ISSN (Online) : 2454 -7190 **ISSN (Print) 0973-8975**
Copyright reserved © J.Mech.Cont.& Math. Sci., Vol.-14, No.2, March-April (2019) pp 385-401

ASSESSMENT OF STRUCTURAL DESIGN CAPABILITY OF BUILDING INFORMATION MODELING (BIM) TOOLS IN BUILDING INDUSTRY OF PAKISTAN

***[1]Muhammad Shoaib Khan, [2]Mohammad Adil, [3]Adeed Khan**

[1, 2] Department of Civil Engineering, University of Engineering and Technology Peshawar, Pakistan

[3] Department of Civil Engineering, Iqra National University, Pakistan

Email: 15pwciv4320@uetpeshawar.edu.pk[1], adil@uetpeshawar.edu.pk[2] adeedkhan@hotmail.com[3],

https://doi.org/10.26782/jmcms.2019.04.00030

Abstract

In Pakistan, lack of adoption of modern automated designs tools have kept the drafting, designing and construction industry, unintegrated. Almost all draftsman provide their architecture design in AutoCAD with a lot of limitation. These limitation tends to create hurdles for structural engineer while designing. After design detailing in AutoCAD and preparation of BOQ and cost estimation in a non-interoperable software is a tedious work and require time. The Architecture Engineer and Construction (AEC) trades needs such techniques to drop project rate, delivery time and increase quality, efficiency and productivity. Building Information Modeling technology can be used as a choice to get above mention parameters in which an accurate BIM model is constructed in software which is used for planning, designing and construction of the facility. In this paper BIM tools Revit and Robot structural analysis professional software are used for design and analysis of structure and in ETABs software for cross check. Detailing, BOQ and cost estimation reports are prepared at the end.

Keywords: Building Information Modeling, BIM model, Robot structural analysis, cost estimation

I. Introduction

Architects and Structural engineers are looking for new methods and software which is more important tools to stay in competition, save time, coordination and improve products in drafting, designing and construction [11]. Building Information Modeling can helps in these aspects potentially. The main features of BIM is that it has the ability to integrate objects which contain all types of data regarding geometric, semantic etc. which makes model full of integrated information which is needed for architect and engineers while designing. The use of model is not new because big companies like Toyota Company are using models from time during

design and construction phase in manufacturing and complex engineering process (Autodesk 2011). But the application of these models full of information is necessary for infrastructure and building which is developed in AEC industry by BIM. From its initial stage around 1978 Building Information Modeling has been extensively used in drafting, designing and construction industry [6]. Building Information Modeling (BIM) is a set of relating strategies, methods and tools making a "policy to accomplish the necessary building plan and project facts in alpha numeric layout during the building's life-cycle". As a basic part in the project development, contractors play a main role in making guaranteed the project will be delivered on time and within the budget. BIM modernize the AEC agency, being not only a revolution among CAD and parametric modeling with 3-D abilities, but a variation of workflows, methods, practice, and associations. Fundamentally it changes the way trade is done throughout the industry. These modifications may appear too ample to be simply recognized by the industry, the paybacks are ample superior, making Building Information Modeling the prospect for the business.Building Information Modeling (BIM) has lately accomplished well-known consideration in the AEC industry. BIM signifies the change and use of simulated n-Dimension models to put on the formation, design, creation and task of a facility. It helps AEC to envision whatever is to be built in computer-generated setting and to recognize probable design, structure or operative problems.

Using Building Information Modeling (BIM) helps to characterize the method of improvement and use of a simulated model to put on the planning, design, construction and set-up of a capability as shown in Figure 1. The subsequent model, a BIM, is a data-rich, object oriented, intellectual and parametric ordinal illustration of the aptitude, from where the user can assess the suitable data, desires can be take out and examined to create info that can be helps to make the results and to develop the procedure of conveying the ability [2].

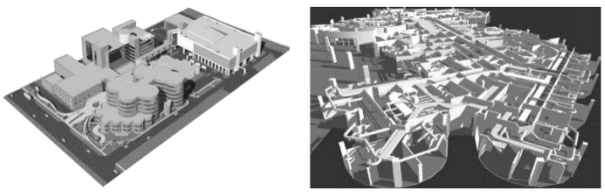


Figure 1.3D Architecture Model

The major alteration stuck between BIM and 2-Dimension CAD is that the second defines a structure by self-determining 2-Dimension views such as plans, cross sections and elevations. If one of these views are edited than all other views should be examined and updated, an error-prone method that is one of the main reasons of bad documentation. Info in these 2-Dimensional drawings are graphical units only, such as semi-circle, lines, and circles, where effects are clear in terms of structural elements such as walls, spaces, columns and beams [5]. Many researchers concludes that BIM is an evolution to CAD technologies and will results effective drafting, designing and construction [10].

A BIM illustrates the geometry, 3-D associations, geographical data, magnitudes and possessions of building basics, rate estimations, solid records and project agenda. This model can be used to establish the whole building life cycle [1]. From the result, magnitudes and mutual assets of materials can be freely pull out. Opportunities of work can be simply insulated and well-defined. Classifications, assemblages, and arrangements can be shown in a kin scale with the whole facility or group of facilities. The structure documents like submittal processes, procurement details, drawings and other terms can be simply organized [9].

