

BIM FOR REINFORCEMENT DETAILING IN R.C.C FRAME STRUCTURES

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Abstract

As it rightly said by Ernest Boyer, "The future belongs to the Integrator's", the AEC industry is now adopting BIM, where different information related to a structure is stored in a virtual model before the structure is actually built at the site. In high rise structures (skyscrapers) BIM can play a vital role in reinforcement works as in R.C.C frame structures the cost of structure is mainly governed by reinforcement cost, therefore the level of reinforcement detailing and quantity takeoff is very critical. In this study in order to solve reinforcement related issues we use BIM for reinforcement detailing and quantity takeoff. By using BIM for reinforcement detailing we can minimize the wastage in steel and hence it can bring down the cost. It likewise provides well detailed 3-D drawings which help to visualize (especially in complicated junctions) and can solve many clashes at the site, hence saves time. In this research the results are compared to the case study of BIM vs. Non BIM approach. Bar Bending Schedule created by using BIM is accurate and can easily be changed within clicks when the reinforcement drawing changes (especially in India, where reinforcement drawing often changes to the extent of slab being executed).

Keywords: Bar Bending Schedule, Building Information Modeling

1. INTRODUCTION

BIM (Building Information Modeling) is a process where the virtual model of a building is prepared digitally. The BIM model contains all the necessary data which are required during construction. When BIM is implemented precisely on a project, it enhances construction process. With development in BIM in AEC industry structural engineers are now finding new ways to solve clashes in projects, provide better detailed drawings rather than estimating quantity and clashes. They also save time in producing these drawings as the changes in the model will update quantities as well and change will reflect in all the views associated with it.

Extensive research has been done in the application of BIM in finding out quantities of concrete, finishing items, brick masonry. This paper deals with the application of BIM in one of the most critical construction activities, i.e., reinforcement works because reinforcement in a R.C.C frame structure acts as a skeleton system of that structure and also the major cost of a R.C.C Structure is governed by reinforcement quantity.

In this research the results are compared to the case study of BIM vs. Non BIM approach. This paper is divided into following parts:

- 1) To begin with literatures available in the context of BIM and reinforcement detailing are considered.
- 2) Subsequently two case studies are taken. In the first case study BIM assessment (with BIM and without BIM analysis) is done from the contractor's side and in second

one BIM is implemented during execution to verify the result of the Case Study-1

- 3) The data is collected and analyzed with respect to cost and wastage in reinforcement in RCC structures.

2. LITERATURE REVIEW:

The BIM technology existed since 1970s. Building Information Model was first appeared in a 1992 paper by G.A. VanNederveen and F. P. Tolman. In 1987 Grahisoft launches ArchiCAD software which was the first CAD product for the personal computers, which was able to create both 2D and 3D geometry. The term BIM was not so popular until Autodesk released a paper titled "Building Information Modeling" in 2002. (9) The US National Building Information Model Standard Project Committee has defined BIM as "Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition"(10)

It is not easy to manage a project involving such a large number of people and documents, so some integration concept has to be developed where all information can be stored in a single place therefore AEC industry has found its solution by implementing BIM on various projects.

BIM gains so much importance that International Code Council is preparing SMART codes using BIM for

automatic checking with codes. The aim of BIM is to reduce the overall effort of structural engineers on a given project for a given fee. Cost of BIM Implementation is not a problem when the project is under budget. 61% of construction firms participated in McGraw Hills Construction Report agree that BIM is important for complex projects. (2) Using Revit (a product of Autodesk) is a faster way to prepare reinforcement detailed drawings with proper cutting lengths of reinforcement bars (4)

It is easy to visualize reinforcement pattern and it helps in reinforcement placement and avoid mistakes during construction and fabrication. BIM could save wastage in reinforcement and can add value for the customers. Bar Bending Schedule created by using BIM is accurate and can easily be changed within clicks when the reinforcement drawings changes. BIM increases productivity, provides better coordination and visualizations. Structural engineers can focus more on solving problems rather than coordinating and finding clashes and errors. BIM can act as a waste management tool since it finds quantities accurately. (1)

BIM facilitates integrated design and construction process that results in a better quality building at lower cost. A study by (Zhen Liu October 2011) shows that by implementing BIM can reduce construction waste, waste although its adaptation is relatively slow. (7)

3. DATA COLLECTION AND ANALYSIS

The data collected for case study-1 included all the reinforcement drawings and the quantities calculated without using BIM and with BIM. It was found that by using BIM, the contractor was able to find out the left out quantities.

