Scilab Textbook Companion for RCC Theory and Design by M. G. Shah and C. M. Kale[1]

Created by
Idris Manaqibwala
Civil Engineering
Civil Engineering
VNIT Nagpur
College Teacher
None
Cross-Checked by
None

July 31, 2019

[1]Funded by a grant from the National Mission on Education through ICT, http://spoken-tutorial.org/NMEICT-Intro. This Textbook Companion and Scilab codes written in it can be downloaded from the "Textbook Companion Project" section at the website http://scilab.in

Book Description

Title: RCC Theory and Design

Author: M. G. Shah and C. M. Kale

Publisher: Macmillan

Edition: 2

Year: 1972

ISBN: 033390458-3

Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

Contents

List of Scilab Codes

List of Figures

Chapter 1

Singly Reinforced Sections

Scilab code Exa 1.1 Analysis of Singly Reinforced Section

```
//let the depth of neutral axis be x
b=200//width, in mm
d=350//effective depth, in mm
m=18.66 //modular ratio
sigma_cbc=5//in MPa
sigma_st=140//in MPa
x=d/(1+sigma_st/(m*sigma_cbc))//in mm
mprintf("The depth of neutral axis = %f mm\n", x)
//to find area of steel
Ast=b*x*sigma_cbc/(2*sigma_st)//in sq mm
mprintf("Area of steel = %f mm^2\n", Ast)
//to find percentage steel
pst=Ast*100/(b*d)//in %
mprintf("Percentage of steel = %f percent\n", pst)
```

Scilab code Exa 1.2 Analysis of Singly Reinforced Section

```
//let the depth of neutral axis be x
```

```
b=150//width, in mm
d=400//effective depth, in mm
Ast=804//area of steel, in sq mm
m=18.66//modular ratio
//b(x^2)/2=mAst(d-x)-->this becomes a quadratic
    equation of form px^2+qx+r=0
p=b/2
q=m*Ast
r=-m*Ast*d
//solving the quadratic equation
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
mprintf("The depth of neutral axis = %f mm", x)
```

Scilab code Exa 1.3 Analysis of Singly Reinforced Section

```
//assume d = 400 mm and b = 200 mm
b=200//in mm
d=400//in mm
sigma_cbc=5//in MPa
sigma_st=140//in MPa
m=18.66//modular ratio
Xc=d/(1+sigma_st/m/sigma_cbc)//in mm
z=d-Xc/3//in mm
Mr=b*Xc*sigma_cbc/2*z//in N-mm
Ast=b*Xc*sigma_cbc/2/sigma_st//in sq mm
pt=Ast*100/b/d//in %
mprintf("When d is assumed as 400 mm and b as 200 mm
    \n(a) Position of neutral axis=%f mm\n(b) Lever
    arm=%f mm\n(c) Moment of resistance=%f kN-m\n(d)
    Percentage of steel=%f percent",Xc,z,Mr/10^6,pt)
```

Scilab code Exa 1.4 Analysis of Singly Reinforced Section

```
b=250//width, in mm
d=500//effective depth, in mm
sigma_cbc=5//in MPa
sigma_st=140//in MPa
m=18.66//modular ratio
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
z=d-Xc/3//lever arm, in mm
Mr=b*Xc*sigma_cbc*z/2//in N-mm
mprintf("Moment of resistance of the beam = %f kN-m"
    ,Mr/10^6)
```

Scilab code Exa 1.5 Analysis of Singly Reinforced Section

```
b=250//width, in mm
D=550//overall depth, in mm
Ast=1521//area of steel, in sq mm
cover=25//in mm
d=D-cover//effective depth, in mm
sigma_cbc=7//in MPa
sigma_st=140//in MPa
m=13.33//modular ratio
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//to find actual depth of neutral axis using b(x^2)
    /2=mAst(d-x)--> this will become of the form px
    ^2+qx+r=0
p=b/2
q=m*Ast
r=-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//x>Xc; hence beam is over-reinforced
Mr=b*x*sigma_cbc/2*(d-x/3)//in N-mm
mprintf("Moment of resistance of the beam=%f kN-m",
    Mr/10^6)
```

Scilab code Exa 1.6 Analysis of Singly Reinforced Section

```
b=200//width, in mm
d=450//effective depth, in mm
Ast=3*.785*16^2//three 16 dia bars, in sq mm
sigma_cbc=5//in MPa
sigma_st=140//in MPa
m=18.66//modular ratio
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//to find actual depth of neutral axis using b(x^2)
    /2=mAst(d-x), which becomes of form px^2+qx+r=0
p=b/2
q=m*Ast
r=-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//as x<Xc, beam is under-reinforced
Mr=Ast*sigma_st*(d-x/3)//in N-mm
mprintf("Moment of resistance of the beam = %f kN-m"
    , Mr/10^6)
```

Scilab code Exa 1.7 Analysis of Singly Reinforced Section

```
b=300//width, in mm
D=700//overall depth, in mm
Ast=3*.785*20^2//3-20mm dia bars, in sq mm
cover=50//in mm
d=D-cover//effective depth, in mm
sigma_cbc=7//in MPa
sigma_st=190//in MPa
m=13.33//modular ratio
```

```
l=6//span, in m
w=25//unit weight of concrete, in kN/m^3
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//to find actual depth of neutral axis using b(x^2)
    /2=mAst(d-x), which becomes of the form px^2+qx+r
    =0
p=b/2
q=m*Ast
r=-m*Ast*d
//solving quadratic equation
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//x<Xc, hence beam is under-reinforced
Mr=sigma_st*Ast*(d-x/3)//in N-mm
UDL=(Mr/10^6)*8/l^2//in kN/m
self_weight=w*b*D/10^6//in kN/m
net_weight=UDL-self_weight//in kN/m
mprintf("Moment of resistance=%f kN-m\nSafe
    uniformly distributed load that the beam can
    carry=%f kN/m",Mr/10^6,net_weight)
```

Scilab code Exa 1.8 Analysis of Singly Reinforced Section

```
b=250//width, in mm
D=500//overall depth, in mm
Ast=4*.785*22^2//four 22 mm dia bars, in sq mm
cover=25//in mm
d=D-cover//effective depth, in mm
l=5//effective span, in m
sigma_cbc=5//in MPa
sigma_st=190//in MPa
m=18.66//modular ratio
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//to find actual depth of neutral axis using b(x^2)
```

```
/2=mAst(d-x), which becomes of the form px^2+qx+r=0
p=b/2
q=m*Ast
r=-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//as x>Xc, beam is over-reinforced
Mr=b*sigma_cbc*x/2*(d-x/3)//in N-mm
self_weight=25*(b/10^3)*(D/10^3)//in kN/m
M=Mr/10^6-self_weight*l^2/8//moment of resistance available for external load, in kN-m
W=4*M/l//in kN
mprintf("The concentrated load the beam can support at centre=%f kN",W)
```

Scilab code Exa 1.9 Analysis of Singly Reinforced Section

```
d=120//effective depth of slab, in mm
//consider 1 m strip of slab
b=1000//in mm
s=80//spacing of 12mm dia bars centre-to-centre, in mm
Ast=1000*.785*12^2/s//in sq mm
l=3.2//span, in m
sigma_cbc=7//in MPa
sigma_st=140//in MPa
m=13.33//modular ratio
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//to find actual depth of neutral axis using b(x^2)/2=mAst(d-x), which becomes of the form px^2+qx+r=0
p=b/2
q=m*Ast
r=-m*Ast*d
```

```
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//as x>Xc, the beam is over-reinforced
Mr=b*sigma_cbc*x/2*(d-x/3)/10^6//in kN-m
UDL=Mr*8/l^2//in kN/m
self_weight=25*(d/10^3)*(b/10^3)//in kN/m
W=UDL-self_weight//in kN/m
mprintf("The safe load for slab=%f kN/m",W)
```

Scilab code Exa 1.10 Analysis of Singly Reinforced Section

```
b=300//width, in mm
D=700//overall depth, in mm
Ast=4*.785*25^2//four 25mm dia bars, in sq mm
cover=30//in mm
d=D-cover//effective depth, in mm
M=130*10^6//bending moment, in N-mm
m=18.66//modular ratio
//to find actual depth of neutral axis using b(x^2)
    /2=mAst(d-x), which becomes of the form px^2+qx+r
    =0
p=b/2
q=m*Ast
r=-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
z=d-x/3//lever arm, in mm
//assuming under-reinforced section, Mr=Ast*sigma_st
    (d-x/3) and equating Mr to M
sigma_st=M/(Ast*z)//in MPa
sigma_st=116//round-off, in MPa
sigma_cbc=(sigma_st/m)*x/(d-x)//in MPa
sigma_cbc=5//round-off, in MPa
mprintf("Stress in steel=%d N/mm^2\nStress in
    concrete=%d N/mm^2",sigma_st,sigma_cbc)
```

Scilab code Exa 1.11 Analysis of Singly Reinforced Section

```
b=350//width, in mm
D=650//overall depth, in mm
Ast=4*.785*22^2//four 22mm dia bars, in sq mm
cover=25//in mm
d=D-cover//effective depth, in mm
W=20//UDL, in kN/m
l=7//span, in m
M=W*l^2/8*10^6//bending moment, in N-mm
m=13.33//modular ratio
//to find actual depth of neutral axis using b(x^2)
    /2=mAst(d-x), which becomes of the form px^2+qx+r
    =0
p=b/2
q=m*Ast
r=-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
z=d-x/3//lever arm, in mm
//assuming under-reinforced section, Mr=Ast*sigma_st
    (d-x/3) and equating Mr to M
sigma_st=M/(Ast*z)//in MPa
sigma_cbc=(sigma_st/m)*x/(d-x)//in MPa
mprintf("Stress in steel=%f N/mm^2\nStress in
    concrete=%f N/mm^2",sigma_st,sigma_cbc)
```

Scilab code Exa 1.12 Design of Singly Reinforced Section

```
b=250//width, in mm
sigma_cbc=5//in MPa
sigma_st=190//in MPa
m=280/(3*sigma_cbc)//modular ratio
```

```
M=75*10^6//bending moment, in N-mm
//critical depth of neutral axis, Xc=d/(1+sigma_st/(
    m*sigma_cbc))=a*d
a=1/(1+sigma_st/(m*sigma_cbc))
d=(M/(b*sigma_cbc*a*(1-a/3)/2))^0.5//in mm
d=640//round-off, in mm
Xc=a*d//in mm
Ast=b*Xc*sigma_cbc/(2*sigma_st)//in sq mm
mprintf("Effective depth=%d mm\nArea of steel=%f mm
    ^2",round(d),Ast)
```

Scilab code Exa 1.13 Design of Singly Reinforced Section

```
//b=d/2 (given)
sigma_cbc=5//in MPa
sigma_st=140//in MPa
m=18.66//modular ratio
M=65*10^6//bending moment, in N-mm
//critical depth of neutral axis, Xc=d/(1+sigma_st/(
    m*sigma_cbc))=a*d
a=1/(1+sigma_st/(m*sigma_cbc))
d=(M/(sigma_cbc*a*(1-a/3)/4))^(1/3)//in mm
d=530//round-off, in mm
Xc=a*d//in mm
b=d/2//in mm
Ast=M/sigma_st/0.87/d//in sq mm
Ast=1007//round-off, in sq mm
mprintf("Dimensions of section=%d x %d mm\nArea of
    steel=%d mm^2",b,d,Ast)
```

Chapter 2

Doubly Reinforced Sections

Scilab code Exa 2.1 Analysis of Doubly Reinforced Section

```
b=200//width, in mm
D=400//overall depth, in mm
m=18.66//modular ratio
Ast=4*0.785*22^2//four 22 mm dia bars at bottom, in
   sq mm
Asc=3*0.785*20^2//three 20 mm dia bars at top, in sq
    mm
bottom_cover=30//in mm
top_cover=25//in mm
d=D-bottom_cover//effective depth, in mm
//to find x using b(x^2)/2 + (1.5m-1)Asc(x-d')=mAst(
   d-x), which becomes of the form px^2+qx+r=0
p=b/2
q=(1.5*m-1)*Asc+m*Ast
r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
mprintf("Depth of neutral axis=%f mm",x)
```

Scilab code Exa 2.2 Analysis of Doubly Reinforced Section

```
b=280//width, in mm
D=540//overall depth, in mm
Ast=5*0.785*22^2//five 22 mm dia bars on tension
    side, in sq mm
Asc=4*0.785*20^2//four 20 mm dia bars on compression
     side, in sq mm
bottom_cover=40//in mm
top_cover=30//in mm
sigma_cbc=5//in MPa
sigma_st=140//in MPa
m=18.66//modular ratio
d=D-bottom_cover//effective depth, in mm
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//to find x using b(x^2)/2 + (1.5m-1)Asc(x-d')=mAst(
    d-x), which becomes of the form px^2+qx+r=0
p=b/2
q=(1.5*m-1)*Asc+m*Ast
r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//as x<Xc, beam is under-reinforced
sigma_cbc=(sigma_st/m)*x/(d-x)//in MPa
sigma_cbc_dash=sigma_cbc*(x-top_cover)/x//in MPa
sigma_sc=1.5*m*sigma_cbc_dash//in MPa
//stress in compression steel is found to be less
    than its permissible limit of 130 N/mm^2
Mr=b*x*sigma_cbc*(d-x/3)/2+(1.5*m-1)*Asc*
    sigma_cbc_dash*(d-top_cover)//in N-mm
mprintf("Moment of resistance of the beam=%f kN-m",
    Mr/10^6)
```

Scilab code Exa 2.3 Analysis of Doubly Reinforced Section

```
b=300//width, in mm
d=600//effective depth, in mm
```

```
Ast=1256//in sq mm
Asc=1256//in sq mm
top_cover=30//in mm
sigma_cbc=7//in MPa
sigma_st=190//in MPa
m=13.33//modular ratio
//using elastic theory method
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//to find x using b(x^2)/2 + (1.5m-1)Asc(x-d')=mAst(d-x), which becomes of the form px^2+qx+r=0
p=b/2
q=(1.5*m-1)*Asc+m*Ast
r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//as x<Xc, beam is under-reinforced
sigma_cbc=(sigma_st/m)*x/(d-x)//in MPa
sigma_cbc_dash=sigma_cbc*(x-top_cover)/x//in MPa
sigma_sc=1.5*m*sigma_cbc_dash//in MPa
//stress in compression steel is found to be less than its permissible limit of 130 N/mm^2
Mr1=b*x*sigma_cbc*(d-x/3)/2+(1.5*m-1)*Asc*sigma_cbc_dash*(d-top_cover)//in N-mm
//using steel beam theory method
Mr2=Ast*sigma_st*(d-top_cover)//in N-mm
mprintf("Moment of resistance of the beam using elastic theory method=%f kN-m\nMoment of resistance of the beam using elastic theory method=%f kN-m",Mr1/10^6,Mr2/10^6)
```

Scilab code Exa 2.4 Analysis of Doubly Reinforced Section

```
b=250//width, in mm
D=550//overall depth, in mm
Ast=4*0.785*25^2//four 25 mm dia bars on tension
```

```
side, in sq mm
Asc=3*0.785*22^2//three 22 mm dia bars on compression side, in sq mm
bottom_cover=50//in mm
top_cover=30//in mm
d=D-bottom_cover//effective depth, in mm
sigma_cbc=5//in MPa
sigma_st=140//in MPa
sigma_sc=130//in MPa
m=18.66//modular ratio
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//to find x using b(x^2)/2 + (1.5m-1)Asc(x-d')=mAst(d-x), which becomes of the form px^2+qx+r=0
p=b/2
q=(1.5*m-1)*Asc+m*Ast
r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//as x>Xc, beam is over-reinforced
sigma_cbc_dash=sigma_cbc*(x-top_cover)/x//in MPa
sigma_sc=1.5*m*sigma_cbc_dash//< 130 MPa, hence OK
//stress in compression steel is found to be less than its permissible limit of 130 N/mm^2
Mr=b*x*sigma_cbc*(d-x/3)/2+(1.5*m-1)*Asc*sigma_cbc_dash*(d-top_cover)//in N-mm
mprintf("Moment of resistance of the beam=%f kN-m",Mr/10^6)
```

Scilab code Exa 2.5 Analysis of Doubly Reinforced Section

```
b=250//width, in mm
d=450//effective depth, in mm
Ast=4*0.785*22^2//four 22 mm dia bars on tension side, in sq mm
Asc=Ast
```

```
top_cover=30//in mm
sigma_cbc=7//in MPa
sigma_st=140//in MPa
sigma_sc=130//in MPa
m=13.33//modular ratio
l=5.7//effective span, in m
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//to find x using b(x^2)/2 + (1.5m-1)Asc(x-d')=mAst(d-x), which becomes of the form px^2+qx+r=0
p=b/2
q=(1.5*m-1)*Asc+m*Ast
r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//as x<Xc, beam is under-reinforced
sigma_cbc=(sigma_st/m)*x/(d-x)//in MPa
sigma_cbc_dash=sigma_cbc*(x-top_cover)/x//in MPa
sigma_sc=1.5*m*sigma_cbc_dash//in MPa
//stress in compression steel is found to be less than its permissible limit of 130 N/mm^2
Mr=b*x*sigma_cbc*(d-x/3)/2+(1.5*m-1)*Asc*sigma_cbc_dash*(d-top_cover)//in N-mm
W=(Mr/10^6)*8/l^2//in kN/m
mprintf("Uniformly distributed load the beam can carry (including self-weight)=%f kN/m",W)
```

Scilab code Exa 2.6 Analysis of Doubly Reinforced Section

```
b=200//width, in mm
D=480//overall depth, in mm
Ast=4*0.785*25^2//four 25 mm dia bars on tension side, in sq mm
Asc=3*0.785*22^2//three 22 mm dia bars on compression side, in sq mm
bottom_cover=30//in mm
```

```
top_cover=30//in mm
d=D-bottom_cover//effective depth, in mm
m=18.66//modular ratio
M=100*10^6//in N-mm
//to find x using b(x^2)/2 + (1.5m-1)Asc(x-d')=mAst(d-x), which becomes of the form px^2+qx+r=0
p=b/2
q=(1.5*m-1)*Asc+m*Ast
r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//sigma_cbc_dash=sigma_cbc*(x-d')/x=a*sigma_cbc
a=(x-top_cover)/x
sigma_cbc=M/(b*x*(d-x/3)/2+(1.5*m-1)*Asc*a*(d-top_cover))//in MPa
sigma_st=m*sigma_cbc*(d-x)/x//in MPa
sigma_cbc_dash=a*sigma_cbc//in MPa
sigma_sc=1.5*m*sigma_cbc_dash//in MPa
mprintf("Stress in concrete=%f N/mm^2\nStress in tension steel=%f N/mm^2\nStress in compression steel=%f N/mm^2",sigma_cbc,sigma_st,sigma_sc)
```

Scilab code Exa 2.7 Analysis of Doubly Reinforced Section

```
b=300//width, in mm
d=500//effective depth, in mm
Ast=4*0.785*20^2//four 20 mm dia bars on tension and compression side, in sq mm
Asc=Ast
top_cover=25//in mm
m=13.33//modular ratio
M=120*10^6//in N-mm
//to find x using b(x^2)/2 + (1.5m-1)Asc(x-d')=mAst(d-x), which becomes of the form px^2+qx+r=0
p=b/2
q=(1.5*m-1)*Asc+m*Ast
```

```
r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//sigma_cbc_dash=sigma_cbc*(x-d')/x=a*sigma_cbc
a=(x-top_cover)/x
sigma_cbc=M/(b*x*(d-x/3)/2+(1.5*m-1)*Asc*a*(d-
   top_cover))//in MPa
sigma_st=m*sigma_cbc*(d-x)/x//in MPa
sigma_cbc_dash=a*sigma_cbc//in MPa
sigma_sc=1.5*m*sigma_cbc_dash//in MPa
mprintf("Stress in concrete=%f N/mm^2\nStress in
   tension steel=%f N/mm^2\nStress in compression
   steel=%f N/mm^2",sigma_cbc,sigma_st,sigma_sc)
```

