assembly of schedules and costs of the frame. Hence, Tekla had an important role in the project delivery with transparency, schedule and cost. This project won the Tekla BIM Award 2017 for best design. See Appendix 1 for various work designs of Easton Helsinki. (Davidson 2017.)

3.3.2 Abu Dhabi International Airport Midfield Terminal

Abu Dhabi international midfield terminal is a huge project in the United Arab Emirates. There are many big constructions such as the construction of Burj Khalifa, Palm Island, many skyscraper buildings, smart roads, and the renowned airport are some prominent examples. A perfect example of best building construction is the Midfield Terminal Building-CPA -Abu Dhabi International Airport (Camateros-Mann, 2016). BIM was introduced during its construction to result in a structurally strong and architecturally beautiful building. The project comprised the construction of X-shaped building premises for Abu Dhabi International Airport Midfield terminal with a total build up area of 700,000 square meters with a six-floor central processor and 4 piers. (Ashford 2018.)

The Midfield Terminal Building project was a huge task for all working in their field. BIM was applied during all design and construction phases. The target of the project was to create a sustainable design and minimize the direct impacts of the project on environment. Because of its size, the project might result in a waste of energy. To minimize the waste, the experts worked hard towards sustainability. The BIM models for the project were designed using Tekla Structures to generate various formats for all working bodies in a centralised digital working environment. Consolidated Contractors Company (CCC), along with Arabtec and TAV worked together for pre-planning and technical understanding of the project. The IT and BIM department of CCC took a bold initiation to develop 3D BIM platform for the project. (Ashford 2018.)

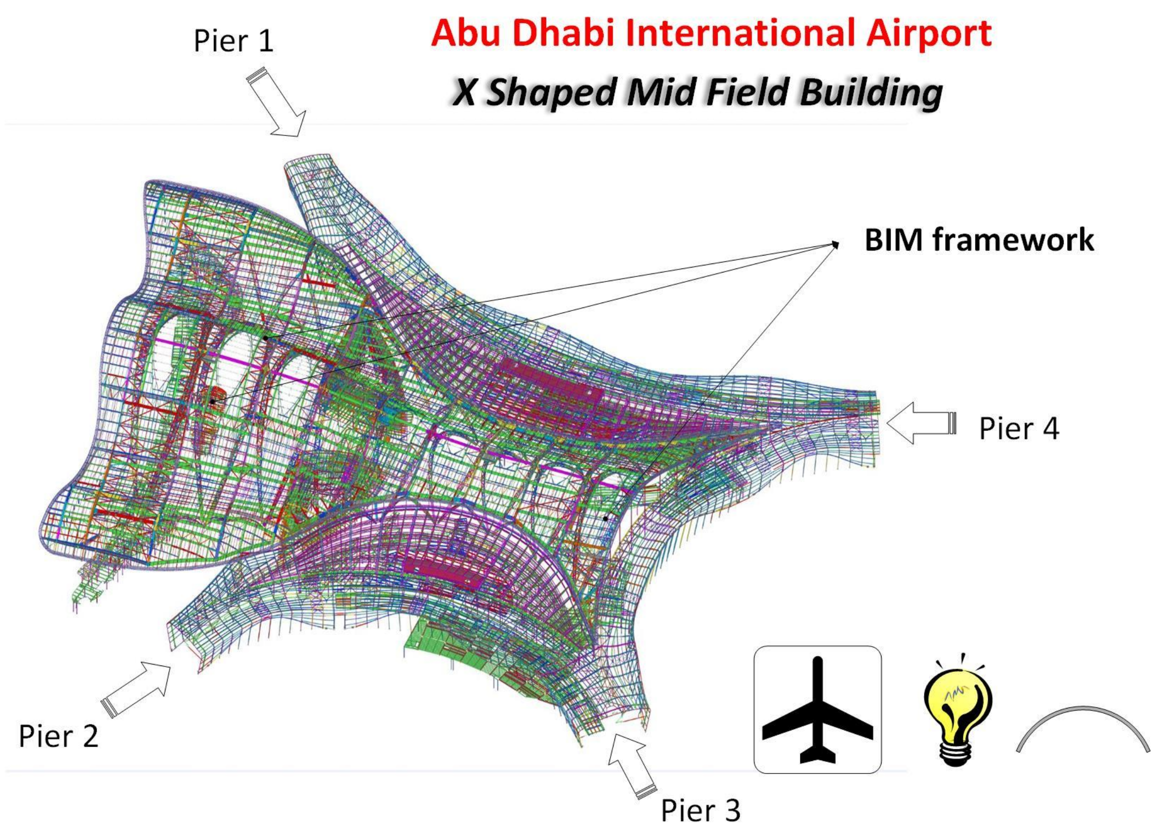

Figure 6. Structural design of MTB

The 3D model design files that were produced in the project are of IFC, DGN and DWG format. All BIM files were imported to Tekla collected from concrete, MEP, roof cladding and façade. They were checked to minimize the clash in the model (Trimble, 2018). Working environment was only accessible with a unique identity of each object, denoted by numbers designed for individual client. This prevented the leakage of data. The BIM resourcing was done from the BIM academy of CCC in Athens to develop BIM intellectual and BIM engineers according to their quality of experience divided into senior, experienced and young engineers. The engineers were experts in BIM workflows, project control, design coordination process and conceptual ideas necessary for productive and efficient BIM implementation. (Trimble 2018.)

The study of the two major projects shows the importance of Tekla Structures. The utilization of Tekla Structures has resulted in better outcome with minimum waste and completion of project before the scheduled time. In the context of Nepal, there are many big construction projects for e.g. bridge construction, including suspension bridges, an overpass bridge in a city, hospitals, fully integrated shopping malls, and apartment buildings. The utilization of Tekla Structures in the projects has resulted in cost savings, time and error management, common working environment for different parties and a similar database for elements. There could be many possibilities in Nepal to implement similar BIM projects. The BIM implementation would be a positive asset in developing countries to support rapid economic growth as well as to maintain transparency in construction projects.

4 Implementation Methodology of Tekla Structures in Nepal

BIM has been widely implemented in developed countries. The research activities and early adopters of BIM have already provided enough evidence about the importance of BIM in construction projects. BIM implementation has been government mandated like in UK or a common interest topic like in Finland. (McGraw Hill 2014.)

While the interest in BIM implementation is quickly rising in developing and booming countries, there is a necessity to plan and have implementation strategy in place to boost rapid growth and implementation. The research also resulted in some approaches and practice for BIM implementation. This study focuses on BIM implementation in Nepal and analyses the educational and commercial approaches as discussed in the chapters 4.1 and 4.2 respectively. (Smith 2014.)

