VOL. 14, NO. 5, MARCH 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

NOVEL FLOWCHART TO COMPUTE MOMENT MAGNIFICATION FOR LONG R/C COLUMNS

Abdul Kareem M. B. Al-Shammaa[1] and Ehsan Ali Al-Zubaidi[2]
[1]Department of Urban Planning, Faculty of Physical Planning, University of Kufa, Iraq
[2]Department of Computer and Internet, Faculty of Physical Planning, University of Kufa, Iraq
E-Mail: abdulkareem.baqir@uokufa.edu.iq

ABSTRACT

For computing moment magnification and then design R/C columns with rectangular or circular sections, there is a number of procedural steps and equations provided by ultimate strength design method according to ACI-Code. The large number of equations and fork of solution steps causes a lot of confusion and boredom for the students or designers. Having consulted the most common and authoritative textbooks that dealt with design of reinforced concrete structures as well as my long experience in teaching reinforced concrete material. I have concluded that the novel flowchart according to ACI 318-2011 has more effect to give beginner engineering students speed to achieve design steps by less time and effort. This study focuses on compression members within braced (nonsway) or unbraced (sway) frames which have rectangular or circular sections subjected to axial compression loads and uniaxial moment. Finally, the author has enabled to draw a simplified flowchart to track steps of moment magnification easily and conveniently by using SI units.

Keywords: column strength, long column, braced frame, unbraced frame, lateral deflection.

1. INTRODUCTION

In general, columns are subjected to applied moments and axial loads combined with lateral deflection due to wind and earthquakes. Lateral deflection with axial load produce additional moment, added to the applied moment to yield new moment called magnified moment M_c. Effect and magnitude of moment magnification depend on whether the frame is braced or unbraced against sideways. If lateral bracing elements, such as shear wall, shear trusses and diaphragm are provided or the columns have substantial lateral stiffness, then the lateral deflections produced are relatively small and their effect on the column strength is substantially low. Also, increase of their effect depends on slenderness ratio of columns which is greater at long columns than short columns. Therefore, slender or long column have more effect by lateral or vertical deflection than short column.

ACI-Code and many textbooks are dealt with how to compute magnify moment. But, with a large number of equations and fork of solution steps, the author has not found anyone to tell us a simple and easy way for computation. Author has been personal suffering in conveying information of this subject to the beginner engineering students. So, the author has adopted a technique to simplify procedures by creating novel flowchart.

According to the content of ACI-2011, computing of moment magnification has been started from item 10.6 and ended with item 10.7 within seven pages. By creating a flowchart, seven pages may be summed up in addition to what is mentioned in the textbooks in this regard. This flowchart is a roadmap to facilitate steps to determine moment magnification of long R/C columns and to distinguish between the short and long columns. This is what I can confirm it through signs of acceptance and satisfaction which show on the face of my students during teaching this subject.

2. EXPERIMANTAL PROCEDURE

The study related to prepare flowchart shown in Figure-1 has the following properties:

a) It has been made for rectangular R/C columns, using ultimate strength design method by ACI -2011with SI unit for all equations and values.

b) The minimum moment (M_{min}) must be applied to the ends of compression members which represented by the equation $P_u(15 + 0.03h)$. Thu as shown in flow- chart, the magnified moment (M_c) always compare with(M_{min}), which shall not been taken less than(M_{min}). In general, application of (M_{min}) equation is very necessary to calculate, if computations show that there is no moment (or less amount) at both ends of a compression member or that computed end eccentricities are less than $(15 + 0.03h)$.