Scilab code Exa 2.8 Design of Doubly Reinforced Section

```
b=250//width, in mm
D=600//overall depth, in mm
bottom_cover=50//in mm
top_cover=50//in mm
d=D-bottom_cover//effective depth, in mm
sigma_cbc=5//in MPa
sigma_st=140//in MPa
m=18.66//modular ratio
M=95*10^6//in N-mm
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//to find Ast1
Ast1=b*Xc*sigma_cbc/(2*sigma_st)//in sq mm
Ast1=982//round-off, in sq mm
Mr=b*Xc*sigma_cbc/2*(d-Xc/3)//moment of resistance
   of singly reinforced beam, in N-mm
M1=M-Mr//remaining bending moment, in N-mm
//to find Ast2
Ast2=M1/(sigma_st*(d-top_cover))//in sq mm
Ast2=421//round-off, in sq mm
```

```
Ast=Ast1+Ast2//in sq mm
//to find Asc
Asc=m*Ast2*(d-Xc)/((1.5*m-1)*(Xc-top_cover))//in sq mm
Asc=565//round-off, in sq mm
mprintf("Tensile steel required=%d mm^2\nCompression steel required=%d mm^2",Ast,Asc)
```

Scilab code Exa 2.9 Design of Doubly Reinforced Section

```
b=360//width, in mm
d=750//effective depth, in mm
top_cover=50//in mm
sigma_cbc=7//in MPa
sigma_st=190//in MPa
m=13.33//modular ratio
M=300*10^6//in N-mm
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//to find Ast1
Ast1=b*Xc*sigma_cbc/(2*sigma_st)//in sq mm
Ast1=1638//round-off, in sq mm
Mr=b*Xc*sigma_cbc/2*(d-Xc/3)//moment of resistance of singly reinforced beam, in N-mm
M1=M-Mr//remaining bending moment, in N-mm
//to find Ast2
Ast2=M1/(sigma_st*(d-top_cover))//in sq mm
Ast=Ast1+Ast2//in sq mm
//to find Asc
Asc=m*Ast2*(d-Xc)/((1.5*m-1)*(Xc-top_cover))//in sq mm
mprintf("Tensile steel required=%f mm^2\nCompression steel required=%f mm^2",Ast,Asc)
```

Chapter 3

T and L Beams

Scilab code Exa 3.1 T beam

```
Bf=1300//width of flange, in mm
Df=80//thickness of flange, in mm
d=600//effective depth, in mm
sigma_cbc=7//in MPa
sigma_st=140//in MPa
m=13.33//modular ratio
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
Xc=240//round-off, in mm
//to find Ast
Ast=Bf*Df*(Xc-Df/2)/(m*(d-Xc))//in sq mm
mprintf("Neutral axis depth=%d mm\nArea of steel=%f
   mm^2", Xc,Ast)
```

Scilab code Exa 3.2 T beam

```
Bf=1500//width of flange, in mm
Bw=300//breadth of web, in mm
```

```
Df=100//thickness of flange , in mm
d=700//effective depth , in mm
m=18.66//modular ratio
Ast=8*0.785*25^2//eight 25 mm dia bars , in sq mm
//assume depth of neutral axis is less than or equal
    to thickness of flange; find x using Bf(x^2)/2=
   mAst(d-x), which becomes of the form px^2+qx+r=0
p=Bf/2
q=m*Ast
r=-m*Ast*d
//solving quadratic equation
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//x>Df; hence our assumption is incorrect; equating
   moments of area on compression and tension sides
   about N.A.
x=(m*Ast*d+Bf*Df^2/2)/(m*Ast+Bf*Df)//in mm
x=263//round-off , in mm
mprintf("Neutral axis depth=%d mm", x)
```

Scilab code Exa 3.3 T beam

```
Bf=1200//width of flange , in mm
Bw=200//breadth of web, in mm
Df=100//thickness of flange , in mm
d=400//effective depth , in mm
m=13.33//modular ratio
Ast=4*0.785*18^2//four 18mm dia bars , in sq mm
//assume x > Df; ; equating moments of area on
   compression and tension sides about N.A.
x=(m*Ast*d+Bf*Df^2/2)/(m*Ast+Bf*Df)//in mm
//as x < Df; our assumption was incorrect
//x < Df; find x using Bf(x^2)/2=mAst(d-x), which
   becomes of the form px^2+qx+r=0
p=Bf/2
q=m*Ast
```

```
r=-m*Ast*d
//solving quadratic equation
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//x<Df; hence our assumption is correct
mprintf("Neutral axis depth=%f mm", x)
```

Scilab code Exa 3.4 T beam

```
Bf=1500//width of flange, in mm
Bw=300//breadth of web, in mm
Df=100//thickness of flange, in mm
d=700//effective depth, in mm
sigma_cbc=5//in MPa
sigma_st=140//in MPa
m=18.66//modular ratio
Ast=8*0.785*25^2//eight 25 mm dia bars, in sq mm
//assume x < Df; find x using Bf(x^2)/2=mAst(d-x), which becomes of the form px^2+qx+r=0
p=Bf/2
q=m*Ast
r=-m*Ast*d
//solving quadratic equation
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//x > Df; hence our assumption is incorrect; equating moments of area on compression and tension sides about N.A.
x=(m*Ast*d+Bf*Df^2/2)/(m*Ast+Bf*Df)//in mm
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//as x < Xc, beam is under-reinforced
sigma_cbc=sigma_st/m*x/(d-x)//in MPa
sigma_cbc_dash=sigma_cbc*(x-Df)/x//in MPa
//to find lever arm
z=d-(sigma_cbc+2*sigma_cbc_dash)/(sigma_cbc+sigma_cbc_dash)*Df/3//in mm
```

```
Mr=Bf*Df*(sigma_cbc+sigma_cbc_dash)*z/2//in N-mm
mprintf("Moment of resistance of the beam=%f kN-m",
    Mr/10^6)
```

Scilab code Exa 3.5 T beam

```
Bf=1200//width of flange, in mm
Bw=200//breadth of web, in mm
Df=100//thickness of flange, in mm
d=400//effective depth, in mm
sigma_cbc=7//in MPa
sigma_st=190//in MPa
m=13.33//modular ratio
Ast=4*0.785*18^2//four 18 mm dia bars, in sq mm
//assume x < Df; find x using Bf(x^2)/2=mAst(d-x),
    which becomes of the form px^2+qx+r=0
p=Bf/2
q=m*Ast
r=-m*Ast*d
//solving quadratic equation
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//x < Df; hence our assumption is correct
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//as x < Xc, beam is under-reinforced
sigma_cbc=sigma_st/m*x/(d-x)//in MPa
//taking moments about tensile steel
Mr=Bf*x*sigma_cbc*(d-x/3)/2//in N-mm
mprintf("Moment of resistance of the beam=%f kN-m",
    Mr/10^6)
```

Scilab code Exa 3.6 T beam

```
Bf=1500//width of flange , in mm
Bw=200//breadth of web, in mm
Df=100//thickness of flange , in mm
d=400//effective depth , in mm
sigma_cbc=5//in MPa
sigma_st=140//in MPa
m=18.66//modular ratio
Ast=2190//in sq mm
//assume x>Df
x=(m*Ast*d+Bf*Df^2/2)/(m*Ast+Bf*Df)//in mm
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//as x<Xc, beam is under−reinforced
sigma_cbc=sigma_st/m*x/(d-x)//in MPa
sigma_cbc_dash=sigma_cbc*(x-Df)/x//in MPa
//to find lever arm
z=d-(sigma_cbc+2*sigma_cbc_dash)/(sigma_cbc+
   sigma_cbc_dash)*Df/3//in mm
//taking moments about tensile steel
Mr=Bf*Df*(sigma_cbc+sigma_cbc_dash)*z/2//in N−mm
mprintf("Moment of resistance of the beam=%f kN−m",
   Mr/10^6)
```

Scilab code Exa 3.7 T beam

```
Bf=1200//width of flange , in mm
Bw=300//breadth of web, in mm
Df=120//thickness of flange , in mm
d=500//effective depth , in mm
sigma_cbc=7//in MPa
sigma_st=190//in MPa
m=13.33//modular ratio
Ast=5*0.785*20^2//five 20 mm dia bars , in sq mm
l=6//span , in m
//assume depth of neutral axis is less than or equal
```

```
    to thickness of flange; find x using Bf(x^2)/2=
    mAst(d-x), which becomes of the form px^2+qx+r=0
p=Bf/2
q=m*Ast
r=-m*Ast*d
//solving quadratic equation
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//x < Df; hence our assumption is correct
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//as x<Xc, beam is under-reinforced
sigma_cbc=sigma_st/m*x/(d-x)//in MPa
//taking moments about tensile steel
Mr=Bf*x*sigma_cbc*(d-x/3)/2//in N-mm
W=(Mr/10^6)*8/l^2//in kN/m
mprintf("Moment of resistance of the beam=%f kN-m\
    nCapacity to take uniformly distributed load(
    including self-weight)=%f kN/m", Mr/10^6,W)
```

Scilab code Exa 3.8 T beam

```
Bf=1400//width of flange, in mm
Df=120//thickness of flange, in mm
d=600//effective depth, in mm
m=18.66//modular ratio
Ast=4000//in sq mm
M=160*10^6//in N-mm
//Assume x>Df; equating moments of area on
    compression and tension sides about N.A.
x=(m*Ast*d+Bf*Df^2/2)/(m*Ast+Bf*Df)//in mm
//let sigma_cbc_dash=a*sigma_cbc
a=(x-Df)/x
//to find lever arm
z=d-(1+2*a)/(1+a)*Df/3//in mm
sigma_cbc=2*M/(Bf*Df*(1+a)*z)//in MPa
```

```
sigma_st=m*sigma_cbc*(d-x)/x//in MPa
mprintf("Stress in concrete=%f N/mm^2\nStress in tension steel=%f N/mm^2",sigma_cbc,sigma_st)
//answer given in textbook is incorrect
```

Scilab code Exa 3.9 T beam

```
Bf=1250//width of flange, in mm
Df=120//thickness of flange, in mm
d=700//effective depth, in mm
m=13.33//modular ratio
Ast=5500//in sq mm
W=60//UDL including self-weight, in kN/m
l=8//span, in m
M=W*l^2/8*10^6//in N-mm
//Assume x>Df. Equating moments of area on compressiona and tension sides about N.A.
x=(m*Ast*d+Bf*Df^2/2)/(m*Ast+Bf*Df)//in mm
//let sigma_cbc_dash=a*sigma_cbc
a=(x-Df)/x
//to find lever arm
z=d-(1+2*a)/(1+a)*Df/3//in mm
sigma_cbc=2*M/(Bf*Df*(1+a)*z)//in MPa
sigma_st=m*sigma_cbc*(d-x)/x//in MPa
mprintf("Stress in concrete=%f N/mm^2\nStress in tension steel=%f N/mm^2",sigma_cbc,sigma_st)
```

Scilab code Exa 3.10 T beam

```
Bf=1300//width of flange, in mm
Df=100//thickness of flange, in mm
d=500//effective depth, in mm
sigma_cbc=5//in MPa
```

```
sigma_st=275//in MPa
m=18.66//modular ratio
Ast=1570//in sq mm
Asc=1256//in sq mm
top_cover=30//in mm
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//assume x>Df; equating moments of area on compression and tension sides about N.A.
x=(m*Ast*d+Bf*Df^2/2+(1.5*m-1)*Asc*top_cover)/(m*Ast+Bf*Df+(1.5*m-1)*Asc)//in mm
//as x<Xc, beam is under-reinforced
sigma_cbc=sigma_st/m*x/(d-x)//in MPa
sigma_cbc_dash=sigma_cbc*(x-top_cover)/x//stress in concrete at level of compression steel, in MPa
sigma_cbc_double_dash=sigma_cbc*(x-Df)/x//stress in concrete at the underside of the slab, in MPa
//to find lever arm
z=round(d-(sigma_cbc+2*sigma_cbc_double_dash)/(sigma_cbc+sigma_cbc_double_dash)*Df/3)//in mm
//taking moments about tensile steel
Mr=Bf*Df*(sigma_cbc+sigma_cbc_double_dash)*z/2+(1.5*m-1)*Asc*sigma_cbc_dash*(d-top_cover)//in N-mm
mprintf("Moment of resistance of the beam=%f kN-m",Mr/10^6)
```

Scilab code Exa 3.11 T beam

```
Bf=1500//width of flange, in mm
Df=150//thickness of flange, in mm
d=600//effective depth, in mm
sigma_cbc=7//in MPa
sigma_st=230//in MPa
m=13.33//modular ratio
Ast=1964//in sq mm
```

```
Asc=1140//in sq mm
top_cover=50//in mm
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//assume x>Df; equating moments of area on compression and tension sides about N.A.
x=(m*Ast*d+Bf*Df^2/2+(1.5*m-1)*Asc*top_cover)/(m*Ast+Bf*Df+(1.5*m-1)*Asc)// in mm
//we find that x<Df, hence our assumption that x>Df is wrong
//to find x using Bf(x^2)/2 + (1.5m-1)Asc(x-d')=mAst(d-x), which becomes of the form px^2+qx+r=0
p=Bf/2
q=m*Ast+(1.5*m-1)*Asc
r=-(m*Ast*d+(1.5*m-1)*Asc*top_cover)
//solving quadratic equation
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//as x<Xc, beam is under-reinforced
sigma_cbc=sigma_st/m*x/(d-x)//in MPa
sigma_cbc_dash=sigma_cbc*(x-top_cover)/x//stress in concrete at level of compression steel, in MPa
//taking moments about tensile steel
Mr=Bf*x*sigma_cbc*(d-x/3)/2+(1.5*m-1)*Asc*sigma_cbc_dash*(d-top_cover)//in N-mm
mprintf("Moment of resistance of the beam=%f kN-m",Mr/10^6)
//answer given in textbook is incorrect
```

Scilab code Exa 3.12 T beam

```
Bf=1450//width of flange, in mm
Df=120//thickness of flange, in mm
d=400//effective depth, in mm
m=13.33//modular ratio
Ast=1800//in sq mm
```

```
Asc=450//in sq mm
top_cover=30//in mm
M=200*10^6//in N-mm
//assume x>Df; equating moments of area on
   compression and tension sides about N.A.
x=(m*Ast*d+Bf*Df^2/2+(1.5*m-1)*Asc*top_cover)/(m*Ast
   +Bf*Df+(1.5*m-1)*Asc)//in mm
//we find that x<Df, hence our assumption that x>Df
   is wrong
//to find x using Bf(x^2)/2 + (1.5m-1)Asc(x-d')=mAst
   (d-x), which becomes of the form px^2+qx+r=0
p=Bf/2
q=m*Ast+(1.5*m-1)*Asc
r=-(m*Ast*d+(1.5*m-1)*Asc*top_cover)
//solving quadratic equation
x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
//as x<Xc, beam is under-reinforced; let stress in
   concrete at level of steel be equal to 'a' times
   the stress in concrete at top
a=(x-top_cover)/x
//taking moments about tensile steel
sigma_cbc=M/(Bf*x*(d-x/3)/2+(1.5*m-1)*Asc*a*(d-
   top_cover))//in MPa
sigma_st=m*sigma_cbc*(d-x)/x//in MPa
sigma_sc=1.5*m*a*sigma_cbc//in MPa
mprintf("Stress in concrete=%f N/mm^2\nStress in
   tension steel=%f N/mm^2\nStress in compression
   steel=%f N/mm^2",sigma_cbc,sigma_st,sigma_sc)
//answer in textbook is incorrect
```

Scilab code Exa 3.13 L beam

```
Bf=500//width of flange, in mm
Bw=250//breadth of web, in mm
Df=100//thickness of flange, in mm
```

```
d=500//effective depth, in mm
sigma_cbc=5//in MPa
sigma_st=140//in MPa
m=18.66//modular ratio
Ast=2000//in sq mm
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
//assume x>Df
x=(m*Ast*d+Bf*Df^2/2)/(m*Ast+Bf*Df)//in mm
//as x>Xc, beam is over-reinforced
sigma_cbc_dash=sigma_cbc*(x-Df)/x//in MPa
//to find lever arm
z=d-(sigma_cbc+2*sigma_cbc_dash)/(sigma_cbc+sigma_cbc_dash)*Df/3//in mm
//taking moments about tensile steel
Mr=Bf*Df*(sigma_cbc+sigma_cbc_dash)*z/2//in N-mm
mprintf("Moment of resistance of the beam=%f kN-m",Mr/10^6)
```

Scilab code Exa 3.14 L beam

```
Bf=750//width of flange, in mm
Bw=250//breadth of web, in mm
Df=100//thickness of flange, in mm
d=700//effective depth, in mm
sigma_cbc=7//in MPa
sigma_st=190//in MPa
m=13.33//modular ratio
M=460*10^6//in N-mm
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
sigma_cbc_dash=sigma_cbc*(Xc-Df)/Xc//in MPa
//to find lever arm
z=d-(sigma_cbc+2*sigma_cbc_dash)/(sigma_cbc+sigma_cbc_dash)*Df/3//in mm
```

```
//taking moments about tensile steel
Ast=M/(sigma_st*z)//in sq mm
Ast=3699//round-off , in sq mm
mprintf("Area of steel required=%d mm^2", Ast)
```

Scilab code Exa 3.15 L beam

```
Df=120//thickness of flange , in mm
Bw=200//breadth of web, in mm
d=550//effective depth , in mm
l=6//span , in m
Bf=l*1000/12+Bw+3*Df//in mm
m=13.33//modular ratio
Ast=3200//in sq mm
M=190*10^6//in N-mm
//assume x>Df; equating moments of area on
    compression and tension sides about N.A.
x=(m*Ast*d+Bf*Df^2/2)/(m*Ast+Bf*Df)//in mm
//we find that x>Df, hence our assumption that x>Df
    is correct
//as x<Xc, beam is under-reinforced; let stress in
    concrete at underside of slab be equal to 'a'
    times the stress in concrete at top
a=(x-Df)/x
//to find lever arm
z=d-(1+2*a)/(1+a)*Df/3//in mm
z=500//round-off , in mm
//taking moments about tensile steel
sigma_cbc=M/(Bf*Df*(1+a)*z/2)//in MPa
sigma_st=m*sigma_cbc*(d-x)/x//in MPa
mprintf("Stress in concrete=%f N/mm^2\nStress in
    tension steel=%f N/mm^2",sigma_cbc,sigma_st)
```

Chapter 4

Shear and Development Length

Scilab code Exa 4.1 Shear

```
b=250//width, in mm
d=500//effective depth, in mm
W=20//UDL including self-weight, in kN/m
Pt=1//percentage tensile steel
l=6//span, in m
V=W*l/2//in kN
Tv=(V*10^3)/(b*d)//in MPa
//for Pt=1% and for M15 grade concrete
Tc=0.37//in MPa
//as Tv>Tc, shear reinforcement is required
mprintf("Nominal shear stress in beam=%f MPa\nShear
   strength of concrete=%f MPa", Tv,Tc)
```

Scilab code Exa 4.2 Shear

```
b=230//width, in mm
d=500//effective depth, in mm
W=24//UDL including self-weight, in kN/m
```

```
Ast=4*0.785*20^2//four 20 mm dia bars, in sq mm
Pt=Ast/(b*d)*100//percentage tensile steel
l=4.5//span, in m
V=W*l/2//in kN
Tv=(V*10^3)/(b*d)//in MPa
//for Pt=1.1% and for M20 grade concrete
Tc=0.40//in MPa
//as Tv>Tc, shear reinforcement is required
mprintf("Nominal shear stress in beam=%f MPa\nShear
    strength of concrete=%f MPa", Tv,Tc)
```