4.1 Educational Plan

To employ BIM, education is necessary. Developments such as road construction, hospitals, renovation of bridges, tunnel formation has been employed in Nepal. They require qualified engineers and designers to follow up the projects. BIM implementation would be an asset to all parties of construction projects. The educational plan intends to educate the person affiliated to construction. The education helps to understand the utilization of BIM in a project and its advantages. The implementation strategy has been focused on educational institutions as they are the primary education provider. It enhances to educate students and the future graduates with a new enhanced way of optimizing construction projects. Nat (Rooney, 2014) stated that an industry reluctance to change, a ‘wait and see’ approach and a shortage of experienced and educated BIM practitioners or a technicians is slowing the inevitable uptake of BIM in the AEC industry. Tertiary education institutions, with the support of government and industry, need to fully incorporate BIM education into their curricula, to provide the AEC industry with the 'BIM-ready' graduates required for the collaborative BIM working environments to which will be part of in the future. Educational plan is discussed in the following chapters 4.1.1, 4.1.2 and 4.1.3 respectively. (Rooney 2014.)

4.1.1 Training Institute

There is a need to set up a training course for those who will be able to train others in Nepal in order to establish a training institie. Personnel already involved in software coaching, with an idea about building design and construction, should be appointed as trainers. Steps are to be followed wisely to implement and minimize the risks. Firstly, data collection should be done to select suitable candidates for the project. Secondly, the institute needs to arrange a seminar and provide the trainers with necessary trainings and hand over materials.

The process of establishing training institute takes time to make place in current market. For the establishment, new innovative ideas and plans should be employed to grab the attention of clients. Some ideas that could help increase number of trainees and students are listed below.

a) Selection of easily accessible location of training institute from all parts of the Kathmandu valley
b) Selection of expert level trainer (From India, Finland)
c) Closed camp (training) of at least 7-10 days to the trainers (advanced level training)
d) Advertisement in various media, both social media, newspaper, radio, and others.
e) Web application form to select the candidates according to level of knowledge
f) Classes for the students are then sub divided into beginner, advanced and expert
g) Free participation or discount provision for teachers of engineering schools to boost the number of participations
h) Students get chance to represent in educational fair
i) Provision of certificates after completion of training
j) Placement opportunities in renowned BIM operating company

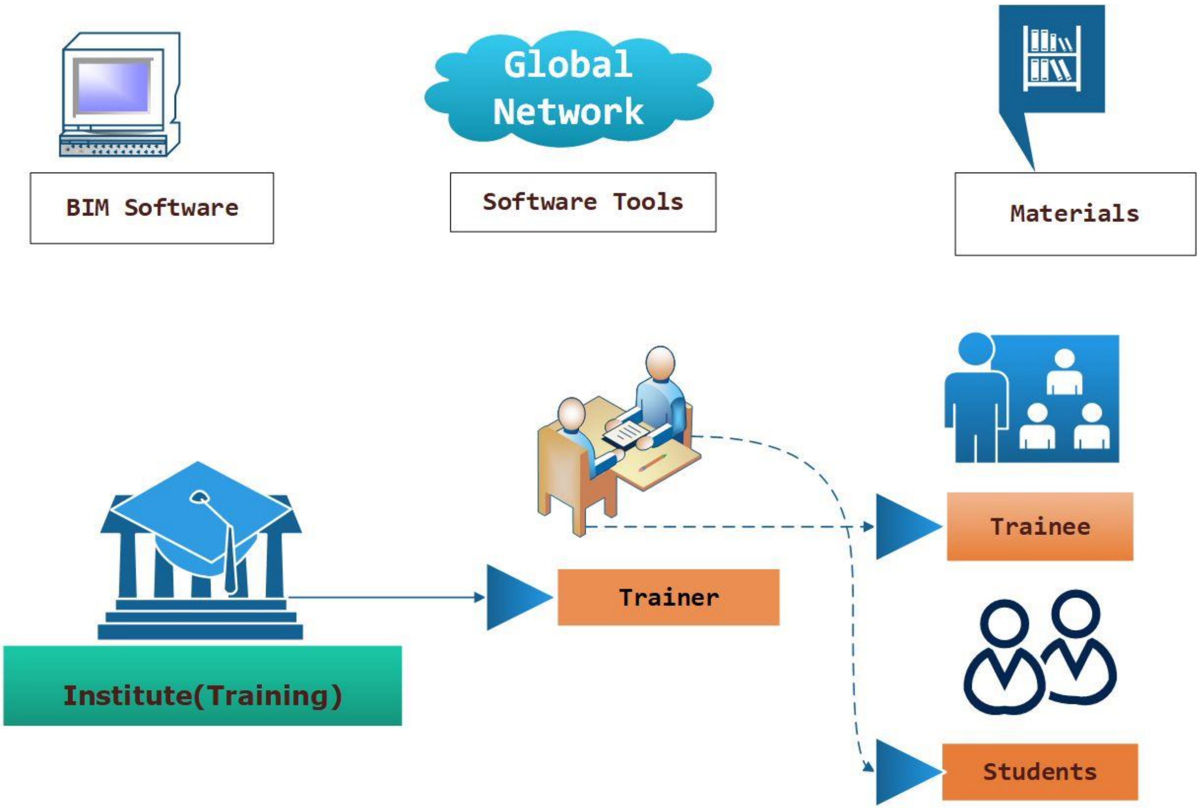

Figure 7. Description of training institute

Figure 7 describes the setting of training institute where the students learn about the BIM and its utilization in the project.

4.1.2 Engineering Colleges

In Nepal, there are six universities in various locations around the country educating thousands of engineering students every year to become a productive and qualified engineer. There is an allocated number of seats in every faculty depending upon the size of the institute and the materials necessary for the students. A total of 2,429 seat for civil engineering in the Kathmandu University, Tribhuwan University, Purbanchal University, Pokhara University, Far Western University and Mid-Western University combined. For

Bachelor of Architecture students, there are 401 seats overall universities in Nepal. Table 3 below gives the brief number of seats in Nepal (Nepal Engineering Council 2017.)

Table 3. Number of students in universities

	University	**Number of Civil Engineering students**	**Number of Architecture students**
1	Tribhuwan University	1217	127
2	Kathmandu University	60	30
3	Pokhara University	1056	96
4	Purbanchal University	1068	148
5	Far-Western	48	
6	Mid-Western	48	
	Total	2429	401

After the completion of training at a BIM institute, the teachers would be qualified to guide the students. Introducing new content or courses in accredited programs require government approval for the changes. It might be a cumbersome effort get the approval for including BIM content within engineering degree. Thus, promoting free trainings for the CAD teachers might be the best option for fast inclusion of upgrading CAD courses.

4.1.3 Polytechnic Colleges

There are two Polytechnic colleges, Pathibhara Centre for Advanced Studies and Calibre College of Engineering, with a total of 144 seats for degree programmes in Civil Engineering. As polytechnic colleges are based on practical studies, BIM education would be advantage for both the colleges and the students for their future career. (Nepal Engineering Council 2017.)

4.1.4 Justification for educational plan

The number of students that could benefit from BIM knowledge were estimated to be 2,429 annually in the engineering colleges in Nepal. According to the Nepal Engineers’

Association in 2015, total number of registered engineers in Nepal is 29,722 out of whom about 41% are civil engineers, or about 12,000. The Nepalese civil engineers look for opportunity as the competition is high. Not all graduates are employed. It is a great opportunity to sharpen up skills with new technology and learn about it.