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

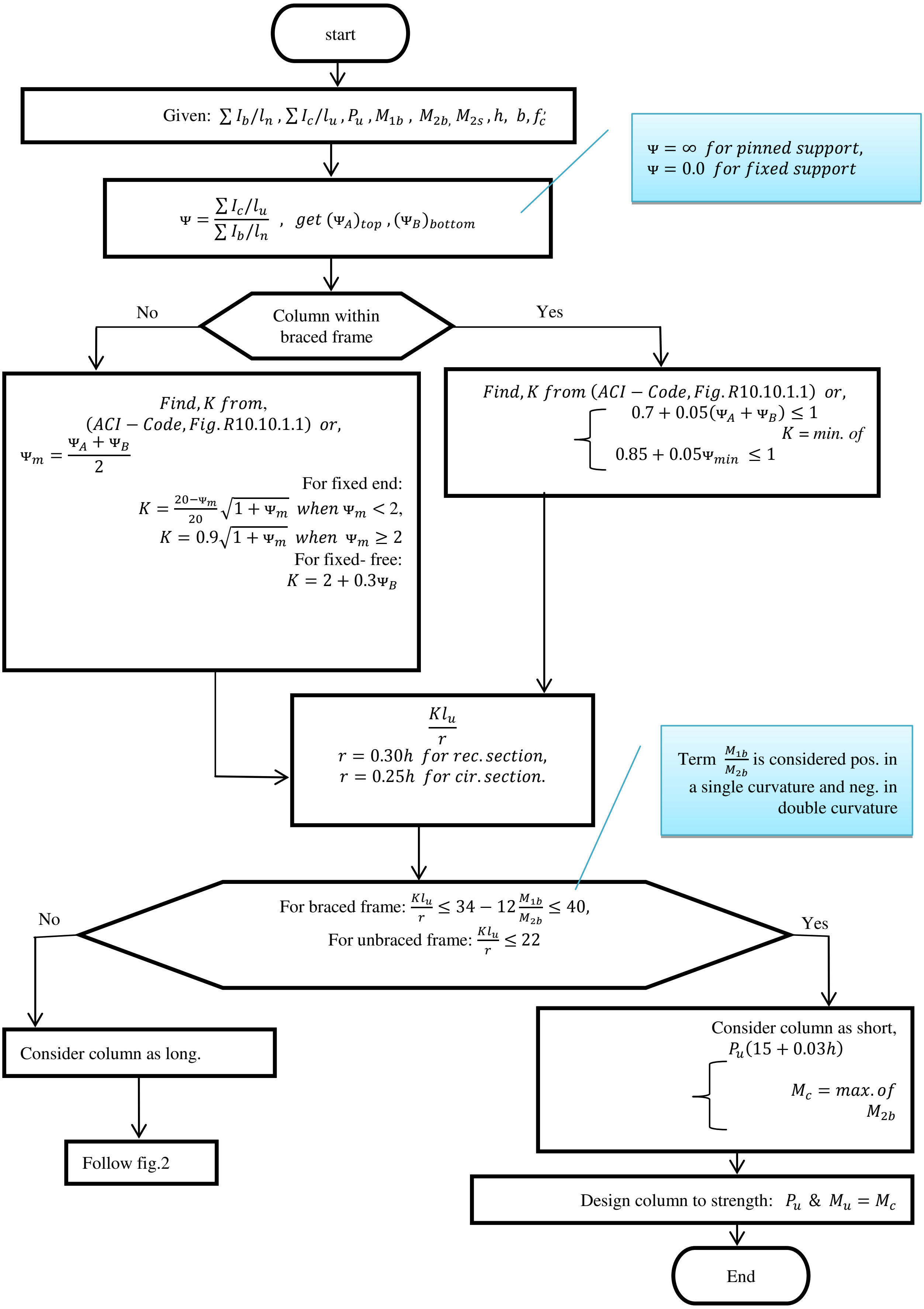

Figure-1. Flowchart to compute the magnified moment of short R/C columns.