Scilab code Exa 4.3 Shear

```
b=300//width, in mm
d=600//effective depth, in mm
W=100//UDL including self-weight, in kN/m
Pt=2//percentage tensile steel
l=7.2//span, in m
sigma_cbc=7//in MPa
sigma_st=190//in MPa
m=13.33//modular ratio
V=W*l/2//in kN
Tv=(V*10^3)/(b*d)//in MPa
Tcmax=1.8//in MPa
//as Tv>Tcmax, section is to be redesigned so that
    Tv becomes less than Tcmax
mprintf("Nominal shear stress in beam=%f MPa\nFor
    given grade of concrete, Tcmax=1.8 MPa and as Tv
    > Tcmax, section is to be redesigned so that Tv
    becomes less than Tcmax", Tv)
```

Scilab code Exa 4.4 Shear

```
b=1000//consider 1 m width of slab
D=100//depth of slab, in mm
cover=20//in mm
d=D-cover//effective depth, in mm
W=7//uniformly distributed load, in kN/m^2
dia=10//in mm
s=100//spacing of 10 mm dia bars, in mm
l=4//span, in m
V=W*l/2//in kN
Pt=1000*.785*dia^2/(s*b*d)*100//in %
Tv=(V*10^3)/(b*d)//in MPa
//for given Pt and M15 grade concrete
Tc=0.37//in MPa
//and for solid slabs
k=1.3
Tc=k*Tc//in MPa
mprintf("Nominal shear stress in slab, Tv=%f MPa\nShear strength of slab, Tc=%f MPa. As Tc > Tv, no shear reinforcement is required", Tv, Tc)
```

Scilab code Exa 4.5 Shear

```
b=300//width, in mm
d=1010//effective depth, in mm
W=45//UDL including self-weight, in kN/m
Ast=6*0.785*22^2//six 22 mm dia bars, in sq mm
l=7//span, in m
sigma_cbc=5//in MPa
sigma_sv=140//in MPa
Fy=250//in MPa
V=W*l/2//in kN
Tv=(V*10^3)/(b*d)//in MPa
Tcmax=1.6//in MPa
//Tv<Tcmax; OK
Pt=Ast/(b*d)*100//percentage tensile steel
```

```
//for given Pt and for M15 grade concrete
Tc=0.34//in MPa
Vs=V-Tc*b*d/10^3//in kN
//providing 6 mm dia stirrups
dia=6//in mm
Asv=2*0.785*dia^2//in sq mm
Sv1=Asv*sigma_sv*d/(Vs*10^3)//in mm
Sv1=145//round-off, in mm
//Sv<0.75d or 450 mm, whichever is less; hence OK
//calculating minimum spacing of shear reinforcement
Sv2=Asv*Fy/(b*0.4)//in mm
Sv2=118//round-off, in mm
Sv=min(Sv1,Sv2)
mprintf("Provide 6 mm dia bars at %d mm c/c
   throughout the length of the beam, as shear
   reinforcement", Sv)
```

Scilab code Exa 4.6 Shear

```
Bf=1600//width, in mm
Df=100//thickness of slab, in mm
d=400//effective depth, in mm
Bw=225//breadth of web, in mm
b=Bw
W=30//UDL including self-weight, in kN/m
Ast=5*0.785*22^2//five 22 mm dia bars, in sq mm
l=9.2//span, in m
sigma_cbc=5//in MPa
sigma_sv=230//in MPa
Fy=415//in MPa
V=W*l/2//in kN
Tv=(V*10^3)/(b*d)//in MPa
Tcmax=1.6//in MPa
//Tv<Tcmax; OK
Pt=Ast/(b*d)*100//percentage tensile steel
```

```
//for given Pt and for M15 grade concrete
Tc=0.44//in MPa
Vs=V-Tc*b*d/10^3//in kN
//providing bent-up bars
Asv=0.785*22^2//in sq mm
Vs1=Asv*sigma_sv*sind(45)/10^3//in kN
//but shear taken up by bent-up bar is limited to Vs/2
Vs1=Vs/2//in kN
//providing 6 mm dia stirrups, which will take up remaining shear force
Vs2=Vs-Vs1//in kN
dia=6//in mm
Asv=2*0.785*dia^2//in sq mm
Sv=Asv*sigma_sv*d/(Vs2*10^3)//in mm
Sv1=105//round-off, in mm
//Sv<0.75d or 450 mm, whichever is less; hence OK
//calculating minimum spacing of shear reinforcement
Sv2=Asv*Fy/(b*0.4)//in mm
Sv2=260//round-off, in mm
//to calculate distance 'x' from support where shear stress in concrete is equal to Tc
x=Tc/Tv*l/2//in m
mprintf("Provide 6 mm dia stirrups at %d mm c/c upto %f m from both ends\nFor the remaining portion, provide 6 mm dia stirrups at %d mm", Sv1,(l/2-x),Sv2)
```

Scilab code Exa 4.7 Development Length

```
D=100//thickness of slab, in mm
l=3//span of slab, in m
s=0.23//thickness of support, in m
Lef=l+s//effective span, in m
W=5//UDL, in kN/m
```

```
cover=15//in mm
R=W*Lef/2//in kN
M=(R*s/2-W*s^2/2)*10^6//bending moment at face of wall, in N-mm
//10 mm dia bars at 145 mm c/c as main steel
dia=10//in mm
c=145//spacing of reinforcement, in mm
Ast=1000*0.785*dia^2/c//in sq mm
//as alternate bars are bent up
Ast=Ast/2//available steel reinforcement at face of wall, in sq mm
d=D-10/2-cover//in mm
//assuming balanced section
z=0.87*d//in mm
sigma_st=M/(Ast*z)//in MPa
Tbd=0.6//bond stress, in MPa
Ld=dia*sigma_st/(4*Tbd)//in mm
Ld=177//round-off, in mm
mprintf("Development length required from the face of the support = %d mm",Ld)
//answer given in textbook is incorrect
```

Scilab code Exa 4.8 Development Length

```
b=230//width, in mm
d=500//effective depth, in mm
l=6//span, in m
s=0.3//thickness of support, in m
Lef=l+s//effective span, in m
W=60//UDL, in kN/m
Ast=6*0.785*20^2//six 20 mm dia bars at bottom, in sq mm
Asc=2*0.785*20^2//two 20 mm dia bars at top, in sq mm
dia=20//in mm
```

```
sigma_cbc=5//in MPa
sigma_st=230//in MPa
m=18.66//modular ratio
R=W*l/2//in kN
M=(R*s/2-W*s^2/2)*10^6//bending moment at face of
    wall, in N-mm
//assuming balanced section
z=0.87*d//in mm
sigma_st1=M/(Ast*z)//in MPa
Tbd=0.6*1.4//bond stress in MPa for deformed steel
    and M15
Ld1=dia*sigma_st1/(4*Tbd)//in mm
//to find critical depth of neutral axis
Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
Xc=144//round-off, in mm
//at face of support
sigma_cbc=sigma_st1/m*Xc/(d-Xc)//in MPa
sigma_sc=1.5*m*sigma_cbc//in MPa
Tbd=1.68//bond stress in MPa for M15 and deformed
    steel in compression
Ld2=dia*sigma_sc/(4*Tbd)//in mm
mprintf("Development length required from the face
    of the support for tension steel = %d mm\
    nDevelopment length required from the face of the
     support for compression steel = %d mm",Ld1,Ld2)
```

Scilab code Exa 4.9 Development Length

```
D=120//thickness of slab, in mm
l=1.5//span of slab, in m
s=0.23//thickness of support, in m
Lef=l+s//effective span, in m
W1=3//UDL, in kN/m^2
cover=15//in mm
sigma_cbc=5//in MPa
```

```
sigma_st=140//in MPa
m=18.66//modular ratio
W2=(D/10^3)*1*25//self load, in kN/m
W=W1+W2//in kN/m
M=W*l^2/2*10^6//bending moment at face of wall, in N-mm
//10 mm dia bars at 145 mm c/c as main steel
dia=10//in mm
d=D-dia/2-cover
c=100//spacing of reinforcement, in mm
Ast=1000*0.785*dia^2/c//in sq mm
//assuming balanced section
z=0.87*d//in mm
sigma_st=M/(Ast*z)//in MPa
Tbd=0.6//bond stress in MPa
Ld=dia*sigma_st/(4*Tbd)//in mm
Ld=412//round-off,in mm
mprintf("Development length required from the face of the support = %d mm",Ld)
```

Chapter 5

Columns

Scilab code Exa 5.1 Short Column

```
sigma_cc=4//in MPa
sigma_sc=130//in MPa
Asc=4*0.785*25^2//four 25 mm dia bars, in sq mm
b=300//width, in mm
D=300//depth, in mm
Ag=b*D//in sq mm
Ac=Ag-Asc//in sq mm
P=sigma_cc*Ac+sigma_sc*Asc//in N
mprintf("Permissible load on the column = %f kN", P
   /10^3)
```

Scilab code Exa 5.2 Short Column

```
sigma_cc=5//in MPa
sigma_sc=190//in MPa
Asc=6*0.785*20^2//six 20 mm dia bars, in sq mm
b=250//width, in mm
D=400//depth, in mm
```

```
Ag=b*D//in sq mm
Ac=Ag-Asc//in sq mm
P=sigma_cc*Ac+sigma_sc*Asc//in N
mprintf("Permissible load on the column = %f kN\n",
    P/10^3)
//design of links
dia=20/4//in mm
//as this is less than 6
dia=6//in mm
//spacing of links
s1=b//in mm
s2=16*20//in mm
s3=48*dia//in mm
s=min(s1,s2,s3)
mprintf("Provide %d mm dia links at spacing equal to
     least of (i)Least lateral dimension = %d mm, (ii
    ) 16 times longitudinal bar dia = %d mm, (iii) 48
     times link bar dia = %d mm, i.e., 250 mm\nHence,
     spacing or pitch = %d mm\n",dia,b,16*20, 48*dia,
    s)
Pc=Asc*100/(b*D)//percentage steel
mprintf("Percentage of steel is in between 0.8 to 4
    as prescribed by IS code")
```

Scilab code Exa 5.3 Short Column

```
sigma_cc=5//in MPa
sigma_sc=130//in MPa
b=300//width, in mm
D=400//depth, in mm
P=1000//axial load, in kN
Ag=b*D//in sq mm
Asc=(P*10^3-sigma_cc*Ag)/(sigma_sc-sigma_cc)//in sq
    mm
//provide 25 mm dia bars
```

```
n=round(Asc/(0.785*25^2))
mprintf("Provide %d no. 25 mm dia bars\n", n)
//design of links
dia=20/4//in mm
//provide 8 mm dia links (available as per market
    size)
dia=8//in mm
//spacing of links
s1=b//in mm
s2=16*25//in mm
s3=48*dia//in mm
s=min(s1,s2,s3)
mprintf("Provide %d mm dia links at spacing equal to
     least of (i)Least lateral dimension = %d mm, (ii
    ) 16 times longitudinal bar dia = %d mm, (iii) 48
     times link bar dia = %d mm, i.e., 300 mm\nHence,
     spacing or pitch = %d mm\n",dia,b,16*25,48*dia,s
    )
```

Scilab code Exa 5.4 Short Column

```
sigma_cc=4//in MPa
sigma_sc=130//in MPa
Asc=6*0.785*12^2//six 12 mm dia bars, in sq mm
D=200//dia of column, in mm
Ag=0.785*D^2//in sq mm
Ac=Ag-Asc//in sq mm
P=sigma_cc*Ac+sigma_sc*Asc//in N
dia=6//dia of links used, in mm
//spacing of links
s1=D//in mm
s2=16*12//in mm
s3=48*dia//in mm
s=min(s1,s2,s3)
mprintf("Permissible load on the column = %f kN\
```

```
nProvide %d mm dia links at spacing equal to
least of (i)Least lateral dimension = %d mm, (ii)
 16 times longitudinal bar dia = %d mm, (iii) 48
times link bar dia = %d mm, i.e., %d mm\nHence,
spacing or pitch = %d mm", P/10^3, dia,D,16*12,
48*dia,s,s)
```

Scilab code Exa 5.5 Short Column with Helical Bending

```
dia=300//in mm
Asc=8*0.785*20^2//8-20 mm dia bars, in sq mm
helical_dia=8//in mm
pitch=25//in mm
cover=40//in mm
sigma_cc=5//in MPa
sigma_sc=130//in MPa
fck=25//in MPa
fy=250//in MPa
Ag=0.785*dia^2//in sq mm
Ac=Ag-Asc//in sq mm
P=sigma_cc*Ac + sigma_sc*Asc//in N
//to find volume of helical reinforcement
core_dia=dia-2*cover+2*helical_dia//in mm
l=%pi*core_dia//length of helical steel for one
    revolution, in mm
Ab=l*0.785*helical_dia^2/pitch//volume of helical
    reinforcement per mm height of column, in mm^3
Ak=0.785*core_dia^2-Asc//in sq mm
Ac=0.785*core_dia^2//in sq mm
m=Ab/Ak
n=0.36*(Ag/Ac-1)*fck/fy
//as m > n
P=1.05*P//in N
mprintf("Safe load=%f kN",P/10^3)
```

Scilab code Exa 5.6 Long Column

```
b=250//width, in mm
D=350//depth, in mm
Asc=4*0.785*22^2//four 22 mm dia bars, in sq mm
Lef=5//effective length of column, in m
sigma_cc=4//in MPa
sigma_sc=130//in MPa
a=Lef*10^3/b
//as Lef/b > 12, it is a long column
Cr=1.25-Lef*1000/(48*b)//reduction coefficient
sigma_cc=Cr*sigma_cc//in MPa
sigma_sc=Cr*sigma_sc//in MPa
Ag=b*D//in sq mm
Ac=Ag-Asc//in sq mm
P=sigma_cc*Ac+sigma_sc*Asc//in N
mprintf("The safe load on the column=%f kN", P/10^3)
```

Scilab code Exa 5.7 Long Column

```
dia=500//in mm
Asc=6*%pi/4*25^2//six 25 mm dia bars, in sq mm
Lef=8//effective length of column, in m
sigma_cc=5//in MPa
sigma_sc=190//in MPa
a=Lef*10^3/dia
//as Lef/b >12, it is a long column
Cr=1.25-Lef*1000/(48*dia)//reduction coefficient
sigma_cc=Cr*sigma_cc//in MPa
sigma_sc=Cr*sigma_sc//in MPa
Ag=%pi/4*dia^2//in sq mm
Ac=Ag-Asc//in sq mm
```

```
P=sigma_cc*Ac+sigma_sc*Asc//in N
mprintf("The safe load on the column=%f kN", P/10^3)
//the answer doesn't match with that given in
    textbook due to round-off error
```

Scilab code Exa 5.8 Design of column

```
P=850//in kN
sigma_cc=4//in MPa
m=18.66//modular ratio
sigma_sc=130//in MPa
Lef=5*1.001//effective length, in m
//assume 1% steel
Ag=P*10^3/(sigma_cc*0.99+sigma_sc*0.01)//in sq mm
l=sqrt(Ag)//in mm
l=400//approximately, in mm
a=Lef*1000/l
//as a>12, it is a long column
//Method I-section to be changed
b=Lef*1000/12//in mm
b=420//approximately, in mm
Ag=b^2//in sq mm
Asc=(P*1000-sigma_cc*Ag)/(sigma_sc-sigma_cc)//in sq
    mm
minimum_steel=0.8/100*b^2//in sq mm
//as Asc < minimum steel
Asc=minimum_steel//in sq mm
//assume 20 mm dia bars
n=Asc/(%pi/4*20^2)//no. of bars
n=5//round-off
//design of links
dia=1/4*20//in mm
//as dia < 6 mm, provide 6 mm diameter links
dia=6//in mm
spacing=min(b,16*20,48*dia,300)//in mm
```

```
mprintf("Method I\nColumn size %d x %d mm\nMain
    steel =%d-20 mm dia bars\nLinks=6 mm dia links @
    %d mm c/c\n", b,b,n,spacing)
//Method II-same section
b=400//in mm
Ag=b^2//in sq mm
Cr=1.25-Lef*1000/(48*b)//reduction coefficient
sigma_cc=Cr*sigma_cc//in MPa
sigma_sc=Cr*sigma_sc//in MPa
Asc=(P*1000-sigma_cc*Ag)/(sigma_sc-sigma_cc)//in MPa
n=round(Asc/(%pi/4*20^2))//no. of bars
//design of links
dia=1/4*20//in mm
//as dia < 6 mm, provide 6 mm diameter links
dia=6//in mm
spacing=min(b,16*20,48*dia,300)//in mm
mprintf("Method II\nColumn size %d x %d mm\nMain
    steel =%d-20 mm dia bars\nLinks=6 mm dia links @
    %d mm c/c", b,b,n,spacing)
```

Scilab code Exa 5.9 Design of column

```
P=400//in kN
b=200//width, in mm
sigma_cc=4//in MPa
sigma_sc=190//in MPa
Lef=3.5//effective length, in m
//assume 1% steel
Ag=P*10^3/(sigma_cc*0.99+sigma_sc*0.01)//in sq mm
D=Ag/b//in mm
D=340//round-off, in mm
a=Lef*1000/b
//as a > 12, it is a long column
Cr=1.25-Lef*1000/(48*b)//reduction coefficient
sigma_cc=Cr*sigma_cc//in MPa
```

```
sigma_sc=Cr*sigma_sc//in MPa
Asc=(P*1000-sigma_cc*Ag)/(sigma_sc-sigma_cc)//in sq
    mm
//assume 18 mm dia bars
n=Asc/(%pi/4*18^2)//no. of bars
n=4//round-off
//design of links
dia=1/4*20//in mm
//as dia < 6 mm, provide 6 mm diameter links
dia=6//in mm
spacing=min(b,16*20,48*dia,300)//in mm
mprintf("Column size %d x %d mm\nMain steel =%d-18
    mm dia bars\nLinks=6 mm dia links @ %d mm c/c\n",
    b,D,n,spacing)
```

Scilab code Exa 5.10 Eccentrically Loaded Column

```
P=280//in kN
e=50//eccentricity , in mm
b=300//width , in mm
D=300//depth , in mm
sigma_cc=4//in MPa
sigma_cbc=5//in MPa
m=18.66//modular ratio
cover=50//in mm
Asc=4*0.785*20^2//four 20 mm dia bars , in sq mm
Ag=b*D//in sq mm
Ac=Ag-Asc//in sq mm
sigma_cc_cal=P*10^3/(Ac+1.5*m*Asc)//in MPa
I=b*D^3/12 + (m-1)*Asc*(D/2-cover)^2//in mm^4
z=I/(D/2)//in mm^3
sigma_cbc_cal=P*10^3*e/z//in MPa
sigma_max=sigma_cc_cal + sigma_cbc_cal//in MPa
sigma_min=sigma_cc_cal - sigma_cbc_cal//in MPa
mprintf("Maximum stress = %f MPa (compressive)\
```

```
nMinimum stress = %f MPa (tensile)", sigma_max,
sigma_min)
```