Table 4: Calculation of expenditure for establishing at Training Institute for BIM

S. N	Items	Pcs	Price in Nepali rupees
1	Rental space	1	80,000
2	Computers	10	10*40,000= 400,000
3	Furniture	15	15*15,000=225,000
4	Educational License	1	125,000 per year
5	Electricity		3000 per month
6	Registration	1	1000
7	Internet	1	5000 per month
8	Trainer (Foreign)	2	2*250,000= 500,000
9	Expenditure		15,000 per week
	Total		1354000 (10832€)

An educational license costs about 1,000€ per year. The total cost assumption for starting up the training institute would be about 2 Million Nepali rupees. According to current exchange rate 1€ ~ 125 Nepali rupees, so the total investment is about 16,232€ which is not considered as huge investment.

Similarly, including BIM education in engineering education would promote the business for BIM applications like Tekla. BIM implementation could be promoted as a beginner is course to the first-year students, advanced to the second year and so on. This would support progressive learning as BIM education and training is very important towards the evolution of AEC industry.

4.2 Commercial Plan

The Construction field is a leading business field in Nepal. Nepal is a developing country and therefore, several large-scale construction projects such as highway construction, hydro-power construction, bridge construction and building construction are planned and currently under construction, for example Narayangarh- Mugling highway widening project which, (Rimal, 2018), Melamchi hydropower project and Kalanki flyover bridge. (Rimal 2018)

According to the statistics of the Strategic Road Network (SRN), there are 12,142 kilometers of roads and 1,674 bridges in Nepal (The World Bank 2018) out of which probably require renovation. This implies varied levels of construction which consists of structural design, fabrications and conceptual design. BIM implementation here would be a time minimizing and cost-efficient tool. Project donations for development programmes from countries like Unites States, Japan, China, South Korea and India are not new ventures. Government bodies such as the Department of Urban Development and Building Construction, Ministry of Planning Commission and Ministry of Physical Infrastructure and Transports receive the money to be utilized for re-construction projects. The work is then divided to different fields of expertise such as contractors and sub-contractors. (The World Bank 2018.)

4.2.1 Construction Companies

A construction company is an enterprise in a large or medium scale established to carry out major construction like roads, bridges and buildings with a varied number of workers for example engineers, construction workers, electricians, plumbers, painters and architects, with a budget. In Nepal, 870 construction companies are working actively/passively. (NepalYP 2018)

Figure 8. Number of Construction company in Nepal (NepalYP 2018)

From figure 8 it can be noticed that most construction companies are centrally located in the capital city, Kathmandu. This is because materials and equipment can be acquired in Kathmandu. There are various projects out of Kathmandu too. The working bodies such as structural designers, architects, and installer get a common working platform of BIM where they could share their work with each other. There are many unfinished construction projects with the problem of project schedule, project delivery, and cost calculations. BIM could be the solution to tabulate all problems and work with effectively.

4.2.2 Consultancies and Firms

When introducing BIM in Nepal, it should be done through engineering consultancies and architect companies since they are responsible for designs. There are 61 architectural firms in Nepal, in different cities working under the regulations of Department of Urban Planning and Building Construction. The main tasks of Nepalese consultancies are listed below:

a) Planning and designing of family houses
b) Valuation of property (private housing)

c) Structural analysis of the construction site for building construction
d) Interior design of buildings
e) Road maps formation
f) Mechanical, Electrical and Plumbing (MEP) design

Figure 9 below is a map showing the location of Nepalese architectural firms. (NepalYP 2018.)

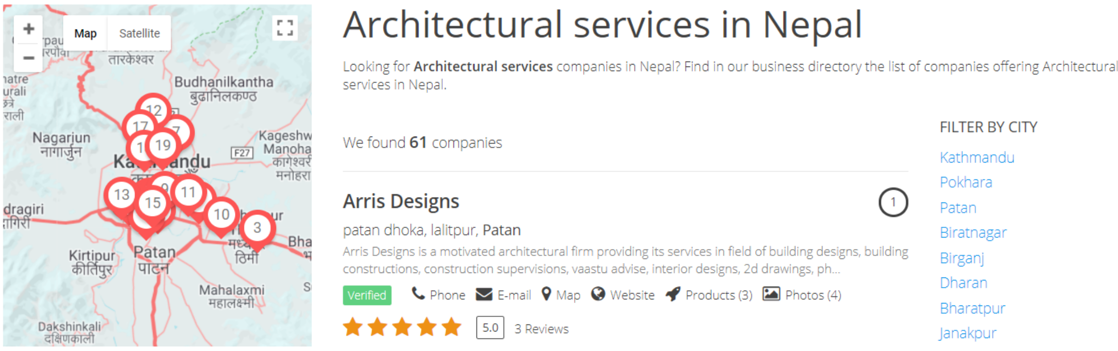

Figure 9. Description of consultancies and firms in Nepal with their position in the map

The majority of tasks done in consultancies are focused on conceptual design and structural design. It would be a great asset to a company to accept BIM, with a better result in time and cost saving. There could be additional cost during the implementation phase of training and education about BIM and use of software. After few years of implementation, the outcome of BIM implementation would be beneficial. Due to numerous possibilities that BIM offer for making the workflow smoother, it can be assumed that it would be beneficial to implement BIM.

4.2.3 BIM Return on Investment

Potential cost savings through implementation of BIM can be further enhanced with the explanation of return on investment. Return on Investment (ROI) is a way to evaluate proposed investments, defined as the ratio of earnings from the investment to the cost of investment. (Giel 2009.) Similarly, to calculate percentage indicator, the value after the calculation is multiplied by 100 to get a percentage. The formulae to calculate ROI is given in Equation 1. (Feibel 2003.)

$$ROI = \frac{Gain\ from\ the\ Investment - Cost\ of\ Investment}{Cost\ of\ Investment} \quad (1)$$

According to Autodesk, calculation on the first year's Return on Investment for BIM can be carried out by the formula below:

$$\frac{Monthly\ Labor\ Costs - \frac{Monthly\ Labor\ costs}{(1+\%\ of\ productivity\ gain\ after\ training)} \times (12\ training\ time)}{(Cost\ of\ hardware\ and\ software) + (Monthly\ labor\ cost \times\ Training\ time\ x\ \%\ of\ productivity\ loss}$$

(2)

Calculation of the Return on Investment could be done after one year of establishment. During the study of ROI, a real case study of the Holder's Hilton Aquarium project in Atlanta was taken into consideration. The total project budget was $46 million including the parking garage, whereas the project time duration was 21 months design and 9 months overlap. With the BIM scope of design assistance, clash detection and work sequencing there was cost benefit of $600,000 and time saving of 1143 hours (48 days). Hence, the estimated BIM savings was $800,000 and net savings of $710,000. The complete project return on investment was 780%. (Gilligan 2007.)

Equation 2 can be used to calculate the ROI for BIM implementation. The ROI calculation is not enough for the investment solution with regards to the owners'. It is generally the measure to calculate the value of BIM. Lately the use of BIM is shifting among many countries especially in Europe and the USA, the economic value of BIM technology in a building's lifecycle, starting from design to construction and operations and maintenance, is measured with ROI. McGraw Hill survey report found that the ROI values for the construction project in different countries in Europe and the USA ranged from 300-500%. (Giel 2009.)