In order to verify the result of the case study-1, the case study-2 was taken which was compared to small project but was also an R.C.C frame structure of the same nature. All the 2-D reinforcement drawings of the case study-2 were collected and a BIM model was prepared. The quantities and wastage with BIM and without BIM approach were compared.

3.1 Case Study-1 Introduction

The project was a high rise residential project. The project comprises of 4 towers (G+45). The main concern of implementing BIM from the contractor's side is that the project documents were not integrated and engineers got changed so there were many elements whose reinforcement quantity has been left out during calculation. Since the project was a high rise project having typical floors, therefore any quantity variation in the document leads to the huge wastage in the project. So the contractor has implemented BIM and claimed the left out quantities.

Table -1: Case Study-1 Details

DESCRIPTION	CASE STUDY-1
Type of project	RCC Frame Structure
Project location	Mumbai
Project cost	INR 388 CR
Project details	4 Towers (G+55)
Reinforcement Work Quantity (without BIM)	16388 TON
Reinforcement Grade	Fe 500
BIM Implementation	Post Construction

Table -2: Case Study-1 Quantity Comparison of BIM and Non BIM Approach (Finding left out quantities).

TOWER NO.	A CLAIMED QUANTITIES (MT)	B CLAIMED AS PER BIM MODEL (MT)	C=B-A DIFF IN QTY (MT)
Tower-3	5245.772	5250.962	5.19
Tower-4	3988.394	3988.354	-0.04
Tower-5	3836.933	3836.433	-0.5
Tower-6	3317.4	3334.659	17.259
TOTAL	16388.1	16410.69	21.909

% Difference = $\frac{(21.909)}{16388.10} = 0.13\%$

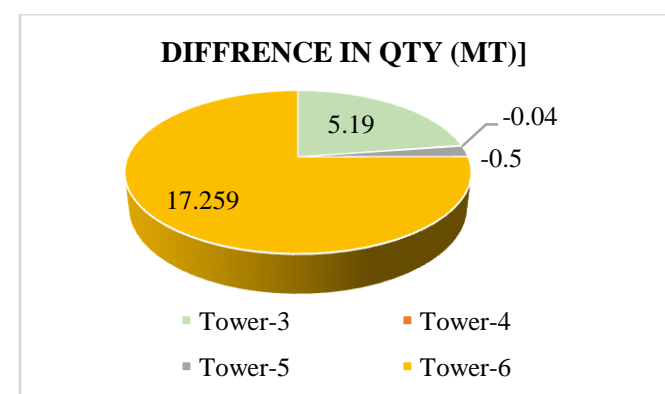


Fig -1: Difference in quantities of BIM and non BIM approach

3.2 Case Study-1 Outcomes

Table -3: Issues at site with Solution through BIM

Sr.No	Problems	BIM Solution
1	Drawings and data were not organized properly. Revised drawings were not kept separate	All the reinforcement drawings and data are integrated in a BIM Model.
2	Difficult to find left out quantities	As 3D model was prepared every structural element was reinforced, so left out quantities can easily be found.
3	Changes in drawings have been very often, so quantities should be updated accordingly.	Changes in the drawings will automatically change the quantities in the model and hence it saves time and money.
4	Manual errors were there in the quantity sheets.	As the model was visualized in 3-D, chances of manual errors were eliminated.

Table -4: Cost Analysis for Case Study-1

Sr No.	Description	Quantity Surveyor	BIM Engineer
1	Salary/month	INR 30, 000 /month	INR 35, 000 INR/month
2	Number of engineers	3	1
3	Cost of software	Nil	INR 80,000
4	Time taken for Reinforcement steel quantity takeoff (months)	7	5
5	Total cost	INR 6,30,000	INR2,55,000
7	Cost Saved by BIM	-	INR 9,85,905 (Refer Note)

NOTE: 1. Cost saved by BIM, is calculated by quantity recovered multiplied by my market rate of steel (INR 45, 000 * 21.909).

2. Total cost = (salary/month * number of engineers *time) + software cost.

2. Cost of BIM software is INR 2, 00,000 in total but cost considered is INR 80, 000 because software is used to calculate the quantity of concrete and formwork as well.