Scilab code Exa 5.11 Eccentrically Loaded Column

```
P=200//in kN
b=200//width, in mm
D=350//depth, in mm
sigma_cc=5//in MPa
sigma_cbc=7//in MPa
m=13.33//modular ratio
Mxx=6//in kN-m
Myy=4//in kN-m
cover=40//in mm
eff_cover=cover+25/2//in mm
Asc=4*0.785*25^2//four 25 mm dia bars, in sq mm
Ag=b*D//in sq mm
Ac=Ag-Asc//in sq mm
sigma_cc_cal=P*10^3/(Ac+1.5*m*Asc)//in MPa
//to find bending stress on XX axis
Ixx=b*D^3/12 + (m-1)*Asc*(D/2-eff_cover)^2//in mm^4
Zxx=Ixx/(D/2)//in mm^3
sigma_cbc_xx=Mxx*10^6/Zxx//in MPa
//to find bending stress on YY axis
Iyy=D*b^3/12 + (m-1)*Asc*(b/2-eff_cover)^2//in mm^4
Zyy=Iyy/(b/2)//in mm^3
sigma_cbc_yy=Myy*10^6/Zyy//in MPa
sigma_cbc_cal=sigma_cbc_xx + sigma_cbc_yy//in MPa
sigma_max=sigma_cc_cal + sigma_cbc_cal//in MPa
sigma_min=sigma_cc_cal - sigma_cbc_cal//in MPa
mprintf("Maximum stress = %f MPa (compressive)\
   nMinimum stress = %f MPa (tensile)", sigma_max,
   sigma_min)
```

Scilab code Exa 5.12 `Cracked Section`

```
b=450//width, in mm
D=900//depth, in mm
c=80//cover, in mm
d=D-c//in mm
Asc=4000//in sq mm
Ast=Asc//in sq mm
P=500//in kN
e=600//in mm
m=18.66
//equation for x is: x^2 + (k1 - k2 / sigma_cbc_dash) x - k3 = 0
k1=2/b*((1.5*m-1)*Asc+m*Ast)
k2=2*P*10^3/b
k3=2/b*(c*(1.5*m-1)*Asc+d*m*Ast)
//equation for sigma_cbc_dash is: sigma_cbc_dash = Q1 x /(Q2 x^2 (d - x/3) + Q3 (x - c))
Q1=P*10^3*(e+d-D/2)
Q2=b/2
Q3=(1.5*m-1)*(d-c)*Asc
sigma_cbc_dash=7//assume, in MPa
//solving equation for x
p=1
q=(k1-k2/sigma_cbc_dash)
r=-k3
x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
sigma_cbc_dash = Q1*x/(Q2*x^2*(d-x/3)+Q3*(x-c))//in MPa
//this process is repeated till convergence
//solving equation for x
p=1
q=(k1-k2/sigma_cbc_dash)
r=-k3
```

```
x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
sigma_cbc_dash = Q1*x/(Q2*x^2*(d-x/3)+Q3*(x-c))//in
    MPa
//solving equation for x
p=1
q=(k1-k2/sigma_cbc_dash)
r=-k3
x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
sigma_cbc_dash = Q1*x/(Q2*x^2*(d-x/3)+Q3*(x-c))//in
    MPa
//solving equation for x
p=1
q=(k1-k2/sigma_cbc_dash)
r=-k3
x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
sigma_cbc_dash = Q1*x/(Q2*x^2*(d-x/3)+Q3*(x-c))//in
    MPa
//solving equation for x
p=1
q=(k1-k2/sigma_cbc_dash)
r=-k3
x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
sigma_cbc_dash = Q1*x/(Q2*x^2*(d-x/3)+Q3*(x-c))//in
    MPa
//solving equation for x
p=1
q=(k1-k2/sigma_cbc_dash)
r=-k3
x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
sigma_sc=m*sigma_cbc_dash*(x-c)/x//in MPa
sigma_st=m*sigma_cbc_dash*x/(d-x)//in MPa
//answer in textbook is incorrect
```

Chapter 7

Slab Design One Way

Scilab code Exa 7.1 Design of One Way Simply Supported Slab

```
sigma_cbc=5//in MPa
sigma_st=140//in MPa
MF=1.6//modification factor
//let a be span to depth ratio
l=4//span, in m
a=MF*20
D=l*1000/a//in mm
//to calculate loading
self_weight=25*(D/10^3)//in kN/m
finish=1//in kN/m
live_load=2//in kN/m
W=self_weight+finish+live_load//total load, in kN/m
lef=l+D/1000//in m
M=W*lef^2/8//in kN-m
//check for depth
d=round((M*10^6/(0.87*1000))^0.5)//in mm
//assume 12 mm dia bars
D=d+12/2+15//in mm
//the calculated value of D is more than its assumed value
D=150//revised value of depth, in mm
```

```
self_weight=25*(D/10^3)//in kN/m
finish=1//in kN/m
live_load=2//in kN/m
W=self_weight+finish+live_load//total load, in kN/m
lef=l+D/1000//in m
M=W*lef^2/8//in kN-m
//check for depth
d=round((M*10^6/(0.87*1000))^0.5)//in mm
D=d+12/2+15//in mm
Ast=round(M*10^6/(sigma_st*0.87*d))//in sq mm
s1=1000*0.785*12^2/Ast//which is less than 3d= 387 mm
s1=120//approximately, in mm
Ads=0.15/100*1000*D//distribution steel, in sq mm
//assume 8 mm dia bars
s2=1000*0.785*8^2/Ads//which is less than 5d= 645 mm
s2=220//approximately, in mm
//to calculate development length
w=0.345//support width, in m
lef=l+w//in m
R=W*lef/2//reaction at support, in kN
M1=R*w/2-W*w^2/2//bending moment at the face of wall, in kN-m
sigma_st=M1*10^6/(Ast/2*0.87*d)//in MPa
Tbd=0.6//in MPa
Ld=12*sigma_st/(4*Tbd)//in mm
La=w*1000-25//available length for bar over wall, which is greater than development length
//check for shear
V=W*4.15/2//in kN
Tv=V*10^3/(1000*d)//in MPa
Tc=0.33//permissible shear in concrete for p=0.71 and M15, in MPa
Tc=1.3*Tc//permissible shear for slabs, in MPa
//Tc>Tv; hence no shear reinforcement is required
mprintf("Summary of design\nSlab thickness=%d mm\nCover=15 mm\nMain steel = 12 mm dia @ %d mm c/c\nAlternate bars are bent up @ 45-degree at
```

```
    support at a distance l/7 from support face\
    nDistribution steel=8 mm dia @ %d mm c/c",D,s1,s2
    )
```

Scilab code Exa 7.2 Design of One Way Simply Supported Slab

```
sigma_cbc=5//in MPa
sigma_st=230//in MPa
MF=1.4//modification factor
//let a be span to depth ratio
l=4.5//span, in m
a=MF*20
D=l*1000/a//in mm
D=160//approximately, in mm
//to calculate loading
self_weight=25*(D/10^3)//in kN/m
finish=1//in kN/m
partitions=1//in kN/m
live_load=4//in kN/m
W=self_weight+finish+partitions+live_load//total
    load, in kN/m
lef=l+D/1000//in m
M=W*lef^2/8//in kN-m
//check for depth
d=(M*10^6/(0.9*sigma_cbc/2*0.29*1000))^0.5//in mm
//assume 12 mm dia bars
D=d+12/2+15//in mm
//the calculated value of D is more than its assumed
    value
D=1.1*D//revised value of depth, in mm
D=250//assume, in mm
self_weight=25*(D/10^3)//in kN/m
finish=1//in kN/m
partitions=1//in kN/m
live_load=4//in kN/m
```

```
W=self_weight+finish+partitions+live_load//total load, in kN/m
lef=l+D/1000//in m
M=W*lef^2/8//in kN-m
//check for depth
d=round((M*10^6/(0.9*sigma_cbc/2*0.29*1000))^0.5)//in mm
D=d+12/2+15//in mm
D=250//approximately, in mm
Ast=round(M*10^6/(sigma_st*0.9*d))//in sq mm
s1=1000*0.785*12^2/Ast//which is less than 3d= 690 mm
s1=155//approximately, in mm
pt=Ast/1000/d*100//in %
Ads=0.12/100*1000*D//distribution steel, in sq mm
//assume 8 mm dia bars
s2=1000*0.785*8^2/Ads//which is less than 5d= 1150 mm
s2=165//approximately, in mm
//to calculate development length
w=0.23//support width, in m
l=l+w//in m
R=W*l/2//reaction at support, in kN
M1=R*w/2-W*w^2/2//bending moment at the face of wall, in kN-m
sigma_st=M1*10^6/(Ast/2*0.9*d)//in MPa
Tbd=0.6//in MPa
Ld=12*sigma_st/(4*Tbd)//in mm
La=w*1000-25//available length for bar over wall, which is greater than development length
//check for shear
V=W*lef/2//in kN
Tv=V*10^3/(1000*d)//in MPa
Tc=0.2212//permissible shear in concrete for p=0.315 and M15, in MPa
Tc=1.15*Tc//permissible shear for slabs, in MPa
//Tc>Tv; hence no shear reinforcement is required
mprintf("Summary of design\nSlab thickness=%d mm\
```

```
nCover=15 mm\nMain steel = 12 dia @ %d mm c/c\
nAlternate bars are bent up at 45-degree at
support at a distance of l/7 from support face\
nDistribution steel=8 dia @ %d mm c/c",D,s1,s2)
```

Scilab code Exa 7.3 Design of One Way Continuous Slab

```
sigma_cbc=7//in MPa
sigma_st=230//in MPa
MF=1.22//modification factor
//let a be span to depth ratio
l=5//span, in m
a=MF*26
D=l*1000/a//in mm
D=160//assume, in mm
//to calculate loading
self_weight=25*(D/10^3)//in kN/m
finish=0.75//in kN/m
partitions=1//in kN/m
live_load=3//in kN/m
Wd=self_weight//dead load, in kN/m
Wl=finish+partitions+live_load//live load, in kN/m
lef=5.15//effective span, in m
M1=Wd*lef^2/12+Wl*lef^2/10//bending moment at mid-
    span, in kN-m
M2=Wd*lef^2/10+Wl*lef^2/9//bending moment at support
     next to end support, in kN-m
//check for depth
d=(M2*10^6/(0.89*1000))^0.5//in mm
dia=12//assume 12 mm dia bars
D=d+12/2+15//>160, hence depth not suitable
D=1.1*D//in mm
D=210//assume, in mm
self_weight=25*(D/10^3)//in kN/m
Wd=self_weight//in kN/m
```

```
M1=Wd*lef^2/12+Wl*lef^2/10//bending moment at mid-span, in kN-m
M2=Wd*lef^2/10+Wl*lef^2/9//bending moment at support next to end support, in kN-m
//check for depth
d=round((M2*10^6/(0.9*sigma_cbc/2*0.29*1000))^0.5)// in mm
D=d+12/2+15//<210, hence OK
D=200//assume, in mm
d=D-dia/2-15//in mm
//main steel at mid-span
Ast1=round(M1*10^6/(sigma_st*0.91*d))//in sq mm
s1=1000*0.785*12^2/Ast1//in mm
s1=175//approximately, in mm
//main steel at support
Ast2=round(M2*10^6/(sigma_st*0.91*d))//in sq mm
//alternate bars from mid-span are available at the central support as bent up bars; assuming same amount of steel is available from another adjoining mid-span steel
Ast2=Ast2-Ast1//which is nominal, hence no separate steel is required
Ads=0.12/100*1000*D//distribution steel, in sq mm
//assume 8 mm dia bars
s2=1000*0.785*8^2/Ads//in mm
s2=200//approximately, in mm
mprintf("Summary of design\nSlab thickness=%d mm\nMain steel = 12 mm dia @ %d mm c/c\nAlternate bars are bent up at support\nDistribution steel=8 mm dia @ %d mm c/c",D,s1,s2)
//answer given in textbook is incorrect
```

Scilab code Exa 7.4 Design of Cantilever Chajja

```
sigma_cbc=5//in MPa
```

```
sigma_st=230//in MPa
MF=1.4//modification factor
//let a be span to depth ratio
l=1//span, in m
a=MF*7
D=l*1000/a//in mm
D=105//assume, in mm
//to calculate loading
self_weight=25*(D/10^3)*1.5//in kN/m
finish=0.5*1.5//in kN/m
live_load=0.75*1.5//in kN/m
W=self_weight+finish+live_load//in kN/m
lef=l+0.23/2//effective span, in m
M=W*lef/2//in kN-m
//check for depth
d=(M*10^6/(0.65*1500))^0.5//in mm
dia=12//assume 12 mm dia bars
D=d+12/2+15//<105, hence OK
D=100//assume, in mm
d=D-dia/2-15//in mm
//main steel at mid-span
Ast=M*10^6/(sigma_st*0.9*d)//in sq mm
s1=1500*0.785*12^2/Ast//>3d = 237 mm
s1=235//assume, in mm
Ads=0.12/100*1000*D//distribution steel, in sq mm
//assume 6 mm dia bars
s2=1000*0.785*6^2/Ads//in mm
s2=235//assume, in mm
Tbd=0.84//in MPa
Ld=dia*sigma_st/4/Tbd// in mm
Ld=821//round-off, in mm
Tv=W*10^3/1500/d//in MPa
As=1500*0.785*12^2/235//in sq mm
pt=As/1500/d*100//in %
Tc=0.316//in MPa
//as Tc>Tv, no shear reinforcement required
mprintf("Summary of design\nThickness of slab = %d
    mm\nCover = 15mm\nMain steel = 12 mm dia @ %d mm
```

```
c/c\nProvide development length of %d mm in the
beam from face of beam\nDistribution steel = 6 mm
 dia @ %d mm c/c",D,s1,Ld,s2)
```

Chapter 8

Slab Design Two Way Reinforced

Scilab code Exa 8.1 Design of Two Way Simply Supported Slab

```
lx=3.5//in m
ly=4//in m
sigma_cbc=5//in MPa
sigma_st=140//in MPa
D=lx*10^3/35//in mm
W1=(D/10^3)*25//self-weight, in kN/m
W2=1.5//live load, in kN/m
W=W1+W2//in kN/m
a=ly/lx
Ax=0.078
Ay=0.0602
Mx=Ax*W*lx^2//in kN-m
My=Ay*W*lx^2//in kN-m
d=sqrt(Mx*10^6/0.87/10^3)//in mm
d=70//assume, in mm
//assume 10 mm dia bars
dia=10//in mm
D=d+dia/2+15//<100 mm assumed value
D=100//in mm
```

```
d=D-dia/2-15//in mm
//steel - short span
z=0.87*d//in mm
Ast=Mx*10^6/sigma_st/z//in sq mm
s1=1000*0.785*dia^2/Ast//in mm
s1=200//assume, in mm
//long span
d=d-dia/2-dia/2//in mm
Ast=My*10^6/sigma_st/0.87/d//in sq mm
s2=1000*0.785*dia^2/Ast//>3d = 210 mm
s2=210//assume, in mm
mprintf("Summary of design\nSlab thickness=%d mm\nCover=15 mm\nSteel-\n(i)Short span = 10 mm dia @ %d mm c/c\n(ii)Long span = 10 mm dia @ %d mm c/c\nAlternate bars are bent up at l/7 from support in both directions",D,s1,s2)
```

Scilab code Exa 8.2 Design of Two Way Continuous Slab

```
sigma_cbc=5//in MPa
sigma_st=230//in MPa
lx=3.75//in m
ly=4//in m
D=lx*10^3/40//in mm
D=100//assume, in mm
W1=(D/10^3)*25//self-weight, in kN/m
W2=0.5//floor finish, in kN/m
W3=2//live load, in kN/m
W=W1+W2+W3//in kN/m
a=ly/lx
//panels I and III belong to case 8 and panel II belong to case 6
//for panels I and III
//at mid-span
Ax=0.0483
```

```
Ay=0.043
Mx1=Ax*W*lx^2//in kN-m
My1=Ay*W*lx^2//in kN-m
//at support
Ay=0.057
Ms=Ay*W*lx^2//in kN-m
//for panel II
//at mid-span
Ax=0.0403
Ay=0.035
Mx2=Ax*W*lx^2//in kN-m
My2=Ay*W*lx^2//in kN-m
//at support
Ay=0.045//<0.057, hence not considered
d=sqrt(Ms*10^6/0.65/10^3)//in mm
d=80//assume, in mm
//assume 10 mm dia bars
dia=10//in mm
D=d+dia/2+15
//steel at centre
//for panels I and III
//short span
z=0.9*d//in mm
Ast=Mx1*10^6/sigma_st/z//in sq mm
s1=1000*0.785*dia^2/Ast//>3d
//long span
Ast=My1*10^6/sigma_st/z//in sq mm
s2=1000*0.785*dia^2/Ast//>3d
//for panel II
//short span
Ast=Mx2*10^6/sigma_st/z//in sq mm
s3=1000*0.785*dia^2/Ast//>3d
//long span
Ast=My2*10^6/sigma_st/z//in sq mm
s3=1000*0.785*dia^2/Ast//>3d
//steel at support
Ast=Ms*10^6/sigma_st/z//in sq mm
s4=1000*0.785*dia^2/Ast//>3d
```

```
s=3*d//maximum spacing of bars in both directions as per IS 456, in mm
Ast=1000*0.785*dia^2/s//in sq mm
pt=Ast/10^3/d*100//in %
//steel for torsion, provide 6 mm dia bars
//(i)at outer corner of slab
At1=3/4*Ast//in sq mm
l=lx/5//in m
s5=750*0.785*6^2/At1//in mm
s5=85//assume, in mm
//(ii)at continuous support
At2=At1/2//in sq mm
s6=750*0.785*6^2/At2//in mm
s6=170//assume, in mm
mprintf("Summary of design\nSlab thickness=%d mm\nCover=15 mm\nSteel for both panels I and II-\nMain steel= 10 mm dia bars @ %d mm c/c both ways. Alternate bars are bent up at supports.\nTorsion steel=(i) At corners, 6 mm dia bars @ %d mm c/c both ways\n(ii) At continuous support, 6 mm dia bars @ %d mm c/c both ways",D,s,s5,s6)
```