BIM has application in structural engineering and engineer can take benefits of that while designing buildings as the model can be updated with any changes at any time and changes in one view will apply in all model while keeping data accurate [3]. Research and development in academics and industry has brought many powerfull,interoperbale and practicle BIM tools for structural analysis and design,detailing and estimation [10]. BIM will help structural engineer through most important design steps like conceptual design, detailed design, structural analysis, detailing and drafting, and the most important step which is calculation of bill of quantity and cost estimation. Structural engineer can take benefits of BIM in drawings and coordination [7]. BIM allow the different team members to coordinate fabrication of building system and not limited to show design to owners and stakeholders [11]. The beginning of BIM has more application in arhcitectural design but with evolution of new tools in the field has increased its application for structure engineer. BIM allow collaboration among engineer, architect, electrical, plumbing and mechanical professional to work on the same model [4] and this is the most important application of BIM that many professional can take advantage from one same model [7] . BIM model contain information related to structural analysis, project management, Cost estimation and energy analysis.

This paper has focused on the application of Building Information Modeling tools that can helps for structural analysis and design of buildings. For this REVIT and Robot structural analysis professional software are implemented for analysis and design of building and also detailing, BOQ and cost estimation reports were prepared at the last. Some part of this paper [8] has been done and further study are continued in this paper and improved.

II. Modeling in Revit and Robot Structural Analysis Professional Software

In order to assess the structural capability of BIM tools first model will be created in BIM tools which is Revit and Robot structural analysis professional software.This method is totally based on software work. So first step in analysis and design procedure to create an accurate 3D model in software before going to analysis and design.For this 3D model was created using Revit software and it will be used as support to structural engineer to do analysisafter it will be exported into Robot structural analysis professional software for analysis and design. Revit software has both physical and analytical model. Physical model is used for coordination and drawings while analytical is exported for structural analysis and design through plugin. Project will be started as new or open in Revit software andunits setting is important before starting and grids and levels should be defined for project.

Now BIM model will be created in Revit which having information in the form of geometry which is given in below table 1. These information will be used for further analysis and design, drawings and quantity of these geometries will get BOQ and cost estimation reports. By using Revit it is easy to prepare model with input and all the data can be directly transferred from Revit analytical model to Robot structural model. Analytical model in Revit is shown in figure 4 and Robot software structure model in figure 6.

Table 1. Geometric properties of BIM model

S.No	Beams (in.)	Columns (in.)	Slabs (in)
1	12x16	15x15	5

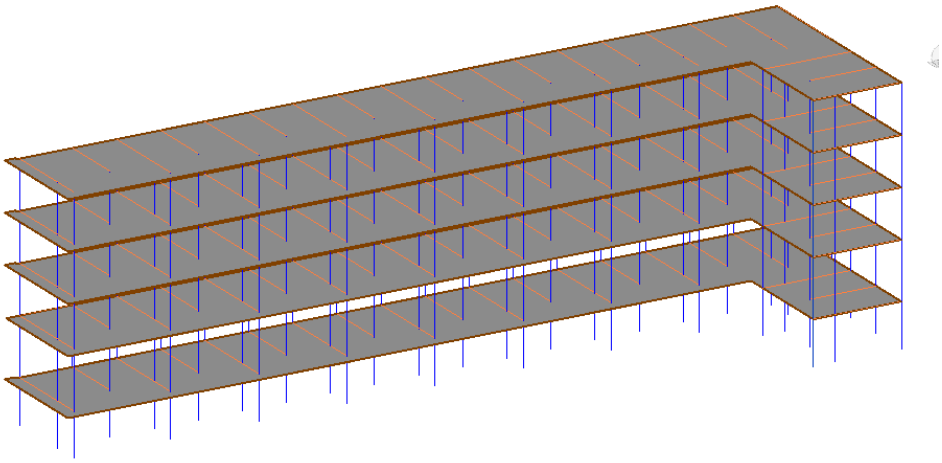


Figure 3. Analytical BIM Model

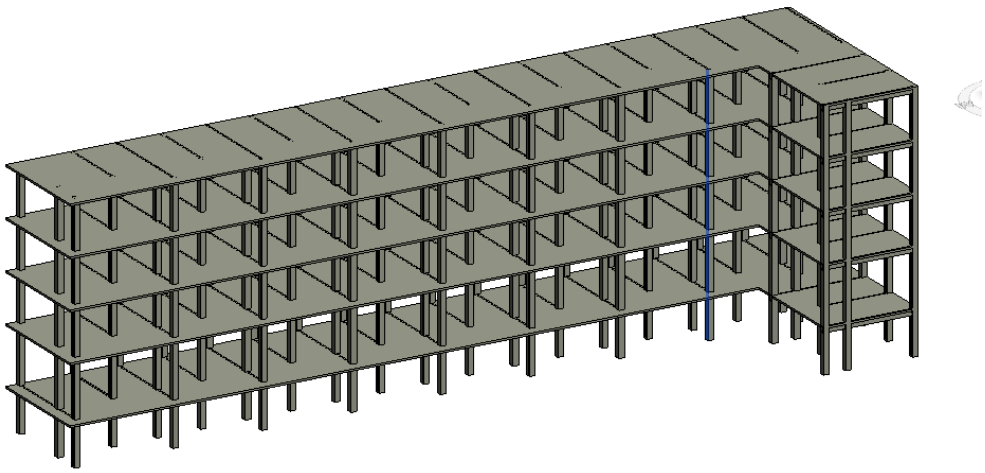


Figure 4. 3D physical BIM model

Physical model is created in Revit software by using families of concrete beams, columns and slabs as shown in above figure 4, 5. In this model changes in one view will apply to all views. This model is exported into Robot SAS through structural analysis toolkit 2107 plugin [12]. Now the model is ready to export to Robot structural analysis software for analysis and design. Minor mistake are noticed and are corrected. Model in Robot structural analysis software is shown in figure 6. After exporting the model from Revit to Robot few steps were followed like material are defined in geometry tab and strengths are specified to each material. Also loads are defined in load tab. After defining each material mashed structure are created for exact analysis. Simply the structure is analyzed by clicking on calculation and results which will give the results as shown in figure 7, 8.

