Automation of Design Process Using Etabs, Microsoft Excel and AutoCAD

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Abstract: *In past few years civil engineering industry is on boom due to fact that, India is being the developing country many new projects start day by day which needs to be completed in given time scenario. The major factor for completion of projects is designing and implementation which helps the structure to be stand still for 100 of years. In this paper, we have presented our new approach for Automation of design process using Etabs, Microsoft Excel and AutoCAD. We have firstly designed the structure and simulate by applying various loads in Etabs software. The combination of values which gives us best result by performing no. of iterations are exported to MS Excel and further processing of exported results is done to design commands which could be directly used in the AutoCAD for designing the structure by just copy and paste the commands. Our proposed approach result shows the technique is very much efficient, time and cost saving. Normally designing process is very lengthy which take couple of hours to finalize the structure design but with the help of proposed technique efficient results could be achieved in just few minutes.*
Keyword: *ETabs, AutoCAD, Automation of Design Process, DSM.*

I. Introduction

Every building consists of two components superstructure and substructure foundations. The superstructure is the upper portion of building which serves purpose of its intended use whereas substructure is the lower portion of the building which transmits the load of the superstructure to the sub soil and the lower portion of the foundation which has direct contact with the sub-soil is known as footing. The foundation is the most important part of a building. The signs of failure of foundation are noticeable until it affected the building. A foundation ought to be sufficiently robust to prevent excessive settlement also as unequal settlement. Unequal settlement or differential settlement is caused by:-

(i)   Weak sub-soils, like created up ground
(ii)   Shrinkable and expansive soils (such as clay),
(iii)   First action.
(iv)   Movement of water, and uplift pressure,
(v)   Excessive vibrations, because of traffic, machinery etc.,
(vi)   Slow consolidation of saturated clays, and
(vii)   Slipping of strata on sloping sites.

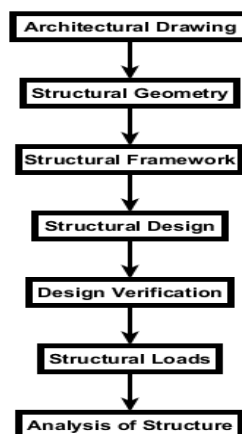When coming up with the foundations therefore, the higher factors should be taken into consideration.

Fig. 1: Structural Design Process

A typical design method of a construction project involves varied participants from completely different style disciplines. Most often, these stakeholders move with one another in an advert hoc manner that enforces a scenario of ill-structured info exchanges. When these exchanges of knowledge occur ceaselessly in cycles/loops, it's referred as design iterations [7]. Iteration is ineluctable in any design project [2]. Because the project evolves in quality, iterations become tougher. In India, structural designers perform the analysis and style in STAAD (Structural Analysis And Design) [1] computer code by following many steps like process nodes and incidences, material properties, support conditions, hundreds and their mixtures, analyses, design choices, etc. Structural style endures mental and manual iterations many times throughout this design tenure. A number of these iterations are performed either because of changes in structural loads, mixtures or to get best suited and optimized design section. The objective of this paper is to automatize the structural design iterations to realize this objective, a framework comprising of STAAD and DSM (Design Structure Matrix) was planned. STAAD pro is a comprehensive structural engineering software system that addresses all aspects of structural engineering as well as model development, verification, analysis, style and review of results. It includes advanced dynamic analysis and push over analysis for wind load and earthquake load.

1.1 Structure Design Iteration: A structural design method is characterized by the iterative steps of drawback understanding and synthesis where individual style solutions are tried and optimized. Iteration may be a method that happens throughout the entire designing and style part of any project. During the planning stages of style, structural designers are responsible for selecting a configuration of material and members to resist a group of applied loads and they focus on optimizing the solutions inside the planning requirements boundary. Figure 1 illustrates a generic structural design process that starts with identifying use of structure. As seen in the figure, once the criterion for design is met then the drawings and specifications prepared at the end of design process are sent for verification. The fabrication and erection follows the design verification. Alternately, if the design does not satisfy the criteria, member sections will be redesigned and these iterations are highlighted using dotted lines in the figure.

1.2 DSM Iteration Model: DSM (Design/Dependency Structure matrix) is a tool for planning iteration and also for evaluating alternate sequences. DSM can determine the basic sequence and also identify the existence of loops which are grouped as blocks. There are many strategies for executing the activities inside the blocks. The choice of the 'speed' is decided based on the two parameters:-
(a) Estimation of duration
(b) No of repetition of the activities

A DSM is a square matrix, representing linkages between the systems elements are shown in Fig. 2. Table 1 represents the list of activities comprising the entire design. The system elements are often labeled in the rows to the left of the matrix and/or in the columns above the matrix. These elements can represent for example product components, organization teams, or project activities. The off-diagonal cells are used to indicate relationships between the elements. A marking of the cell indicates a directed link between two elements and can represent design relations or constraints between product components, communication between teams, information flow or precedence relations between activities. In one convention, reading across a row reveals the outputs that the element in that row provides to other elements, and scanning a column reveals the inputs that the element in that column receives from other elements. For example, in the DSM, the marking in row A and column C indicated a link from A to C (output from A, input to C). Alternatively, the rows and columns may be switched.