3. Salary of engineer which is taken into account is only for the Bar Bending Schedule preparation work.

3.3. Case Study-2 Introduction

The project was a 5 floor residential project. The project in comparison to the previous case study-1 is smaller. The BIM is implemented parallel to the traditional way of Non BIM approach. The quantity take off for all the construction materials is done by the same engineer at site. There were many complicated junctions in reinforcement which has been solved by BIM (in case of combined footing). The decision of implementing BIM is taken by the owner of the project because of his previous losses in wastage and to get the nearest estimated quantity of steel used in the project. The BIM and non BIM based quantities were compared at different phases of construction so that the client can monitor the wastage at various levels. Although the project was small scale but BIM has delivered its benefits. Since the BIM is implemented from the clients' side so BIM is

implemented right from the beginning of the project, so at various stages the reinforcement quantities with BIM and without BIM based were compared. Hence by monitoring through BIM they easily found out the wastage at different construction levels.

Table -5: Case Study-2 Details

Description	Case Study -2
Type of project	R.C.C Frame Structure
Project location	Ahmedabad
Project cost	INR 8 CR
Project details	1 Tower (Parking +5 Typical Floors)
Reinforcement Work Quantity	34.816 TON
Reinforcement Grade	Fe 500
BIM Implementation	During Construction
Level of detail of drawings	All 2D And 3D drawings

3.4 Case Study-2 Methodology

In Case study-2 the entire model of the structure is virtually modeled and the quantities of reinforcement are exported and compared with the quantities with the Non BIM approach. The difference in quantities is analyzed and the wastage has been calculated as given in table-6. Fig 2 gives the methodology adopted.