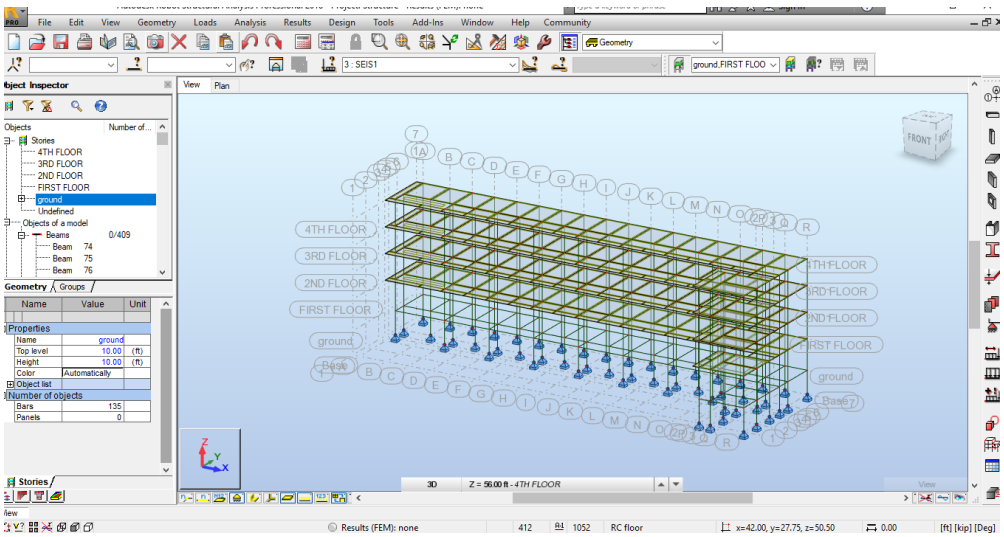


Figure 5. Robot structural analysis software model

Structural model needed information of element, types and its properties, loads and boundary condition which is assigned to BIM model and now we can proceed for structural analysis and design. Now the benefit of using BIM is that if structural engineer update its model during analysis it will be updated automatically for draftsman and BIM has interoperability and its tools are interconnected.

The material properties used for structural analysis in Robot software are listed below in table 2.

Table 2. Material Properties

S.No	Material Description	Material Property	Remarks
1	Concrete used In R.C members	compressive strength=3500psi Modulus of Elasticity = 3368ksi Poisson's ratio = 0.20	28-days compressive cylinder strength
2	Reinforcement steel used in R.C members	Yield Strength = 60,000 psi Modulus of Elasticity =29000ksi Poisson's ratio = 0.30	Grade-60 deformed round bars conforming to ASTM A-615

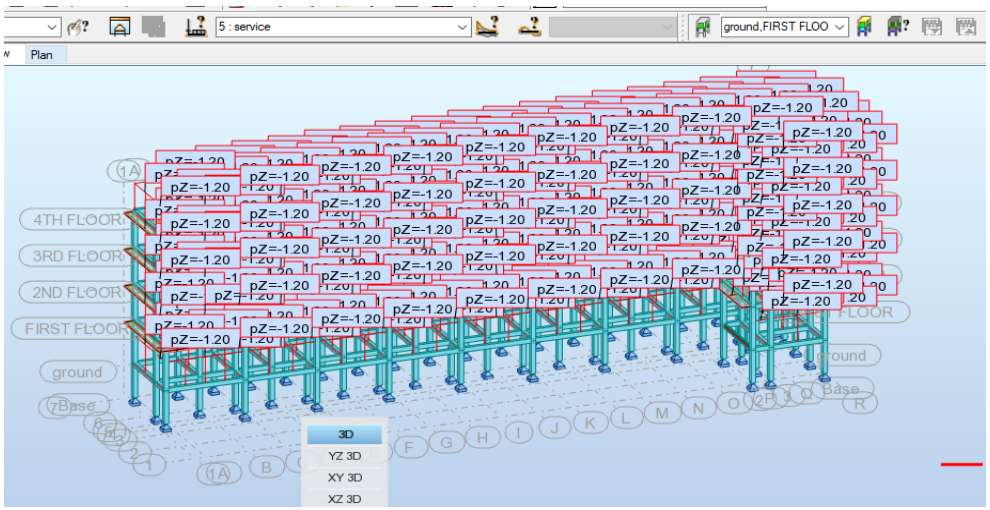


Figure 6. Analysis of meshed structure

III. Modeling in Etabs Software

Etabs becomes common design industry tool in Pakistan used for analysis of buildings is used in this paper for cross check with BIM tools. So model is also created in Etabs software for analysis. The material and geometric properties used for analysis are listed in Table 1, 2.

The above parameter were used for used for modeling in Etabs 9.7.4. Loads are defined and assigned according to standard method load applied were consistent with the robot structural analysis model. For modelling beam and column line elements were used and shell elements were used for modelling slab and shear walls. 3D model in Etabs software and loaded structure are shown in figure 9, 10.

