

Modelling, Analysis and Design of a Multi-Story Building by Using Building Information Modelling (BIM) Approach

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Abstract - In the current paper, Building Information Modelling (BIM) approach presents by modelling, analysis and design G+5 building. The paper illustrates the strength of BIM tools in 3D modelling and analysis as well as design, where these software are able to understand the input as a structural member, not only lines or areas. Three different software had used with a good integration between them. The paper demonstrates that the software are just tools to come up with a good result, high efficiency and proper construction with lesser difficulties and mistakes, because BIM is not limited in some tools. Indian Standard I.S 456-2000 had used for design purposes, and checking the design results of the software. The beams, columns had been designed by Robot Structural Analysis (RSA) Professional software, while the structural and architectural model had been done by Autodesk Revit. Scheduling of columns and beams is done for this work.

Key Words: BIM, RCC structure, 3D Modelling, Structural Analysis and Design, I.S 456-2000, Architectural Modelling.

1. INTRODUCTION

The building information modelling (BIM) has many different definitions, and every definition has a specific meaning. The BIM is a digital representation of physical and functional characteristics of a facility (1). BIM is not a new technology in the capital facilities industry, where it was under different terms such as product model, virtual building, and intelligent object model, and these technologies have been found and used for over twenty years (2). In Building Information Modelling Belgian Guide for The Construction Industry (3), there are two definitions for BIM, one of them means, the BIM is a process, which can be done by more than one engineer by doing the work together as a team, by that, the number of errors will be decreased and the construction will be faster, because the exchange of information (data and geometry) and collaborate is faster with high efficiency so that will produce less waste. And the second definition means, BIM is a deferent software platform which allowed the working team to understand the information and detailing of a project by knowing the properties of every element in the 3D model. Also BIM can be defined as a 3D modelling of a project including all the project components with links to all the required information connected with the project's construction or process planning, and decommissioning. So based on above definitions, it can be realized that BIM is applicable in various field in the lifecycle of a project, and one of them is the phase of analysis and design a project by using

BIM tools (software) to be ready for scheduling, drafting and construction. The BIM deals with any software in this field as a tool only, and the users have to use these tools carefully to come up with high quality and efficiency. The 2D drawing is not enough to understand all details of a structure, and it takes a lots of time to show some important detailing, this problem forced the engineers to try finding good tools to avoid all 2D drawing problems. For example, by using Revit software, the engineers are able to find the problems and solve it before construction, and the client or owner is able to see the looking and view of the structure, and the manager will be able to deal with the structure easier. The structural analysis and design software which are working by the concept of BIM are many, and one of them is Robot Structural Analysis (RSA) Professional from Autodesk company. This software has a very good integration with Autodesk Revit (software from Autodesk company, it is used for 3D modelling and scheduling for Architecture, Structure, and MEP modelling). RSA Professional is used in analysis and design for deferent type of structures. The software has many design codes for steel structures as well as RCC structures even some codes for design timber structures. In this software, it is possible to design steel and RC column and beam with good details, also the design of footing and raft foundation is available, as well as slabs. In 2015, Autodesk added wind load simulation, and CFD modelling in RSA Professional, where the software takes care the calculation of wind pressure on building and show the pressures on members. In this paper, the strength of BIM is shown by modelling, analysis, and design a G+5 building under vertical load only, because the object of this work is to show the integration between tools of BIM and how BIM safe time and cost.

2. Description the RCC members and materials

The building has parking and 5 stories. The parking height is 3.5 m and the other stories having height 3m, so the total height is 18.5m with area 207 m² in every story. The cross-section of columns and beams is deferent due to the deference of load value on these members. The size of used columns was (250x450, 250x300 and 250x500) mm² unit, where the size of beams was (250x400 and 300x500) mm². And the slab thickness was 150 mm. The M25 concrete grade has been assumed for all beams and slabs, while M30 grade for all columns. The steel grade was assumed 415 MPa for main reinforcement, and 250 MPa or 330 MPa for secondary reinforcement. The design code which has been used was I.S 456-2000. The architectural model is shown in Fig.1 by using

Autodesk Revit, and the structural modelling is shown in Fig.2 by using RSA professional.