4.2.4 Justification for commercial plan

Possible benefits of BIM implementation in the construction project of Diamond Hydropower in Nepal with a project cost of €15,683,412 and construction time of 24 months are cost savings, better quality of design and better communication between the parties. (Kalika group 2016.)

Using a Virtual Design Construction (VDC) processes, like BIM, in the project could save 5-15% by reducing the additional change orders. Utilizing VDC might increase design costs but compared to traditional construction VDC results in better design quality, less 2D documents, better understanding and communication within the parties, less risks and positive return in investment through potential savings of time a designer needs to invest. A 5% saving in the Hydropower project would be 784,170€. This would help justify that use of BIM in the construction project. (Sireeni 2013.)

5 Aspects of BIM Implementation in Nepal

A devastating earthquake in April 2015 swept away many lives and houses in Nepal. For a country like Nepal, BIM would be a positive impact in the development of urban planning and building construction. Major focus is given towards the earthquake destruction by the government to prevent in future. The Department of Urban Development and Building Construction have prepared a design catalogue for the construction of earthquake resistant houses. The number of buildings destroyed in the earthquakes on the 25th April and 12th May 2015 is shown in the table 4 according to the functions of the buildings. (Department of Urban Development and Building Construction 2015.)

Table 5: Number of buildings destroyed in the 25 April and 12 May 2015 Earthquakes in Nepal (Department of Urban Development and Building Construction 2015.)

S.N.	Function	Number
1.	Government	6,400
2.	Health	960
3.	Schools	8,500
4.	Private	600,000
5.	Partially damaged (private)	285,000

There is a need to overcome this trauma of people directly and indirectly affected by the earthquakes. Most of the buildings, both private and public are concrete structures and less steel structures. Tekla Structures allows a significant environment for steel or concrete detailing. Impacts of BIM implementation could be visualized from the chapters 5.1 and 5.2 respectively.

5.1 Earthquake Resistant Buildings

Seismic events with natural and man-made phenomenon generated by seismic waves coming from soil and rock is defined as earthquake (Khan, 2013). When an earthquake occurs, a building shakes which results in inertial force. The force develops acceleration setting the building to motion. Wood frame buildings act better than reinforced concrete buildings. For a building to be earthquake resistive, it needs to follow building acts, laws and criteria. A catalogue for construction has been published by Department of Urban Development and Building Construction (DUDBC) to every construction sector to spread the knowledge of seismic vibration, damage that it can cause and about preventive measures. Attention was paid on houses in cities and villages. DUDBC have decided to divide the building materials into four categories namely; stone and mud mortar masonry, brick and mud mortar masonry, stone and cement mortar masonry and brick and cement mortar masonry. (Khan 2013.)

The National Building Code of Nepal added a few things in the catalogue which includes information about 3D view, floor plan, elevations, sections and technical details. Earthquake resistant design is a subject of major concern in the world. For more of the detailed data about the new construction techniques and models designed by Department of Urban Development and Building Construction see Appendix 2.

Table 6. List of Model houses in Nepal (Department of Urban Development and Building Construction 2015.)

List of Model Houses housing model Volume I

Structural Type	No. of Floor	Model No.	Designed by	Page
Stone masonry in cement mortar, P5- SMC	1	SMC-1.1	JICA	9
	1	SMC-1.2	JICA	15
	2	SMC-2.1	JICA	21
	2	SMC-2.2	DUDBC	27
	2	SMC-2.3	DUDBC	33
	2	SMC-2.4	DUDBC	39
	2+ATTIC	SMC-2.5	DUDBC	45
	2+TERRACE	SMC-2.6	DUDBC	51
		Technical details		57
		Flexible design		67
Brick masonry in cement mortar P71- BMC	1	BMC-1.1	JICA	74
	1	BMC-1.2	JICA	80
	2	BMC-2.1	JICA	86
	2	BMC-2.2	DUDBC	92
	2	BMC-2.3	DUDBC	98
	2+ATTIC	BMC-2.4	DUDBC	104
	2+TERRACE	BMC-2.5	DUDBC	110
		Technical details		116
		Flexible design		125
Stone masonry in mud mortar, P129- SMM	1	SMM-1.1	DUDBC	135
		Technical details		141
		Flexible design		143
Brick masonry in mud mortar, P147- BMM	1	BMM-1.1	DUDBC	153
		Technical details		159
		Flexible design		161

Table 6 defines the model houses of different structural types as mentioned above designed by two different agencies, DUDBC and Japan International Cooperation Agency (JICA). They have separate designs for houses in every category. Technical designs, drawings, and IFC materials are accessible with BIM applications. Therefore, Tekla structures could be utilized to design the model houses prescribed by DUDBC. Tekla Structures is efficient with many features such as 3D work plan, IFC objects import or export, steel and concrete detailing with clarity in design and selection of hidden parts. The software is updated every year with a new version with many changes and excellent features. (Trimble 2017.)

5.2 Reconstruction of historical heritage buildings

Historical heritage has a lot of importance in Nepal. Historical buildings are architecturally and conceptually unique. To preserve them, possible measures and steps should be taken by the government as well as by the private sector. A great number of heritage structures were destroyed completely or damaged partially during a massive earthquake in April 2015. The epicenter was 75 km north east of Kathmandu, and a major after shock at 7.3 of Richter's magnitude affecting most of the surroundings near Kathmandu. Three historical heritage spots, Bhaktapur Durbar Square, Patan Durbar Square and Kathmandu Durbar Square are in the valley. Historical buildings with amazing art work were destroyed. Implementing BIM applications like Tekla Structures will aid in the documentation of historically important buildings and provide documentation required for timely renovation. Further, Tekla Structures would provide a digital repository of the buildings that can be virtually accessed as a virtual touristic site that could bring revenue.