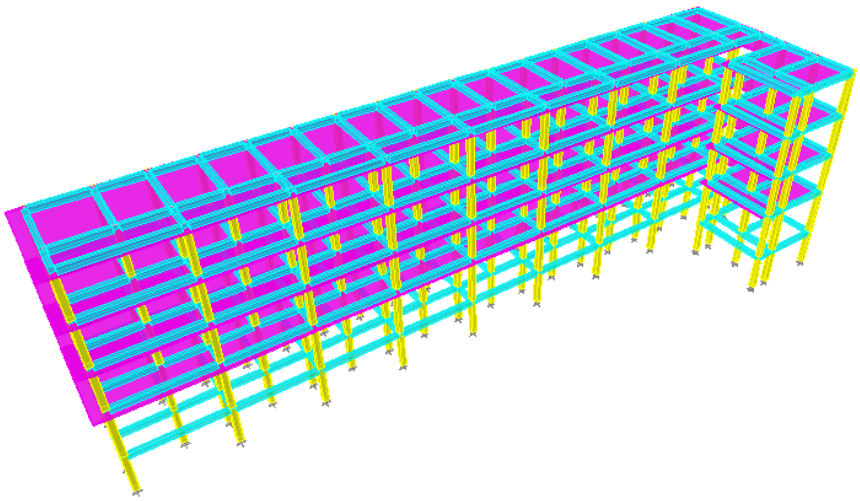


Figure 7. Etabs Model

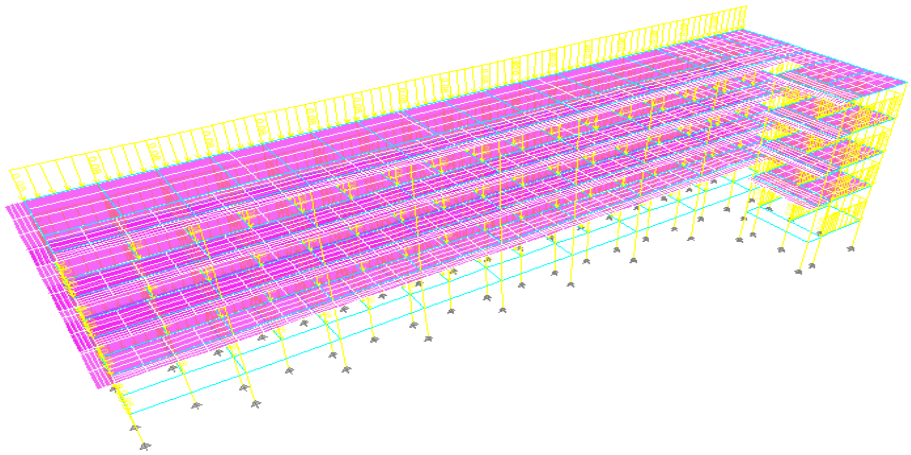


Figure 8. Loaded Meshed Structure

After assigning all loads to each member the model is ready for analyzing but before analysis mesh will be created for better analysis results. Meshed structure are shown in figure 11.

IV. Results and Discussion

A. Robot Structural Analysis Professional Software Results

The next step is to analyze building and show its results. The structure was analyzed under the applied load and its response can be shown in tables, diagrams with values. We continued with our structural model and its meshed model is created shown in figure 11. We can check for diagrams or table to see results as robot software is a versatile and fast computing software and calculates results of most complex structure within minutes. Deflected shape of model is shown in figure 12. Stresses in members, deformation, reactions can be listed in table or in diagrams.

