Design of RC Column And Footing Using ETABS API

Naveen Shivannavar M[1], Prateek Cholappanavar[2]
[1]Dept of Civil Engineering
[2]Assistant Professor, Dept of Civil Engineering
[1, 2] SDMCET Dharwad

Abstract- *Presently the structural designers in India use ETABS software to execute the structural analysis, but for the design purpose still manual calculations and excel spread sheets are being used. It leads to cumbersome and time consuming process to obtain analysis results from ETABS to design calculations, hence to automate this process an MS excel spread sheet has been developed. A VBA program has been developed to access the analysis results from ETABS to MS excel such that the design process is fully automated which reduces manual interference.*

Keywords- MS Excel, ETABS API, VBA, IS 456:2000, Analysis, Design, Column, Footing.

I. INTRODUCTION

ETABS API (Application program interface) is a collection of revealed tasks, that permits the engineers to extract to ETABS routine and interior tasks and also the graphical requirements. ETABS API utilizes application of visual basic for macros to execute such tasks as repetitive automating modelling or tasks of post-processing or embedding routine of customized design. It permits ETABS API that can be utilized in macro application that are Autodesk, AutoCAD or Microsoft excel.

ETABS API permits engineers and operators to connect in-house or ETABS applications with third party Microsoft excel a computer code agenda generated from Microsoft, this permits utilizers to arrange systematically calculation of data using formulas with the help of spreadsheet. The code is the unit of Microsoft office retinue. Is the consistent for distinct applications in office retinue.

Application of visual basic is a programming for design work with the help of application of Microsoft office. units in application are revealed as objects to the performers to utilize and manipulate in a desired extend. almost everything could be made with the normal utilize of the office application to link the task with programming.

Automation work has been made to extract the STAAD Pro results to MS Excel using VBA coding [1]. Introduced PSA (Program for Structural Analysis) Software, and compared the results obtained from OpenSTAAD and analysis done in PSA to MS excel [2]. An Automation of structural analysis design iterations using DSM (Design Structural Matrix) and OpenSTAAD has been carried out, further the work has been extended for optimal design of sections [3]. Presented Design Optimization of Steel Members Using OpenSTAAD and Genetic Algorithm [4]. Developed Excel Sheets for the Design of Columns Under Tension or Compression, Biaxial Bending, Shear in Both Directions and Torsion [5]. A spreadsheet has been developed for the design of Selective Catalytic Reduction Pile Cap Foundation, the micro piles were modelled in STAAD Pro v8i and the forces extracted to an Excel spreadsheet through OpenSTAAD VBA macro [6].

II. PROPOSED METHODOLOGY

A. Analysis

A typical example model was considered for the analysis, and the frame was modelled in ETABS software, the initial beam properties were assigned based on vertical deflection limits and for the column based on slenderness ratio of IS 456:2000[9], The dead load, live load, earthquake load and wind load are assigned to the frame according to IS 875(Part 1, Part 2 & Part 3)-1987[9], [10], [11] and IS 1893 (Part 1): 2002. Static Analysis of the frame was carried out based on various load combinations. After analyzing the structure in ETABS analysis engine, the data required for design of column and footing are exported to the MS Excel.

B. ETABS API

Following Syntaxes have been coded in MS Excel VB macro to open the ETABS software, retrieve geometry and design forces for all the footing and column for all the load combinations. An interface is created including various syntaxes such as “Open ETABS”, “Reactions”, “Close ETABS” and “Exit” for the automation of opening of ETABS, getting reactions, closing the ETABS and exiting the interface. The data such as number of columns, load patterns, load combinations, column dimensions, column forces and moments, unique names, coordinates and grid data.

III. DESIGN FORMULATION

A. RC COLUMNS: Following equations for the design of RC Columns have been used in the form of VB syntax in MS Excel VBA macro.

1. Effective cover is calculated from table 16 and 16A of IS-456-2000, and based on maximum diameter of bar to be used.

$$Eff.cover = clear.cover + \frac{Dai.ofbar}{2} \quad (1)$$

2. Effective length of column: The factors for calculating the effective length for various end conditions are given in table number 28 of IS 456: 2000 [8].
3. Check for slenderness ratios:

$$\frac{l_{ex}}{D}, \frac{l_{ez}}{b} \le 12 \quad (2)$$

4. Check for minimum eccentricity: The expression for calculation of minimum eccentricity according to clause number 25.4 of IS 456: 2000 [8].

$$e_{min.x} = \frac{l_{ex}}{500} + \frac{D}{30} \ge 20mm \quad (3)$$

$$e_{min.z} = \frac{l_{ez}}{500} + \frac{b}{30} \ge 20mm \quad (4)$$

5. Moments dew eccentricity:

$$M_{ex} = P_u e_{min.x} \quad (5)$$

$$M_{ez} = P_u e_{min.z} \quad (6)$$

6. Calculation moments for a slender column from clause 39.7.1 of IS-456-2000 [8].

$$M_{ax} = \frac{P_u D}{2000}\left\{\frac{l_{ex}}{D}\right\}^2 \quad (7)$$

$$M_{az} = \frac{P_u b}{2000}\left\{\frac{l_{ez}}{b}\right\}^2 \quad (8)$$

7. Total moments

The total moments consist of sum of the moments dew to slenderness and actual moments,

$$M_{ux} = M_{emin.x} + M_x \quad (9)$$

$$M_{uz} = M_{emin.z} + M_z \quad (10)$$

8. Axial load capacity taken by the assumed reinforcement and section, is formulated from the equation given in table number 60 of SP16 [9].