Scilab code Exa 8.3 Design of Two Way Continuous Slab

```
sigma_cbc=7//in MPa
sigma_st=275//in MPa
lx=6//in m
ly=7//in m
D=lx*10^3/35//in mm
D=180//assume, in mm
W1=(D/10^3)*25//self-weight, in kN/m
W2=0.5//floor finish, in kN/m
W3=1//partitions, in kN/m
W4=5//live load, in kN/m
W=W1+W2+W3+W4//in kN/m
```

```
a=ly/lx
//panels I, II, V and VI belong to case 4 and panels III and IV belong to case 3
//for panels I, II, V and VI
//at mid-span
Ax=0.043
Ay=0.035
Mxm1=Ax*W*lx^2//in kN-m
Mym1=Ay*W*lx^2//in kN-m
//at support
Ax=0.058
Ay=0.047
Mxs1=Ax*W*lx^2//in kN-m
Mys1=Ay*W*lx^2//in kN-m
//for panels III and IV
//at mid-span
Ax=0.036
Ay=0.028
Mxm2=Ax*W*lx^2//in kN-m
Mym2=Ay*W*lx^2//in kN-m
//at support
Ax=0.047
Ay=0.037//<0.047, hence will not be considered
Mxs2=Ax*W*lx^2//in kN-m
//check for depth
M=max(Mxm1,Mym1,Mxs1,Mys1,Mxm2,Mym2,Mxs2)//in kN-m
d=sqrt(M*10^6/0.81/10^3)//in mm
d=170//assume, in mm
//assume 10 mm dia bars
dia=10//in mm
D=d+dia/2+15//>180 mm assumed value
D=190//in mm
d=D-dia/2-15//in mm
//main steel-short span
//for panels I, II, V and VI-at mid-span
z=0.92*d//in mm
Astm=Mxm1*10^6/sigma_st/z//in sq mm
s1=1000*0.785*dia^2/Astm//in mm
```

```
s1=195//assume, in mm
//at support
Ast=Mxs1*10^6/sigma_st/z//in sq mm
Astr=Ast-Astm//balance steel required at support, in
    sq mm
s2=1000*0.785*dia^2/Astr//in mm
s2=565//assume, in mm
//for panels III and IV-at mid-span
Astm=Mxm2*10^6/sigma_st/z//in sq mm
s3=1000*0.785*dia^2/Astm//in mm
s3=235//assume, in mm
//at support
Ast=Mxs2*10^6/sigma_st/z//in sq mm
Astr=Ast-Astm//balance steel required at support, in
    sq mm
s4=1000*0.785*dia^2/Astr//in mm
s4=775//assume, in mm
//long span
//at mid-span
//for panels I, II, V and VI
Astm1=Mym1*10^6/sigma_st/z//in sq mm
s5=1000*0.785*dia^2/Astm1//in mm
s5=240//assume, in mm
//for panels III and IV
Astm2=Mym2*10^6/sigma_st/z//in sq mm
s6=1000*0.785*dia^2/Astm2//in mm
s6=300//assume, in mm
//at support
//for panels I, II, V and VI
Ast=Mys1*10^6/sigma_st/z//in sq mm
Astr=Ast-Astm1/2-Astm2/2//balance steel required at
   support, in sq mm
s7=1000*0.785*dia^2/Astr//in mm
s7=550//assume, in mm
//steel for torsion, provide 6 mm dia bars
//(i)at outside corners of slab
Ast=Mxm1*10^6/sigma_st/z//in sq mm
At1=3/4*Ast//in sq mm
```

```
l=lx/5//in m
s8=l*10^3*0.785*6^2/At1//in mm
s8=110//assume, in mm
//(ii)at continuous support
At2=At1/2//in sq mm
s9=l*10^3*0.785*6^2/At2//in mm
s9=225//assume, in mm
mprintf("Summary of design\nSlab thickness=%d mm\nCover=15 mm\nSteel:(A)Panels I, II, V and VI-\n1. Short span (lx=6 m)\nMid-span - 10 mm dia bars @ %d mm c/c. Alternate bars are bent up at supports at a distance lx/4 from centre of support\nSupport - 10 mm dia @ %d mm c/c\n2. Long span (ly=7 m)\nMid-span - 10 mm dia bars @ %d mm c/c. Alternate bars are bent up at supports at a distance ly/4 from centre of support\nSupport - 10 mm dia @ %d mm c/c\n(B)Panels III and IV-\n1. Short span (lx=6 m)\nMid-span - 10 mm dia bars @ %d mm c/c. Alternate bars are bent up at supports at a distance lx/4 from centre of support\nSupport - 10 mm dia @ %d mm c/c\n2. Long span (ly=7 m)\nMid-span - 10 mm dia bars @ %d mm c/c. Alternate bars are bent up at supports at a distance ly/4 from centre of support\nSupport - 10 mm dia @ %d mm c/c\nTorsion steel\nOutside corners- 6 mm dia bars @ %d mm c/c both ways at top and bottom for a length of %f m\nContinuous support- 6 mm dia bars @ %d mm c/c both ways at top and bottom for a length of %f m",D,s1,s2,s5,s7,s3,s4,s6,s7,s8,l,s9,l)
//answer in textbook is incorrect
```

Chapter 9

Beam Design

Scilab code Exa 9.1 Design of Lintel Beam

```
l=3//span, in m
b=225//wall thickness, in mm
Dm=19.2//weight of masonry, in kN/cu m
sigma_cbc=5//in MPa
sigma_st=230//in MPa
fy=415//in MPa
//area of triangle of brick masonry
A=sqrt(3)/4*l^2//in sq m
V=A*(b/10^3)//volume of triangle of masonry, in cu m
W=V*Dm//weight of masonry, in kN
M1=W*l/6//in kN-m
D=l*10^3/12//in mm
D=300//approximately, in mm
self_weight=25*(D/10^3)*(b/10^3)//in kN/m
M2=self_weight*l^2/8//in kN-m
M=M1+M2//in kN-m
//check for depth
d=sqrt(M*10^6/0.65/b)//in mm
d=265//approximately, in mm
dia=10//in mm
D=d+dia/2+25//<300 mm, hence OK
```

```
D=300//in mm
Ast=M*10^6/sigma_st/0.9/d//in sq mm
n=Ast/0.785/10^2//no. of 10 mm dia bars required
//provide 2-10 mm dia + 1-8 mm dia bars
Ast=2*0.785*10^2+0.785*8^2//in sq mm
pt=Ast/b/d*100//pt=0.35, approximately
W=W+self_weight*l//in kN
V=W/2//in kN
Tv=V*10^3/b/d//in MPa
//for M15 grade concrete and pt=0.35
Tc=0.248//in MPa
//as Tc>Tv, no shear reinforcement required; provide
    nominal stirrups
//provide 6 mm dia bars
Asv=2*0.785*6^2//in sq mm
Sv=Asv*fy/0.4/b//in mm
Sv=260//approximately, in mm
Svmax=0.75*d//in mm
Svmax=200//approximately, in mm
Sv=min(Sv,Svmax)//in mm
mprintf("Summary of design\nSize of lintel beam=%d x
    %d mm\ncover = 35 mm\nsteel = 2-10 mm dia bars +
    1-8 mm dia bar\nstirrups = 6 mm dia @ %d mm c/c
   throughout",b,D,Sv)
```

Scilab code Exa 9.2 Design of Rectangular Beam

```
l=4.2//span, in m
b=225//width, in mm
D=300//depth, in mm
sigma_cbc=5//in MPa
sigma_st=230//in MPa
fy=415//in MPa
m=18.66//modular ratio
W1=25*(D/10^3)*(b/10^3)//self-weight, in kN/m
```

```
W2=6//load on beam, in kN/m
W=W1+W2//in kN/m
M=W*l^2/8//in kN-m
dia=12//in mm
d=D-dia/2-25//in mm
Xc=0.29*d//in mm
Mr=0.65*b*d^2/10^6//M>Mr, hence doubly reinforced beam
Ast1=round(Mr*10^6/sigma_st/0.9/d)//steel required for singly reinforced beam, in sq mm
M1=M-Mr//balance of moment, in kN-m
d1=25//top cover, in mm
Ast2=round(M1*10^6/sigma_st/(d-d1))//in sq mm
Ast=Ast1+Ast2//in sq mm
n1=Ast/0.785/12^2//no. of 12 mm dia bars on tension side
n1=3//assume
Asc=m*Ast2*(d-Xc)/(1.5*m-1)/(Xc-d1)//in sq mm
n2=Asc/0.785/12^2//no. of 12 mm dia bars on compression side
n2=3//assume
V=W*l/2//in kN
Tv=V*10^3/b/d//in MPa
pt=n1*0.785*12^2/b/d*100//pt=0.56, approximately
//for M15 grade concrete and pt=0.56
Tc=0.302//in MPa
//as Tc>Tv, no shear reinforcement required; provide nominal stirrups
//provide 6 mm dia bars
Asv=2*0.785*6^2//in sq mm
Sv=Asv*fy/0.4/b//in mm
Sv=260//approximately, in mm
Svmax=0.75*d//in mm
Svmax=200//approximately, in mm
Sv=min(Sv,Svmax)//in mm
mprintf("Summary of design\nSize of beam = %d x %d mm\nCover, bottom = 25 mm\nTop = 25 mm\nSteel, bottom = %d-12 mm dia bars\nTop = %d-12 mm dia
```

```
bars\nStirrups = 6 mm dia @ %d mm c/c throughout",b,D,n1,n2,Sv)
```

Scilab code Exa 9.3 Design of Rectangular Beam

```
l=7//span, in m
sigma_cbc=5//in MPa
sigma_st=140//in MPa
fy=250//in MPa
m=18.66//modular ratio
b=300//assume, in mm
W1=35//imposed load on beam, in kN/m
M=W1*l^2/8//in kN-m
d=(M*10^6/0.87/b)^0.5//in mm
d=910//approximately, in mm
D=1.1*d+50//increase d by 10% for self-weight and cover is 50 mm
D=1050//approximately, in mm
W2=25*(b/10^3)*(D/10^3)//self-weight, in kN/m
W=W1+W2//in kN/m
M=W*l^2/8//in kN-m
d=(M*10^6/0.87/b)^0.5//in mm
d=1000//approximately, in mm
dia=20//in mm
D=d+dia/2+35//in mm
Ast=round(M*10^6/sigma_st/0.87/d)//in sq mm
n=Ast/0.785/20^2//no. of 20 mm dia bars
n=7//assume
Ast=n*0.785*20^2//in sq mm
pt=Ast/b/D*100//pt=0.7, approximately
As=round(0.85/fy*b*d)//minimum steel, As<Ast, hence OK
Asf=0.1/100*b*d/2//side faced steel on each face, in sq mm
//provide 6 mm dia bars
```

```
s=1000*0.785*6^2/Asf//in mm
s=188//assume, in mm
V=W*l/2//in kN
Tv=V*10^3/b/d//<Tcmax=1.6 MPa, hence OK
//for M15 grade concrete and pt=0.7
Tc=0.33//in MPa
//as Tv>Tc, shear reinforcement required
Vs=V-Tc*b*d/10^3//in kN
//provide 6 mm dia bars
Asv=2*0.785*6^2//in sq mm
sigma_sv=140//in MPa
Sv=Asv*sigma_sv*d/Vs/10^3//in mm
Sv=155//approximately, in mm
Svmin=Asv*fy/0.4/b//in mm
Svmin=117//approximately, in mm
Sv=min(Sv,Svmin)//in mm
mprintf("Summary of design\nSize of beam = %d x %d
   mm\nCover = 35 mm\nSteel= %d-20 mm dia bars\
   nStirrups = 6 mm dia @ %d mm c/c throughout\nSide
    faced steel-6 mm dia @ %d mm c/c on both
   vertical faces of beam",b,D,n,Sv,s)
```

Scilab code Exa 9.4 Design of T beam

```
l=10//span, in m
sigma_cbc=5//in MPa
sigma_st=140//in MPa
fy=250//in MPa
m=18.66//modular ratio
Df=100//slab thickness, in mm
D=l*10^3/12//in mm
D=850//approximately, in mm
d=D-100//cover=100 mm
bw=300//in mm
bf=l*10^3/6+bw+6*Df//>2500 mm c/c distance of beams
```

```
bf=2500//in mm
W1=(bw/10^3)*(d-Df)/10^3*25//in kN/m
W2=(Df/10^3)*(bf/10^3)*25//in kN/m
W3=(bf/10^3)*5//imposed load, in kN/m
W=W1+W2+W3//in kN/m
W=24//approximately, in kN/m
M=W*l^2/8//in kN-m
V=W*l/2//in kN
Ast=round(M*10^6/sigma_st/0.87/d)//in sq mm
//provide 4-25 mm dia bars + 4-20 mm dia bars
Ast=4*0.785*25^2+4*0.785*20^2//in sq mm
//verification of trial section
//assume x>Df
x=(m*Ast*d+bf*Df^2/2)/(bf*Df+m*Ast)//in mm
//sigma_cbc'=sigma_cbc (x-Df)/x
a=(x-Df)/x
z=d-(1+2*a)/(1+a)*Df/3//in mm
sigma_st=M*10^6/Ast/z//<140 MPa, hence OK
sigma_cbc=sigma_st/m*x/(d-x)//<5 MPa, hence OK
Tv=V*10^3/bw/d//in MPa
pt=Ast*100/(bw*d+(2500-300)*100)//pt=0.72, approximately
//for M15 grade concrete and pt=0.72
Tc=0.33//in MPa
//as Tv>Tc, shear reinforcement required
Vs=V-Tc*bw*d/10^3//in kN
//provide 6 mm dia bars
Asv=2*0.785*6^2//in sq mm
sigma_sv=140//in MPa
Sv=Asv*sigma_sv*d/Vs/10^3//in mm
Sv=130//approximately, in mm
Svmin=Asv*fy/0.4/bw//in mm
Svmin=117//approximately, in mm
Sv=min(Sv,Svmin)//in mm
mprintf("T beam:bf=%d mm\nDf=%d mm\nd=%d mm\nbw=%d mm\nCover = 50 mm\nSteel= 4-25 mm dia + 4-20 mm dia bars\nStirrups = 6 mm dia @ %d mm c/c throughout",bf,Df,d,bw,Sv)
```

Chapter 10

Staircase

Scilab code Exa 10.1 Design of Cantilever Stair

```
l=1//span, in m
t=0.27//tread in m
sigma_cbc=5//in MPa
sigma_st=140//in MPa
MF=1.6
a=MF*7
D=l*10^3/a//in mm
D=100//assume, in mm
W1=D/10^3*t*25//in kN/m
M1=W1*l/2//in kN-m
M2=t*3*l/2//in kN-m
M3=1.3*l//in kN-m
M=M1+max(M2,M3)//in kN-m
d=sqrt(M*10^6/0.87/t/10^3)//in mm
d=83//in mm
//assume 8 mm dia bars
dia=8//in mm
D=d+dia/2+15//this is slightly more than assumed
    value, hence OK
D=100//in mm
z=0.87*d//in mm
```

```
Ast=M*10^6/sigma_st/z//in sq mm
n=Ast/0.785/8^2
n=4//assume
Ads=0.15/100*D*t*10^3//distribution steel, in sq mm
//provide 6 mm dia bars
s=1000*0.785*6^2/Ads//>5d=415 mm
s=415//in mm
Tbd=0.6//in MPa
Ld=dia*sigma_st/4/Tbd//in mm
Ld=470//assume, in mm
mprintf("Summary of design\nThickness of steps=%d mm\nCover from top=15 mm\nMain steel = 8 mm dia, %d in each step with development length of %d mm\nDistribution steel = 6 mm dia @ %d mm c/c",D,n,Ld,s)
```

Scilab code Exa 10.2 Design of Staircase

```
l=2.7+1//span, in m
R=0.15//rise, in m
t=0.27//tread, in m
sigma_cbc=5//in MPa
sigma_st=230//in MPa
//assuming 50 mm per 1 m of span
D=50*l//in mm
D=200//assume, in mm
W1=D/10^3*25*sqrt(R^2+t^2)/t//slab load on plan, in kN/m
W2=1/2*R*t*25/t//load of step per metre, in kN/m
W3=3//live load, in kN/m
W=W1+W2+W3//in kN/m
M=W*l^2/8//in kN-m
d=sqrt(M*10^6/0.65/10^3)//in mm
d=170//in mm
//assume 10 mm dia bars
```

```
dia=10//in mm
D=d+dia/2+25//which is equal to assumed value, hence
    OK
z=0.9*d//in mm
Ast=M*10^6/sigma_st/z//in mm
s1=1000*0.785*dia^2/Ast//spacing of 10 mm dia bars
s1=150//assume, in mm
Ads=0.12/100*D*10^3//distribution steel, in sq mm
//provide 8 mm dia bars
s2=1000*0.785*8^2/Ads//in mm
s2=210//in mm
//let span-to-depth ratio be 'a'
a=l*10^3/D
//for Fe415 grade steel and pt=.32
MF=1.2
b=20*MF//permissible span-to-depth ratio
//as a<b, hence OK
mprintf("Summary of design\nSlab thickness=%d mm\
   nCover = 25 mm\nMain steel = 10 mm dia bars @ %d
   mm c/c\nDistribution steel = 8 mm dia @ %d mm c/c
   ",D,s1,s2)
```

Scilab code Exa 10.3 Design of Staircase

```
l=2.5+1.5//span, in m
R=0.15//rise, in m
t=0.25//tread in m
sigma_cbc=7//in MPa
sigma_st=275//in MPa
//assuming 50 mm per 1 m of span
D=50*l//in mm
W1=D/10^3*25*1.5*sqrt(R^2+t^2)/t//slab load on plan,
    in kN/m
W2=1/2*R*t*1.5*25/t//load of step per metre, in kN/m
W3=1.5*5//live load, in kN/m
```

```
W=W1+W2+W3//in kN/m
M=W*l^2/8//in kN-m
d=sqrt(M*10^6/0.81/1.5/10^3)//in mm
d=177//in mm
//assume 10 mm dia bars
dia=10//in mm
D=d+dia/2+25//which is slightly more than assumed
    value, hence OK
D=200//in mm
d=D-dia/2-25//in mm
z=0.92*d//in mm
Ast=M*10^6/sigma_st/z//in sq mm
s1=1500*0.785*dia^2/Ast//spacing of 10 mm dia bars,
    in mm
s1=130//assume, in mm
Ads=0.12/100*D*1.5*10^3//distribution steel, in sq
    mm
//provide 8 mm dia bars
s2=1000*0.785*8^2/Ads//in mm
s2=140//in mm
//let span-to-depth ratio be 'a'
a=l*10^3/D
pt=Ast/1500/D*100//pt=0.3
//for Fe500 grade steel and pt=.3
MF=1.2
b=20*MF//permissible span-to-depth ratio
//as a<b, hence OK
mprintf("Summary of design\nSlab thickness=%d mm\
    nCover = 25 mm\nMain steel = 10 mm dia bars @ %d
    mm c/c\nDistribution steel = 8 mm dia @ %d mm c/c
    ",D,s1,s2)
```

Scilab code Exa 10.4 Design of Staircase

```
R=0.15//rise, in m
```

```
t=0.3//tread, in m
sigma_cbc=5//in MPa
sigma_st=230//in MPa
l1=1.8+1.5//span for flight AB, in m
l2=1.2+1.5+1.5//span for flight BC, in m
l3=1.8+1.5//span for flight CD, in m
//assuming 50 mm slab thickness per 1 m of span
D=50*l2//slab thickness, in mm
W1=D/10^3*25*1.5*sqrt(R^2+t^2)/t//slab load on plan, in kN/m
W2=1/2*R*t*1.5*25/t//load of step per metre, in kN/m
W3=1.5*5//live load, in kN/m
W=W1+W2+W3//in kN/m
//bending moment
//(a) flight AB and CD, refer Fig. 10.9
Rb=(W/2*1.5*(1.8+1.5/2)+W*1.8^2/2)/(1.5+1.8)//in kN
Ra=W/2*1.5+W*1.8-Rb//in kN
x=Ra/Rb//point of zero shear force from Ra, in m
M1=Ra*x-W*x^2/2//maximum bending moment, in kN-m
//(b) flight BC, refer Fig. 10.10
Rb=(W/2*1.5^2/2+W*1.2*(1.2/2+1.5)+W/2*1.5*(1.5+1.2+1.5/2))/(1.5+1.2+1.5)//in kN
Rc=Rb//in kN
//maximum bending moment will be at centre
M2=Rb*(1.5+1.2/2)-W/2*1.5*(1.5/2+1.2/2)-W*(1.2/2)^2/2//maximum bending moment, in kN-m
M=max(M1,M2)//in kN/m
d=sqrt(M*10^6/0.65/1.5/10^3)//in mm
//assume 10 mm dia bars
dia=10//in mm
D=d+dia/2+25//< 210 mm (assumed value)
D=210//in mm
d=D-dia/2-25//in mm
//steel
//flight AB and CD
z=0.9*d//in mm
Ast=M1*10^6/sigma_st/z//in sq mm
s1=1500*0.785*dia^2/Ast//spacing of 10 mm dia bars,
```

```
    in mm
s1=210//round-off, in mm
Ads=0.12/100*D*1.5*10^3//distribution steel, in sq
    mm
//provide 6 mm dia bars
s2=1000*0.785*6^2/Ads//in mm
s2=70//round-off, in mm
//flight BC
Ast=M2*10^6/sigma_st/z//in sq mm
s3=1500*0.785*dia^2/Ast//spacing of 10 mm dia bars,
    in mm
s3=130//round-off, in mm
//distribution steel is same as flights AB and CD
//let span-to-depth ratio be 'a'
a=12*10^3/D
//for Fe415 grade steel and pt=.32
MF=1.2//modification factor
b=20*MF//permissible span-to-depth ratio
//as a < b, hence OK
mprintf("Summary of design\nSlab thickness=%d mm\
    nCover = 25 mm\n(a)Flight AB and CD\nMain steel =
     10 mm dia bars @ %d mm c/c\nDistribution steel =
     6 mm dia @ %d mm c/c\n(b)Flight BC\nMain steel =
     10 mm dia bars @ %d mm c/c\nDistribution steel =
     6 mm dia @ %d mm c/c",D,s1,s2,s3,s2)
//answer in textbook is incorrect
```