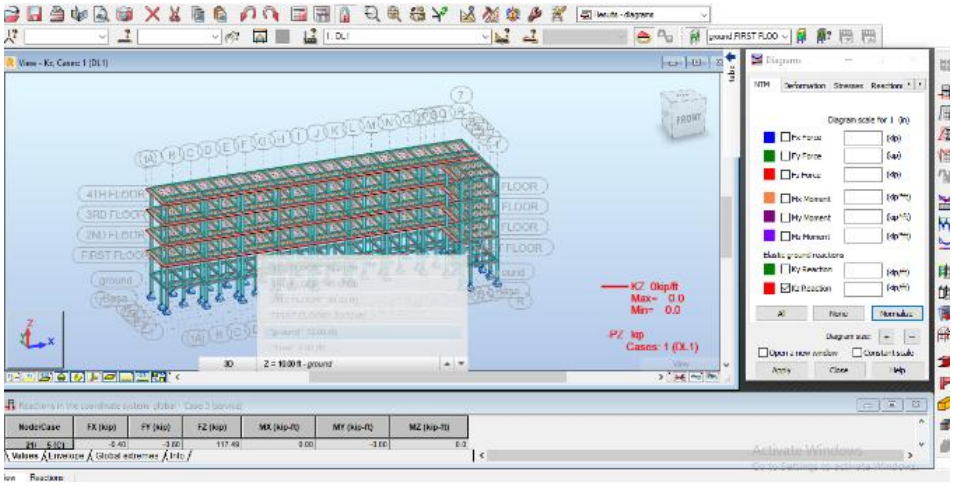


Figure 9. Analyzed Meshed structure

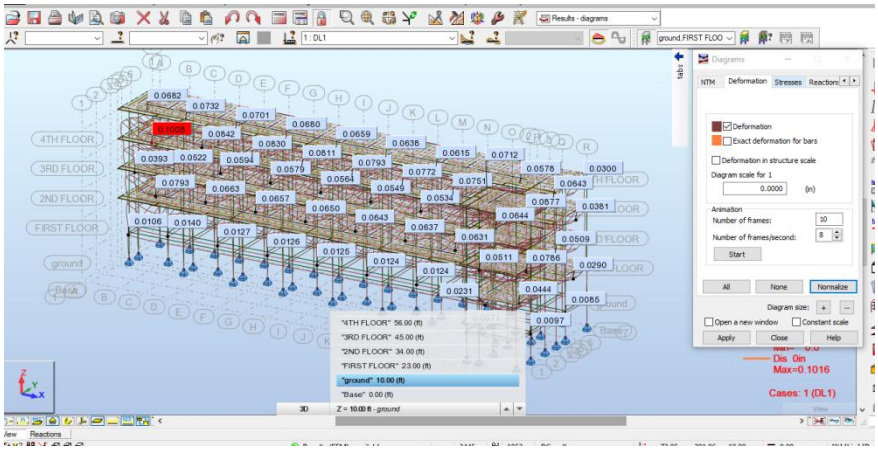


Figure 10. Deflected Shape

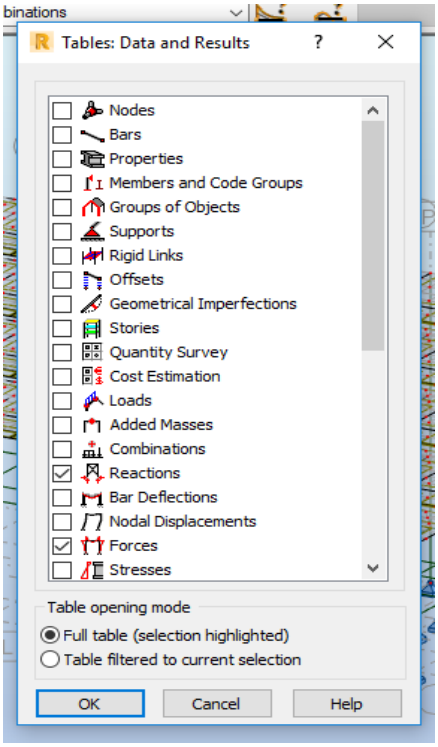


Figure 11. Table

From above figure 13 it is clear that different results can be computed in Robot software which is useful in structural analysis and design. Also quantity can be calculated and its cost which is then used in documentation. Drawings can also be drawn for same model and its detailing can be shown in diagrams or in tables. Beams drawings and quantity are shown in figure 14, 15.

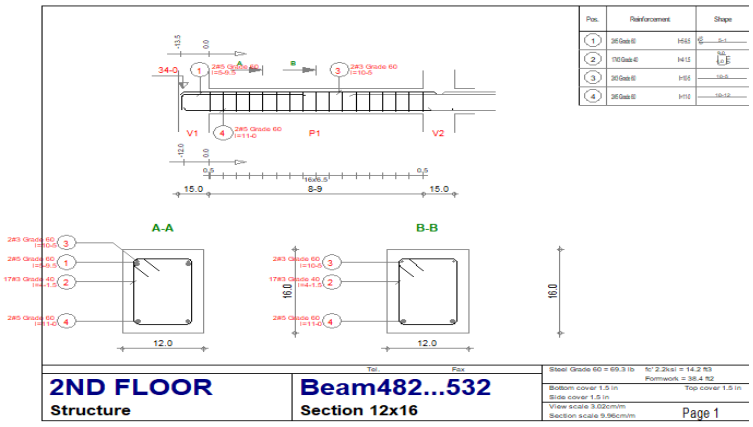


Figure 12. Beam drawings

Type	Number	Length (ft)	Unit weight (kip/ft)	Bar weight (kip)	Total weight (kip)	Painting area (ft2)
STEEL						
W 16x4	1	20.01	0.04	0.80	1	99.06
Total per						
W 16x4	1	20.01	0.04	0.80	1	99.06
Total					1	99.06
concrete						
B R12x	10	5.02	0.20	1.01	10	234.25
B R12x	50	6.53	0.20	1.31	65	1523.40
B R12x	5	7.78	0.20	1.56	8	181.43
B R12x	185	10.01	0.20	2.01	371	8639.00
B R12x	10	12.01	0.20	2.41	24	560.37
B R12x	105	15.03	0.20	3.01	316	7362.86
B R12x	39	20.01	0.20	4.01	156	3642.39
B R12x	5	22.01	0.20	4.41	22	513.67
C R15x	54	10.01	0.23	2.35	127	2701.77
C R15x	162	11.02	0.23	2.59	419	8929.13
C R15x	54	13.02	0.23	3.06	165	3516.73
Total per						
B R12x	409	4855.15	0.20	972.87	973	22657.37
C R15x	270	3029.53	0.23	711.39	711	15147.64
Total					1684	37805.01

Type	Number	Thickness (in)	Unit weight (kip/ft2)	Area (ft2)	Volume (ft3)	Total weight (kip)
concrete						
TH12_	212	5.00	0.06	19180.00	7991.67	1201
Total				19180.00	7991.67	1201

Figure 13. Quantity reports

Detailed quantity reports and drawings were papered in Revit software. This same model is transferred into Revit software for detailing and documentation. BIM model is reinforced in Revit software which is shown in figure 16.