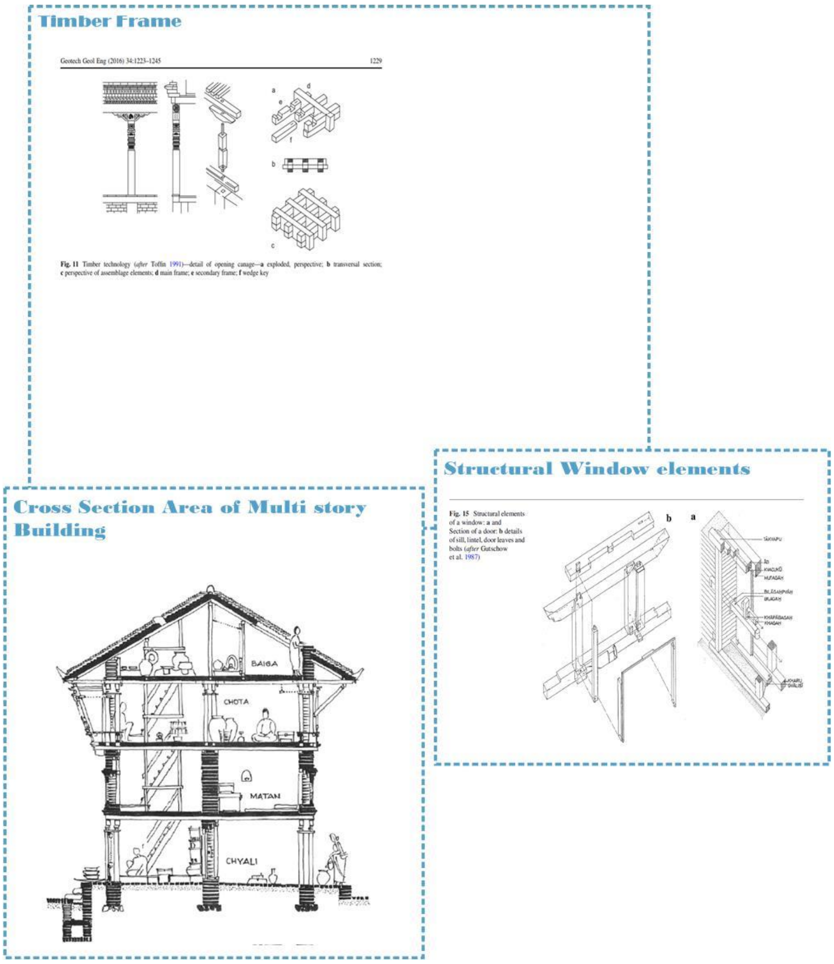

Figure 10. Structural Elements of historical Buildings in Nepal (Tsuneo Ohsumi 2016.)

Figure 11 defines the different structural elements, that were used in the historical buildings of Nepal. Timber frames and structural window elements could be exported in the data dictionary of Tekla Structures to redesign the structures if needed. (Tsuneo Ohsumi 2016.)

6 Structural Analysis Software used in Nepal and Tekla

Building construction is a key factor in a developing nation like Nepal. Building construction such as family house, apartment buildings, shopping malls, schools, industries, and sports halls, should follow the building standards of the specific area. Structural engineers in Nepal use software like STAAD.PRO, Structural Analysis Program (SAP) and AutoCAD for 2D drawings. (Bently 2018.)

STAAD.Pro is a structural analysis and design software from Bently, that simplifies any BIM workflow with the aid of a physical model that is automatically converted into an analytical model for structural assay. It results in cost effective designs which is valued in the construction market. Similarly, Structural Analysis Program (SAP) is a finite element analysis program for structural analysis (CSI, 2018). It is an easy and productive solution for structural analysis. The specific features of SAP are that complex models can be generated and meshed with built-in templates and an integrated design code could generate wind, wave, bridge and seismic loads with automatic steel and concrete design code checks according to design standards of the USA, Canada and others. (CSI 2018.)

When comparing Tekla Structures to STAAD.pro and SAP 2000, following points could be noted. Starting with Tekla Structures, which is a BIM solution that collaborates with other project parties to create documentation that includes construction drawings, detailed drawings, reports, BOQ and schedules whereas STAAD.pro and SAP 2000 is structural analysis program that calculates the loading stresses and strains on the elements, moments, shears and deflections on objects under different loading conditions. There is always a direct link between STAAD.pro and Tekla Structures and SAP and Tekla Structures. Tekla solution allows structural engineers to coordinate with architects, service engineers, detailers and contractors using standard file formats and integration links whereas SAP could import geometry and material properties of STAAD.pro models but import is not possible from STAAD.pro to SAP. In Tekla, the solution is fully automated and packed with various features for optimized concrete and steel design to compare design schemes, manage changes and collaborate with BIM platforms where as in STAAD.pro and SAP collaboration with BIM platform is difficult and not relevant. (Trimble 2017.)

Tekla structures provides a common tool as a reference model called IFC model. It has specific features of 3D work plane to place the tools conveniently in their meant position. The features of the software are elaborated annually to easily access the software, GA drawings, cloud and so on. Also, the structural design of buildings which include steel and concrete as a lead product is an important feature. (Trimble 2017.)

7 Conclusion

Implementation of BIM is a step towards coordinating with all BIM users in the world. It is a slow and steady process with a desired output of optimizing construction projects and processes. It is never late to start a good initiation for development of a country. When project parties as designers, architects, fabricators and structural engineers work together, it helps in saving time, cost as well as minimize errors.

The structural analysis software that already exist in Nepal were compared with Tekla Structures in chapter 6 to determine its advantages and disadvantages. Tekla Structures showed numerous advantages of 3D working environment, supporting file formats, drawing creations, required components from the data dictionary, open BIM, schedule, Bill of Quantities, etc. Similarly, heritage buildings and other public buildings destroyed in an earthquake which need quick recovery were discussed. With the structural BIM implementation, the reconstruction work could be done with lower construction cost, minimized error and early project delivery.

The goal of this thesis was to study the importance of BIM implementation and suggest a suitable methodologies of BIM implementation in Nepal. Therefore, it can be concluded that the educational and commercial approach is the suitable methods of BIM implementation in the Nepalese context. Starting from educating people to implementing in construction companies would asset in the construction development of a country.

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Appendix 1

The BIM models of Easton Helsinki consisting of conceptual design, structural design, pipe and ducts, were worked out by different companies as explained in the chapter 3.3.1. Here are some designs.