VOL. 14, NO. 5, MARCH 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

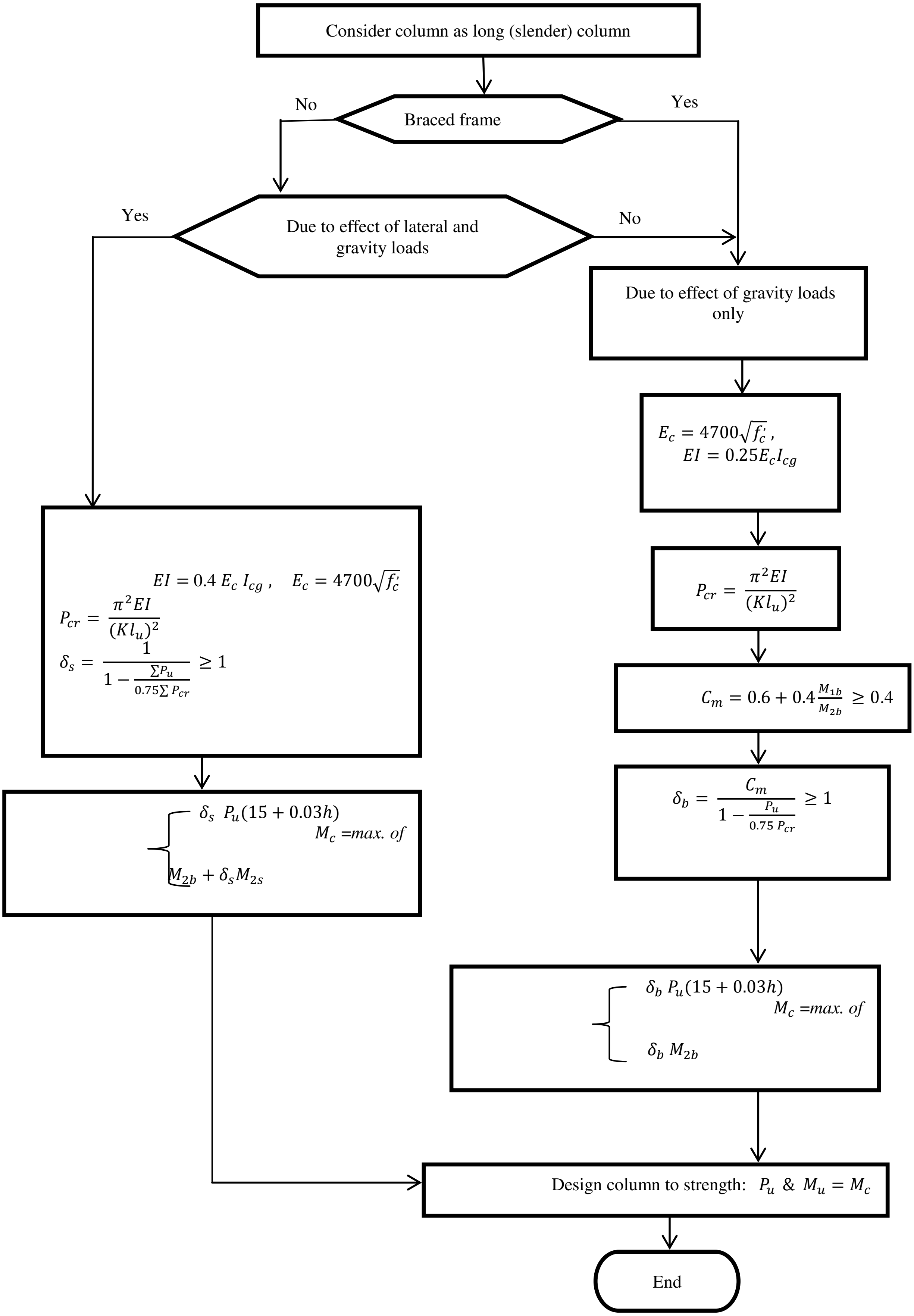

Figure-2. Flowchart to compute the magnified moment of long R/C columns.

c) the sequence of design steps for slender columns in sway frames is similar to that for nonsway frames, except for the requirement that loads be separated into gravity loads, which are assumed to produce no sway, and lateral loads producing sway. Separate frame analysis is required, and different equivalent length factor K must be applied.

d) Stiffness equation $EI = \frac{0.4E_c I_{cg}}{1+\beta_{dns}}$, can be simplified to $EI = 0.25E_c I_{cg}$ for braced frames, and $EI = 0.4E_c I_{cg}$ for unbraced frames. For simplification, it can be assumed that creep coefficient $\beta_{dns} = 0.6$ and $\beta_{dns} = 0$ for braced and unbraced frames respectively, as mentioned in the commentary of ACI-Code.

3. APPLICATION EXAMPLES

The following examples are Applications to the suggested flowchart as shown in Figures 1 and 2.

A) Example- 1

The column section 600x400mm (23.62x15.75 in.) bent about its major axis (i.e, h=600mm) carries factored gravity loads P_u= 1510 kN (339.5 K) and M_{2b}=390 kN.m (287.61 K.ft) (due to combined dead and live loads). The column is part of frame that is unbraced (sway) against sidesway. The end-restraint factors are Ψ_A =0.8 and Ψ_B =2 and the unsupported length is l_u =5 m (16.4 ft). Determine the magnified moment. Use f_c' =28 MPa (4 ksi), assumed moments at both ends of the column are equal and cause bent the column in single curvature.

