REINFORCED CONCRETE BEAM AND COLUMN PROGRAMMING BASED ON SNI:2847-2019 ON SMARTPHONE USING TEXAS INSTRUMENTS

Toni Hartono Bagio¹, Eugene Yudhistira Baggio², Sri Wiwoho Mudjarnako³, Pio Ranap Tua Naibaho⁴

¹,⁴ Department of Civil Engineering, Universitas Tama Jagakarsa, Jakarta, INDONESIA
¹,²,³ Department of Civil Engineering, Universitas Narotama Surabaya, INDONESIA
E-mail: tony@narotama.ac.id

ABSTRACT

The development of technology in the last few years cannot be denied that it has developed very rapidly. In building construction, reinforced concrete beam and columns calculations also utilizing that technology development. Input data used to calculate reinforcement of beam and column are material property, section property and internal forces. Calculation of reinforcement beam using quadratic equation method and reinforcement column using Newton-Raphson method and divided-by-two method. Calculation results are flexural reinforcement As (longitudinal compression area) and As’ (longitudinal tension area), shear reinforcement Av (transversal area) and S (distance of Av), torsional reinforcement Avt (transversal area due to torsional and/or shear), S (distance of Avt), Along (longitudinal area due to torsional buckling), column circular reinforcement Atot (total of longitudinal area), column rectangular two faces reinforcement Atot (total of longitudinal area), column rectangular four faces reinforcement Atot (total of longitudinal area), column biaxial reinforcement Atot (total of longitudinal area). The program determines As, As’ and Atot, the code is written using the Texas Instruments programming language, so that it can be applied to smartphones. Smartphone and manual calculation, for all cases not more than 5%, the calculation using Texas Instrument is accurate.

Keywords: smartphone; texas instruments; Newton-Raphson method; divided by two method; beam and column reinforcement.

Received: 2021-07-27
Revised: 2021-08-16
Accepted: 2021-10-05
Available online: 2021-10-20

INTRODUCTION

Reinforced concrete beams are assumed to be multi-layered, which consists of layers of concrete and layers of reinforcement, analyzed with an element model, using the FORTRAN language (Abdi.FN, 2008). STAAD software, to analyze and design concrete beams and columns and compiled in Excel to summarize the results of STAAD (Fernandez.RJ, et.al, 2017). The mix design program, written in the Borland Delphi programming language, but does not discuss concrete reinforcement (Vectoriarda.US, et.al, 2014). Other researchers discuss reinforcing concrete columns, without using programming (Kriastianto,A.et.al, 2012; Bagio.TH, Kusuma.B, 2012; Nawy, et.al, 2010). Multiple reinforcement with optimum design, using annealing simulation, which discusses the design of reinforced concrete with the ultimate strength design method (Bagio.TH, Kusuma.B, 2012; Ferguson,PM,et.al, 1986).

Constraints used in this study were bending beam, minimum beam width, and deflection, while the optimization was using annealing simulation method (GalebAC, 2018). Program for special reinforcement for columns, [9]. Analysis and design of beam column joints based on SNI 2847-2019 (Bagio.TH, Kusuma.B, 2012; Nawy, et.al, 2010;LeungCK, Simmonds,SH, 1984bhatt,P, et.al, 2006; McCormacJC, Brown,RH, 2014; Kadamningsh,R.et.al, 2017). Column reinforcement, based on the column equivalence concept, where the axial load on the column, indirectly gives an additional moment, assuming eccentricity (Afefy,HM, El-Tony,TM, 2016).

A computer program for concrete reinforcement in portals, based on cracked beams, discusses iterative procedures, ACI (American Code) and CEB (Euro Code) models are compared (ACI, International, 201; ACI Comittee318, 2014; Computers & Structures Inc, 2004; Computers & Structures Inc, 2004). Reinforced concrete with and without limitation (curtailment) of

General programs for calculating concrete reinforcement for beams and/or columns are all using a PC or a laptop, in the new era, smartphone is not only to call, but it will come to replacing PC in your hand, with Wabbitemu applications and using the TI (Texas Instruments) programming language (Texas Instrument, 2019; Texas Instruments, 2019).