Fig-1: Architectural view of building

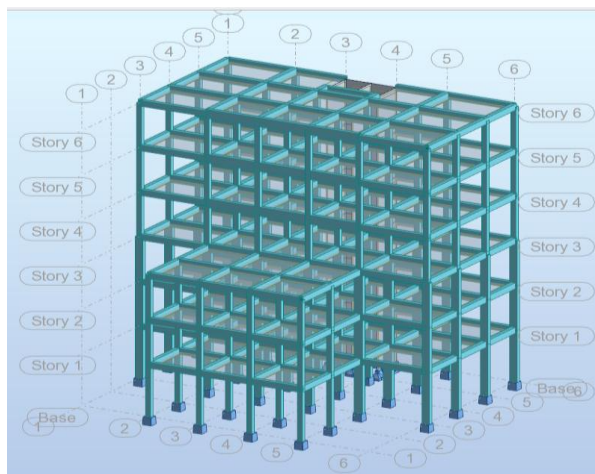


Fig-2: Analytical (structural)model

3. THE METHODOLOGY and PROCESS

In the beginning, the cross-sections of beams, columns and slabs were assumed, and the structure was modelled in Autodesk Revit 2017, to show clearly the members and to ensure the correctness of structural model by comparing the model with the architectural model which has done also in Revit. Fig.3 is shown the structural model in Autodesk Revit 2017. After completion the structural model, the model sent to RSA professional directly. It is worth to note that the integration between these two software is very good, because both of them from same company, and both of them are BIM tools. It is worth noting that, while definition of beams, columns or any structural member, the Autodesk Revit understands those members as a beam or column and so on, so that means the analytical model is generated directly in Autodesk Revit, even the material can be defined in it before sending to RSA Professional. Then after exporting

the structural model from Revit to RSA, the model has been analyzed under gravity loads only (as the objective of paper is showing the BIM steps and tools, the load cases were taken as a simple case, live loads and dead load including self-weight).

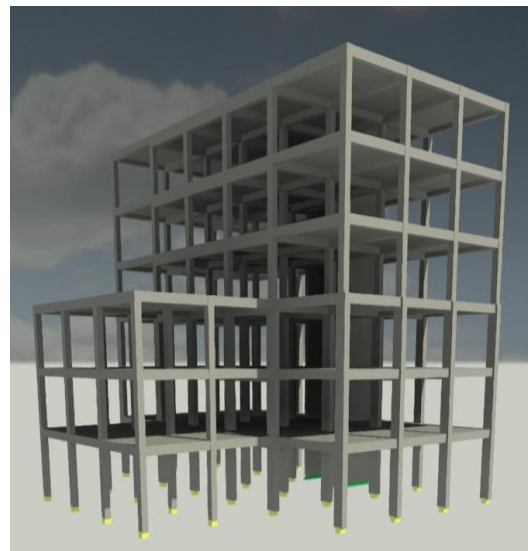


Fig -3: Structural model in Autodesk Revit 2017

It is recommended to do verification before starting analysis to ensure that the structure is ready to analyze.

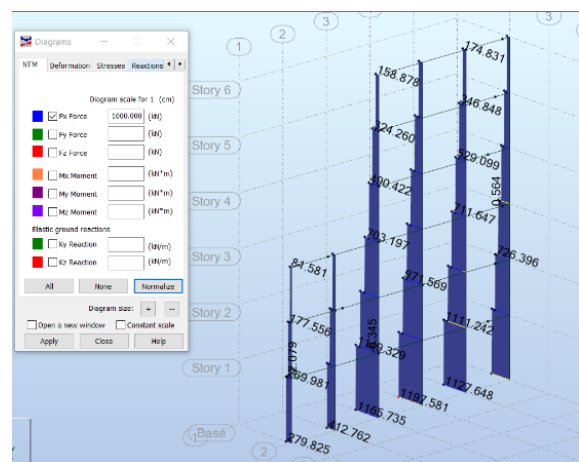
The load combination was done by using ULS and SLS, as shown,

$$ULS = 1.5 \times \text{Dead load} + 1.5 \times \text{Live load}$$

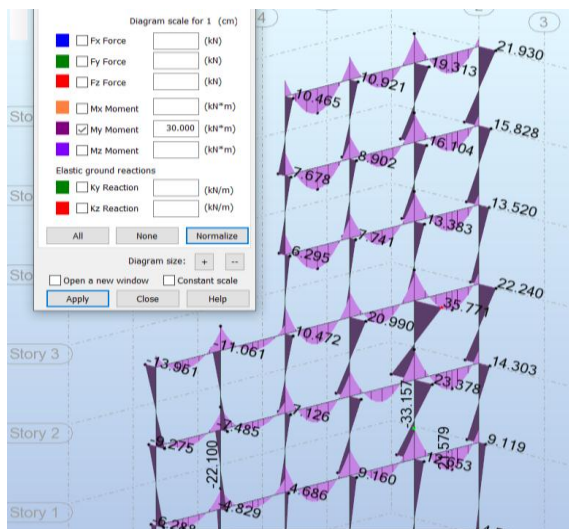
$$SLS = 1 \times \text{Dead load} + 1 \times \text{Live load}$$