	A	B	C	D	E	F	G
Element A	A	1				1	
Element B		B		1			
Element C	1		C				1
Element D				D	1		
Element E		1			E	1	
Element F			1			F	
Element G	1				1		G

Fig. 2: Structured Design Matrix with DSM

Table 1: List of activities for the structural design flow

A	Architectural drawing
B	Structural geometry
C	Structural framework
D	Structural design
E	Design verification
F	Structural loads
G	Analysis of structure
H	Fabrication and erection
I	Inspection and approval

1.3 Automation of iterations using DSM and OpenSTAAD

In base paper, OpenSTAAD was planned to modify the STAAD iteration. OpenSTAAD provides a standard platform to both STAAD and DSM so as to perform the structural analysis, design and additionally to change the identified iterations. Further, it will export the look output when every iteration. As seen in Figure 3, STAAD is liable for executing structural analysis and style whereas surpass will model the DSM and determine iterations. At present, the refinement and completion of section sizes in STAAD are done manually. Moreover, after every and each information update in style like load combos or new section property to be assigned, etc. structural analysis and style must be performed manually for every iteration. When the 2 models (i.e. STAAD and DSM) area unit integrated exploitation OpenSTAAD as represented within the Figure 3, it facilitates the constant customization and up gradation of structural framework in STAAD user interface (Graphical User Interface) by triggering the look iterations mechanically. Few instance that area unit worthy to mention are alteration within the structural geometry, introducing a new member to framework or continuous refinements in member section sizes to attain optimization, etc. STAAD includes a large in-built database of varied section sizes that is prompted by OpenSTAAD and runs the analysis and style when trying the required section kind. With the integrated VBA editor of OpenSTAAD, designers will establish the need for iteration or process from the DSM model in Excel and direct the command to STAAD user interface to incorporate the required changes and re-run the structural analysis and design.
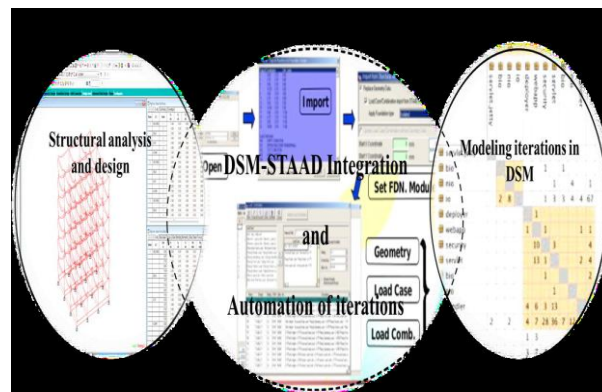

Fig. 3: Base Paper integration framework

II. Literature Review

P. Mujumdar et.al in (2015) modeled and automate the structural layout iterations the use of DSM and OpenSTAAD respectively. This proposed framework becomes implemented to a case example of six storey building. Preliminary effects of the model are presented herewith [3].

Soo-Haeng Cho et.al in (2005) presented a technique modeling and analysis technique for dealing with complicated design initiatives using advanced simulation. The version computes the chance distribution of lead time in a stochastic, aid-constrained task network where iterations take area amongst sequential, parallel, and overlapped responsibilities. The version makes use of the layout structure matrix illustration to capture the records flows between responsibilities. We use a simulation-primarily based analysis to account for plenty practical aspects of layout process conduct which were not feasible in previous analytical fashions. We advise a heuristic for the stochastic, resource-restricted challenge scheduling hassle in an iterative project community [2].

Purva Mujumdar et.al in (2015) examined if there exist any correlation a few of the numerous sorts of DSMs (crew DSM to parameter DSM or activity DSM to team DSM, etc.) formed. To acquire this objective, facts was amassed for an offshore mission through interactions and discussions with experts of the eight teams for several weeks. For the present day study, 4 teams—mechanical, HVAC, piping and structure which interact frequently was considered. To ease the analysis, deliverables DSM and group DSM turned into simplest taken into consideration. Through partitioning procedure, the sequences of deliverables and groups had been determined and different factors which include parameters or sports have been neglected. It was discovered that there exists no relation among the extraordinary DSMs fashioned [4].

Purva Mujumdar et.al in (2017) designed segment of any construction assignment entails several designers who alternate records with each other most usually in an unstructured way for the duration of the layout segment. When those records exchanges appear to occur in cycles/loops, it is termed as layout iteration. Iteration is an inherent and unavoidable element of any design phase which calls for proper planning. Till date, only a few researchers have explored the design new release ("complexity") in construction quarter. Hence, the goal of this paper was to report and evaluation the complexities of generation all through design phase of production tasks for green layout planning [5].