**BASIC THEORY**

**Flexural of beam.**

Calculation of reinforced concrete beam due to bending moment, the properties of the beam and the moment from the results of the structural analysis are needed, figure 1.

\[
\beta_1 = 0.85 - \frac{(f'c - 28)}{140} \quad (0.65 \leq \beta_1 \leq 0.85) \tag{1}
\]

\[
f_s' = 600 \frac{c-d'}{c} \leq f_y \tag{2}
\]

\[
a = \frac{As \times fy - As' \left( f_s' - 0.85 f'c \right)}{0.85 f'c \times b} \tag{3}
\]

\[
Mn = \frac{M_u}{\phi} ; \phi = 0.9 \tag{4}
\]

\[
Mn = \left[ As \times fy - As' \left( f_s' - 0.85 f'c \right) \right] \left[ d - \frac{a}{2} \right] + As' \left( f_s' - 0.85 f'c \right) (d-d') \tag{5}
\]

**Shear Beam Reinforcement**

Inclined cracks can develop in the webs of reinforced concrete beams, either as extensions of flexural cracks or occasionally as independent cracks. The first of these two types is the flexure – shear cracks.
**Figure 2.** Beam with vertical stirrups *(Source: McCORMAC, 2014)*

Property of beams same as flexural beam, $fc$, $fy$, $b$, $d$, $h$, $fyt$ = yield strength of stirrups (MPa), $Vu$ = shear force of beam (kN), $Av$ = Area of stirrups (mm$^2$), $s$ = space of stirrups (mm), $ds$ = diameter of stirrups, $nk$ = numbers of stirrups legs ($\geq 2$)

$$V_u = \frac{Vu}{\phi}; \phi = 0.75$$

$$V_c = 2\sqrt{f_{c'} \times b_w \times d}$$

$$Av = nk \times 0.25 \times \pi \times ds^2$$

**Torsion Beam Reinforcement**

Reinforced concrete members are subjected to pure torsion, they will crack along 45° spiral lines when the resulting diagonal tension exceeds the design strength of the concrete.

Property of torsional beams same as beam with shear, $fc$, $fy$, $fyt$, $bw$, $d$, $h$, $Vu$, $Av$, $s$, $ds$, $At$ = torsional stirrups (mm$^2$), $Tu$ = torsional moment (kNm), $Vn$, $Vc$ from equation (6), and equation (7)

$$T_u = \frac{Tu}{\phi}; \phi = 0.75$$

$$At = 2 \times 0.25 \times \pi \times ds^2$$

$$X = bw; Y = h$$

**Figure 3.** Imaginary space truss *(Source: McCORMAC, 2014)*

**Figure 4.** Cross section of beam *(Source: Bagio, 2019)*

$$X_1 = X - 2 \times \left( \frac{d' + ds}{2} \right); \ Y_1 = Y - 2 \times \left( \frac{d' + ds}{2} \right)$$

$$A_{cp} = X \times Y; \ A_{oh} = X_1 \times Y_1; \ A_o = 0.85 \times A_{oh}$$
\[ P_{cp} = 2 \times (X + Y) \quad P_{h} = 2 \times (X_{1} + Y_{1}) \]  

(14)

\[ T_{c} = \frac{\sqrt{f_{c}'} \times A_{cp}^{2}}{12} \times \frac{P_{cp}}{P_{cp}} \]  

(15)

IF \( T_{a} \leq T_{c} \) THEN \( T_{a} = 0 \);

**Column Reinforcement**

All columns are subjected to some bending as well as axial forces, and they need to be proportioned to resist both. Property of rectangular column and circular same as flexural beam \( fc', f_y, b, h, Mu \), special for circular column \( b = 0 \), and \( P_{u} = \text{Axial load (kN)} \).