Solution

$$\Psi_m = \frac{\Psi_A + \Psi_B}{2} = \frac{0.8 + 2}{2} = 1.4 < 2$$

$$K = \frac{20 - \Psi_m}{20}\sqrt{1 + \Psi_m} = \frac{20 - 1.4}{20}\sqrt{1 + 1.4}$$

$$K = 1.44$$

$$\frac{Kl_u}{r} = \frac{1.44(5 * 10^3)}{0.3(600)} = 40 > 22,$$

The slenderness effect must be considered. Due to gravity load only, get:

$$E_c = 4700\sqrt{f_c'} = 4700\sqrt{28}$$

$$E_c = 24.87 * 10^3 \text{MPa (3607 ksi)}$$

$$I_{cg} = \frac{bh^3}{12} = \frac{400(600)^3}{12}$$

$$I_{cg} = 7.2 * 10^9 \text{ mm}^4 \text{ (17300 in.}^4\text{)}$$

$$EI = 0.25E_c I_{cg}$$

$$EI = 0.25(24.87 * 10^3)(7.2 * 10^9) * 10^{-9}$$

$$EI = 44766 \text{ kN.m}^2 \text{ (108335 K.ft}^2\text{)}$$

$$P_{cr} = \frac{\pi^2 EI}{(Kl_u)^2} = \frac{\pi^2(44766)}{(1.44 * 5)^2}$$

$$P_{cr} = 8522.8 \text{ kN (1916.1 K)}$$

$$C_m = 0.6 + 0.4\frac{M_{1b}}{M_{2b}}$$

$$C_m = 0.6 + 0.4(1) = 1 > 0.4 \ \dots\dots (o.k)$$

$$\delta_b = \frac{C_m}{1 - \frac{P_u}{0.75\, P_{cr}}} = \frac{1}{1 - \frac{1510}{0.75(8522.8)}}$$

$$\delta_b = 1.31$$

Since the frame has no appreciable sidesway, then the enter moment M_u is taken as equal M_{2b} and magnification factor δ_s is taken as equal to zero. As mentioned above no need to apply equation $\delta_b\, P_u(15 + 0.03h)$.

$$M_c = \delta_b\, M_{2b} = 1.31(390)$$

$$M_c = 510.9 \text{ kN.m (376.77 K.ft)}$$

Design column to strength P_u= 1510 kN and $M_u = 510.9$ kN.m

B) Example- 2

The column section 400x250mm (15.75x9.84 in.) carries factored loads as shown in fig.3. The column is part of frame that is unbraced (sway) against sidesway. Determine the magnified moment. Use:

$E_c = 20600$ MPa (2987.7 ksi),
$I_b = 3330 * 10^6 \text{mm}^4$ (8001 in.^{4}),
$I_c = 933.3 * 10^6 \text{mm}^4$ (2242 in.^{4}),
$l_u = 2970$mm (10 ft), $l_n = 7300$mm (24 ft).

Solution

$$(\Psi_A)_{top} = \frac{\sum \frac{I_c}{l_u}}{\frac{\sum I_b}{l_n}} = \frac{933.3 * \frac{10^6}{2970}}{3330 * \frac{10^6}{7300}}$$

$$(\Psi_A)_{top} = 0.69$$

$$(\Psi_B)_{bottom} = \infty$$

From the chart $(\text{ACI} - \text{Code, Fig. R10.10.1.1})$, K=2 for an unbraced frame.

$$\frac{Kl_u}{r} = \frac{2(2970)}{0.3(400)} = 49.5 > 22,$$

consider column as slender

$$E_c\, I_{cg} = 20600\left(\frac{250 * 400^3}{12}\right) * 10^{-9}$$

$$E_c\, I_{cg} = 27467 \text{ kN.m}^2 \text{ (66470 K.ft}^2\text{)}$$

$$EI = 0.4E_c I_{cg} = 0.4(27467)$$

$$EI = 10986.8 \text{ kN.m}^2 \text{(26590 K.ft}^2\text{)}$$

$$P_{cr} = \frac{\pi^2 EI}{(Kl_u)^2} = \frac{\pi^2(10986.8)}{(2 * 2970 * 10^{-3})^2}$$