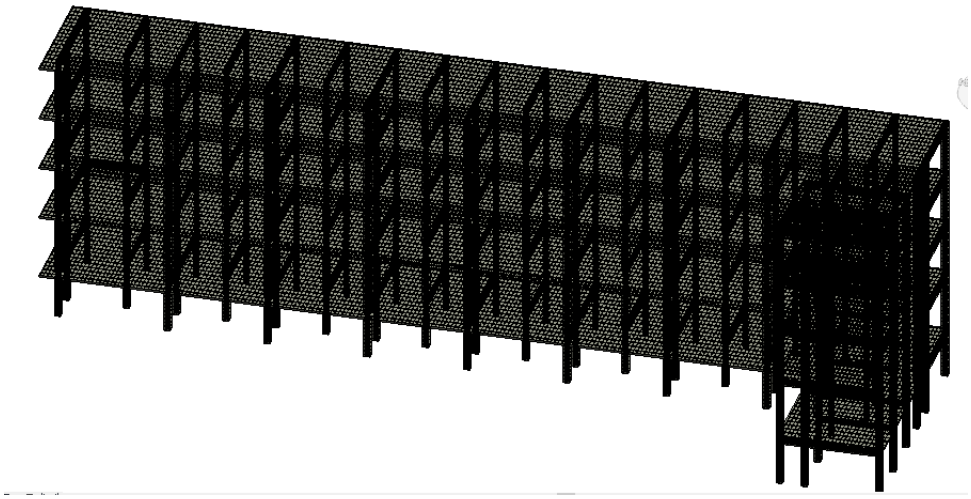


Figure 14. Reinforced structure

Above model is created once and was used for analysis and design in Robot software and now it is reinforced automatically in Revit software and detailing at any section can be done in a minute with simple clicks. One section details is shown in figure 17.

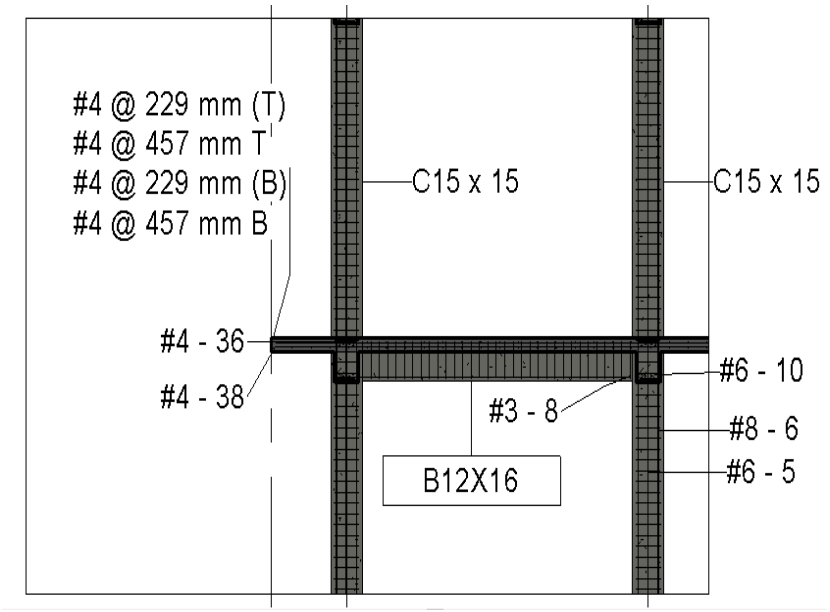
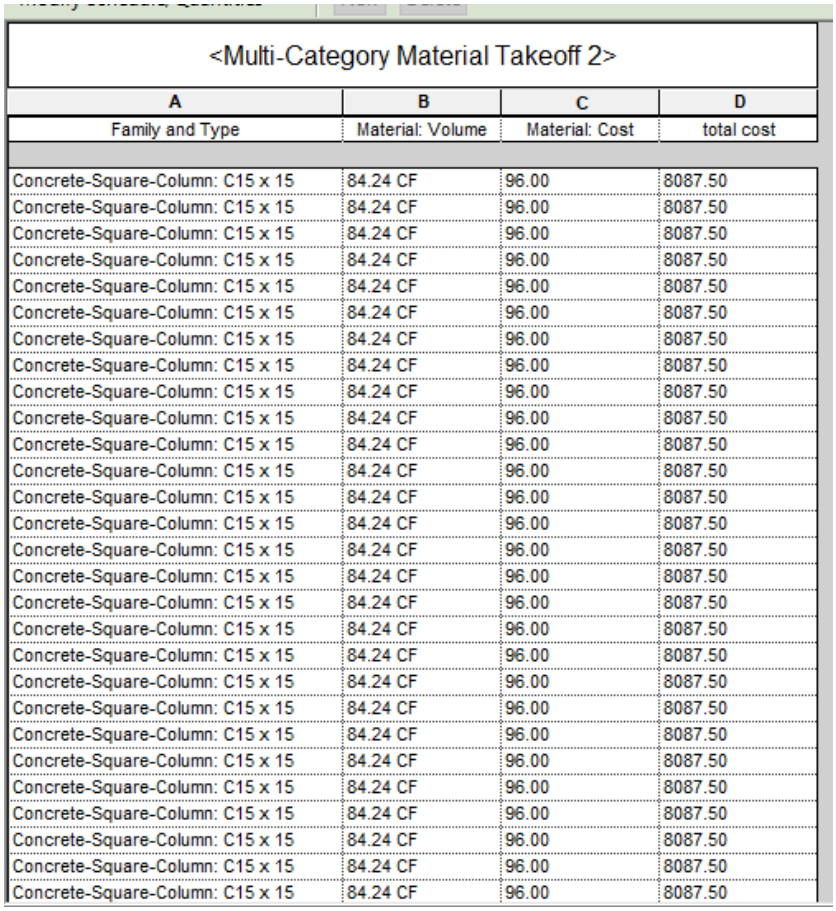


Figure 15. Section detailing

Detailing of section is shown and it can be seen that Revit has capability of most effective drawings. Also for special resisting moment frame column reinforcement must pass through beams which can be seen clearly in above section. Also reinforcement clash detection can be done easily in BIM.The most important benefit of using BIM is that we can takeoff quantity and cost estimation in the same model and in same software. Also this reports can be transferred into excel sheets through Di roots Plugin [13]. In figure 18 concrete column quantity, Cost per CF and total cost is shown. The same was done for beam and slabs and total cost of beam, column and slabs can be seen in figure 19, 20, 21. In the same manner steel quantity is taken off and its cost is calculated shown in figure 22.