4. THE RESULTS

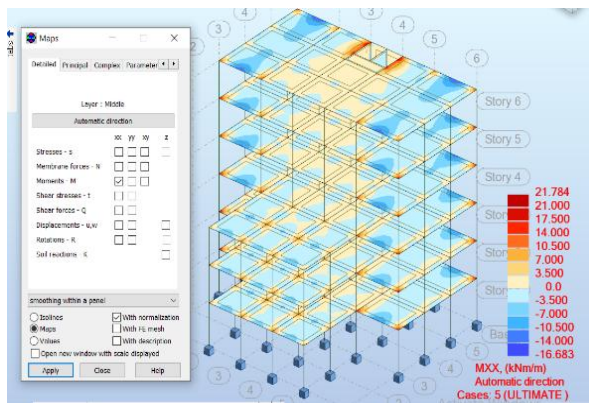
So after running the software to start analysis, the results had been shown as in Fig.4



a. A.F.D of single frame



b. B.M.D for single frame in building



c. B.M map of slabs at ultimate case

Fig-4: Results of analysis

In RSA professional, it is able to show multi-results once (e.g. B.M.D and S.F.D), and it becomes easier to represent and understand the behavior of structure. Due to the small value of loading, almost the columns and beams were required minimum reinforcement as will be shown in design part.

5. DESIGN of COLUMNS and BEAMS

By referring I.S 456-2000, the design has been done and verified. The software is able to give calculation notes with clear diagram of B.M.D and S.F.D for every beam with ultimate load case (critical case), even the quantity of reinforcement and concrete for every member. The calculation note contains

1. Level, which is including name, reference level, and environmental case
2. Material properties, geometry, calculation options, Calculation results (internal forces and diagramme)
3. Required reinforcement
4. Checking the deflection
5. Reinforcement in detail, then

6. Materials survey

So this will allow to calculate the estimate quantity and full understanding the design steps and analysis results. Fig.5 is shown in details the shear reinforcement and longitudinal reinforcement in continuous beam. The hooks have been provided at the end of beam, and not in mid-span of the continuous beam, so this gives sense that software following the code recommendations.

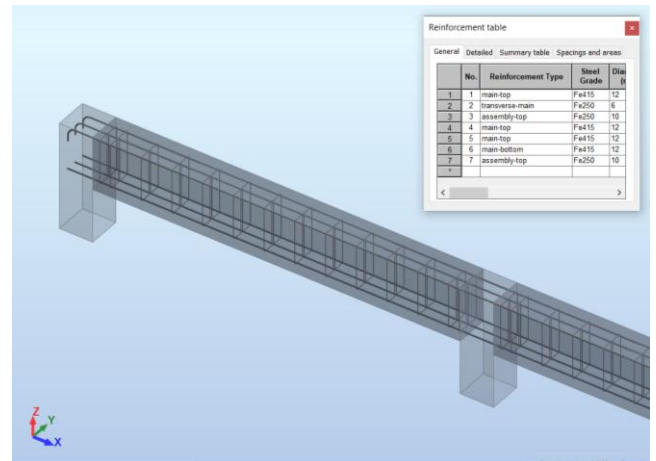


Fig-5: Beam reinforcement as shown in 3D view

Minimum spacing between the columns and first ties was kept 5 cm. The Fig.6 is shown the provided reinforcement of column with showing the dowel reinforcement. It is worth noting that, the minimum reinforcement has been provided for this column, where the cross-section of this column is (250x500 mm²) and the total reinforcement is 1130.97 mm², where, in I.S 456-2000, the minimum reinforcement for columns is 0.89%.

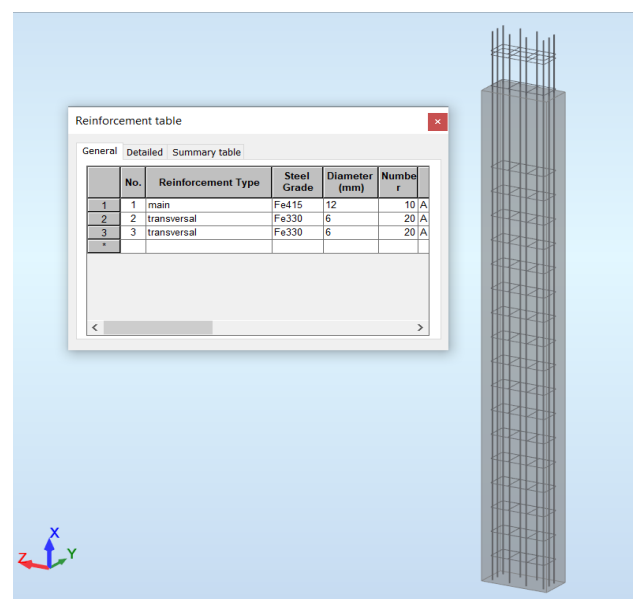


Fig-6: RCC column with its provided reinforcement

And as per I.S 456 code the minimum reinforcement for beam can be found out by follow below formula

