Development of P-M Interaction Diagrams for Reinforced Prestressed Concrete Sections Under Uniaxial Bending and Axial Load

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Abstract: The flexural strength of the concrete columns can be increased by adopting prestressing in the columns. So to analyze and check the adequacy of such prestress concrete columns the use of P-M interaction curves is easy and safe. To develop the force-moment interaction curves for the prestress concrete short columns subjected to uniaxial bending and axial load the user defined computer application is prepared by using VB.net software. The study focuses on preparation of user defined application in VB.net to develop P-M interaction curves for atomized evaluation and eliminations of laborious manual calculation to obtain the same. Finally, the results were cross verified by pre-planned spread sheets.

***Index Terms* – Prestress Concrete Column, P-M Interaction Curves, VB.net, Flexural Strength**

I. INTRODUCTION

Generally, columns are the member of structural frame which are subjected to axial compressive load as well as bending moments both. A column which carry only axial load is practically not possible. The application of moment in column may because of gravity loads, earthquake or wind loads. Even in such frame having symmetricity of building, the column is subjected to moments due to the application of different intensity of live load with different arrangement.

Columns are the members in building used to transfer vertical loads to the foundation and to resist the moments due to eccentricity of loads. To overcome such large uniaxial bending moments in columns the prestressed concrete columns are introduced. It is not much difficult to calculate Pu and Mu for the already given location of neutral axis but it becomes more complex to find out the position of neutral axis for the given value of Pu and Mu. By using interaction curves user can design economical and efficient section to resist uniaxial bending by adopting prestressing in the columns. So the work introduces the easiest and quickest development of interaction curves for any user defined properties of square or rectangular shape of prestress column by using VB.net a computer software.

II. CONSEQUENCE OF THE WORK

We have mostly dealt with flexural members only but in case of compression members prestressing are helpful for eccentrically loaded structures which are subjected to tension and bending. For pure compressive column prestressing is not advantageous but for the column having large eccentricity of load as well as moments due to lateral loads prestressing is much helpful. For the columns subjected to large uniaxial bending moments where only conventional reinforcement is not sufficient, so the prestressing steel are used in combination with non-prestressing steel.

To analyze the columns subjected to prestressing the interaction curves are prepared and to prepare the interaction curve the equations were already available but to obtaining the values for plotting the chart it is very time consuming and laborious procedure. By using the application, the user can get the interaction curve in quick and easy way.

III. P-M INTERACTION CURVES FOR PRESTRESSED CONCRETE COLUMN

A load-moment interaction diagram planned on the P-M interaction chart represents the specific axial load capacity and ultimate bending moment capacity of a given section of column. The uniaxial bending moment capacity and axial load can be computed by using the principal of static symmetry and strain compatibility.

The impact of the concrete to the column strength is seen as a continuous curve, and the contribution of the steel bar (prestressing steel) and the structural steel in both faces as a curve with two lines comparatively straight which inter connect each other at a point. In that case of column with a high steel ratio, the shape of the interaction diagram become more linear and in case of low steel ratio, the interaction diagram is more curved. Strength is conventionally represented by plot of axial load capacity Pu versus the moment on the section at ultimate. Any combination of axial force and bending moment applied to the column cross section that falls inside the interaction curve is safe and be carried out by cross section. while any point outside curve represents a combination of axial force in moment that exceeds the strength of cross section.

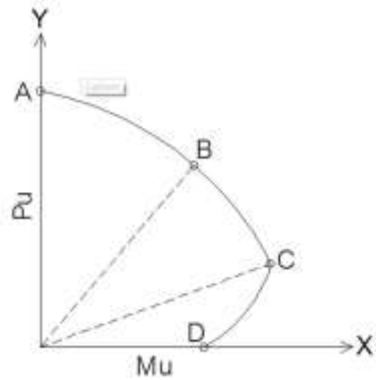

Fig. 1: Typical Interaction Curve

Description of various points on curve are as follow: Point A on the vertical axis represents the axial compression. Point B represents zero tension point at face i.e. the combination of axial force Pu and moment Mu, when combined with prestrains caused by prestress which produces zero strain in the extreme concrete fiber. Point C is known as the balanced failure point. So the position of neutral axis lies inside the cross section. Point D is the pure bending point where the axial force is zero.