Purva Mujumdar et.al in (2015) accumulated statistics for an offshore mission via interactions and discussions with experts of the eight teams for several weeks. For the modern-day have a look at, four teams—mechanical, HVAC, piping and shape which have interaction frequently became considered. To ease the analysis, deliverables DSM and group DSM changed into handiest considered. Through partitioning procedure, the sequences of deliverables and teams were determined and different elements including parameters or activities had been left out. It changed into located that there exists no relation between the unique DSMs shaped [6].

D. V. Steward et.al in (1981) designed system entails the determination of interdependent variables. Thus the precedence ordering for the tasks of determining those variables entails circuits. Circuits require planning decisions about how to iterate and in which to apply estimates. Conventional planning strategies, such as critical course, do no longer deal with those problems. Techniques are shown which acknowledge those circuits inside the layout of structures. These techniques may be used to broaden an effective engineering plan, displaying where estimates are for use, how design iterations and reviews are dealt with, and how data flows during the layout paintings [8].

Ali A. Yassine et.al in (2004) designed and improved complicated engineering products require the efforts and collaboration of hundreds of contributors from various backgrounds resulting in complicated relationships amongst both humans and duties. Many of the conventional undertaking management gear (PERT, Gantt and CPM techniques) do now not deal with issues stemming from this complexity. While these tools allow the modeling of sequential and parallel methods, they fail to address interdependency (remarks and generation), that is commonplace in complex product improvement (PD) projects. To cope with this problem, a matrix-primarily based tool called the Design Structure Matrix (DSM) has advanced [9].

III. Problem Formulation

The different methods are reviewed, and sufficient studies are done to indicate the wide range of problems in structural design to which they have been applied. The base paper presented how currently available software fails to meet the needs of structural engineers. This is followed by a sample program specification to show how a system could be arranged to effectively integrate analysis, design, and drawing development processes. Because engineering judgment is an essential element of the structural design process, the keys to an effective system are: a high level of interactivity for the user to control analysis and design processes; a central data base that permits the user to extract segments for processing; and special purpose routines for the analysis and design of simple elements. These combine to give engineers the ability to develop judgment for the structure and implement their own decisions within the system.

IV. Resrearch Methodology

In this paper, we have taken a typical RC frame structure. To achieve the above objective research will undertake:

✓ Identification of design activities involved in the structural design process and their information interdependencies.

✓ A framework comprising of ETABS and DSM (Design Structure Matrix) will be planned and proved DSM as a potential matrix-based, compact tool for modeling iterations using MS Excel.

✓ Once the ETABS are initiated; structural geometry is established by importing the architectural drawings and layouts. Then, the structural framework is modeled by assigning supports, member properties, and loads/load combinations.

✓ Once the structure is modeled in ETABS, EXPORTS THE RESULTS OF ETABS TO MS EXCEL A changes in design as well as further refinement of member sections is done by undergoing iterations introduced by DSM using trial and error approach until the optimized sections are obtained.

OpenSTAAD will be planned for automating the iterations. It is basically API (Application Programming Interface) functionality with VBA (Visual Basic for Applications) editor to STAAD engines.

The entire concept will be modeled with Excel VBA. The next is to discuss the structural design iteration in STAAD followed by modeling of those iterations using DSM. OpenSTAAD will provide the design outputs and results after each iteration as well as the final design reports once all the iterations are undergone and optimized section sizes are obtained. The analysis and design are performed on the structural framework. If there is a necessity to redesign or optimize, the DSM iteration model can reveal the upcoming iterations to be performed. At this juncture, OpenSTAAD starts executing the design iterations and optimization in the STAAD design model. OpenSTAAD prints the design results every time once the analysis is done after incorporating each iteration.

V. Results

We have presented the proposed work for Automation of design process using Etabs, Microsoft Excel and AutoCAD. The structure is firstly implemented using Etabs software, then the designed structure parameters are exported to excel sheet and equations are manipulated according to structure design which are further used to design the structure components using AutoCAD. In Etabs software from file option New Model option is selected then a window popups in which units are selected and grid only view is Chosen.
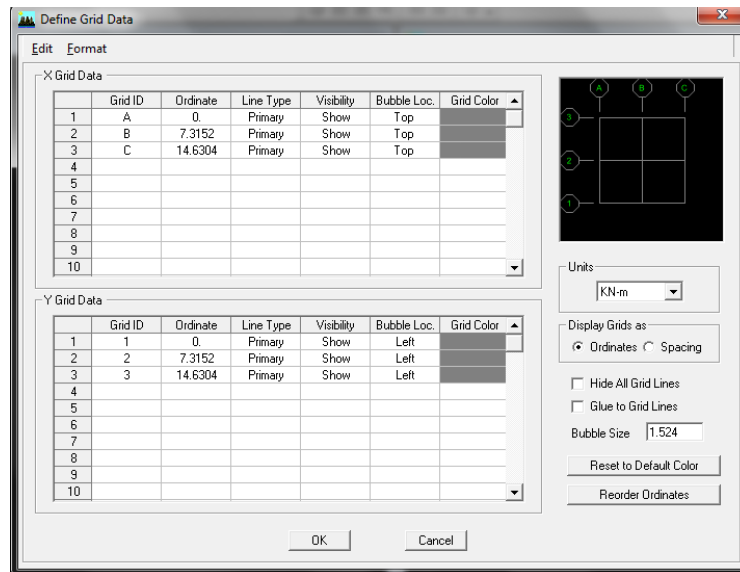
Fig. 4: Define Grid Data