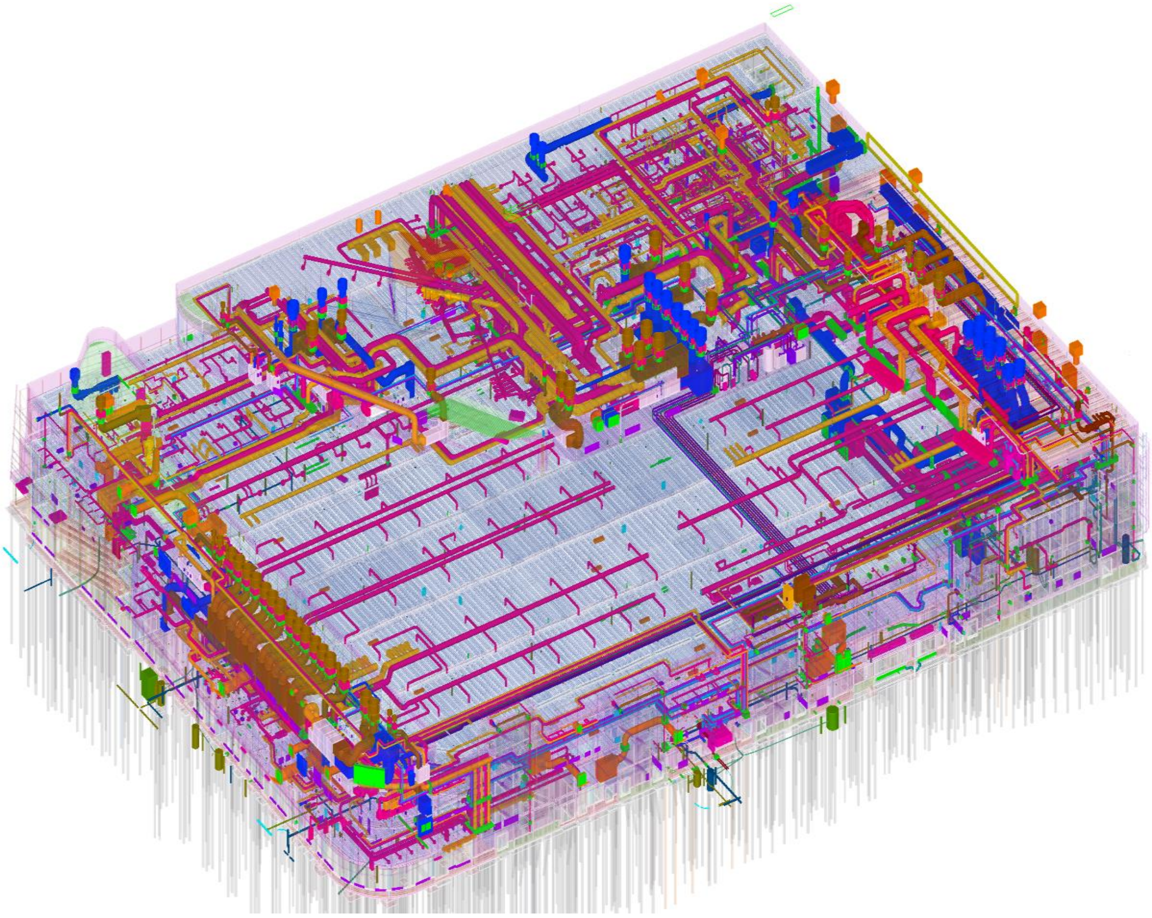

Figure 1. Collaboration of design in Easton Helsinki

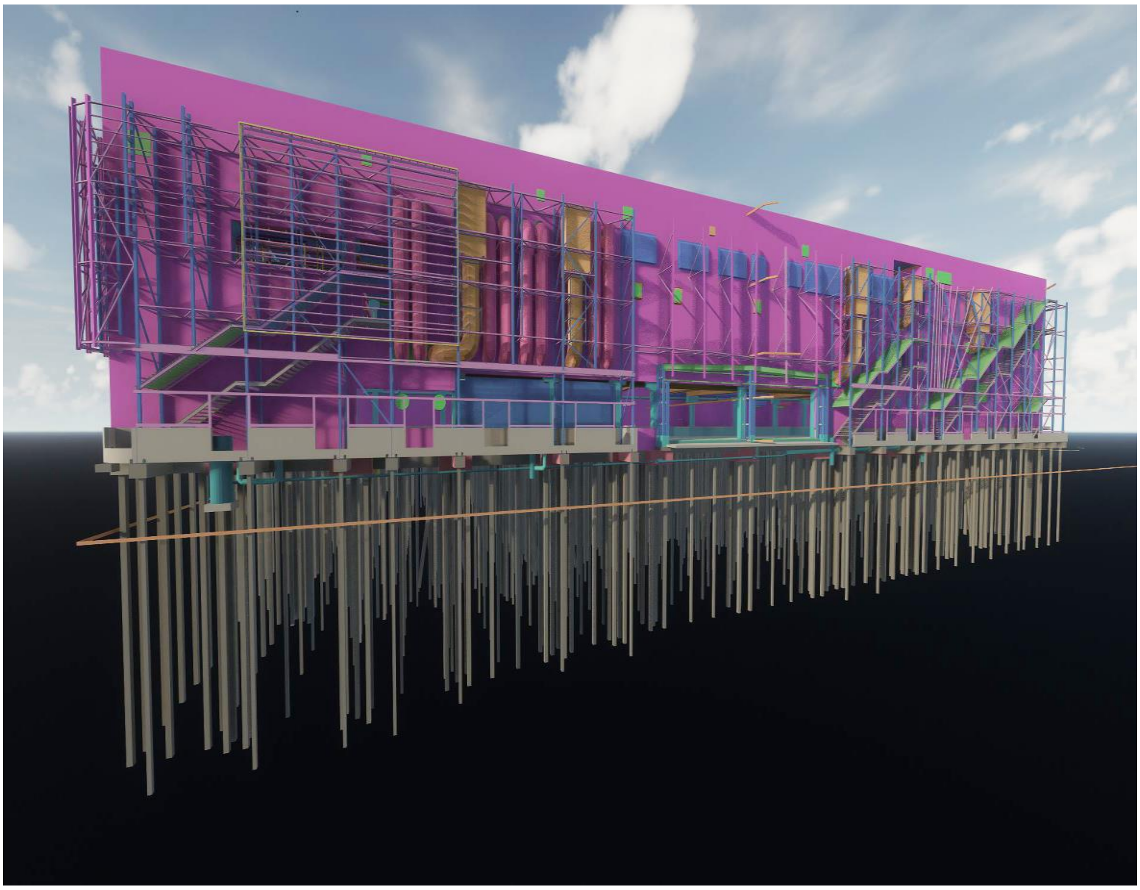

Figure 2. Conceptual design of Easton Helsinki

Figure 3. Virtual display of different parties working for collaboration

Appendix 2

Department of Urban Development and Building Construction in co-ordination with JICA designed technical requirements and models for different types of housing depending on Concrete masonry or Brick masonry. Here are some technical characteristics