IV. EQUATIONS AND ASSUMPTIONS FOR DEVELOPMENT OF CURVES

R. I. Gilbert and N. C. Mickleborough given idealized method and equations to obtain the values for preparing interaction curves. For prestressed concrete short columns subjected to uniaxial bending and axial load. The idealized rectangular stress block specified in ACI-318-11 are used to determine the concrete compressive strength.

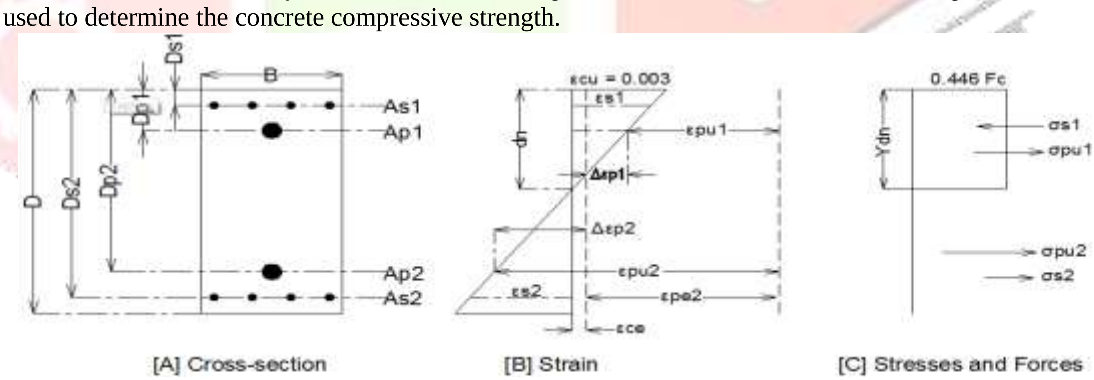

Fig. 2: Ultimate stresses and strains on a cross-section in combined compression and uniaxial bending

Notations used:

B = dimension in transverse direction of bending

D = dimension in direction of bending

Ap1 & Ap2 = area of prestressing steel in compression and tension zones, respectively

As1 & As2 = area of non-prestressing steel in compression and tension zone respectively

Ds1&Ds2 = distance of non prestressing steel from extreme fiber respectively

Dp1&Dp2 = distance of prestressing steel from extreme fiber respectively

Strain in prestressing steel εpe and concrete εce are calculated from below equations. The value of compressive strain failure for concrete is taken as $\varepsilon cu = 0.003$ in accordance with ACI codes. The computation of Pu and Mu for typical cases of various position of Xu are as follows.

$$\varepsilon_{ce} = \frac{P_e}{[(m-1)\,A_s + A_y]\,E_c} \qquad \varepsilon_{pe} = \frac{F_p}{E_p}$$

$$C = 0.446 f_c (A_g - A_p - A_s)$$

$$\sigma_{pu} = E_p(\varepsilon_{pe2} - \varepsilon_{cu} + \varepsilon_{ce}) \quad and \quad C = 0.446 f_c \gamma b d_n$$

$$C_s or\, T_s = 0.87 A_s f_y \;\; or \;\; A_s \varepsilon_s E_s$$

$$T_{p1} = A_{p1}E_p\left[\varepsilon_{pe1} - \frac{0.003(d_n - d_{p1})}{d_n} - \varepsilon_{ce}\right] \quad And \quad T_{p2} = A_{p2}E_p\left[\varepsilon_{pe2} - \frac{0.003(d_n - d_{p2})}{d_n} + \varepsilon_{ce}\right]$$

$$P_U = C + (C_{s1} + T_{s2}) - (T_{p1} + T_{p2})$$

$$M_u = P_u e = C_c\left(\frac{D}{2} - \gamma d_n\right) + C_{s1}\left(\frac{D}{2} - d_{s1}\right) - T_{p1}\left(\frac{D}{2} - d_{p1}\right) + T_{p2}\left(d_{p2} - \frac{D}{2}\right) + T_{s2}\left(d_{s2} - \frac{D}{2}\right)$$

$$e = \frac{M_u}{P_u}$$

V. DEVELOPMENT OF CURVE USING VB.NET

Different variable and constant data to be taken in program to plot the chart are as:

1) Grade of concrete, Fc = M30, M40, M45, M50, M55 & M60
2) Grade of prestressing steel = 1860 N/mm2
3) Grade of non-prestressing steel = Fe415 & Fe500
4) Modulus of elasticity for prestressed and non-prestressed steel are = 1.95 X 105 N/mm2 & 2 X 105 N/mm2 resp.
5) Cross-Section dimensions B & D as per user's requirement.
6) % of steel: Min. 0.8 % and max. 6 % in combination with prestressing & non-prestressing steel.