![Figure 5. Column rectangular stress-strain diagram (Source: Nawy, 2010)](image)

![Figure 6. Column circular stress-strain diagram (Source: Nawy, 2010)](image)

**Rectangular column (Figure 5)**

Moment capacity and forces capacity in concrete area

\[
\begin{align*}
\alpha & = \beta_{1} \times c \\
Cc & = 0.85 \times f_{c}' \times b \times a \\
M_{c} & = Cc \times (h - a)/2
\end{align*}
\]  

(16)

(17)

(18)

**Circular column (Figure 6)**

Moment capacity and forces capacity in concrete area

\[
\begin{align*}
z & = (1 - 2 \times \beta_{1} \times c/h) \\
\theta & = \text{ArcCos}(z) \\
A_{c} & = 0.25 \times h^{2} \times [0 - 0.5 \times \sin(2 \times \theta)] \\
y & = \frac{(h \times \sin(\theta))^{3}}{12 \times A_{c}} \\
Cc & = 0.85 \times f_{c}' \times A_{c} \\
M_{c} & = 0.85 \times f_{c}' \times A_{c} \times y
\end{align*}
\]  

(19)

(20)

(21)

(22)

(23)

(24)
Column Biaxial Bending

Many columns are subjected to biaxial bending, that is, bending about both axes. Corner columns in buildings where beams and girders frame into the columns from both directions are the most common cases.

![Column Biaxial Bending Diagram](image)

**Figure 7.** Column biaxial bending and axial load (Source: Nawy, 2010)

Property of biaxial bending moment for column same as rectangular column $f_c', f_y, b, h, P_u, M_{ux} = \text{Moment at x-direction (kNm)}, M_{uy} = \text{Moment at y-direction (kNm)}$

Interaction formula load contour modified method,

$$
\left( \frac{P_u - P_{nb}}{P_{no} - P_{nb}} \right) + \left( \frac{M_{ux}}{M_{nbx}} \right)^{1.5} + \left( \frac{M_{uy}}{M_{nby}} \right)^{1.5} \approx 1
$$

(25)

Texas Instrument

Programming using TI (Texas Instrument) difference with programing using PC. The variables on TI, only 27 variables (PC unlimited variables). Display on TI84 Plus C Silver Edition has 8 lines and 24 columns, and TI 84 Plus has 8 lines and 16 columns.

![Texas Instruments Display](image)

(a) TI84 Plus C Silver, (b) TI-84 Plus

**Figure 8.** Texas Instruments display (a) TI84 Plus C Silver, (b) TI-84 Plus

RESEARCH METHODS

Research method to calculate beam reinforcement due to bending, shear and torsion as well as calculating uniaxial or biaxial column reinforcement is $f_c', f_y, b, h, \text{ and external forces such as } M_u, V_u, T_u, \text{ and for columns } M_{ux}, M_{uy}, P_u$. It will be explained in detail in the next chapter.
Flexural Design of Beams.

\[ c_{\text{max}} = \frac{3}{8}d \]  
(26)

\[ a_{\text{max}} = \frac{3}{8}b_1d \]  
(27)

IF \( d < \sqrt[4]{\frac{M_n}{0.425f'_c b}} \) THEN “CHANGE DIMENSION”

\[ a = d - \sqrt{d^2 - \frac{M_n}{0.425f'_c b}} \]  
(28)

IF \( a > a_{\text{max}} \) THEN \( a = a_{\text{max}} \)

\[ \lambda = f_y \left( d - \frac{a}{2} \right) \]  
(29)

\[ \gamma = \left( f_y - 0.85f'_c \right) \times \left( \frac{a}{2} - d' \right) \]  
(30)

\[ C_c = 0.85 \times f'_c \times a \times b \]  
(31)

\[ \delta = \frac{M_n \times f_y - C_c \times \lambda}{M_n \times f'_c + C_c \times \gamma} \]  
(32)

\[ A_s = \frac{M_n}{\lambda + \delta \times \gamma} \]  
(33.a)

\[ A_{s'} = \delta \times A_s \]  
(33.b)

Shear Cracking of Reinforced Concrete Beams.

\[ V_s = V_n - V_c \]  
(34)

\[ A_{v_{\text{min}}} = \kappa \times \frac{b_w \times s}{f_{yt}} ; \kappa = \sqrt{\frac{f'_c}{16}} \geq 0.35 \]  
(35)