The window of defining grid data is shown in Fig. 4. There X and Y grid data properties are defined.
Loads:
- (i) 100mm Floor.
- (ii) $3KN/m^2 LL(1,2)$
- (iii) $1.5\ KN/m^2$ on terrace LL(3,4)
- (iv) 9" Wall $\frac{230}{1000} X\ 20\ X\ H$
- (v) Seismic Load
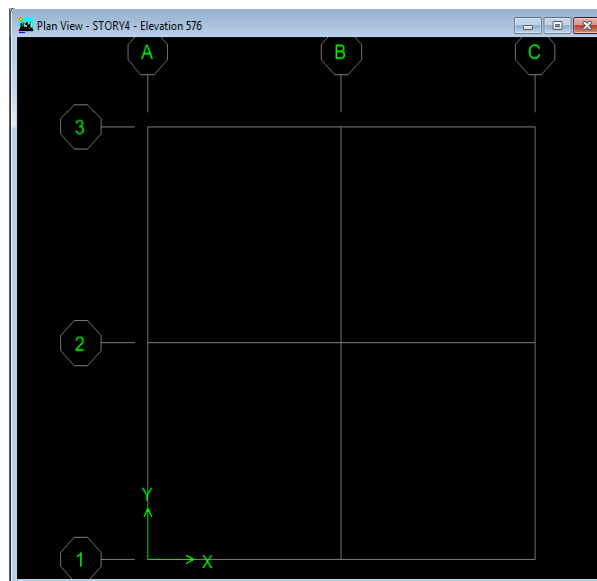
Fig. 5: Plain View of 4 Storey Structure

The plain view of 4 storey structure is shown in Fig. 5. In figure X and Y labels are shown with grid ID's 1, 2 and 3 for Y label whereas A, B and C for X label.
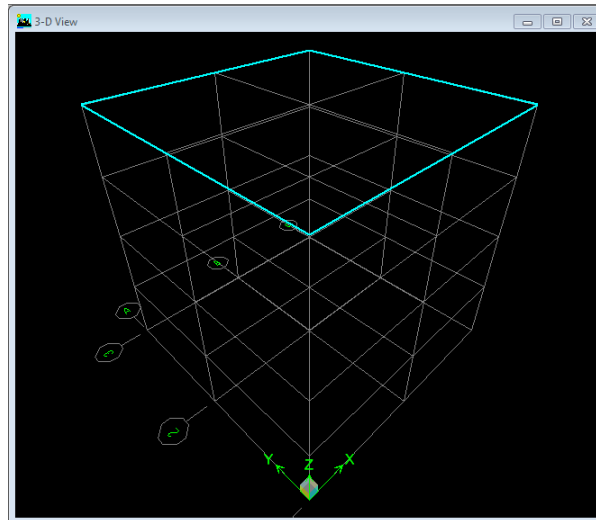
Fig. 6: 3D View of 4 Storey Structure

The 3D view of 4 storey structure is shown in Fig. 6. In figure X, Y and Z labels are marked.
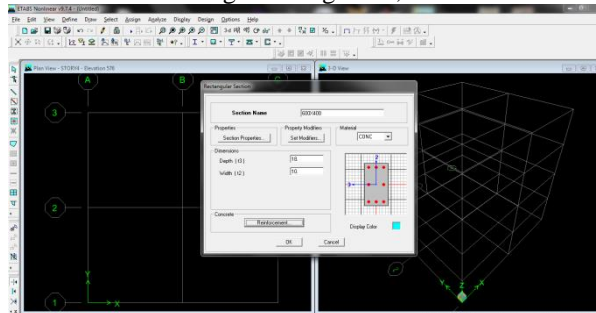
**Fig. 7:** Define Material Properties of Rectangular Section