Step wise flow chart according to VB.net program is as below:

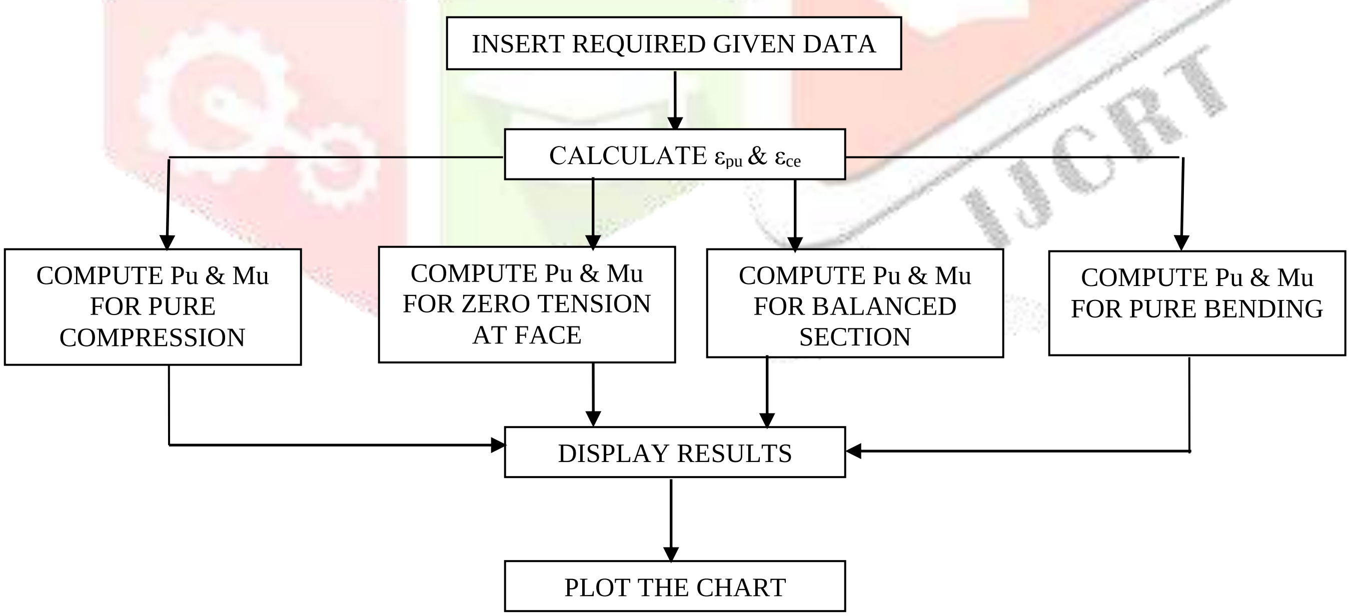

Fig 3: Flow chart for program

B	D	Fc	Fy
230	450	50	415

B	D	Fc	Fy
230	450	40	415

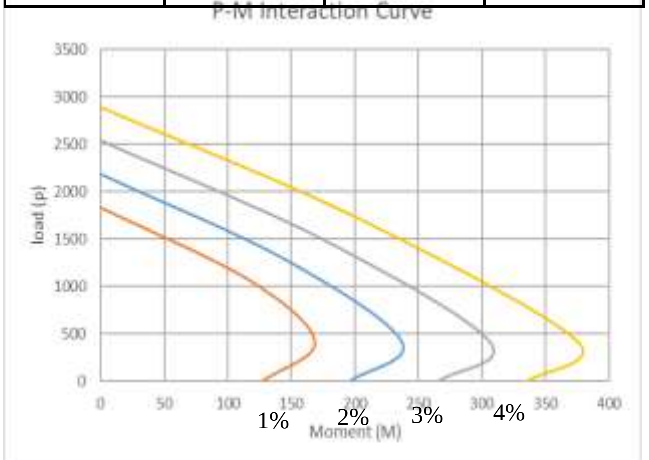

Fig 4: P-M Interaction Curve

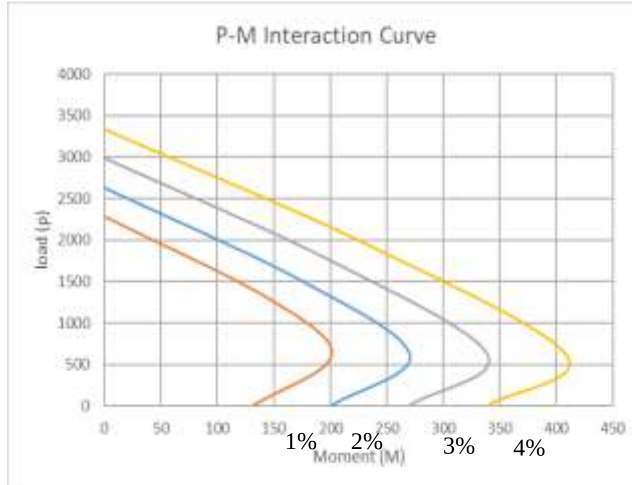

Fig 5: P-M Interaction Curve

B	D	Fc	Fy
300	600	50	415

B	D	Fc	Fy
300	600	40	415

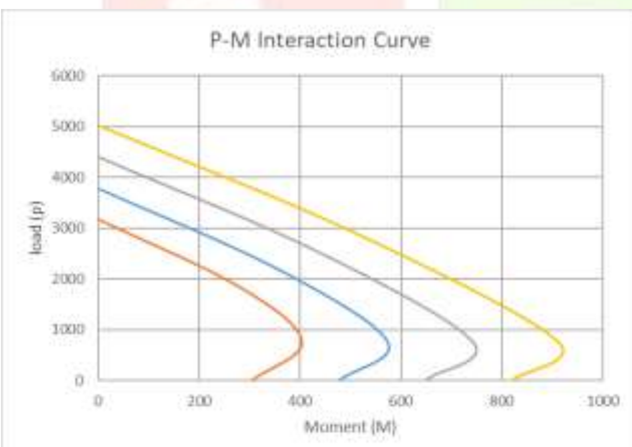

Fig 6: P-M Interaction Curve

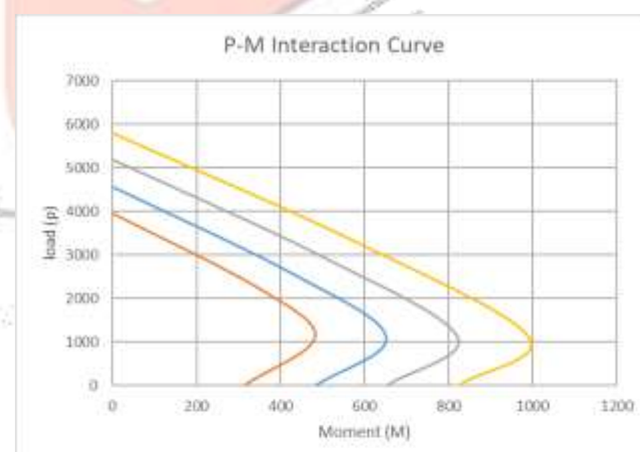

Fig 7: P-M Interaction Curve

B	D	Fc	Fy
300	750	40	415

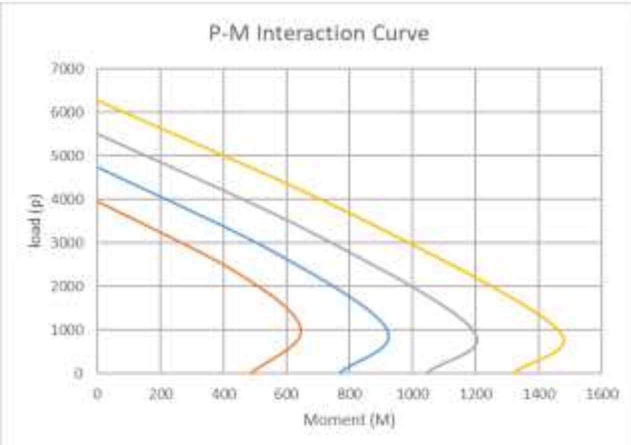

Fig 8: P-M Interaction Curve

B	D	Fc	Fy
300	750	50	415

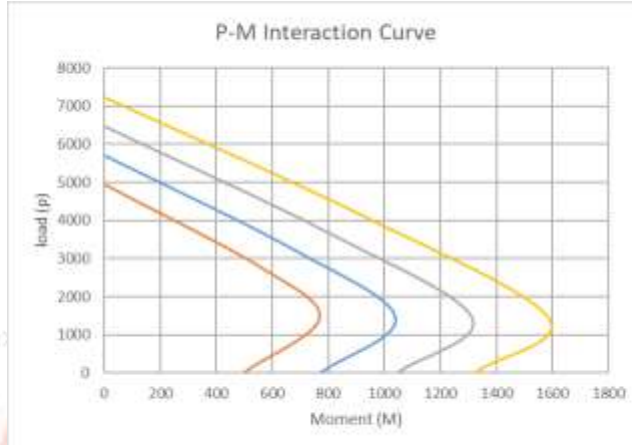

Fig 9: P-M Interaction Curve

B	D	Fc	Fy
450	600	50	415

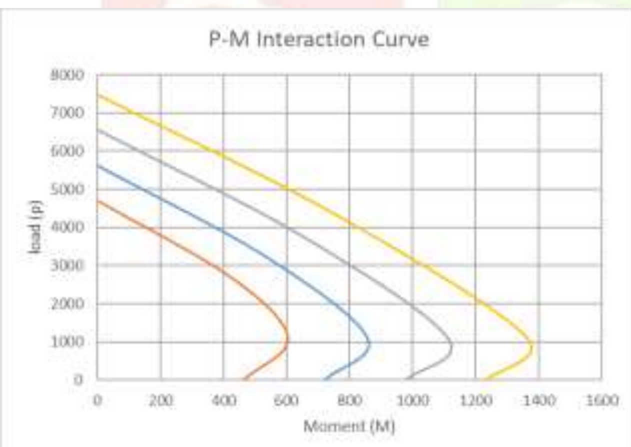

Fig 10: P-M Interaction Curve

B	D	Fc	Fy
450	600	40	415