Chapter 11

Column Footing Design

Scilab code Exa 11.1 Design of Column Footing

```
b=0.2//column width in m
D=0.3//column depth in m
fck=15//in MPa
sigma_cbc=5//in MPa
sigma_st=230//in MPa
P1=600//load on column in kN
P2=0.05*P1//weight of footing , in kN
P=P1+P2//in kN
q=150//bearing capacity of soil in kN/sq m
A=P/q//in sq m
L=sqrt(A)//assuming footing to be square
L=2.1//assume , in m
p=P1/L^2//soil pressure , in kN/sq m
p=136//assume , in sq m
bc=b/D
ks=0.5+bc//>1
ks=1
Tc=0.16*sqrt(fck)*10^3//in kN/sq m
Tv=Tc
//let d be the depth of footing in metres
//case I: consider greater width of shaded portion
```

```
    in Fig. 11.3 of textbook
d1=L*(L-b)/2*p/(Tc*L+L*p)//in m
//case II: refer Fig. 11.4 of textbook; we get a
    quadratic equation of the form e d^2 + f d + g =
    0
e=p+4*Tc
f=b*p+D*p+2*(b+D)*Tc
g=-(L^2-b*D)*p
d2=(-f+sqrt(f^2-4*e*g))/2/e//in m
d2=0.362//assume, in m
//bending moment consideration, refer Fig. 11.5 of
    textbook
Mx=1*((L-b)/2)^2/2*p//in kN-m
My=1*((L-D)/2)^2/2*p//in kN-m
d3=sqrt(Mx*10^6/0.65/10^3)//<362 mm, hence OK
z=0.9*d2*10^3//lever arm, in mm
Ast1=(Mx*10^6/sigma_st/z)//in sq mm
Ast=L*Ast1//steel required for full width of 2.1 m,
    in sq mm
//provide 12 mm dia bars
dia=12//in mm
n=Ast/0.785/dia^2//no. of 12 mm dia bars
n=16//assume
Tbd=0.84//in MPa
Ld=dia*sigma_st/4/Tbd//in mm
Ld=825//assume, in mm
c=50//side cover, in mm
La=(L-D)/2*10^3-c//>Ld, hence OK
D=d2*10^3+dia/2+100//in mm
mprintf("Summary of design:\nOverall depth of
    footing=%d mm\nCover=100 mm bottom; 50 mm side\
    nSteel-%d bars of 12 mm dia both ways",D,n)
```

Scilab code Exa 11.2 Design of Column Footing

```
b=0.4//column width, in m
D=0.4//column depth, in m
fck=15//in MPa
sigma_cbc=5//in MPa
sigma_st=140//in MPa
P1=1000//load on column, in kN
P2=0.05*P1//weight of footing, in kN
P=P1+P2//in kN
q=200//bearing capacity of soil, in kN/sq m
A=P/q//in sq m
L=sqrt(A)//assuming footing to be square
L=2.3//assume, in m
p=P1/L^2//soil pressure, in kN/sq m
p=189//assume, in kN/sq m
bc=b/D
ks=0.5+bc//>1
ks=1
Tc=0.16*sqrt(fck)*10^3//in kN/sq m
Tv=Tc
//let d be the depth of footing in metres
//case I: consider greater width of shaded portion
   in Fig. 11.7 of textbook
d1=L*(L-b)/2*p/(Tc*L+L*p)//in m
//case II: refer Fig. 11.8 of textbook; we get a
   quadratic equation of the form e d^2 + f d + g =
   0
e=p+4*Tc
f=b*p+D*p+2*(b+D)*Tc
g=-(L^2-b*D)*p
d2=(-f+sqrt(f^2-4*e*g))/2/e//in m
d2=0.425//assume, in m
d=max(d1,d2)//in m
//bending moment consideration, refer Fig. 11.9 of
   textbook
Mx=1*((L-b)/2)^2/2*p//in kN-m
d3=sqrt(Mx*10^6/0.87/10^3)//<425 mm, hence OK
z=0.87*d*10^3//lever arm, in mm
Ast1=(Mx*10^6/sigma_st/z)//in sq mm
```

```
Ast=L*Ast1//steel required for full width of 2.3 m,
    in sq mm
//provide 18 mm dia bars
dia=18//in mm
n=Ast/0.785/dia^2//no. of 18 mm dia bars
n=15//assume
Tbd=0.6//in MPa
Ld=dia*sigma_st/4/Tbd//in mm
c=50//side cover , in mm
La=(L-D)/2*10^3-c//in mm
//providing hook at ends
La=La+16*dia//>Ld, hence OK
D=d2*10^3+dia/2+100//in mm
mprintf("Summary of design:\nOverall depth of
    footing=%d mm\nCover=100 mm bottom; 50 mm side\
    nSteel-%d bars of 18 mm dia both ways",D,n)
```

Scilab code Exa 11.3 Design of Column Footing

```
B=0.5//column diameter , in m
fck=20//in MPa
sigma_cbc=7//in MPa
sigma_st=230//in MPa
P1=1600//load on column , in kN
P2=0.05*P1//weight of footing , in kN
P=P1+P2//in kN
q=300//bearing capacity of soil , in kN/sq m
A=P/q//in sq m
L=sqrt(A)//assuming footing to be square
L=2.4//assume , in m
p=P1/L^2//soil pressure , in kN/sq m
p=278//assume , in kN/sq m
bc=1
ks=0.5+bc//>1
ks=1
```

```
Tc=0.16*sqrt(fck)*10^3//in kN/sq m
Tv=Tc
//let d be the depth of footing in metres
//case I: refer Fig. 11.11 of textbook
d1=L*(L-B)/2*p/(Tc*L+L*p)//in m
//case II: refer Fig. 11.12 of textbook; we get a quadratic equation of the form e d^2 + f d + g = 0
e=%pi/4*p+%pi*Tc
f=2*%pi/4*B*p+%pi*B*Tc
g=-(L^2-%pi/4*B^2)*p
d2=(-f+sqrt(f^2-4*e*g))/2/e//in m
d2=0.57//assume, in m
d=max(d1,d2)//in m
//bending moment consideration, refer Fig. 11.13 of textbook
M=1*((L-B)/2)^2/2*p//in kN-m
d3=sqrt(M*10^6/0.88/10^3)//<570 mm, hence OK
z=0.9*d*10^3//lever arm, in mm
Ast1=(M*10^6/sigma_st/z)//in sq mm
Ast=L*Ast1//steel required for full width of 2.4 m
//provide 20 mm dia bars
dia=20//in mm
n=Ast/0.785/dia^2//no. of 20 mm dia bars
n=9//assume
Tbd=1.12//in MPa
Ld=dia*sigma_st/4/Tbd//in mm
Ld=1030//assume, in mm
c=50//side cover, in mm
La=(L-B)/2*10^3-c//in mm
//bend bar at right angle and provide length, l
l=Ld-La//in mm
D=d*10^3+dia/2+100//in mm
mprintf("Summary of design:\nOverall depth of footing=%d mm\nCover:100 mm bottom; 50 mm side\nSteel:%d-20 mm dia bars both ways",D,n)
//answer in textbook is incorrect
```

Scilab code Exa 11.4 Design of Rectangular Column Footing

```
b=0.3//column width in m
c1=0.4//column depth in m
fck=20//in MPa
sigma_cbc=7//in MPa
sigma_st=275//in MPa
P1=1200//load on column, in kN
P2=0.05*P1//weight of footing, in kN
P=P1+P2//in kN
q=200//bearing capacity of soil, in kN/sq m
A=P/q//in sq m
L1=2//in m
L2=A/L1//assuming footing to be square
L2=3.2//assume, in m
p=P1/L1/L2//soil pressure, in kN/sq m
bc=b/c1
ks=0.5+bc//>1
ks=1
Tc=0.16*sqrt(fck)*10^3//in kN/sq m
Tv=Tc
//let d be the depth of footing in metres
//case I, refer Fig. 11.15 of textbook
//short direction
d1=L1*(L2-c1)/2*p/(Tc*L1+L1*p)//in m
//long direction
d2=L2*(L1-b)/2*p/(Tc*L2+L2*p)//in m
//case II: refer Fig. 11.16 of textbook; we get a
    quadratic equation of the form e d^2 + f d + g =
    0
e=p+4*Tc
f=b*p+c1*p+2*(b+c1)*Tc
g=-(L1*L2-b*c1)*p
d3=(-f+sqrt(f^2-4*e*g))/2/e//in m
```

```
d3=0.47//assume, in m
d=max(d1,d2,d3)//in m
//bending moment consideration, refer Fig. 11.17 of textbook
Mx=1*((L1-b)/2)^2/2*p//in kN-m
My=1*((L2-c1)/2)^2/2*p//in kN-m
d4=sqrt(My*10^6/0.8/10^3)//in mm
d4=480//>470 mm (provided for shear)
d=d4//in mm
z=0.92*d//lever arm, in mm
//short direction
Ast1=(Mx*10^6/sigma_st/z)//in sq mm
Ast=L2*Ast1//steel required for full width of 3.2 m, in sq mm
b1=L1//central band width, in m
beta=L2/L1
Astc=L1/(beta+1)*Ast//in sq mm
//provide 12 mm dia bars
dia=12//in mm
n1=Astc/0.785/dia^2//no. of 12 mm dia bars
n1=13//assume
Astr=Ast-Astc//steel in remaining width, in sq mm
n2=Astr/0.785/dia^2
n2=4//assume
n2=n2/2//on each side
Tbd=1.12//in MPa
Ld=dia*sigma_st/4/Tbd//in mm
c=50//side cover, in mm
La=(L1-b)/2*10^3-c//>Ld, hence OK
//long direction
Ast1=(My*10^6/sigma_st/z)//in sq mm
Ast=L1*Ast1//steel required for full width of 2 m, in sq mm
//provide 18 mm dia bars
dia=18//in mm
n=Ast/0.785/dia^2//no. of 18 mm dia bars
n=12//assume
Ld=dia*sigma_st/4/Tbd//in mm
```

```
c=50//side cover, in mm
La=(L2-c1)/2*10^3-c//>Ld, hence OK
D=d+dia/2+100//in mm
D=590//assume, in mm
mprintf("Summary of design:\nOverall depth of footing=%d mm\nCover=100 mm bottom; 50 mm side\nSteel-long direction\n%d bars of 18 mm dia in %d m width equally spaced\nShort direction\nCentral band %d m:%d-12 mm dia bars equally spaced\nRemaining sides:%d-12 mm dia bars on each side",D,n,L1,L1,n1,n2)
```

Chapter 12

Retaining Walls

Scilab code Exa 12.1 Design of Cantilever Retaining Wall

```
sigma_cbc=5//in MPa
sigma_st=230//in MPa
phi=30//angle of repose, in degrees
H=5//height of wall, in m
B=0.6*H//assume, in m
T=B/4//assume toe to base ratio as 1:4
W=16//density of retained earth, in kN/cu m
P=W*H^2/2*(1-sind(phi))/(1+sind(phi))//in kN
P=67//assume, in kN
M1=P*H/3//in kN-m
M1=112//assume, in kN-m
//bending moment at 2.5 m below the top
h=2.5//in m
M2=W*h^2/2*(1-sind(phi))/(1+sind(phi))*h/3//in kN-m
M2=14//in kN-m
//thickness of stem (at the base)
d=sqrt(M1*10^6/0.65/1000)//in mm
d=415//in mm
dia=20//assume 20 mm dia bars
D1=d+dia/2+25//in mm
D2=200//thickness at top, in mm
```

```
D3=D2+(D1-D2)*h/H//in mm
d3=sqrt(M2*10^6/0.65/1000)//in mm
D3=d3+dia/2+25//< 325 mm (provided), hence OK
D3=325//in mm
d3=D3-dia/2-25//in mm
//main steel
//(a) 5 m below the top
Ast=M1*10^6/sigma_st/0.9/d//in sq mm
//provide 20 mm dia bars
s1=1000*0.785*20^2/Ast//in mm
s1=240//assume, in mm
//(b) 2.5 m below the top
Ast=M2*10^6/sigma_st/0.9/d3//in sq mm
Astmin=0.12/100*10^3*D3//in sq mm
Ast=max(Ast,Astmin)//in sq mm
//provide 12 mm dia bars
s2=1000*0.785*12^2/Ast//in mm
s2=290//assume, in mm
//distribution steel
Ads=0.12/100*10^3*D3//in sq mm
//provide 8 mm dia bars
s3=1000*0.785*8^2/Ads//in mm
s3=125//assume, in mm
//check for shear
V=P//in kN
Tv=V*10^3/10^3/d//in MPa
//for M15 grade concrete and pt=0.31
Tc=0.22//in MPa
//as Tc > Tv, no shear reinforcement required
//development length
//(a) At the base of stem
dia=20//in mm
Tbd=0.84//in MPa
Ld=dia*sigma_st/4/Tbd//in mm
Ld=1370//assume, in mm
//(b) At 2.5 m below the top
dia=12//in mm
Ld=dia*sigma_st/4/Tbd//in mm
```

```
Ld=825//assume, in mm
//check for stability
D4=500//thickness of base, in mm (assume)
V1=1/2*(D1-D2)/10^3*H*25//in kN
V2=(D2/10^3)*H*25//in kN
V3=(D4/10^3)*B*25//weight of base, in kN
V4=(B-T-D1/10^3)*H*W//weight of soil, in kN
V=V1+V2+V3+V4//in kN
M=V1*(T+2/3*(D1-D2)/10^3)+V2*(T+(D1-D2)/10^3+D2
    /10^3/2)+V3*B/2+V4*(B-(B-T-D1/10^3)/2)//in kN-m
x=M/V//in m
x=1.8//assume, in m
//factor of safety
//for overturning
F1=V*x/P/(H/3)//> 1.5, hence OK
mu=0.5
//for sliding
F2=mu*V/P//> 1.5, hence OK
mprintf("Summary of design:\nThickness of stem (at
    base) = %d mm\nThickness of stem at top = %d mm\
    nRefer Fig. 12.4 of textbook for reinforcement
    details",D1,D2)
```

Scilab code Exa 12.2 Design of Stem of Retaining Wall

```
sigma_cbc=5//in MPa
sigma_st=140//in MPa
phi=35//angle of repose, in degrees
H=6//height of wall, in m
B=0.4*H//assume, in m
T=B/4//assume toe to base ratio as 1:4
W=18//density of retained earth, in kN/cu m
P=W*H^2/2*(1-sind(phi))/(1+sind(phi))//in kN
P=88//assume, in kN
M1=P*H/3//in kN-m
```

```
//bending moment at 3 m below the top
h=3//in m
M2=W*h^2/2*(1-sind(phi))/(1+sind(phi))*h/3//in kN-m
M2=22//in kN-m
//thickness of stem (at the base)
d=sqrt(M1*10^6/0.87/1000)//in mm
d=450//in mm
dia=20//assume 20 mm dia bars
D1=d+dia/2+25//in mm
D2=200//thickness at top, in mm
D3=D2+(D1-D2)*h/H//in mm
d3=sqrt(M2*10^6/0.87/1000)//in mm
D3=d3+dia/2+25//< 342.5 mm (provided), hence OK
D3=342.5//in mm
d3=D3-dia/2-25//in mm
//main steel
//(a) 6 m below the top
Ast=M1*10^6/sigma_st/0.87/d//in sq mm
//provide 20 mm dia bars
s1=1000*0.785*20^2/Ast//in mm
s1=95//assume, in mm
//(b) 3 m below the top
Ast=M2*10^6/sigma_st/0.87/d3//in sq mm
//provide 10 mm dia bars
s2=1000*0.785*10^2/Ast//in mm
s2=130//assume, in mm
//distribution steel
Ads=0.15/100*10^3*D3//in sq mm
//provide 10 mm dia bars
s3=1000*0.785*10^2/Ads//in mm
s3=150//assume, in mm
//check for shear
V=P//in kN
Tv=V*10^3/10^3/d//in MPa
//for M15 grade concrete and pt=0.71
Tc=0.34//in MPa
//as Tc > Tv, no shear reinforcement required
//development length
```

```
//(a) At the base of stem
dia=20//in mm
Tbd=0.6//in MPa
Ld=dia*sigma_st/4/Tbd//in mm
Ld=1170//assume, in mm
//(b) At 3 m below the top
dia=10//in mm
Ld=dia*sigma_st/4/Tbd//in mm
Ld=590//assume, in mm
//check for stability
D4=500//thickness of base, in mm (assume)
V1=1/2*(D1-D2)/10^3*H*25//in kN
V2=(D2/10^3)*H*25//in kN
V3=(D4/10^3)*B*25//weight of base, in kN
V4=(B-T-D1/10^3)*H*W//in kN
V=V1+V2+V3+V4//in kN
M=V1*(T+2/3*(D1-D2)/10^3)+V2*(T+(D1-D2)/10^3+D2/10^3/2)+V3*B/2+V4*(B-(B-T-D1/10^3)/2)//in kN-m
x=M/V//in m
//factor of safety
//for overturning
F1=V*x/P/(H/3)//> 1.5, hence OK
mu=0.5
//for sliding
F2=mu*V/P//< 1.5, hence it is not safe against sliding
mprintf("Summary of design:\nThickness of stem (at base) = %d mm\nThickness of stem at top = %d mm\nRefer Fig. 12.7 of textbook for reinforcement details",D1,D2)
//answers in textbook for factor of safety against overturning and sliding are incorrect
```