Zone area and \( \lambda = 1 \):

Zone 1: \( V_n \leq 0.5 \times V_c \) \; ; \; \frac{A_y}{s} = 0  
(36.a)

Zone 2: \( 0.5 \times V_c < V_n \leq V_c \) \; ; \; \frac{A_y}{s} = \frac{b_w}{f_{yt}} ; \; \kappa = \sqrt{\frac{f'_c}{16}} \geq 0.35 \; ; \; s = d / 2 \leq 600  
(36.b)

Zone 3: \( V_c < V_n \leq 3 \times V_c \) \; ; \; \frac{A_y}{s} = \frac{V_s}{f_{yt} \times d} \; ; \; s = d / 2 \leq 600  
(36.c)
Zone 4 : \(3 \cdot V_c < V_n \leq 5 \cdot V_c\); \(A_v = \frac{V_s}{f_{yt} \times d}\); \(s = d / 4 \leq 300\) \((36.d)\)

Zone 5 : \(V_n > 5 \cdot V_c\); “CHANGE DIMENSION” \((36.e)\)

**Design of Torsional Reinforcing.**

section get shear and torsion forces (from figure 3 and figure 4)

\[
\begin{align*}
VarL &= \left(\frac{V_n}{b_w \times d}\right)^2 + \left(\frac{T_n \times P_h}{1.7 \times A_{oh}}\right)^2; \\
VarR &= \frac{V_c}{b_w \times d} + \frac{2\sqrt{f_c'}}{3}
\end{align*}
\]

\((37)\)

IF \(VarL > VarR\) THEN “CHANGE DIMENSIONS”

\[
\frac{A_{t, min}}{s} = \kappa \frac{b_w}{f_{yt}}; \quad \kappa = \frac{\sqrt{f_c'}}{16} \geq 0.35
\]

\((38)\)

\[
\begin{align*}
A_{t, mn} &= \frac{5}{12} \sqrt{f_c'} A_{cp} - \frac{A_t}{s} P_h \frac{f_{yt}}{f_y} \\
\frac{A_t}{s} &= \frac{T_n \times \tan(\theta)}{2 \times A_p \times f_{yt}} \\
\frac{A_{at}}{s} &= 2 \frac{A_t}{s} + \frac{A_v}{s}
\end{align*}
\]

\((39)-(41)\)

\[
At = \frac{A_t}{s} P_h \frac{f_{yt}}{f_y} \cot^2 \theta
\]

\((42)\)

**Design of Column with Axial Load and Bending Moment**

Rectangular column (Figure 10.a)

Number of rows’ layer = N, number of columns’ layer = Nk; \(Nk = \text{INT} \left(\frac{b}{h} \times N\right) + 1\)

Number of total bars (ntot) = \(2(Nk + N - 2)\)

Section area, \(A_{gr} = b \times h\)

Rebar area, \(A_{s(i)} = \rho t \times A_{gr} \times nb\), where:

If \((i = 1 \text{ or } i = N)\) THEN \(nb = Nk/ntot\), ELSE \(nb = 2\)

Circular column (Figure 10.b)

Number of bars = \(N\)

Number of total bars (ntot) = \(2 \times N\)

Section area (Agr) = \(0.25 \pi \times h^2\)

Rebar area as(i) = \(\rho t \times Agr \times 2\)

General

\(A_{total} = \rho t \times Agr\), \(1% \leq \rho t \leq 8%\)

Spacing of rebars, \(s(i) = d' + (i - 1)(d - d') / (N - 1)\)

Rebar stressing, \(f_{ss}(i) = 600 \times (c - s(i)) / c\)
Compression force and tension force in the reinforcement and moment of the internal forces of the column concrete

\[ C_s = \sum_{i=1}^{N} fss(i) \times As(i) \]  
(43)

\[ M_s = \sum_{i=1}^{N} fss(i) \times As(i) \times \frac{(h - s(i))}{2} \]  
(44)

Internal force total, IF rectangular column, \( C_c \) from equation (17), \( M_c \) from equation (18), IF circular column \( C_c \) from equation (23), \( M_c \) from equation (24)

\[ P_o = C_c + C_s \]  
(45)

\[ M_o = M_c + M_s \]  
(46)

\[ e_u = \frac{M_o}{P_o} \]  
(47)

\[ e_o = \frac{M_o}{P_o} \]  
(48)

Using Newton-Raphson method until, \( e_o \approx e_o \), to get \( c \) value
Design reinforcement column with Biaxial Bending.