In Etabs software from Define option Material Properties option is selected then a window popups in which properties of rectangular section are defined. The window of defining material properties of rectangular section is shown in Fig. 7. The name of rectangular section, dimensions (Depth and Width) and material chosen are provided for beam formation. Proper ties of column formed are shown in Fig. 8.
Beam 400x400 – 4th Floor.
Beam 600x600 – 3rd Floor.
Beam 700x400 – 1st and 2nd Floor.
Also define columns same as beam. Define wall, slab deck sections and slab membrane.
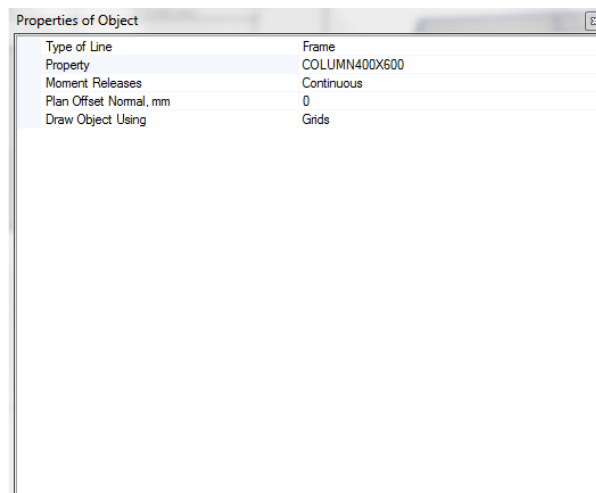
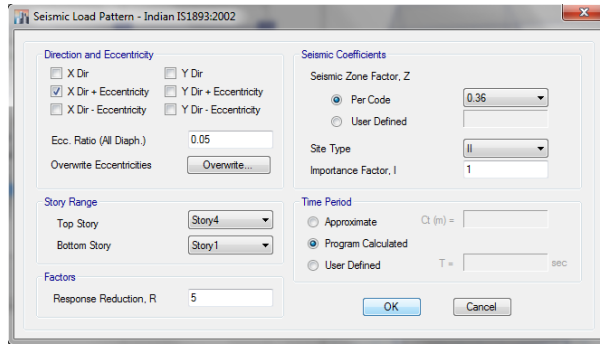**Fig. 8:** Properties of Object

Fig. 9: Seismic Load Pattern

In Etabs software from Define option Load Pattern option is selected then two window popups first is seismic load pattern and second is define load pattern. The window of seismic load pattern is shown in Fig. 9 and window of define load pattern is shown in Fig. 10. In seismic load pattern direction of seismic load is defined as per IS1893-2002. In define load pattern dead load, live load or combinational load is selected.
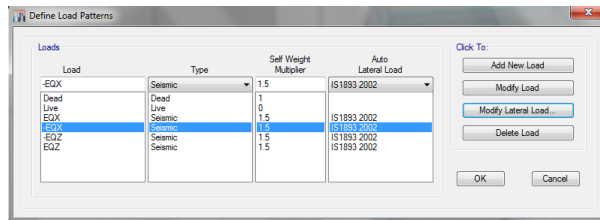

Fig. 10: Define Load Patterns

Define static load case add EQ_x, EQ_y and EQ_z. Also define dead and live loads.
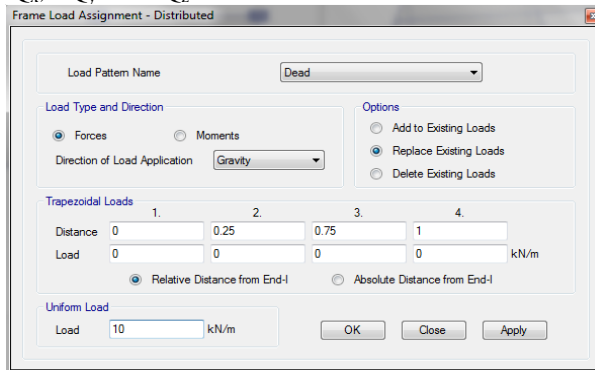

Fig. 11: Frame Load Assignment

In Etabs software from Assign option Frame Load option is selected then Distributed option is selected then window popups frame load assignment. The window of frame load assignment is shown in Fig. 11.
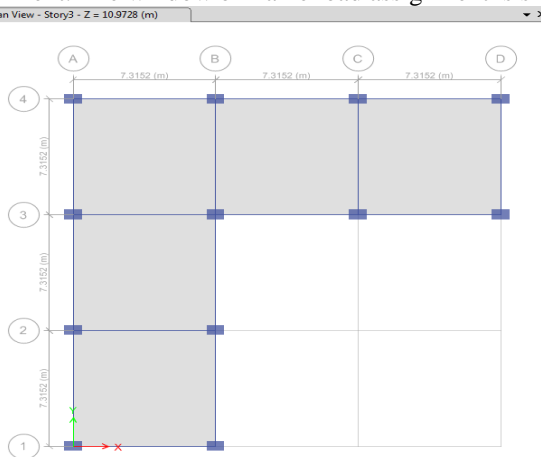