$$P_{bx} = \left(k_1 + k_2\frac{p}{f_{ck}}\right) f_{ck} bD \quad (11)$$

$$P_{bz} = \left(k_1 + k_2\frac{p}{f_{ck}}\right) f_{ck} bD \quad (12)$$

$$k_x = \frac{P_{uz} - P_u}{P_{uz} - P_{bx}} \le 1 \quad (13)$$

$$k_z = \frac{P_{uz} - P_u}{P_{uz} - P_{bz}} \le 1 \quad (14)$$

9. Design parameters are interpolated from interaction charts for P_u vs M_{ux} and P_u vs M_{uz} based on clause 3.2.3 of SP-16 [9].

$$\frac{P_u}{f_{ck} bd} \quad (15)$$

$$\frac{M_{uax}}{f_{ck} bd^2} \quad (16)$$

$$\frac{M_{uaz}}{f_{ck} bd^2} \quad (17)$$

10. Design check has been obtained on the basis of moments due to design loads and, moment capacity due to axial load and biaxial bending from clause 39.6 of IS-456-2000 [8].

$$\left[\frac{M_{ux}}{M_{ux1}}\right]^{\alpha_n} + \left[\frac{M_{uz}}{M_{uz1}}\right]^{\alpha_n} \le 1.0 \quad (18)$$

Where

$$P_{uz} = 0.45 f_{ck} A_c + 0.75 f_y A_{sc} \quad (19)$$

For values of $P_u / P_{uz} = 0.2 to 0.8$, the values of α_n vary gradually from 1.0 to 2.0. For values < 0.2, α_n is 1.0; for values > than 0.8, α_n is 2.0.

6.2 Design charts

Following cases obtained from clause 3.2.3 of SP-16 have been used to obtain the interaction chart results [9].

a. For purely axial compression case.

$$\frac{P_u}{f_{ck} bD} = 0.446 + \frac{p}{100 f_{ck}}\left(f_{si} - 0.446 f_{ck}\right) \quad (20)$$

b. Neutral axis lying outside the column section.

$$\frac{P_u}{f_{ck} bD} = C_1 + \sum_{i=1}^{n} \frac{p_i}{100 f_{ck}}\left(f_{si} - f_{ci}\right) \quad (21)$$

$$\frac{M_u}{f_{ck}bD^2} = C_1(0.5 - C_2) + \sum_{i=1}^{n} \frac{p_i}{100 f_{ck}} (f_{si} - f_{ci}) \left(\frac{y_i}{D} \right) \quad (22)$$

c. Neutral axis lying within the column section

$$\frac{P_u}{f_{ck}bD} = 0.36k + \sum_{i=1}^{n} \frac{p_i}{100 f_{ck}} (f_{si} - f_{ci}) \quad (23)$$

$$\frac{M_u}{f_{ck}bD^2} = 0.36k(0.5 - 0.416k) + \sum_{i=1}^{n} \frac{p_i}{100 f_{ck}} (f_{si} - f_{ci}) \left(\frac{y_i}{D} \right) \quad (24)$$

B. RC FOOTING

Following equations for the design of RC Columns have been used in the form of VB syntax in MS Excel VBA macro.

1. Assume self-weight of footing as 10% of Pu, Total load,

$$P = \frac{Pu \times 1.1}{1.5} \quad (25)$$

2. Area of footing required,

$$A = \frac{P}{SBC} \quad (26)$$

   a. If square footing, then size of footing:

$$\text{B or L} = \sqrt{A_{reqd}} \quad (27)$$

   b. If rectangular footing, assume one side L Then,

$$B = \frac{A}{SBC} \quad (28)$$

3. Upward soil pressure:

$$P_{uplift} = \frac{P}{A} + \frac{Mx}{1.5Zz} + \frac{My}{1.5Zx} \quad (29)$$

   Check for footing size:

   P_{uplift} is less than SBC, Hence the provided footing dimensions are "SAFE"

4. BM calculations:

   a. Moment along x-x passing:

$$Muyy = PuB\left(\frac{L-l}{2}\right)\left(\frac{L-l}{4}\right) \quad (30)$$

   b. Moment along y-y passing:

$$Muxx = PuL\left(\frac{B-b}{2}\right)\left(\frac{B-b}{4}\right) \quad (31)$$

5. Calculation of depth required:

The maximum moment (M_{umax}) is considered for further design and the depth required according to IS 456:2000 will be [9].

$$Mu\lim = 0.36\frac{Xu\max}{d}\left(1 - 0.42\frac{Xu\max}{d}\right)Fckbd^2 \quad (32)$$