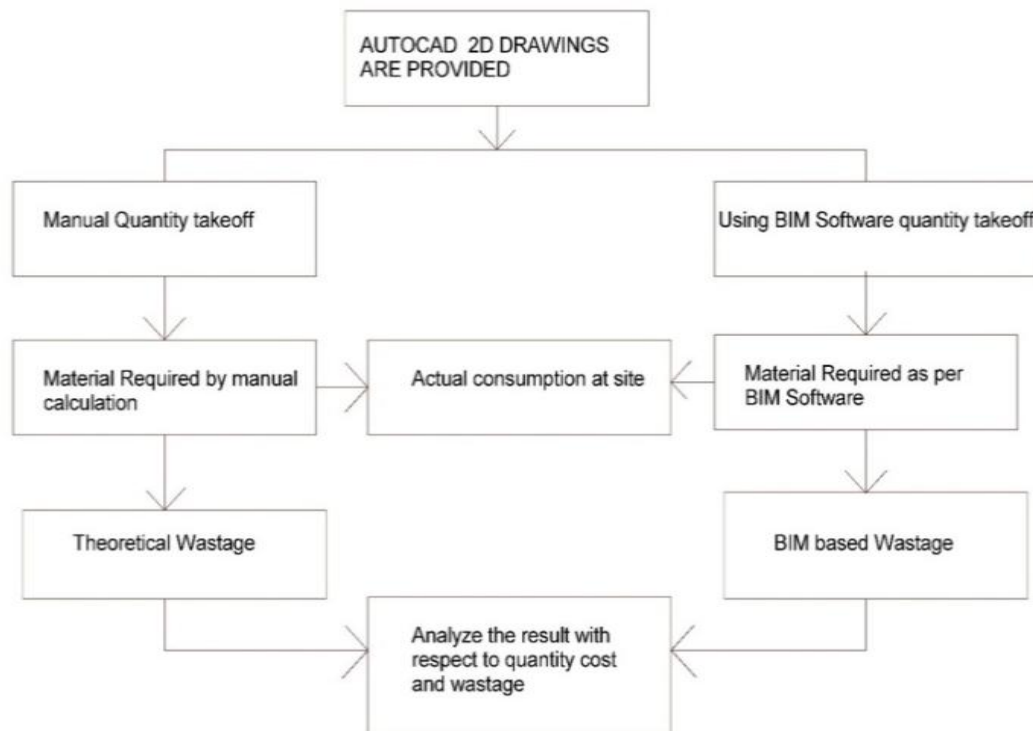


Fig -2: Methodology Adopted for Case Study-2

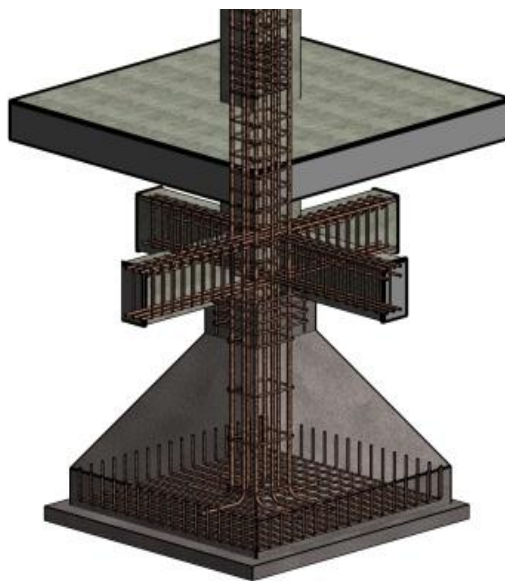


Fig -3: Footing reinforced by using BIM.

Table -6: Quantity Comparison BIM and Non BIM approach for Case Study-2

Sr.no.	Description	A BIM Based Quantity (MT)	B Without BIM Based Quantity(MT)	C=B-A DIFF (MT)
1	Total Quantity in Column verticals	12.752	13.201	0.449
2	Total Quantity in column footings	1.121	1.124	0.003
3	Tie beams	1.198	1.187	- 0.011
4	Typical floor beams	12.690	13.21	0.52
5	Typical floor (slabs+stairs)	7.055	8.021	0.966
	Total	34.816	36.743	1.927

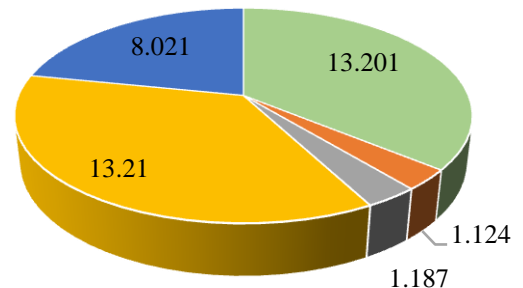
Table -7: Wastage Comparison BIM vs. Non BIM Approach

ACTUAL CONSUMPTION AT SITE (METRIC TON)	MATERIAL WASTAGE AS PER BIM BASED PROCESS (TON)	MATERIAL WASTAGE AS PER NON BIM PROCESS (TON)
13.345	0.593	0.114
1.237	0.116	0.113
1.265	0.067	0.078
13.82	1.130	0.61
8.325	1.270	0.304
37.992	3.176	1.249

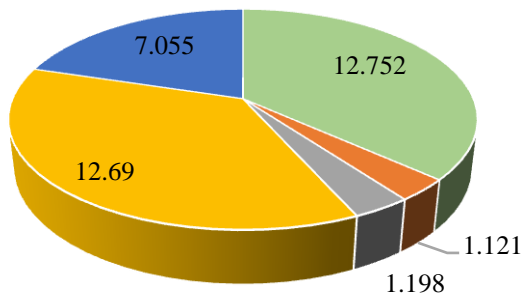
Note: Material wastage = (actual consumption – actual BIM and non BIM based quantities).

% Difference = $\frac{(36.743 - 34.816)}{34.816} = 5.53\%$

(Non BIM Approach quantity – BIM based approach quantity) / Non BIM Approach quantity * 100

QTY (ton) CALCULATED AS PER NON BIM APPROACH

- TOTAL QTY IN COLUMN VERTICALS
- TOTAL QTY IN COLUMN FOOTINGS
- TIE BEAMS
- TYPICAL FLOOR BEAMS
- TYPICAL FLOOR SLABS

Fig -5: Quantities as per BIM Approach**QTY(ton) CALCULATED AS PER BIM APPROACH**

- TOTAL QTY IN COLUMN VERTICALS
- TOTAL QTY IN COLUMN FOOTINGS
- TIE BEAMS
- TYPICAL FLOOR BEAMS
- TYPICAL FLOOR SLABS

Fig -4: Quantities as per Non BIM Approach**Table -8:** Cost Study of Case Study-2