Fig. 12: Plain View of 4 Storey Structure

The plain view of 4 storey structure is shown in Fig. 12. In figure Rectangular Section is also shown on grid points.
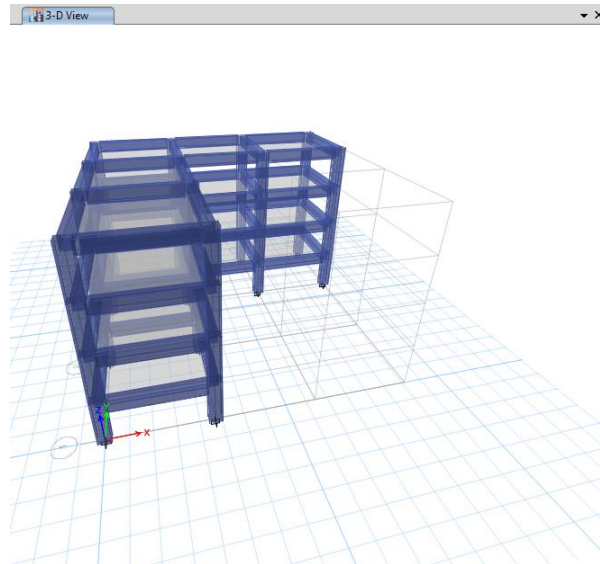

Fig. 13: 3D View of 4 Storey Structure

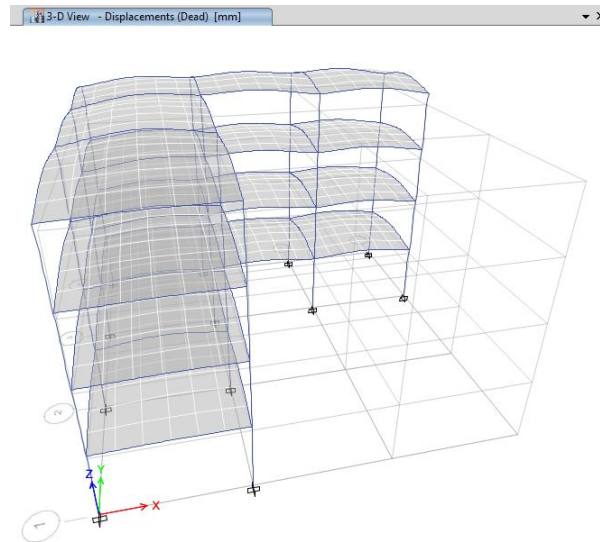The 3D view of 4 storey structure is shown in Fig. 13. In figure 3D Rectangular Section is also shown on grid points.

Fig. 14: 3D View of 4 Storey Structure Displacements

In Etabs software from Analyze option Run Analysis option is selected then displacements according to load applied and material selected are shown in software. The 3D View of 4 Storey Structure Displacements is shown in Fig. 14.

After performing the all steps mentioned above we come to certain result by performing several iterations and table for various values of load dimensions are formed which are to be exported from Etabs to MS Excel and further analysis are performed to design the equations for drawing Beams and Columns etc. for the structure. Then these equations could be directly used in AutoCAD for Structure Designing Process Automation.

Exported Tables:
－ **Joint Co-ordinate Data**
－ **Joint Co-ordinates**
－ **Load Pattern**
－ **Base reactions**
－ **Joint reactions**

- **Design reactions**
- **Frame reactions**
- **Column Connectivity Data**
- **Frame Assignment**

In MS Excel a lot calculations are performed for defining commands of various parameters such as footing, bearing pressure, area of reinforcement and shear.

1. **Footing Design**
- Load Case
- DL – Dead load
- LL – Live load
- EQ_x – Seismic load in x direction
- EQ_{xn} – Seismic load in -x direction
- EQ_z – Seismic load in z direction
- EQ_{zn} – Seismic load in -z direction
- F_z, M_x and M_y forces from design table
- Load Combinations

$$DL+LL$$
$$DL+LL+EQ_x$$
$$DL+LL-EQ_{xn}$$
$$DL+LL+EQ_z$$
$$DL+LL-EQ_{zn}$$

By adding or subtracting value of Fz, Mx and My follows load combinations.

Then column size and footing size – exported table by using V-Lookup function to obtain the corresponding values of size with points in the first column. Then enter the values of overall depth (D) and effective depth (d).

2. **Check for Bearing Pressure**

There are four cases. The formula outcome or output values should not be less than 0. Therefore, we have used conditional formatting if the value is less than 0 then the color of resultant cell turn blue.

$$\frac{F_z}{A} + \frac{M_x}{Z_x} + \frac{M_y}{Z_y} \ldots\ldots\ldots\ldots\ldots Case\ (1)$$

$$\frac{F_z}{A} + \frac{M_x}{Z_x} - \frac{M_y}{Z_y} \ldots\ldots\ldots\ldots\ldots Case\ (2)$$

$$\frac{F_z}{A} - \frac{M_x}{Z_x} - \frac{M_y}{Z_y} \ldots\ldots\ldots\ldots\ldots Case\ (3)$$

$$\frac{F_z}{A} - \frac{M_x}{Z_x} + \frac{M_y}{Z_y} \ldots\ldots\ldots\ldots\ldots Case\ (4)$$

3. **Area of Reinforcement**
- Area Required

$$Ast = \frac{Fck}{2F_y} X \left[1 - \sqrt{1 - \frac{4.6Mu}{Fckbd^2}} \right] b\ X\ d$$

These are values from exported table and inputs.
- Area Provided
  Area provided >Area Required
  Here also use condition formatting. If area provided is less than the area required then it will turn red.