Notation of Figure 11.

\[ \text{nb} = \text{number of bars x direction} \]
\[ \text{nh} = \text{number of bars y direction} = \text{INT}(h/b \times \text{nb}) \]
\[ \text{ntot} = \text{total numbers of bars} = 2 \times (\text{nb} + \text{nh} - 2) \]
\[ \text{Asx OR Asy} = \text{rebar area in x-direction OR in y-direction} \]
\[ dx = \text{effective height} \quad dy = \text{effective width} \]
\[ \rho_t = \frac{\text{Astot}}{(b \times h)}; \quad 1\% < \rho_t \leq 8\% \] (49)

see figure 12.a, and figure 12.b

\[ px = \frac{\rho_t}{(h/b +1)} \quad ; \quad \rho_y = \frac{\rho_t}{(b/h +1)} \]

\[ \frac{600 \times (1 - d'/cby)}{cby} \]
\[ cby = \frac{600 \times (1 - d'/cby)}{600 + fy} \]
\[ C_{cx} = 0.85 \times f_{c'} \times b \times ax \]
\[ C_{cy} = 0.85 \times f_{c'} \times h \times ay \]
\[ C_{sx} = Asx' \times (f_{sx'} - 0.85 \times f_{c'}) \]
\[ C_{sy} = Asy' \times (f_{sy'} - 0.85 \times f_{c'}) \]

\[ \Psi = 0.65 + \left(\frac{fy}{200000 - 0.002}\right) \times \frac{250}{3} \]
For Interaction formula using equation (25)

\[
\left( \frac{P_n - P_{nb}}{P_{no} - P_{nb}} \right)^{1.5} + \left( \frac{M_{nx}}{M_{nbx}} \right)^{1.5} + \left( \frac{M_{ny}}{M_{nby}} \right)^{1.5} \approx 1
\]  

(50)

where :

\[
P_n = \frac{P_u}{\varnothing}
\]  

(51)

\[
M_{nx} = \frac{M_{ux}}{\varnothing}
\]  

(52)

\[
M_{ny} = \frac{M_{uy}}{\varnothing}
\]  

(53)

\[
P_{no} = 0.85 \times f_c' \times (A_{gr} - A_{st}) + f_y \times A_{st}
\]  

(54)

\[
P_{nbx} = C_{cx} + C_{sx} - T_x
\]  

(55)

\[
P_{nbx} = C_{cy} + C_{sy} - T_y
\]  

(56)

\[
P_{nb} = \text{MAX} (P_{nbx}, P_{nby})
\]  

(57)

\[
M_{nbx} = C_{cx} \times (dx - d'' - a_x/2) + C_{sx} \times (dx - d' - d'') + T_x \times d''
\]  

(58)

\[
M_{nby} = C_{cy} \times (dy - d'' - a_y/2) + C_{sy} \times (dy - d' - d'') + T_y \times d''
\]  

(59)