<Multi-Category Material Takeoff 2>

A	B	C	D
Family and Type	Material: Volume	Material: Cost	total cost
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50
Concrete-Square-Column: C15 x 15	84.24 CF	96.00	8087.50

Figure 16. Column quantity and Cost Estimation In Revit

Element ID	Family and Type	Volume	Cost	Total Cost
229811	Floor: conrete 5in	2062.80598958	96	198029.37
230539	Floor: conrete 5in	2062.80598958	96	198029.37
230570	Floor: conrete 5in	2062.80598958	96	198029.37
230601	Floor: conrete 5in	2062.80598958	96	198029.37
230632	Floor: conrete 5in	2062.80598958	96	198029.37
				990146.87

Figure 17. Slabs Quantity and Cost estimation

A	B	C	D	E	F	G	H
Element ID	Family and Type	Rebar Number	Reinforcement Volume(in^3	density(ton/in^3)	Mass(tons)	Cost(Rs)	total Cost(Rs)
214523	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
214743	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
214764	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
214765	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
216102	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
216103	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
216104	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217756	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217757	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217818	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217819	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217820	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217821	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217844	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217845	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217846	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217847	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217870	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217871	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217872	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217873	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217896	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217897	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217898	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
217899	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
223814	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
223815	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
223816	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
223817	Rebar Bar: #8	6	525.43137131	0.000132	0.069356941	111598	7740.095903
							1671860.715

Figure 18. #8 Bars Quantity and Cost Estimation

B. Etabs results

This building is also model in Etabs software which is common industry tool for analysis in Pakistan. Building is created and analyzed while having loads applied as that in Robot software. Deflected shape and bending moments, shear force diagram is shown in figure.