1. Stone Masonry in cement Mortar

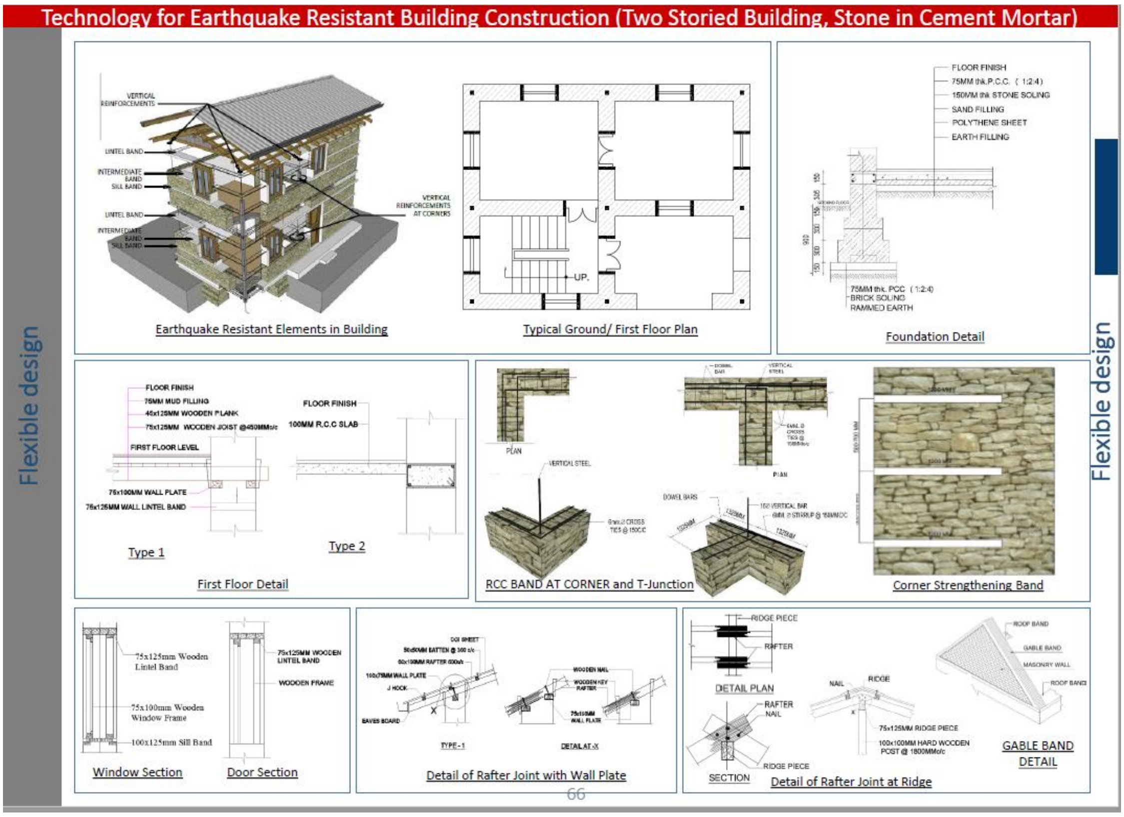

Figure 4. Package of flexible design types and details for stone masonry

Minimum Requirements (MRs) for Stone Masonry in Cement Mortar (NBC202)				Page1
No.	Category			
1	Site Selection	A building shall not be constructed if site is:		
			✔	Geological fault or Raptured Area
			✔	Areas Susceptible to Landslide
			✔	Steep Slope > 20%
			✔	Filled Area
			✔	River Bank and Water-logged Area
2	Shape of House	No. of story	✔	Two storey+ attic, load bearing masonry buildings constructed in cement mortar
		Span of wall	✔	The span of wall shall not more than 4.5 meters
		Size of room	✔	The area of individual floor panel not more than 13.5 square metres
		Height of wall	✔	The height of wall should not be more than 3.0 meters
		Proportion	✔	The house shall be planned in square, rectangular. Avoid long and narrow structure should not be more than 3 times of its width.
3	Foundation	General	✔	The foundation trench shall be of uniform width. The foundation bed shall be on the same level throughout the foundation in flat area.
		Depth	✔	The depth of footing should not be less than 800mm for one story, 900mm for two storey.
		Width	✔	The width of footing should not be less than 600mm in medium soil condition. As depend on soil condition. Shown in detail drawings.
4	Plinth	General	✔	Provide a reinforced concrete band at plinth level, as shown in detail drawings. The top level of plinth should not be less than 300mm from existing ground level. Recommendation is 450mm.
		Height	✔	Minimum height of Plinth band is 150mm.
		Width	✔	Minimum thickness of plinth band width should be equal to wall thickness. 350mm for Stone masomy.
		Reinforcement	✔	Main reinforcement should be 4-12 dia. bars. Use 6mm diameter rings at 150mm. Hook length should be 500mm. Bars shall have a clear cover of 25mm concrete.
5	Walls	General	✔	Masonry should not be laid staggered or straggled in order to avoid continuous vertical joints. At corners or wall junctions, through vertical joints should be avoided by properly laying the masonry. It should be interlocked.
		Joints	✔	Mortar joints should not be more than 20mm and less than 10mm in thickness. The ratio recommend 1:4 (Cement: Sand).
		Through Stone	✔	Through-stone of a length equal to the full wall thickness should be used in every 600 mm lift at not more than 1.2 m apart horizontally.
		Width	✔	The minimum width of wall is 350mm for one-storey and two-storey.

Minimum Requirements (MRs) for Stone Masonry in Cement Mortar (NBC202)				Page2
6	Openings	Location	✔	Openings are to be located away from inside corners by a clear distance should not be less than 600 mm.
		Total length	✔	The total length of openings in a wall is not to exceed half of the length of the wall in single-storey construction.
		Distance	✔	The horizontal distance between two openings is to be not less than 600 mm.
		Lintel level	✔	Keep lintel level same for doors and windows.
7	Vertical Reinforcement	Location	✔	Place vertical steel bars in the wall at all corners, junctions of walls and adjacent to all doors and windows. They shall be covered with cement concrete in cavities made around them during the masonry construction.
		Reinforcement	✔	The vertical reinforcing bar for masonry is given in detail drawings. 12mm dia is minimum requirements for masonry houses.
8	Horizontal Band		Horizontal bands should be provided throughout the entire wall with minimum thickness of 75 to 150 mm at following locations:	
		Sill band	✔	A continuous sill band shall be provided through all walls at the bottom level of opening (specially windows). The minimum height is 75mm.
		Lintel band	✔	A continuous lintel band shall be provided through all walls at the top level of opening. The minimum height is 150mm.
		Stitch	✔	This band shall be provided where dowel-bars are required at all corners, junctions of walls. The minimum height is 75mm.
		Roof band	✔	Roof band shall be provided at the top-level of walls, so as to integrate them properly at their ends and fix them into the walls. The minimum height is 75mm.
		Reinforcement	✔	Main reinforcement should be 4or 2-12 dia. bars. Use 6mm diameter rings at 150mm. Hook length should be 500mm. Bars shall have a clear cover of 25mm concrete.
9	Roof	Light roof	✔	Use light roof comprising wooden or steel truss covered with CGI sheets.
		Connection	✔	All members of the timber truss or joints should be properly connected as shown in detail drawings.
		Cross-tie	✔	Trusses should be properly cross-tied with wooden braces as shown in detail drawings.
		Timber	✔	Well seasoned hard wood without knots should be used for roofing, timber treatment such as use of coal tar or any other preservative can prevent timber from being decayed and attacked by insects
10	Materials	Mortar	✔	Cement sand mortar should not be leaner than 1:4 (1 part cement and 4 parts sand) for masonry and 1:6 for plaster
		Concrete	✔	The concrete mix for seismic bands should not be leaner than 1:1.5:3 (1 part cement, 1.5 parts sand and 3 parts aggregate)
		Reinforcement	✔	High Strength Deformed Bars – Fe415: High strength deformed bars with fy = 415 N/

Flexible design

Figure 5. Minimum requirements for stone masonry flexible design with necessary details

2. Brick Masonry in Cement Mortar

Figure itself is a clear explanation of different types of technology applied for Earthquake preventive construction.