Sr No.	Description	Quantity Surveyor	BIM Engineer
1	Salary/month (excluding site reinforcement checking work)	INR 28,000/month	INR 31,000/month
2	Number of engineers	2	1
3	Cost of software	Nil	INR 80,000
4	Time taken for Reinforcement steel quantity takeoff (months)	3	2
5	Total cost for 8months	INR 1,68,000	INR 1,42,000
6	The amount recovered through BIM	0	INR 86,715 (Refer Note)

Note: 1. The cost saved by BIM, is calculated by quantity recovered multiply by market rate of steel (INR 45,000 * 1.927)

2. Total cost = (salary/month * number of engineers * time) + software cost.

3. Cost of BIM software is INR 2, 00, 00 in total but cost considered here is INR 80, 000 because software is used to calculate the quantity of concrete and formwork.
4. Salary of engineer which is taken into account is only for the Bar Bending Schedule preparation work.

3.5 Reliability of BIM based Software

It is clear that using BIM software cut down the cost and manual work in quantity take off of reinforcement works. As explained by AEC magazine (2013) cost estimates are more precise due to parameters attached to the elements and the ability to label model content and categorized them into different items.

During the research the BIM Engineer explained how the BIM software can reduce the human errors by referring different views during modeling of elements. There are many plugins compatible with BIM software such as Sofisitk which increases the potential of software and give more accurate results and enhance speed of modeling of structures

3.6 Reliability of BIM Based Bar Bending Schedule

In the model the hook lengths, concrete cover, etc. all parameters are there in the BIM software which must be considered during placement of reinforcement bars in the model. The BIM model also contains various templates which can be modified according to Client's requirements and if any bar is left to be tagged in the model, then on the schedule its mark will be shown blank and we can easily find and tag it. Hence it can decrease the risk of incorrect manual inputs in the projects.

4. CONCLUSION

From this research study, it is clear that adopting BIM in projects will lead to reduction in wastage as well as it is cost effective, if it is implemented at the start of the project till the completion of the project. BIM initially may add cost to the project but with time it has the ability to give positive returns since the manual calculation will lead to errors. In Case Study-1 BIM has been implemented just to find out the left out quantities since it was implemented from the contractor side but if it was implemented right from the beginning of the project, the exact wastage could have been found out (as done in Case Study-2). So BIM is much more useful from the client perspective as it can monitor the wastage done by the contractor because he/she then knows the actual quantities with justification in BIM model. BIM can be beneficial to contractors for clash detection, during execution and finding out the maximum quantities he/she can claim. So BIM is beneficial both for the contractors and clients because they both want to know the actual figure of quantity of materials to be ordered at the site with justification.

Benefits of BIM as far as reinforcement works are considered are summarized below:

1. BIM will lead to cost saving in RCC frame structures and the amount saved (wastage) is directly proportional to the scale of the project. It's very effective in terms of cost saving when the structure is a high rise (skyscraper) as number of floors increases reinforcement quantity.
2. BIM hence reduced waste generated on site as it export proper Bar Bending Schedule from its models leading to reducing of bar cutting wastage onsite. It provides well detailed 3D drawings which help to visualize (especially in complicated junctions) and can solve many clashes at the site, hence saves time. Leading BIM software's are able to export information of models in excel and dwg format which is widely used in every large and small scale projects.
3. BIM easily identifies the left out (missing) quantities because of its strength in producing 3D visuals which solves many critical junctions easily.

Table -9: Bar Bending Schedule preparation cost

Description	Non BIM Approach	BIM Approach
Bar Bending Schedule preparation cost for case study-1	INR 63,0,000	INR 2,55,000
Bar Bending Schedule preparation cost for case study-2	INR 1,68,000	INR 1,42,000

Note: Refer table 3 and table 8 for details

Table -10: Results of the two Case Studies

Description	%
% of reinforcement left out quantities recovered during reconciliation in Case Study-1 (Implemented from contractor's side)	0.13% (Refer Table-2)
Wastage reduction in Case Study-2 1 (Implemented from client's side)	5.53% Refer Table-6)

For implementing BIM in reinforcement work at a site, a well experienced person which is familiar with construction site activities and also with BIM tools are required which is rare combination in India.

The initial cost of BIM is high, so most owners and contractors refuses to adopt BIM. Reinforcement in BIM requires high technical skills. It takes time in modeling, structural elements. However, when often changes in drawings take place it modifies quantity within few clicks.

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