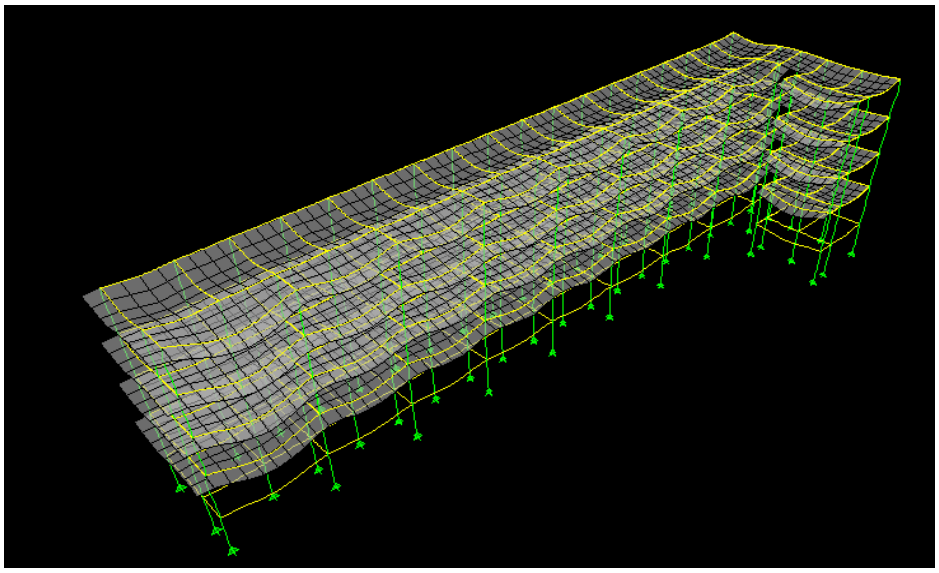


Figure 19. Deflected shape

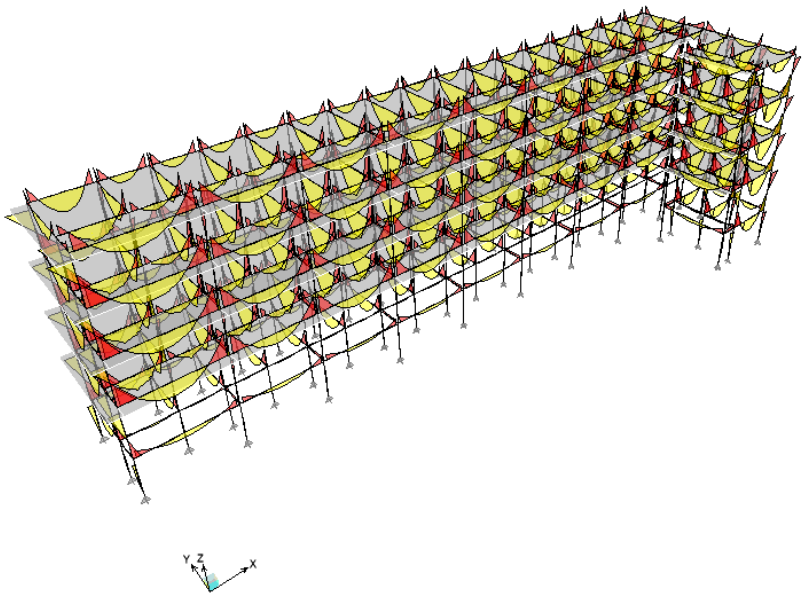


Figure 20. Bending moment Diagram

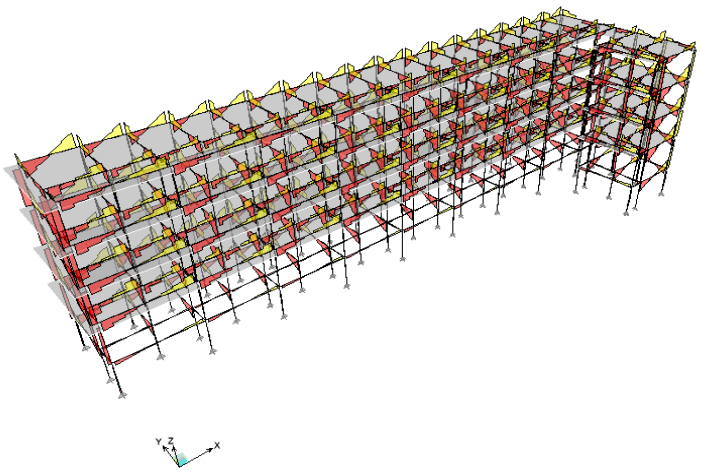


Figure 21. Shear Force Diagram

Results of Etabs software are shown and it is clear that analysis results are efficient and comparable with Robot structural analysis professional software as both are FEM software. But for drawings Etabs is not supporting this and it will be done in AutoCAD manually in which there is no interconnection. Cost estimation without BIM tools will be done manually and take time and have a lot of limitation. Also changes in Etabs models will not be updated in AutoCAD model. As can be seen from the results, modelling in Robot is very advantageous as it gives all results in one go while in ETABS it requires a lot of work. Robot model after analyzing gives us a very comprehensive structural drawings which ultimately reduce time of construction on site as making drawings in AutoCAD takes a lot of time. Also modelling in Robot is very simple and easy as compared to ETABS modelling.

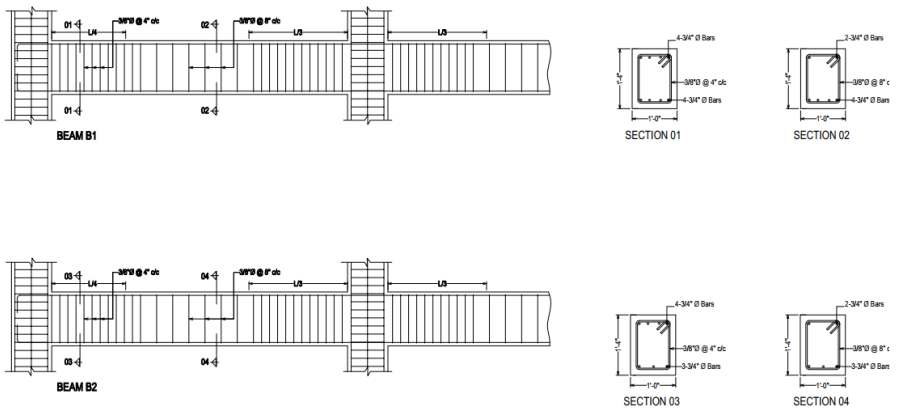


Figure 22. AutoCAD Drawing

V. Conclusion and Recommendation

Following has been concluded after detailed study

1. BIM, being an efficient method of modelling, is becoming crucial for modern age construction.
2. Building information modeling reduces the error and save time.
3. It stores all related data of the building in united, consistent and quickly reachable record.
4. The accessibility of the data facilitates the design analyses.
5. It reduces the chances of user mistakes caused by multiple data entries.
6. Robot as a BIM tool is a well-integrated package for civil engineers of every field.
7. The resulting drawings are fully integrated to the model and any change in the model would subject to change in the drawings.
8. It accurately estimates the bill of quantity and cost of the project. Well documented reports are also generated in Robot for the model.

Following additional research is recommended for future.

1. Robot analysis results can be compared with other FEM software's to check its reliability.
2. It should be find out whether we can use Robot for modelling piles and other soil-structure interaction problems.

References

I. A BIM illustrates the geometry, 3-D associations, geographical data, magnitudes and possessions of building basics, rate estimations, solid records and project agenda. This model can be used to establish the whole building life cycle.

II. America, A. G. C. (2005). The contractors guide to BIM. *URL: http://iweb. agc. org/iweb/Purchase/ProductDetail. aspx*.

III. Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and management in engineering*, *11*(3), 241-252.

IV. Bynum, P., Issa, R. R., & Olbina, S. (2012). Building information modeling in support of sustainable design and construction. *Journal of Construction Engineering and Management*, *139*(1), 24-34.

V. CRC Construction Innovation. (2007). Adopting BIM for Facilities Management: Solutions for Managing the Sydney Opera House, Cooperative Research Center for Construction Innovation, Brisbane, Australia.

VI. Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors*. John Wiley & Sons.

VII. Joannides, M. M., Olbina, S., & Issa, R. R. (2012). Implementation of building information modeling into accredited programs in architecture and construction education. *International Journal of Construction Education and Research*, *8*(2), 83-100.

VIII. Khan M. S., Khan A., Adil M., Role of Building Information Modelling (BIM) in building design Industry, INUMDC 2018, November

IX. Khemlani, L.; Papamichael, K.; and Harfmann, A. (November 02, 2006). The Potential of Digital

X. Migilinskas, D., Popov, V., Juocevicius, V., & Ustinovichius, L. (2013). The benefits, obstacles and problems of practical BIM implementation. *Procedia Engineering*, *57*, 767-774.

XI. Nawari, N. O. (2012). BIM standard in off-site construction. *Journal of Architectural Engineering*, *18*(2), 107-113.

XII. https://apps.autodesk.com/RVT/en/Detail/Index?id=5990906472327823538&appLang=en&os=Win64

XIII. https://diroots.com/plugins/revit-plugin-sheetlink-download/