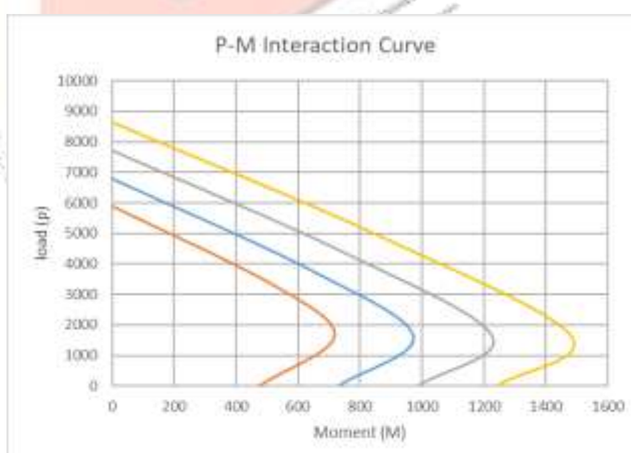

Fig 11: P-M Interaction Curve

VI. CONCLUSION

A computer application is developed in VB.net for development of P-M interaction diagrams for a prestressed columns under uniaxial bending and axial load.

1) By prestressing column, the axial load carrying capacity mar reduce but flexural strength of column can be significantly increase.

2) The interaction diagram to analyse the prestressed column can be obtained quickly and in efficient way.
3) The main contribution is considerable simplification of time consuming evaluation process and elimination for manual derivation of characteristics of cross section shapes.
4) The use of interaction curve is easy and safe tool for the analysis and design of prestressed concrete short columns.
5) Chart can be draw between any % of steel ranges from0.8% to 6% of cross sectional area according to IS provisions.
6) If the prestressing is provided only in tension zone of column, then there is no significant effect on its load carrying capacity but noticeable increment on its flexural strength.
7) For the same moment caring capacity of column the economical section can be achieved by prestressing the column in comparison with non-prestressed column.

VII. REFERENCES

1) R. I. GILBERT, N. C. MICKLEBOROUGH "DESIGN OF PRESTRESSEED CONCRETE", (2004).
2) T. Y. LIN, NED H. BURNS "DESIGN OF PRESTRESSED CONCRETE STRUCTURES", (2012).
3) N KRISHNA RAJU "PRESTRESSED CONCRETE", (2012).
4) ACI 318-11 "BUILDING CODE REQUREMENTS FOR STRUCTURAL CONCRETE"
5) IS 1343-2012 "PRESTRESSED CONCRETE-CODE OF PRACTICE"
6) IS 456-2000 "PLAIN AND REINFORCED CONCRETE-CODE OF PRACTICE"
7) Dr. AMLAN K SENGUPTA AND PROF. DEVDAS MENON "PRESTRESSED CONCRETE STRUCTURES", NPTEL.