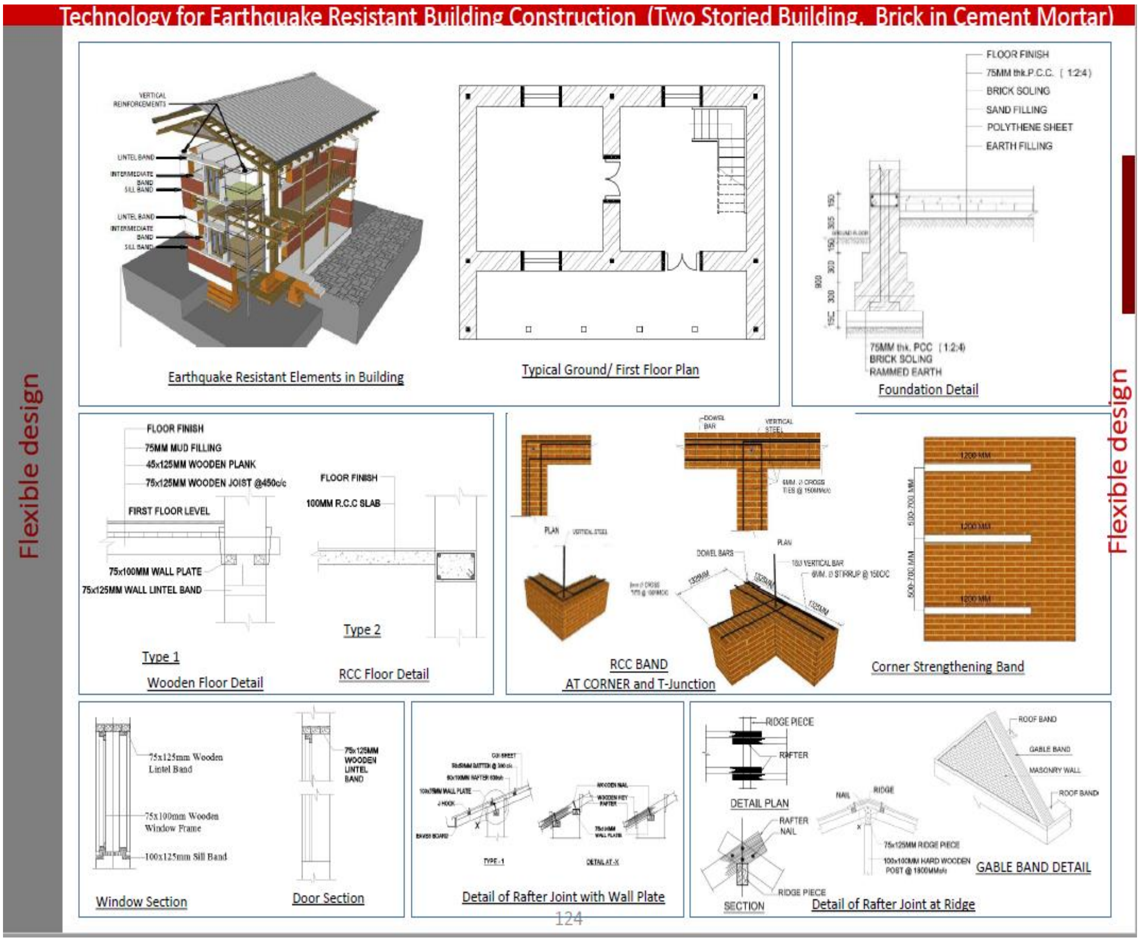

Figure 6. Methodology applied for construction of brick masonry buildings in Nepal

Minimum Requirements (MRs) for Brick Masonry in Cement Mortar (NBC202)				Page1
No.	Category			
1	Site Selection	A building shall not be constructed if site is:		
			✔	Geological fault or Raptured Area
			✔	Areas Susceptible to Landslide
			✔	Steep Slope > 20%
			✔	Filled Area
			✔	River Bank and Water-logged Area
2	Shape of House	No. of story	✔	Two storey+ attic, load bearing masonry buildings constructed in cement mortar
		Span of wall	✔	The span of wall shall not more than 4.5 meters
		Size of room	✔	The area of individual floor panel not more than 13.5 square metres
		Height of wall	✔	The height of wall should not be more than 3.0 meters
		Proportion	✔	The house shall be planned in square, rectangular. Avoid long and narrow structure should not be more than 3 times of its width.
3	Foundation	General	✔	The foundation trench shall be of uniform width. The foundation bed shall be on the same level throughout the foundation in flat area.
		Depth	✔	The depth of footing should not be less than 800mm for one story, 900mm for two storey.
		Width	✔	The width of footing should not be less than 600mm in medium soil condition. As depend on soil condition. Shown in detail drawings.
4	Plinth	General	✔	Provide a reinforced concrete band at plinth level, as shown in detail drawings. The top level of plinth should not be less than 300mm from existing ground level. Recommendation is 450mm.
		Height	✔	Minimum height of Plinth band is 150mm.
		Width	✔	Minimum thickness of plinth band width should be equal to wall thickness. 230mm for brick masonry.
		Reinforcement	✔	Main reinforcement should be 4-12 dia. bars. Use 6mm diameter rings at 150mm. Hook length should be 500mm. Bars shall have a clear cover of 25mm concrete.
5	Walls	General	✔	Masonry should not be laid staggered or straggled in order to avoid continuous vertical joints. At corners or wall junctions, through vertical joints should be avoided by properly laying the masonry. It should be interlocked.
		Joints	✔	Mortar joints should not be more than 20mm and less than 10mm in thickness. The ratio recommend 1:4 (Cement: Sand).
		Width	✔	The minimum width of wall is 230mm for one-storey and 350mm for two-storey of ground floor.

Minimum Requirements (MRs) for Brick Masonry in Cement Mortar (NBC202)				Page2
No.	Category			
6	Openings	Location	✔	Openings are to be located away from inside corners by a clear distance should not be less than 600 mm.
		Total length	✔	The total length of openings in a wall is not to exceed half of the length of the wall in single-storey construction.
		Distance	✔	The horizontal distance between two openings is to be not less than 600 mm.
		Lintel level	✔	Keep lintel level same for doors and windows.
7	Vertical Reinforcement	Location	✔	Place vertical steel bars in the wall at all corners, junctions of walls and adjacent to all doors and windows. They shall be covered with cement concrete in cavities made around them during the masonry construction.
		Reinforcement	✔	The vertical reinforcing bar for masonry is given in detail drawings. 12mm dia is minimum requirements for masonry houses.
8	Horizontal Band			Horizontal bands should be provided throughout the entire wall with minimum thickness of 75 to 150 mm at following locations:
		Sill band	✔	A continuous sill band shall be provided through all walls at the bottom level of opening (specially windows). The minimum height is 75mm.
		Lintel band	✔	A continuous lintel band shall be provided through all walls at the top level of opening. The minimum height is 150mm.
		Stitch	✔	This band shall be provided where dowel-bars are required at all corners, junctions of walls. The minimum height is 75mm.
		Roof band	✔	Roof band shall be provided at the top-level of walls, so as to integrate them properly at their ends and fix them into the walls. The minimum height is 75mm.
		Reinforcement	✔	Main reinforcement should be 4or 2-12 dia. bars. Use 6mm diameter rings at 150mm. Hook length should be 500mm. Bars shall have a clear cover of 25mm concrete.
9	Roof	Light roof	✔	Use light roof comprising wooden or steel truss covered with CGI sheets
		Connection	✔	All members of the timber truss or joints should be properly connected as shown in detail drawings.
		Cross-tie	✔	Trusses should be properly cross-tied with wooden braces as shown in detail drawings.
		Timber	✔	Well seasoned hard wood without knots should be used for roofing, timber treatment such as use of coal tar or any other preservative can prevent timber from being decayed and attacked by insects
10	Materials	Mortar	✔	Cement sand mortar should not be leaner than 1:4 (1 part cement and 4 parts sand) for masonry and 1:6 for plaster
		Concrete	✔	The concrete mix for seismic bands should not be leaner than 1:1.5:3 (1 part cement, 1.5 parts sand and 3 parts aggregate)
		Reinforcement	✔	High Strength Deformed Bars – Fe415: High strength deformed bars with fy = 415 N/

Flexible design

Figure 7. Flexible design with details of every elements in the building