Scilab code Exa 12.3 `Design of Base Slab of Retaining Wall`

```
sigma_cbc=5//in MPa
sigma_st=230//in MPa
phi=30//angle of repose , in degrees
H=5//height of wall , in m
B=0.6*H//assume , in m
T=B/4//assume toe to base ratio as 1:4
t=450//thickness of wall , in mm
W=16//density of retained earth , in kN/cu m
P=W*H^2/2*(1-sind(phi))/(1+sind(phi))//in kN
P=67//assume , in kN
y=1.8//in m
P=67//in kN
Wt=223//in kN
D=0.5//thickness of base , in m
x=1.8-P*(H/3+D/10^3)/Wt//in m
x=1.15//in m
e=B/2-x//in m
q1=Wt/B+Wt*e/(1*B^2/6)//maximum pressure , in kN/sq m
q2=Wt/B-Wt*e/(1*B^2/6)//minimum pressure , in kN/sq m
Pa=q1-(q1-q2)/B*T//pressure at A, in kN/sq m
Pa=100//assume , in kN/sq m
Pb=q1-(q1-q2)/B*(T+t/10^3)//pressure at B, in kN/sq m
Pb=85//assume , in kN/sq m
Ma=Pa*T^2/2+1/2*(q1-Pa)*T*2/3*T-T*D*25*T/2//bending moment at A, in kN-m
Ma=30//round-off , in kN-m
Mb=(B-T-t/10^3)^2*H*W/2+(B-T-t/10^3)^2*D*25/2-q2*(B-T-t/10^3)^2/2-(Pb-q2)*1/3*(B-T-t/10^3)^2/2//bending moment at B, in kN-m
Mb=80//in kN-m
//design of toe
d=sqrt(Ma*10^6/0.65/10^3)//in mm
D=d+10/2+70//<500 mm (provided), hence OK
D=500//in mm
d=D-70//in mm
Ast=Ma*10^6/sigma_st/0.9/d//in sq mm
Astmin=0.12/100*10^3*D//in sq mm
```

```
Ast=max(Ast,Astmin)//in sq mm
s1=1000*0.785*10^2/Ast//in mm
s1=130//assume, in mm
//distribution steel is same as above
//check for shear
V=(q1+Pa)/2*T//in kN
Tv=V*10^3/10^3/d//in MPa
//for M15 grade concrete and pt=0.32
Tc=0.2368//in MPa
//as Tc > Tv, no shear reinforcement required
//development length
dia=10//in mm
Tbd=0.84//in MPa
Ld=dia*sigma_st/4/Tbd//in mm
Ld=685//assume, in mm
//design of heel
d=sqrt(Mb*10^6/0.65/10^3)//< 430 mm (provided), hence OK
d=430//in mm
Ast=Mb*10^6/sigma_st/0.9/d//in sq mm
s2=1000*0.785*10^2/Ast//in mm
s2=85//assume, in mm
//distribution steel: 0.12% of Ag, hence provide 10 mm dia bars @ 130 mm c/c
V=(B-T-t/10^3)*H*W-(Pb+q2)/2*(B-T-t/10^3)//in kN
Tv=V*10^3/10^3/d//in MPa
//for M15 grade concrete and pt=0.32
Tc=0.2368//in MPa
//as Tc > Tv, no shear reinforcement required
//development length
dia=10//in mm
Tbd=0.84//in MPa
Ld=dia*sigma_st/4/Tbd//in mm
Ld=685//assume, in mm
mprintf("Summary of design:\nThickness of base slab=%d mm. Refer to Fig. 12.11 of textbook for reinforcement details.",D)
//answer in textbook for spacing of 10 mm dia bars
```

for main steel in toe and distribution steel is incorrect

Chapter 13

Water Tanks

Scilab code Exa 13.1 Design of Circular Water Tank

```
sigma_cbc=7//in MPa
sigma_ct=1.2//in MPa
sigma_st=100//in MPa
m=13.33//modular ratio
V=200000//capacity, in L
V=V/10^3//in cu m
h=2.5//assumed depth of water in tank, in m
A=V/h//area of tank, in sq m
B=sqrt(4/%pi*A)//diameter, in m
B=10.1//assume, in m
H=h+0.5//including freeboard, in m
w=10//unit weight of water, in kN/cu m
T=w*H*B/2//hoop tension, in kN
Ast=T*10^3/sigma_st//in sq mm
s1=10^3*0.785*16^2/Ast//in mm
s1=130//assume, in mm
t=(T*10^3/sigma_ct-(m-1)*Ast)/1000//in mm
t=110//assume, in mm
//hoop tension steel at 1.5 m below top of wall
h=1.5//in m
T=w*h*B/2//in kN
```

```
Ast=T*10^3/sigma_st//in sq mm
s2=10^3*0.785*16^2/Ast//in mm
s2=260//assume, in mm
Ads=0.3/100*t*10^3//vertical steel as distribution steel, in sq mm
s3=1000*0.785*10^2/Ads//in mm
s3=235//in mm
//design of tank floor
D=150//in mm
Ast=0.3/100*D*1000//in sq mm
s4=1000*0.785*10^2/Ast//in mm
s4=170//in mm
mprintf("Summary of design\nDiameter of tank=%f m\nDepth of tank=%d m\nTank wall thickness=%d mm\nSteel-hoop steel; 3 m to 1.5 m below top=16 mm dia @ %d mm c/c\n1.5 m to 0 m below top=16 mm dia @ %d mm c/c\nvertical steel=10 mm dia @ %d mm c/c\nTank floor: Thickness %d mm\nSteel=10 mm dia @ %d mm c/c",B,H,t,s1,s2,s3,D,s4)
//answer in textbook for spacing of 16 mm dia bars from 1.5 m to 0 m below top is incorrect
```

Scilab code Exa 13.2 Design of Circular Water Tank

```
sigma_cbc=7//in MPa
sigma_ct=1.2//in MPa
sigma_st=170//in MPa
m=13.33//modular ratio
V=400000//capacity, in L
V=V/10^3//in cu m
h=3//assumed depth of water in tank, in m
A=V/h//area of tank, in sq m
B=sqrt(4/%pi*A)//diameter, in m
B=13//assume, in m
H=h+0.5//including freeboard, in m
```

```
w=10//unit weight of water, in kN/cu m
T=w*H*B/2//hoop tension, in kN
Ast=T*10^3/sigma_st//in sq mm
s1=10^3*0.785*12^2/Ast//in mm
s1=80//assume, in mm
t=(T*10^3/sigma_ct-(m-1)*Ast)/1000//in mm
t=175//assume, in mm
//steel at 2 m below top of wall
h=2//in m
T=w*h*B/2//in kN
Ast=T*10^3/sigma_st//in sq mm
s2=10^3*0.785*12^2/Ast//in mm
s2=145//assume, in mm
Ads=0.3/100*t*10^3//vertical steel as distribution
    steel, in sq mm
s3=1000*0.785*10^2/Ads//in mm
s3=150//assume, in mm
//design of tank floor
D=190//in mm
Ast=0.3/100*D*1000//in sq mm
s4=1000*0.785*10^2/Ast//in mm
s4=135//assume, in mm
mprintf("Summary of design\nDiameter of tank=%d m\
    nDepth of tank=%f m\nTank wall thickness=%d mm\
    nSteel-hoop steel; 4 m to 2 m below top=12 mm dia
     @ %d mm c/c\n2 m to 0 m below top=12 mm dia @ %d
     mm c/c\nvertical steel=10 mm dia @ %d mm c/c\
    nTank floor: Thickness %d mm\nSteel=10 mm dia @
    %d mm c/c both ways",B,H,t,s1,s2,s3,D,s4)
```

Chapter 14

Limit State Method

Scilab code Exa 14.1 Analysis of Singly Reinforced Section

```
b=250//width, in mm
d=500//effective depth, in mm
Ast=4*0.785*20^2//four 20 mm dia bars, in sq mm
fck=15//in MPa
fy=250//in MPa
Xu=round(0.87*fy*Ast/0.36/fck/b)//in mm
Xc=0.531*d//in mm
//as Xu<Xc, it is under-reinforced section, hence OK
Mu=0.87*fy*Ast*(d-0.416*Xu)/10^6//in kN-m
mprintf("Moment of resistance of the beam=%f kN-m",
   Mu)
```

Scilab code Exa 14.2 Analysis of Singly Reinforced Section

```
b=300//width, in mm
d=600//effective depth, in mm
fck=15//in MPa
fy=500//in MPa
```

```
Xc=0.456*d//in mm
Mu=0.36*fck*b*Xc*(d-0.416*Xc)/10^6//in kN-m
Ast=round(0.36*fck*b*Xc/0.87/fy)//in sq mm
mprintf("Moment of resistance of the beam=%f kN-m\
   nSteel required=%d sq mm", Mu,Ast)
```

Scilab code Exa 14.3 Analysis of Singly Reinforced Section

```
b=300//width, in mm
d=600//effective depth, in mm
fck=20//in MPa
fy=415//in MPa
Xc=0.479*d//in mm
Mu=0.36*fck*b*Xc*(d-0.416*Xc)/10^6//in kN-m
Ast=round(0.36*fck*b*Xc/0.87/fy)//in sq mm
mprintf("Moment of resistance of the beam=%f kN-m\
   nSteel required=%d sq mm", Mu,Ast)
//answer does not match with textbook because of
   round-off error
```

Scilab code Exa 14.4 Analysis of Singly Reinforced Section

```
b=300//width, in mm
d=650//effective depth, in mm
Ast=942//in sq mm
lef=6//in m
fck=20//in MPa
fy=340//in MPa
Xu=round(0.87*fy*Ast/0.36/fck/b)//in mm
Xc=0.5*d//in mm
//as Xu<Xc, it is under-reinforced beam, hence OK
Mu=0.87*fy*Ast*(d-0.416*Xu)/10^6//in kN-m
Wu=Mu*8/lef^2//in kN/m
```

```
self_weight=25*(b/1000)*(d/1000)//in kN/m
W=Wu/1.5-self_weight//in kN/m
mprintf("Safe load on the beam=%f kN/m",W)
```

Scilab code Exa 14.5 Analysis of Singly Reinforced Section

```
b=1000//width, in mm
d=120//effective depth, in mm
Ast=1412//in sq mm
lef=3.2//in m
fck=20//in MPa
fy=250//in MPa
Xu=0.87*fy*Ast/0.36/fck/b//in mm
Xc=0.531*d//in mm
//as Xu<Xc, it is under-reinforced section, hence OK
Mu=0.87*fy*Ast*(d-0.416*Xu)/10^6//in kN-m
Wu=Mu*8/lef^2//in kN/m
self_weight=25*(b/1000)*(d/1000)//in kN/m
W=Wu/1.5-self_weight//in kN/m
mprintf("Safe load on the slab=%f kN/m",W)
```

Scilab code Exa 14.6 Design of Singly Reinforced Section

```
fck=15//in MPa
fy=250//in MPa
//b=d/2
M=65//in kN-m
Mu=1.5*M//factored moment, in kN-m
d=(Mu*10^6/(0.149*fck*0.5))^(1/3)//in mm
d=445//approximately, in mm
b=d/2//in mm
Xc=0.531*d//in mm
Ast=round(0.36*fck*b*Xc/0.87/fy)//in sq mm
```

```
mprintf("b=%f mm\nd=%f mm\nAst=%f sq mm",b,d,Ast)
//answer does not match with textbook because of round-off error
```

Scilab code Exa 14.7 Design of Singly Reinforced Section

```
b=300//width, in mm
d=500//effective depth, in mm
fck=20//in MPa
fy=500//in MPa
Mu=175//in kN-m
Mulim=0.133*fck*b*d^2/10^6//in kN-m
//as Mu<Mulim, beam is under-reinforced
//using Cu=Tu, Xu=0.87 fy Ast/(0.36 fck b); let Xu=a Ast
a=0.87*fy/(0.36*fck*b)
//Mu=0.87 fy Ast (d-0.416 Xu), putting Xu = a Ast, we get p Ast^2 + q Ast + r =0
p=0.87*0.416*fy*a
q=-0.87*fy*d
r=Mu*10^6
//solving the quadratic equation
Ast=round((-q-sqrt(q^2-4*p*r))/2/p)//in sq mm
mprintf("Area of steel required=%d sq mm",Ast)
```

Chapter 15

Doubly Reinforced Sections

Scilab code Exa 15.1 Analysis of Doubly Reinforced Section

```
b=300//width, in mm
d=800//effective depth, in mm
Ast=3940//in sq mm
Asc=795//in sq mm
top_cover=40//in mm
fck=15//in MPa
fy=250//in MPa
Xc=0.531*d//in mm
fcc=0.446*fck//in MPa
fsc=0.87*fy//in MPa
Mu=(0.36*fck*b*Xc*(d-0.416*Xc)+(fsc-fcc)*Asc*(d-
    top_cover))/10^6//in kN-m
mprintf("Moment of resistance of the beam = %f kN-m"
    ,Mu)
```

Scilab code Exa 15.2 Analysis of Doubly Reinforced Section

```
b=230//width, in mm
```

```
d=600//effective depth, in mm
Asc=554//in sq mm
Ast=1524//in sq mm
top_cover=30//in mm
fck=15//in MPa
fy=415//in MPa
Xc=0.479*d//in mm
fcc=0.446*fck//in MPa
//for d'/d=30/600=0.05 and Fe415 grade steel,
fsc=355//in MPa
Mu=(0.36*fck*b*Xc*(d-0.416*Xc)+(fsc-fcc)*Asc*(d-
    top_cover))/10^6//in kN-m
mprintf("Moment of resistance of the beam = %f kN-m"
    ,Mu)
```

Scilab code Exa 15.3 Analysis of Doubly Reinforced Section

```
b=250//width, in mm
d=550//effective depth, in mm
fck=15//in MPa
fy=250//in MPa
M=95//in kN-m
Mu=1.5*M//factored moment, in kN-m
Mulim=0.149*fck*b*d^2/10^6//in kN-m
//as Mu<Mulim, no steel required on compression side
mprintf("As factored moment is less than limiting
    moment, no steel is required on compression side
    (as per LSM)")
```

Scilab code Exa 15.4 Analysis of Doubly Reinforced Section

```
b=225//width, in mm
d=500//effective depth, in mm
```

```
Asc=125//in sq mm
Ast=754//in sq mm
top_cover=50//in mm
fck=15//in MPa
fy=500//in MPa
Xc=0.456*d//in mm
fcc=0.446*fck//in MPa
//for d'/d=50/500=0.1 and Fe500 grade steel,
fsc=412//in MPa
Mu=(0.36*fck*b*Xc*(d-0.416*Xc)+(fsc-fcc)*Asc*(d-
    top_cover))/10^6//in kN-m
mprintf("Moment of resistance of the beam = %f kN-m"
    ,Mu)
```

Scilab code Exa 15.5 Design of Doubly Reinforced Section

```
b=250//width, in mm
d=500//effective depth, in mm
Mu=165//in kN-m
top_cover=50//in mm
fck=15//in MPa
fy=250//in MPa
Xc=0.531*d//in mm
Mulim=0.149*fck*b*d^2/10^6//in kN-m
Ast1=round(0.36*fck*b*Xc/0.87/fy)//in sq mm
M1=Mu-Mulim//in kN-m
fcc=0.446*fck//in MPa
fsc=0.87*fy//in MPa
Asc=round(M1*10^6/(fsc-fcc)/(d-top_cover))//in sq mm
Ast2=round((fsc-fcc)*Asc/0.87/fy)//in sq mm
Ast=Ast1+Ast2//in sq mm
mprintf("Compression steel = %d sq mm\nTension steel
    = %d sq mm",Asc,Ast)
```

Scilab code Exa 15.6 Design of Doubly Reinforced Section

```
b=200//width, in mm
d=300//effective depth, in mm
Mu=74//in kN-m
top_cover=30//in mm
fck=20//in MPa
fy=415//in MPa
Xc=0.479*d//in mm
Mulim=0.138*fck*b*d^2/10^6//in kN-m
Ast1=round(0.36*fck*b*Xc/0.87/fy)//in sq mm
M1=Mu-Mulim//in kN-m
fcc=0.446*fck//in MPa
//for d'/d=30/300=0.1 and Fe415 grade steel,
fsc=353//in MPa
Asc=round(M1*10^6/(fsc-fcc)/(d-top_cover))//in sq mm
Ast2=round((fsc-fcc)*Asc/0.87/fy)//in sq mm
Ast=Ast1+Ast2//in sq mm
mprintf("Compression steel = %d sq mm\nTension steel
    = %d sq mm",Asc,Ast)
```

Scilab code Exa 15.7 Design of Doubly Reinforced Section

```
b=200//width, in mm
d=200//effective depth, in mm
Mu=32//in kN-m
top_cover=30//in mm
fck=20//in MPa
fy=500//in MPa
Xc=0.456*d//in mm
Mulim=0.133*fck*b*d^2/10^6//in kN-m
Ast1=round(0.36*fck*b*Xc/0.87/fy)//in sq mm
```

```
M1=Mu-Mulim//in kN-m
fcc=0.446*fck//in MPa
//for d'/d=30/200=0.15 and Fe500 grade steel,
fsc=395//in MPa
Asc=round(M1*10^6/(fsc-fcc)/(d-top_cover))//in sq mm
Ast2=round((fsc-fcc)*Asc/0.87/fy)//in sq mm
Ast=Ast1+Ast2//in sq mm
mprintf("Compression steel = %d sq mm\nTension steel
    = %d sq mm",Asc,Ast)
```

Chapter 16

T Beams

Scilab code Exa 16.1 Analysis of T beam

```
Df=120//in mm
bf=1100//in mm
bw=275//in mm
d=450//in mm
Ast=2700//in sq mm
fy=500//in MPa
fck=25//in MPa
Asf=round(0.36*fck*bf*Df/0.87/fy)//area of steel required for flange, in sq mm
//as Ast<Asf, Xu<Df
Xu=0.87*fy*Ast/0.36/fck/bf//in mm
Mu=0.36*fck*bf*Xu*(d-0.416*Xu)/10^6//in kN-m
mprintf("Moment of resistance of T-beam=%f kN-m",Mu)
```

Scilab code Exa 16.2 Analysis of T beam

```
Df=100//in mm
bf=1500//in mm
```

```
bw=300//in mm
d=600//in mm
Ast=4500//in sq mm
fy=415//in MPa
fck=20//in MPa
Asf=round(0.36*fck*bf*Df/0.87/fy)//area of steel
    required for flange, in sq mm
//as Ast>Asf, Xu>Df
Xu=(0.87*fy*Ast-0.446*fck*(bf-bw)*Df)/0.36/fck/bw//
    in mm
Xc=0.479*d//Xc>Xu; hence OK
a=0.43*Xu//as Df<0.43 Xu, stress in flange is
    uniform
Mu=(0.36*fck*bw*Xu*(d-0.416*Xu)+0.446*fck*(bf-bw)*Df
    *(d-Df/2))/10^6//in kN-m
mprintf("Moment of resistance of T-beam=%f kN-m",Mu)
```

Scilab code Exa 16.3 Analysis of T beam

```
Df=100//in mm
bf=1500//in mm
bw=300//in mm
d=700//in mm
Ast=4510//in sq mm
fy=250//in MPa
fck=15//in MPa
Asf=round(0.36*fck*bf*Df/0.87/fy)//area of steel
    required for flange, in sq mm
//as Ast>Asf, Xu>Df
Xu=round((0.87*fy*Ast-0.446*fck*(bf-bw)*Df)/0.36/fck
    /bw)//in mm
Xc=0.531*d//Xc>Xu; hence OK
a=0.43*Xu//as Df>0.43 Xu, stress in flange is not
    uniform
yf=0.15*Xu+0.65*Df//in mm
```

```
Mu=(0.36*fck*bw*Xu*(d-0.416*Xu)+0.446*fck*(bf-bw)*yf*(d-yf/2))/10^6//in kN-m
mprintf("Moment of resistance of T-beam=%f kN-m",Mu)
```

Scilab code Exa 16.4 Analysis of T beam

```
Df=100//in mm
bf=1250//in mm
bw=250//in mm
d=650//in mm
Ast=2800//in sq mm
fy=415//in MPa
fck=20//in MPa
Asf=round(0.36*fck*bf*Df/0.87/fy)//area of steel required for flange, in sq mm
//as Ast>Asf, Xu>Df
Xu=round((0.87*fy*Ast-0.446*fck*(bf-bw)*Df)/0.36/fck/bw)//in mm
//but Xu<Df; this indicates that stress in the flange is not uniform, hence replace Df by yf
Xu=(0.87*fy*Ast-0.446*fck*(bf-bw)*0.65*Df)/(0.36*fck*bw+0.446*fck*(bf-bw)*0.15)//in mm
Xc=0.479*d//Xc>Xu; hence OK
a=0.43*Xu//as Df>0.43 Xu, stress in flange is not uniform
yf=0.15*Xu+0.65*Df//in mm
Mu=(0.36*fck*bw*Xu*(d-0.416*Xu)+0.446*fck*(bf-bw)*yf*(d-yf/2))/10^6//in kN-m
mprintf("Moment of resistance of T-beam=%f kN-m",Mu)
//answer in textbook is incorrect
```

Scilab code Exa 16.5 Analysis of T beam

```
Df=100//in mm
bf=1250//in mm
bw=250//in mm
d=660//in mm
fy=250//in MPa
fck=15//in MPa
Xc=0.531*d//in mm
a=0.43*Xc//Df<0.43 Xu, stress in entire flange is uniform
Mu=(0.36*fck*bw*Xc*(d-0.416*Xc)+0.446*fck*(bf-bw)*Df*(d-Df/2))/10^6//in kN-m
Ast=(0.36*fck*bw*Xc+0.446*fck*(bf-bw)*Df)/0.87/fy//in sq mm
mprintf("Moment of resistance of T-beam=%f kN-m\nArea of steel required=%f sq mm",Mu,Ast)
```