$$\frac{A_{s,min}}{b.d} = \frac{0.85}{f_y} \quad Eq.1$$

$$(p_t)_{min} = \frac{A_{s,min}}{b.d} \times 100 \quad Eq.2$$

Where, $A_{s,min}$ the minimum required reinforcement, f_y the yielding strength of longitudinal reinforcement, p_t the reinforcement ratio, b and d are width of web and effective depth of beam respectively. After completion the design of all beams and columns, the model is ready to send to Autodesk Revit to show the total reinforcement for all members and typical detailing of each member as shown in Fig.7

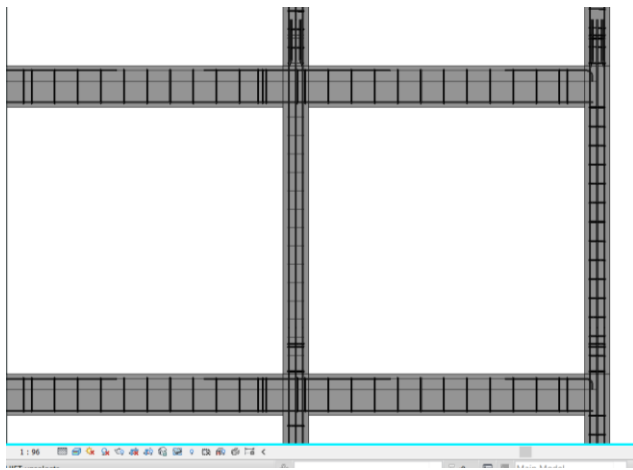
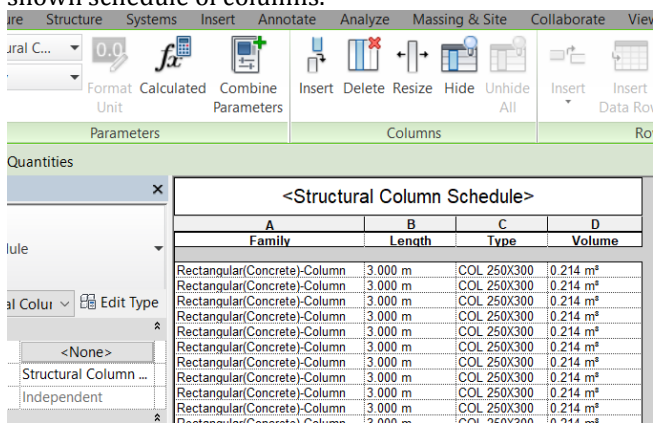


Fig-7: Reinforcement details as shown in Autodesk Revit Structure.

After completion the structural detailing and check the model, the scheduling of materials can be done. Fig.8 is shown schedule of columns.



<Structural Column Schedule>			
A	B	C	D
Family	Length	Type	Volume
Rectangular(Concrete)-Column	3.000 m	COL 250X300	0.214 m³
Rectangular(Concrete)-Column	3.000 m	COL 250X300	0.214 m³
Rectangular(Concrete)-Column	3.000 m	COL 250X300	0.214 m³
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Rectangular(Concrete)-Column	3.000 m	COL 250X300	0.214 m³
Rectangular(Concrete)-Column	3.000 m	COL 250X300	0.214 m³

Fig-8: Columns volumes

7. CONCLUSION

In the present paper, RCC building had been analyzed and designed as per I.S 456-2000 by using Autodesk RSA professional, and the 3D modelling for structural and

architectural purpose had been done in Autodesk Revit. BIM is allowed to the designers to check out the model in details and it shows the design problems before construction, for example, the designers are able to avoid the common problems which usually happen in the piping. Where, usually there are pipes go throughout beams, for that the structural designer will be able to change the design of beams or ask the mechanical engineer to find other solutions (these things can be done in advance level in BIM by finding clash detection between deferent models). The paper shows a good integration between BIM tools in modelling, designing, exporting/ importing, and doing the corrections on models.

8. RECOMMENDATION

1. The developed countries, like USA, UK and others are based on BIM approach because of its advantages, so it is a time to develop this technique in our countries.
2. It is worth noting that, working on BIM, required strong machines to model and analyse without getting problems while analysis, and when the structure is too big, it becomes so difficult to deal with software, for that there is some solutions, but still it is advised to use a computer machine with high properties while working on BIM.
3. It does not matter which software the user is using for modelling and design, it just required a good user with engineering sense, and of course the software should have integration with BIM other tools.

9. REFERENCES

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