RESULTS AND DISCUSSIONS

Smartphone Application

Initial information will appear first, when the smartphone is turned on, followed by the initial selection menu.
<table>
<thead>
<tr>
<th>Figure 14.a. Flexure beam Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEAM</td>
</tr>
<tr>
<td>$f_c' = 35$</td>
</tr>
<tr>
<td>$f_y = 400$</td>
</tr>
<tr>
<td>$b = 300$</td>
</tr>
<tr>
<td>$h = 550$</td>
</tr>
<tr>
<td>$d' = 65$</td>
</tr>
<tr>
<td>$Mu = 630$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Figure 14.b. Flexure beam Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforcement Beam Result</td>
</tr>
<tr>
<td>$b = 300$</td>
</tr>
<tr>
<td>$h = 550$</td>
</tr>
<tr>
<td>$Mu = 630$</td>
</tr>
<tr>
<td>$As' = 1101.805666$</td>
</tr>
<tr>
<td>$As = 4226.571745$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Figure 15.a. Shear beam Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear Only</td>
</tr>
<tr>
<td>$f_c' = 35$</td>
</tr>
<tr>
<td>$f_y = 420$</td>
</tr>
<tr>
<td>$b = 350$</td>
</tr>
<tr>
<td>$h = 700$</td>
</tr>
<tr>
<td>$d' = 65$</td>
</tr>
<tr>
<td>$Vu = 539$</td>
</tr>
<tr>
<td>$ds = 10$</td>
</tr>
<tr>
<td>$nk = 3$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Figure 15.b. Shear beam Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear Result</td>
</tr>
<tr>
<td>$b = 350$</td>
</tr>
<tr>
<td>$h = 700$</td>
</tr>
<tr>
<td>$Vu = 539$</td>
</tr>
<tr>
<td>Zone : 4</td>
</tr>
<tr>
<td>$Av/S = 1.872968593$</td>
</tr>
<tr>
<td>$3 D10 - 125.8$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Figure 16.a. Torsion beam Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>TORSI</td>
</tr>
<tr>
<td>$f_c' = 27.6$</td>
</tr>
<tr>
<td>$f_y = 414$</td>
</tr>
<tr>
<td>$b = 356$</td>
</tr>
<tr>
<td>$h = 635$</td>
</tr>
<tr>
<td>$d' = 65$</td>
</tr>
<tr>
<td>$Tu = 50.9$</td>
</tr>
<tr>
<td>$Vu = 180$</td>
</tr>
<tr>
<td>$ds = 11.3$</td>
</tr>
<tr>
<td>1)Solid/2)Hollow?(1/2)=1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Figure 16.b. Torsion beam Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsion Result</td>
</tr>
<tr>
<td>$b = 356$</td>
</tr>
<tr>
<td>$h = 635$</td>
</tr>
<tr>
<td>$Vu = 180$</td>
</tr>
<tr>
<td>$Tu = 50.9$</td>
</tr>
<tr>
<td>Solid Section</td>
</tr>
<tr>
<td>$Av/S = 1.622424579$</td>
</tr>
<tr>
<td>$2D11.3 - 123.6266915$</td>
</tr>
<tr>
<td>$Along = 1091.543034$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Figure 17.a. Circular column Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLUMN 024=?0</td>
</tr>
<tr>
<td>$f_c' = 27$</td>
</tr>
<tr>
<td>$f_y = 420$</td>
</tr>
<tr>
<td>$D = 400$</td>
</tr>
<tr>
<td>$d' = 40$</td>
</tr>
<tr>
<td>$Mu = 250$</td>
</tr>
<tr>
<td>$Pu = 400$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Figure 17.b. Circular column Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column Result: Circular</td>
</tr>
<tr>
<td>$D = 400$</td>
</tr>
<tr>
<td>$Mu = 250$</td>
</tr>
<tr>
<td>$Pu = 400$</td>
</tr>
<tr>
<td>$c(mm) = 157.6742405$</td>
</tr>
<tr>
<td>$\phi = 0.84$</td>
</tr>
<tr>
<td>$A(%) = 4.39$</td>
</tr>
<tr>
<td>$A_{tot} = 5517.42$</td>
</tr>
</tbody>
</table>
Figure 14 to figure 20, consists of 2 (two) parts, namely part a) is input data and part b) is output result. respectively are beam reinforcement designs namely flexural bending reinforcement (figure 14), shear reinforcement (figure 15), torsion reinforcement (figure 16), and column reinforcement design circular column (figure 17), rectangular column two faces (figure 18), rectangular column four faces (figure 19) and biaxial bending column (figure 20).