4. **Check for Shear**
- One Way Shear
- Two Way Shear

For Drafting in AutoCAD:-

For drafting in AutoCAD make commands in MS Excel so that it can be easily copied to AutoCAD or for automatic drafting. Both footing and columns are in rectangular shape. So, two points are required to make rectangle. If (X,Y) is the midpoint then:-

For Footing:

$$1^{st}\ point - \left[\left(X - \frac{xx}{2} \right), \left(Y - \frac{yy}{2} \right) \right]$$
$$2^{nd}\ point - \left[\left(X + \frac{xx}{2} \right), \left(Y + \frac{yy}{2} \right) \right]$$

For Column:

$$1^{st} \text{ point -} \left[\left(X - \frac{x}{2}\right), \left(Y - \frac{y}{2}\right)\right]$$

$$2^{nd} \text{ point -} \left[\left(X - \frac{x}{2}\right), \left(Y + \frac{y}{2}\right)\right]$$

				end		end	
				-layer		-layer	
				set	button 2	set	
				column		TEXT	
				end		end	
Colmn		second point					
first point							
-0.25	9.85	0.25	10.15	rectangle -0.25,9.85 0.25,10.15	rectangle -3,7.5 3,12.5 rectangle -0.25,9.85 0.25,10.15	-TEXT -3,7.5 column 0 F2	
				end	end		
				end	end		
				end	end		
				end	end		
				end	end		
-0.25	14.85	0.25	15.15	rectangle -0.25,14.85 0.25,15.15	rectangle -3,12.5 3,17.5rectangle -0.25,14.85 0.25,15.15	-TEXT -3,12.5 column 0 F3	
				end	end		
				end	end		
				end	end		
				end	end		
				end	end		
-0.25	4.85	0.25	5.15	rectangle -0.25,4.85 0.25,5.15	rectangle -2.5,2.5 2.5,7.5rectangle -0.25,4.85 0.25,5.15	-TEXT -2.5,2.5 column 0 F4	
				end	end		
				end	end		
				end	end		
				end	end		
				end	end		

In MS Excel Rectangular command for of AutoCAD can be coded as:
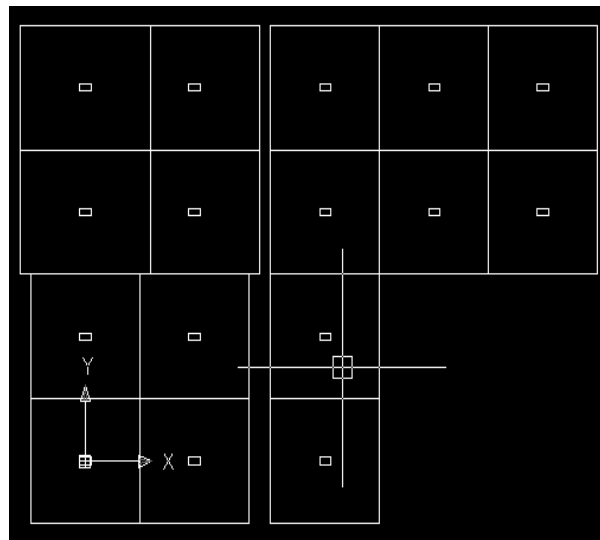="rectangle"&X&","&Y&""""&X&","&Y&""""

For Layer:
end
="_layer"
Set
Foundation
end

For Text:
("-text_"&X&","&4&"_"&(height)&"_0_f"A7)

Finally Compile the Commands, Copy and Paste them in AutoCAD. Rectangular footing and columns designed in AutoCAD after Pasting Commands are shown in Fig. 15.

Fig. 15: Rectangular footing and columns designed in AutoCAD after Pasting Commands
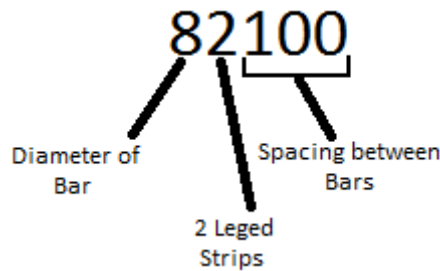
For Beam Design:
- Shape and Size – from exported table (Frame assignment, frame section). Take the corresponding value for beam of storey 4 by using Vloop function.
- Steel Required – detailing, values from table (exported table) also find steel provided and use conditional formatting.