Or by substituting value of $\left(\frac{Xu\max}{d}\right)$ given in IS 456:2000 we will get simplified formula

$$M_{u\lim} = 0.149Fckbd^2 \text{ for Fe250} \quad (33)$$

$$M_{u\lim} = 0.138Fckbd^2 \text{ for Fe415} \quad (34)$$

$$M_{u\lim} = 0.133Fckbd^2 \text{ for Fe5006} \quad (35)$$

6. Area of tensile reinforcement [8]:

Tensile reinforcement in shorter/longer direction according to IS 456:2000 will

$$A_{st} = \frac{0.5 f_{ck}}{f_y}\left(1 - \sqrt{1 - \left(\frac{4.6 M_u}{f_{ck} bd^2}\right)}\right)bd \quad (36)$$

Minimum tensile reinforcement,

$$A_{st\min} = 0.0012BD \quad (37)$$

Area of one bar, ast

$$ast = \frac{\pi d^2}{4} \quad (38)$$

Spacing for the reinforcement, Sv

$$s_v = \frac{ast}{Ast} \quad (39)$$

7. Check for one-way shear: Shear force (V_u) and shear stress (τ_v) is calculated from the equations given below:

$$V_u = P_{uplift}B\left(\left(\frac{L-D}{2}\right) - d\right) \quad (40)$$

$$\tau_v = \frac{V_u}{bD} \quad (41)$$

Percentage of steel provided, p_t

$$p_t = \frac{100 A_{st}}{bd} \quad (42)$$

The design shear is calculated according to SP16 will be [9]

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta} \quad (43)$$

where, $\beta = \dfrac{0.8 f_{ck}}{6.89 p_t}$ but it should not be less than 1

Condition for one-way shear check: If, τv < τc, safe in one-way shear.

8. Check for two-way shear:

$$V_u = P_{uplift} B\left(A - \left(D+d\right)^2\right) \quad (44)$$

$$\tau_v = \frac{V_u}{b_o D} \quad (45)$$

Where, $b_o =$ perimeter:

$$b_o = 2(D+d) + 2(B+b)$$

$$\tau_c = 0.25 F_{ck}$$

Condition for two-way shear check: If, τv < τc, safe in two-way shear.

9. Development length of bar is calculated from clause 26.2.1 of IS-456-2000 [8].

$$L_d = \frac{\phi \sigma_s}{4\tau_{bd}} \quad (46)$$

IV. CONCLUSIONS

The objective for automation of Design of RC column and isolated footing using MS excel and ETABS API have been accomplished. The above Analysis and Design problem has been verified with standard Text Books. It reduces time, as compare to manual calculation for Design of Beam and column elements of a large project.

Similarly, automation work for remaining RC elements of the building can be made. Optimization of RC elements can be carried out.

REFERENCES

[1] Dr. R. J. Fernandes, Javali F. M, Patil S. B, “Analysis and Design of Reinforced Concrete Beams and Columns using open STAAD”, International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-7 Issue-3, July 2017.

[2] Ishwaragouda S. Patil and Dr. Satish A. Annigeri, “Introduction to PSA as a Free Structural Analysis Software,” Bonfring International Journal of Man Machine Interface, Vol. 4, Special Issue, July 2016.

[3] P.Mujumdar and J. U. Maheswari, “Integrated Framework for Automating the Structural Design Iteration,” Proceedings of the International Symposium on Automation and Robotics in Construction, 2015.

[4] Purva Mujumdar and Vasant Matsagar, “Design Optimization of Steel Members Using Openstaad and Genetic Algorithm,” Advances in Structural Engineering, V Matsagar (ed), Springer India 2015, pp.233-244.

[5] Santhosh Kumar P.T, “Development of Excel Sheets for the Design of Columns Under Tension or Compression, Biaxial Bending, Shear in Both Directions and Torsion”, IJERA, ISSN: 2248-9622, TRACE- 24th-25th January 2014.

[6] Jonathan Meyer, “SCR Pile Cap Foundation Design Using STAAD v8i & Excel,” Structures Congress 2011, pp. 2485-2495, April 2012.

[7] IS 456-2000, “Indian standard code of practice for plain and reinforced concrete – code of practice,” Bureau of Indian Standards, New Delhi, 2000.

[8] SP 16-1980, “Design aids for reinforced concrete to IS 456-1978,” Bureau of Indian Standards, New Delhi, 1980.

[9] IS 875(Part 1)-1987, “Design Loads (Other than Earthquake) For Buildings and Structures,” Bureau of Indian Standards, New Delhi, 1987.

[10] IS 875(Part 2)-1987, “Design Loads (Other than Earthquake) For Buildings and Structures,” Bureau of Indian Standards, New Delhi, 1987.

[11] IS 875(Part 3)-1987, “Design Loads (Wind loads) For Buildings and Structures,” Bureau of Indian Standards, New Delhi, 1987.

[12] IS 1893 (Part 1): 2002 - Code of Practice for Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings, Bureau of Indian Standards, New Delhi.