$$P_{cr} = 3073 \text{ kN (691 K)}$$

$$\delta_s = \frac{1}{1 - \frac{\sum P_u}{0.75 \sum P_{cr}}} = \frac{1}{1 - \frac{163}{0.75(3073)}}$$

$$\delta_s = 1.076 > 1 \ \dots\dots (o.k)$$

$$M_c = M_{2b} + \delta_s M_{2s} = 68 + 1.076(30)$$

$$M_c = 100.28 \text{ kN.m (74 K.ft)}$$

Design column to strength P_u= 163 kN and $\text{M}_\text{u} = 100.28$ kN.m.

C) Example- 3

The column section 400x300mm (15.75x11.81 in.), carries factored gravity loads P_u =2000 kN (500 K), M_{2b}=85 kN.m (62.68 K.ft), and M_{1b}=15 kN.m. (11 K.ft).the column is part of frame that is braced against sidesway and bent in double curvature about its major

ARPN Journal of Engineering and Applied Sciences

axis. Determine the magnified moment. Use, f_c' =28 MPa (4ksi), K=0.9 and $l_u = 5\text{m}(16.4\text{ ft})$.

Solution:

$$34 - 12\frac{M_{1b}}{M_{2b}} = 34 - 12\frac{-15}{83} = 36$$

$$\frac{Kl_u}{r} = \frac{0.9(5*10^3)}{0.3(400)} = 37.5 > 36$$

Consider column as slender. For braced frame and due to effect of gravity loads, yield:

$$E_c = 4700\sqrt{f_c'} = 4700\sqrt{28}$$

$$E_c = 24.87 * 10^3 \text{MPa (3607 ksi)}$$

$$EI = 0.25 E_c I_{cg}$$

$$EI = 0.25(24.87 * 10^3)\left(\frac{300*400^3}{12}\right) * 10^{-9}$$

$$EI = 9948 \text{ kN.m}^2 \text{ (24075 K.ft}^2\text{)}$$

$$P_{cr} = \frac{\pi^2 EI}{(Kl_u)^2} = \frac{\pi^2(9948)}{(0.9*5)^2}$$

$$P_{cr} = 4848.5 \text{ kN (1090 K)}$$

$$C_m = 0.6 + 0.4\frac{M_{1b}}{M_{2b}} = 0.6 + 0.4\left(\frac{-15}{83}\right)$$

$$C_m = 0.53 > 0.4 \;\ldots\ldots(o.k)$$

$$\delta_b = \frac{C_m}{1 - \frac{P_u}{0.75\,P_{cr}}} = \frac{0.53}{1 - \frac{2000}{0.75(4848.5)}}$$

$$\delta_b = 1.18 > 1 \ldots\ldots\ldots(o.k)$$

$$M_c = \delta_b\, M_{2b} = 1.18(85)$$

$$M_c = 100.3 \text{ kN.m (74 K.ft)}$$

Design column to strength P_u= 2000 kN and $\mathrm{M_u}$ = 100.3kN. m

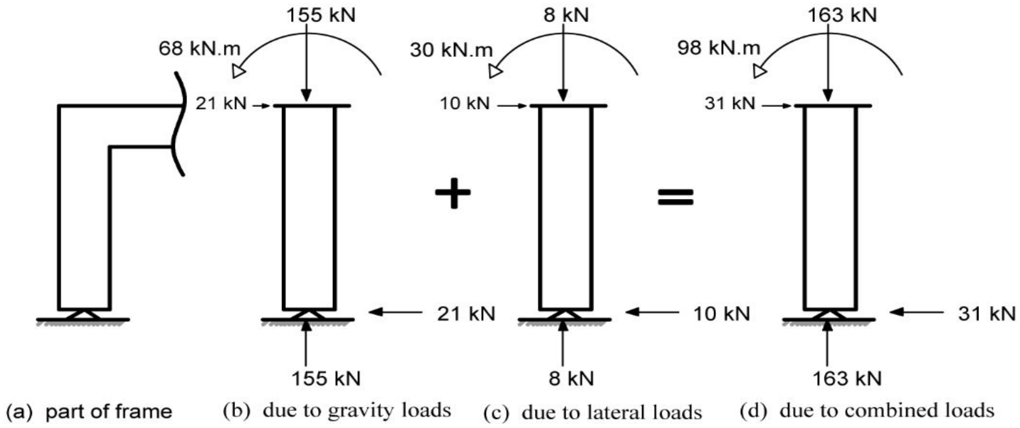

Figure-3. Example 2.