Fig. 16: Excel sheet

- Shear provided – let it be = 82100

Spacing= $Y - \left[Round\ Down\left(\frac{cy}{1000}, 0.1\right)\right] X 1000 \dots\dots (A)$

Diameter=$Round\ Down\left(\frac{y}{1000}\right) X\ 1000 \dots\dots (B)$

No. of leged Strips=$\frac{[Y-(diaX1000)-spacing]}{1000} \dots\dots (C)$

Shear Provided=$\frac{\frac{\pi}{4}*B^2 C}{A} * 1000\ mm^2/m$

Then conditional formatting is used. If shear required is less than shear provided then then green else turn red. Values from exported table:

Span = 7315
Depth = 914.4
Width = 609.6
Clear Cover = 50,40
Length of column: C1=500, C2=500

Table 2: Coordinates for the drafting of beams

Beam Point	X	Y
1S	0	2000
1E	0	0
4S	C_1	2000
4E	C_1	1500
5S	C_1	(1500-d)
5E	C_1	0
8S	$\left(\frac{C_1}{2} + X - \frac{C_2}{2}\right)$	1500
8E	$\left(\frac{C_1}{2} + X - \frac{C_2}{2}\right)$	(1500-d)
9S	$\left(\frac{C_1}{2} + X - \frac{C_2}{2}\right)$	0
9E	$\left(\frac{C_1}{2} + X - \frac{C_2}{2}\right)$	2000
12S	$\left(\frac{C_1}{2} + X + \frac{C_2}{2}\right)$	2000
12E	$\left(\frac{C_1}{2} + X + \frac{C_2}{2}\right)$	0

Table 3: Coordinates for Beam Design in AutoCAD

X_1Y_1	X_2Y_2
1S	1E
1S	4S
1E	5E
4S	4E
5E	5E
4E	8E
5S	9S
8S	8E
9S	9E
8S	12S
9E	12E
12S	12E

Commands for Beam Design in AutoCAD:

1. For Drafting and Line Command

    $=(\text{``L``}\&X_1\&\text{''},\text{``}\&Y_1\text{''} \text{``}\&X_2\&\text{''},\text{``}\&Y_2\&\text{''''})$

2. For Text Command

    $\text{``\_text``}\&X\&\text{''},\text{``}\&Y\&\text{''''}\&NAME\text{''08-2l@300c/c''}$

3. For Leader Command

    $\text{``LEADER``}\&X_1\&\text{''},\text{``}\&Y_1\&\text{''''}\&X_2\&\text{''},\text{``}\&Y_2\&\text{''''}$

4. For Dimlin Command

    $\text{``DIMLIN``}\&X_1\&\text{''},\text{``}\&Y_1\&\text{''''}\&X_2\&\text{''},\text{``}\&Y_2\&\text{''''}$
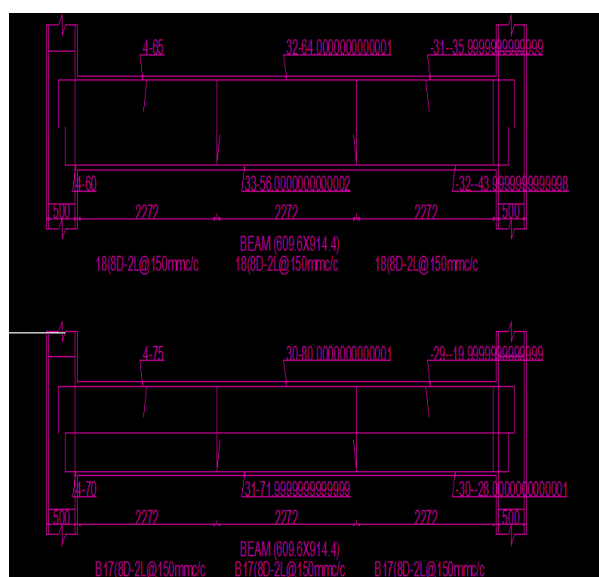
5. For Layer Coommand

    end
    ="layer"
    Set
    _____
    end

Different layers are used:
   a. fDS
   b. fDS_FRAME
   c. fDS_DIMLIN
   d. fDS_TEXT
   e. fDS_STRUPPS
   f. fDS_STEEL

Fig. 17: Beam designed in AutoCAD after Pasting Commands

VI. Conclusion

In this paper, we have presented our new approach for Automation of design process using Etabs, Microsoft Excel and AutoCAD. We have firstly designed the structure and simulate by applying various loads in Etabs software. The combination of values which gives us best result by performing no. of iterations are

exported to MS Excel and further processing of exported results is done to design commands which could be directly used in the AutoCAD for designing the structure by just copy and paste the commands. Our proposed approach result shows the technique is very much efficient, time and cost saving. Normally designing process is very lengthy which take couple of hours to finalize the structure design but with the help of proposed technique efficient results could be achieved in just few minutes.

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