Manual Calculation

Calculation of reinforcement for beams and columns manually using the formula for reinforcement of concrete due to bending, shear, torsion, axial and biaxial bending.

1. Flexural reinforcement
   Initial data required: $f_c' = 35$ MPa; $f_y = 400$ MPa; $b = 300$ mm; $h = 550$ mm; $d' = 65$ mm; $M_u = 450$ kNm. The results of manual calculations are obtained as follows
   \[ \text{Result: } A_s = 1100 \text{ mm}^2; A_{s'} = 4227 \text{ mm}^2 \]

2. Shear reinforcement
   Initial data required: $f_c' = 35$ MPa; $f_y = 420$ MPa; $b = 350$ mm; $h = 700$ mm; $d' = 65$ mm; $n_k = 3; d_s = 10$ mm; $V_u = 539$ kN.
   The results of manual calculations are obtained as follows
   \[ \text{Result: } S = 125.7 \text{ mm} \]
3 Torsion reinforcement
Initial data required: \( f'c = 27.6 \text{ MPa}; f_y = 414 \text{ MPa}; b = 356 \text{ mm}; h = 635 \text{ mm}; d' = 65 \text{ mm}; d_s = 11.3 \text{ mm}; Vu = 180 \text{ kN}; Tu = 50.9 \text{ kNm}; \text{ Solid}. \) The results of manual calculations are obtained as follows

Result: \( S (\text{Eq. 41}) = 125 \text{ mm}; \text{ Along} (\text{Eq. 42}) = 1086 \text{ mm}^2 \)

4 Column uniaxial
Initial data required: \( f'c = 27 \text{ MPa}; f_y = 420 \text{ MPa}; h = 400 \text{ mm}; b = 400 \text{ mm}; d' = 40 \text{ mm}; Pu = 400 \text{ kN}; M_u = 250 \text{ kNm}. \) The results of manual calculations are obtained as follows.

Result: a) Circular: \( A_{\text{tot}} (\text{Eq. 47 & 48}) = 5348 \text{ mm}^2; \) b) Rectangular two faces: \( A_{\text{tot}} (\text{Eq. 47 & 48}) = 3189 \text{ mm}^2; \) c) Rectangular four faces: \( A_{\text{tot}} (\text{Eq. 47 & 48}) = 3522 \text{ mm}^2 \)

5 Column biaxial
Initial data required: \( f'c = 27.6 \text{ Mpa}; f_y = 414 \text{ MPa}; b = 508 \text{ mm}; h = 305 \text{ mm}; d' = 63 \text{ mm}; Pu = 878 \text{ kN}; M_{ux} = 176 \text{ kNm}; M_{uy} = 103 \text{ kNm}. \) The results of manual calculations are obtained as follows.

Result: \( A_s (\text{Eq. 49}) = 6710 \text{ mm}^2; \text{ Interaction} (\text{Eq. 51}) = 98.99\% \)

CONCLUSION
Smartphone calculation and manual calculation are flexural reinforcement, shear reinforcement, torsional reinforcement, column circular reinforcement, column rectangular two faces reinforcement, column rectangular four faces reinforcement, column biaxial reinforcement such as:

Flexural reinforcement: difference \( A_s = 0\%; \text{ difference } A'_s = 0.18\% \)
Shear reinforcement: difference \( S = 0.08\% \)
Torsional reinforcement: difference \( S = 1.12\%; \text{ difference } A_l = 0.51\% \)
Column circular reinforcement: difference \( A_{\text{tot}} = 3.16\% \)
Column rectangular two faces reinforcement: difference \( A_{\text{tot}} = 0.44\% \)
Column rectangular four faces reinforcement: difference \( A_{\text{tot}} = 0.09\% \)
Column biaxial reinforcement: difference \( = 1.15\% \)
for all cases less than 5\%, the calculation of smartphone using Texas Instrument is accurate

REFERENCES
ACI International, ACI Design Handbook, Design of Structural Reinforced Concrete Elements in
Accordance with the Strength Design Method of ACI 318-95. 2001.


ACI Committee 318, Building Code Requirements for Structural Concrete. 2014.