4. CONCLUSIONS

Based on the results of this study, the following conclusions are drawn:

This flowchart is a roadmap to facilitate steps of determines moment magnification of long R/C columns. Author has been personal suffering in conveying information of this subject to the beginner engineering students. So, author go to simplify procedures by create novel flowchart.

Flowchart may be summed up seven pages of ACI-Code which is deal with how to compute magnified moment. This study focuses on compression members within braced (nonsway) or unbraced (sway) frames have rectangular or circular sections subjected to axial compression loads and uniaxial moment. Finally, author enables to draw a simplified flowchart to track steps of moment magnification easily and conveniently by using SI units and ultimate strength design method according to ACI-Code, 2011.

NOTATION AND DEFINITIONS

b	Width of concrete section, mm.
C_m	Factor relating actual moment diagram to an equivalent uniform moment diagram.
d	Overall depth of concrete section, mm.
E_c	Modulus of elasticity of concrete, MPa.
EI	Flexural stiffness of compression member, N·mm^2.
f_c'	Specified compressive strength of concrete, MPa.
h	Overall dimension of concrete section, taken perpendicular to the axis that moment rotation about it. i.e, either width or depth of concrete section, mm.
I_{cg}	Moment of inertia of gross column section about centroid axis, neglecting reinforcement, mm^4.
I_{bg}	Moment of inertia of gross beam section about centroid axis, neglecting reinforcement, mm^4.
I_c	Equivalent moment of inertia of compression member, mm^4.
I_b	Equivalent moment of inertia of flexural member, mm^4.
K	Effective length factor for compression members.
l_n	Span length of flexural member measured center to center of joints, mm.
l_u	Unsupported column length, mm.

M_c Factored moment amplified for the effects of member curvature used for design of compression member, N·mm.
M_u Factored moment used for column design .
M_{2b} Larger factored end moment on compression member. Value of M_{2b} is always positive N·mm.
M_{1b} Smaller factored end moment on compression member, to be taken as positive if member is bent in single curvature, and negative if bent in double curvature, N·mm.
M_{2S} Factored end moment on compression member at the end at which M_{2b} acts, due to loads that cause appreciable sidesway, N·mm.
P_u Factored axial load, N.
P_{cr} Critical buckling load, N.
r Radius of gyration, mm.
δ_b Moment magnification factor to reflect effects of member curvature between ends of compression member.
δ_s Moment magnification factor for frames not braced against sides way, to reflect lateral drift resulting from lateral and gravity loads.
Ψ End restraint factor. i.e, ratio of $\sum E_c I_c / l_u$ of compression members to $\sum E_c I_b / l_n$ of flexural members in a plane at one end of a compression member.
Ψ_m Average of end-restraint factors.
Ψ_{min} Minimum of end-restraint factor.

REFERENCES

[1] ACI Committee 318, 2011. Building Code Requirements for Reinforced Concrete (ACI 318-11). American Concrete Institute, Detroit, USA. pp. 146-154.

[2] Nawy, E. G. 2009. Reinforced Concrete a Fundamental Approach. 6th Edition. Pearson Education, USA. pp. 386-397.

[3] Wang C., Salmon C.G. and Pincheira J.A. 2007. Reinforced Concrete Design. 7th Edition, Wiley, USA. pp. 581-592.

[4] Hassoun M. N. and Al-Manaseer A. 2008. Structural Concrete Theory and Design. 4th Edition, Wiley, USA. pp. 581-592.

[5] Nilson A.H., Darwin D. and Dolan C.W. 2010. Design of Concrete Structures. 14th Edition, McGraw-Hill, USA. pp. 300-320.

[6] Abdulkareem M.B. Al-Shamma. 2014. Novel Flowchart for design of Concrete Rectangular Beams. IJSER. 5(2): 231-233.

[7] Abdulkareem M.B. Al-Shammaa. 2014. Create Shear Stair for Reinforcement of Concrete Beams. IJ RET. 3(1): 412-414.