Scilab code Exa 16.6 Design of T beam

```
Df=100//in mm
bf=1250//in mm
bw=250//in mm
d=550//in mm
Mu=400//in kN-m
fy=415//in MPa
fck=15//in MPa
Asf=0.446*fck*(bf-bw)*Df/0.87/fy//in sq mm
Muf=0.446*fck*(bf-bw)*Df*(d-Df/2)/10^6//in kN-m
Muw=Mu-Muf//in kN-m
//using Cu=Tu, 0.36 fck bw Xu = 0.87 fy Ast, Xu = a Asw
a=0.87*fy/0.36/fck/bw
//Muw=0.87 fy Asw (d-0.416 Xu)
p=0.87*fy*0.416*a
q=-0.87*fy*d
r=Muw*10^6
```

```
Asw=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
Ast=Asw+Asf//in sq mm
mprintf("Area of steel required=%f sq mm",Ast)
```

Chapter 17

Shear and Development Length

Scilab code Exa 17.1 Shear Design

```
b=230//width, in mm
d=500//effective depth, in mm
l=4.5//span, in m
Ast=4*0.785*20^2//four 20 mm dia bars, in sq mm
fck=20//in MPa
W=24//in kN/m
Wu=1.5*W//factored load, in kN/m
Vu=Wu*l/2//in kN
Tv=Vu*10^3/b/d//in MPa
Tcmax=2.8//for M20, in MPa
//Tv<Tcmax, hence OK
p=Ast/b/d*100//p=1.1, approximately
//for p=1.1 and M20 grade concrete
Tc=0.64//in MPa
//Tv>Tc, hence shear reinforcement required
mprintf("Nominal shear stress=%f MPa\nShear strength of concrete=%f MPa",Tv,Tc)
```

Scilab code Exa 17.2 Shear Design

```
b=300//width, in mm
d=1010//effective depth, in mm
l=7//span, in m
Ast=round(6*0.785*22^2)//six 22 mm dia bars, in sq
    mm
fck=15//in MPa
fy=250//in MPa
W=45//in kN/m
Wu=1.5*W//factored load, in kN/m
Vu=Wu*l/2//in kN
Tv=Vu*10^3/b/d//in MPa
//Tv<Tcmax, hence OK
p=Ast/b/d*100//p=0.75, approximately
//for p=0.75 and M15 grade concrete
Tc=0.54//in MPa
//Tv>Tc, hence shear reinforcement required
Vus=Vu-Tc*b*d/10^3//in kN
//provide 6 mm dia stirrups
Sv=0.87*fy*2*0.785*6^2*d/Vus/10^3//in mm
Sv=171//approximately, in mm
Svmin=2*0.785*6^2*fy/b/0.4//in mm
Svmin=118//approximately, in mm
Sv=min(Sv,Svmin)//in mm
mprintf("Provide 6 mm dia stirrups at %d mm c/c as
    shear reinforcement",Sv)
```

Chapter 18

Columns

Scilab code Exa 18.1 Design of Short Axially Loaded Column

```
Pu=3000//in kN
fck=20//in MPa
fy=415//in MPa
l=3//unsupported length , in m
//assume 1% steel
Ag=Pu*10^3/(0.4*fck*0.99+0.67*fy*0.01)//in sq mm
L=sqrt(Ag)//assuming a square column
L=530//in mm
Asc=0.01*L^2//in sq mm
emin=l*10^3/500+L/30//in mm
ep=0.05*L//>emin, hence OK
mprintf("Column size - %d x %d mm",L,L)
```

Scilab code Exa 18.2 Design of Short Axially Loaded Column

```
Pu=1500//in kN
fck=15//in MPa
fy=250//in MPa
```

```
l=2.75//unsupported length , in m
//assume 1% steel
Ag=Pu*10^3/(0.4*fck*0.99+0.67*fy*0.01)//in sq mm
L1=225//assuming a square column
L2=Ag/L1//in mm
L2=880//in mm
Asc=0.01*L1*L2//in sq mm
e1=l*10^3/500+L1/30//in mm
e2=l*10^3/500+L2/30//in mm
ep1=0.05*L1//<e1
ep2=0.05*L2//>e2 , hence Ok
mprintf("The column is safe on long dimension side
    but not on short dimension side. As such , the
    column be checked for eccentricity in short
    direction.")
```

Scilab code Exa 18.3 Uniaxial Bending

```
b=225//in mm
D=500//in mm
c=45//cover , in mm
Asc=2463//in sq mm
Ast=Asc
fck=15//in MPa
fy=250//in MPa
fcc=0.446*fck//in MPa
//(i)
xu=1.1*D//in mm
m=0.43*D//in mm
esc1=0.002*(xu-c)/(xu-m)
esc2=0.002*(xu-D+c)/(xu-m)
//by interpolation
fsc1=217.5//in MPa
fsc2=217.5*esc2/0.0010875//in MPa
//stress block parameters for xu / D = 1.1
```

```
n=0.384
l=0.443
A=n*fck*D//area of stress block
r=l*D//distance of c.g., in mm
Pu=(A*b+Asc*(fsc1-fcc)+Ast*fsc2)/10^3
Mu=(A*b*(D/2-r)+Asc*(fsc1-fcc)*(D/2-c)-Ast*fsc2*(D
   /2-c))/10^6
mprintf("(i) For xu = 1.1 D\nP=%f kN\nMu=%f kN-m\n",
   Pu,Mu)
//answer in textbook is incorrect
//(ii)
xu=330//in mm
esc=0.0035*(xu-c)/xu
est=0.0035*(D-c-xu)/xu
//by interpolation
fsc=217.5//in MPa
fst=217.5//in MPa
Pu=(0.36*fck*b*xu+Asc*(fsc-fcc)-Ast*fst)/10^3//in kN
Mu=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*(fsc-fcc)*(D/2-
   c)+Ast*fst*(D/2-c))/10^6//in kN-m
mprintf("(ii) For xu = 330 mm\nP=%f kN\nMu=%f kN-m",
   Pu,Mu)
```

Scilab code Exa 18.4 Uniaxial Bending

```
b=300//in mm
D=400//in mm
c=30//cover, in mm
Asc=452//in sq mm
Ast=Asc
fck=15//in MPa
fy=415//in MPa
fcc=0.446*fck//in MPa
//(i)
xu=1.4*D//in mm
```

```
m=0.43*D//in mm
esc1=0.002*(xu-c)/(xu-m)
esc2=0.002*(xu-D+c)/(xu-m)
//by interpolation
fsc1=356.8//in MPa
fsc2=238.68//in MPa
//stress block parameters for xu / D = 1.4
n=0.417
l=0.475
A=n*fck*D//area of stress block
r=l*D//distance of c.g., in mm
Pu=(A*b+Asc*(fsc1-fcc)+Ast*fsc2)/10^3//in kN
Mu=(A*b*(D/2-r)+Asc*(fsc1-fcc)*(D/2-c)-Ast*fsc2*(D
    /2-c))/10^6//in kN-m
mprintf("(i) For xu = 1.4 D\nP=%f kN\nMu=%f kN-m\n",
    Pu,Mu)
//(ii)
xu=370//in mm
esc=0.0035*(xu-c)/xu
est=0.0035*(D-c-xu)/xu
//by interpolation
fsc=355.8//in MPa
Pu=(0.36*fck*b*xu+Asc*(fsc-fcc))/10^3//in kN
Mu=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*(fsc-fcc)*(D/2-
    c))/10^6//in kN-m
mprintf("(ii) For xu = 370 mm\nP=%f kN\nMu=%f kN-m",
    Pu,Mu)
```

Scilab code Exa 18.5 Uniaxial Bending

```
b=225//in mm
D=500//in mm
c=50//cover, in mm
Asc=1520//in sq mm
Ast=Asc
```

```
fck=20//in MPa
fy=500//in MPa
fcc=0.446*fck//in MPa
//(i)
xu=1.3*D//in mm
m=0.43*D//in mm
esc1=0.002*(xu-c)/(xu-m)
esc2=0.002*(xu-D+c)/(xu-m)
//by interpolation
fsc1=412.515//in MPa
fsc2=183.794//in MPa
//stress block parameters for xu / D = 1.3
n=0.409
l=0.468
A=n*fck*D//area of stress block
r=l*D//distance of c.g., in mm
Pu=(A*b+Asc*(fsc1-fcc)+Ast*fsc2)/10^3//in kN
Mu=(A*b*(D/2-r)+Asc*(fsc1-fcc)*(D/2-c)-Ast*fsc2*(D/2-c))/10^6//in kN-m
mprintf("(i) For xu = 1.3 D\nP=%f kN\nMu=%f kN-m\n",Pu,Mu)
//(ii)
xu=400//in mm
esc=0.0035*(xu-c)/xu
est=0.0035*(D-c-xu)/xu
//by interpolation
fsc=422.11//in MPa
fst=87.45//in MPa
Pu=(0.36*fck*b*xu+Asc*(fsc-fcc)-Ast*fst)/10^3//in kN
Mu=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*(fsc-fcc)*(D/2-c)+Ast*fst*(D/2-c))/10^6//in kN-m
mprintf("(ii) For xu = 400 mm\nP=%f kN\nMu=%f kN-m",Pu,Mu)
//answer in textbook for Mu in (ii) is incorrect
```

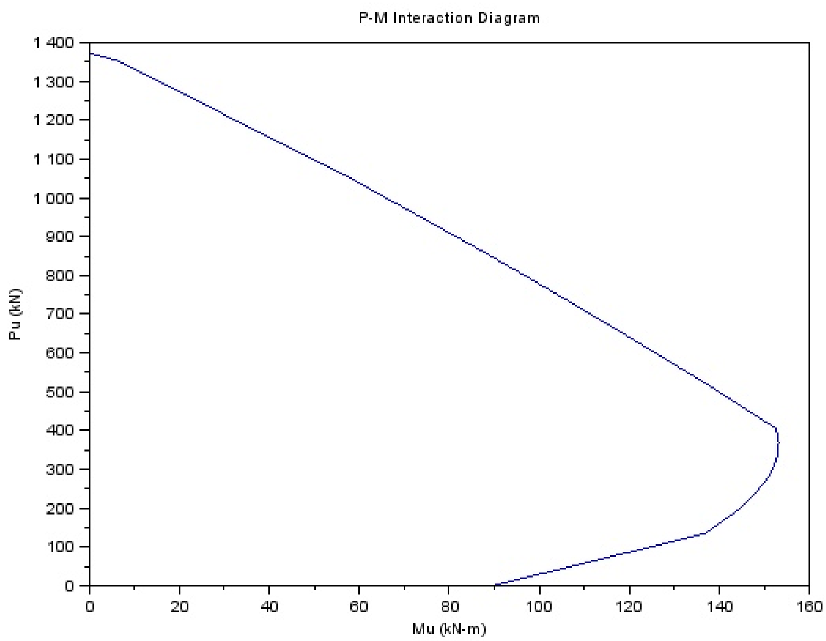

Figure 18.1: Interaction diagram

Scilab code Exa 18.6 Interaction diagram

```
b=250//width, in mm
D=450//depth, in mm
c=50//cover, in mm
Asc=1472//in sq mm
Ast=Asc
fck=15//in MPa
fcc=0.446*fck//in MPa
fy=250//in MPa
Es=2*10^5//in MPa
ey=0.87*fy/Es//strain in mild steel at yield point
fs=0.87*fy//stress in mild steel at yield point, in
    MPa

//xu=infinity
Pu1=(0.446*fck*(b*D-Asc-Ast)+(Asc+Ast)*fs)/10^3//in
    kN
Mu1=0//in kN-m

//xu=1.5 D
xu=1.5*D//in mm
m=0.43*D//in mm
esc1=0.002*(xu-c)/(xu-m)
if(esc1<=ey)
    fsc1=esc1/ey*fs
else
    fsc1=fs
end
esc2=0.002*(xu-D+c)/(xu-m)//>ey
if(esc2<=ey)
    fsc2=esc2/ey*fs
else
    fsc2=fs
```

```
end
//stress block parameters for xu / D = 1.5
n=0.422
l=0.48
A=n*fck*D//area of stress block
r=l*D//distance of c.g.
Pu2=(A*b+Asc*fsc1+Ast*fsc2)/10^3//in kN
Mu2=(A*b*(D/2-r)+Asc*fsc1*(D/2-c)-Ast*fsc2*(D/2-c))
    /10^6//in kN-m

//xu=1.3 D
xu=1.3*D//in mm
m=0.43*D//in mm
esc1=0.002*(xu-c)/(xu-m)
if(esc1<=ey)
    fsc1=esc1/ey*fs
else
    fsc1=fs
end
esc2=0.002*(xu-D+c)/(xu-m)//>ey
if(esc2<=ey)
    fsc2=esc2/ey*fs
else
    fsc2=fs
end
//stress block parameters for xu / D = 1.3
n=0.409
l=0.468
A=n*fck*D//area of stress block
r=l*D//distance of c.g.
Pu3=(A*b+Asc*fsc1+Ast*fsc2)/10^3//in kN
Mu3=(A*b*(D/2-r)+Asc*fsc1*(D/2-c)-Ast*fsc2*(D/2-c))
    /10^6//in kN-m

//xu=1.2 D
xu=1.2*D//in mm
m=0.43*D//in mm
esc1=0.002*(xu-c)/(xu-m)
```

```
if(esc1<=ey)
    fsc1=esc1/ey*fs
else
    fsc1=fs
end
esc2=0.002*(xu-D+c)/(xu-m)//>ey
if(esc2<=ey)
    fsc2=esc2/ey*fs
else
    fsc2=fs
end
//stress block parameters for xu / D = 1.2
n=0.399
l=0.458
A=n*fck*D//area of stress block
r=l*D//distance of c.g.
Pu4=(A*b+Asc*fsc1+Ast*fsc2)/10^3//in kN
Mu4=(A*b*(D/2-r)+Asc*fsc1*(D/2-c)-Ast*fsc2*(D/2-c))
   /10^6//in kN-m

//xu=1.1 D
xu=1.1*D//in mm
m=0.43*D//in mm
esc1=0.002*(xu-c)/(xu-m)
if(esc1<=ey)
    fsc1=esc1/ey*fs
else
    fsc1=fs
end
esc2=0.002*(xu-D+c)/(xu-m)//>ey
if(esc2<=ey)
    fsc2=esc2/ey*fs
else
    fsc2=fs
end
//stress block parameters for xu / D = 1.1
n=0.384
l=0.443
```

```
A=n*fck*D//area of stress block
r=l*D//distance of c.g.
Pu5=(A*b+Asc*fsc1+Ast*fsc2)/10^3//in kN
Mu5=(A*b*(D/2-r)+Asc*fsc1*(D/2-c)-Ast*fsc2*(D/2-c))
    /10^6//in kN-m

//xu = D
xu=D//in mm
m=0.43*D//in mm
esc1=0.002*(xu-c)/(xu-m)
if(esc1<=ey)
    fsc1=esc1/ey*fs
else
    fsc1=fs
end
esc2=0.002*(xu-D+c)/(xu-m)//>ey
if(esc2<=ey)
    fsc2=esc2/ey*fs
else
    fsc2=fs
end
//stress block parameters for xu / D = 1
n=0.361
l=0.416
A=n*fck*D//area of stress block
r=l*D//distance of c.g.
Pu6=(A*b+Asc*fsc1+Ast*fsc2)/10^3//in kN
Mu6=(A*b*(D/2-r)+Asc*fsc1*(D/2-c)-Ast*fsc2*(D/2-c))
    /10^6//in kN-m

//xu=400 mm
xu=400//in mm
esc=0.0035*(xu-c)/xu
if(esc<=ey)
    fsc=esc/ey*fs
else
    fsc=fs
end
```

```
est=0.0035*(D-xu-c)/xu
if(est<=ey)
    fst=est/ey*fs
else
    fst=fs
end
Pu7=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
Mu7=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
   Ast*fst*(D/2-c))/10^6

//xu=375 mm
xu=375//in mm
esc=0.0035*(xu-c)/xu
if(esc<=ey)
    fsc=esc/ey*fs
else
    fsc=fs
end
est=0.0035*(D-xu-c)/xu
if(est<=ey)
    fst=est/ey*fs
else
    fst=fs
end
Pu8=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
Mu8=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
   Ast*fst*(D/2-c))/10^6

//xu=350 mm
xu=350//in mm
esc=0.0035*(xu-c)/xu
if(esc<=ey)
    fsc=esc/ey*fs
else
    fsc=fs
end
est=0.0035*(D-xu-c)/xu
if(est<=ey)
```

```
    fst=est/ey*fs
else
    fst=fs
end
Pu9=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
Mu9=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
   Ast*fst*(D/2-c))/10^6

//xu=325 mm
xu=325//in mm
esc=0.0035*(xu-c)/xu
if(esc<=ey)
    fsc=esc/ey*fs
else
    fsc=fs
end
est=0.0035*(D-xu-c)/xu
if(est<=ey)
    fst=est/ey*fs
else
    fst=fs
end
Pu10=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
Mu10=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
   Ast*fst*(D/2-c))/10^6

//xu=300 mm
xu=300//in mm
esc=0.0035*(xu-c)/xu
if(esc<=ey)
    fsc=esc/ey*fs
else
    fsc=fs
end
est=0.0035*(D-xu-c)/xu
if(est<=ey)
    fst=est/ey*fs
else
```

```
    fst=fs
end
Pu11=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
Mu11=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
   Ast*fst*(D/2-c))/10^6

//xu=275 mm
xu=275//in mm
esc=0.0035*(xu-c)/xu
if(esc<=ey)
    fsc=esc/ey*fs
else
    fsc=fs
end
est=0.0035*(D-xu-c)/xu
if(est<=ey)
    fst=est/ey*fs
else
    fst=fs
end
Pu12=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
Mu12=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
   Ast*fst*(D/2-c))/10^6

//xu=250 mm
xu=250//in mm
esc=0.0035*(xu-c)/xu
if(esc<=ey)
    fsc=esc/ey*fs
else
    fsc=fs
end
est=0.0035*(D-xu-c)/xu
if(est<=ey)
    fst=est/ey*fs
else
    fst=fs
end
```

```
Pu13=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
Mu13=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
   Ast*fst*(D/2-c))/10^6

//xu=225 mm
xu=225//in mm
esc=0.0035*(xu-c)/xu
if(esc<=ey)
    fsc=esc/ey*fs
else
    fsc=fs
end
est=0.0035*(D-xu-c)/xu
if(est<=ey)
    fst=est/ey*fs
else
    fst=fs
end
Pu14=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
Mu14=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
   Ast*fst*(D/2-c))/10^6

//xu=200 mm
xu=200//in mm
esc=0.0035*(xu-c)/xu
if(esc<=ey)
    fsc=esc/ey*fs
else
    fsc=fs
end
est=0.0035*(D-xu-c)/xu
if(est<=ey)
    fst=est/ey*fs
else
    fst=fs
end
Pu15=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
Mu15=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
```

```
    Ast*fst*(D/2-c))/10^6

//xu=150 mm
xu=150//in mm
esc=0.0035*(xu-c)/xu
if(esc<=ey)
    fsc=esc/ey*fs
else
    fsc=fs
end
est=0.0035*(D-xu-c)/xu
if(est<=ey)
    fst=est/ey*fs
else
    fst=fs
end
Pu16=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
Mu16=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
    Ast*fst*(D/2-c))/10^6

//xu=100 mm
xu=100//in mm
esc=0.0035*(xu-c)/xu
if(esc<=ey)
    fsc=esc/ey*fs
else
    fsc=fs
end
est=0.0035*(D-xu-c)/xu
if(est<=ey)
    fst=est/ey*fs
else
    fst=fs
end
Pu17=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
Mu17=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
    Ast*fst*(D/2-c))/10^6
```

```
//xu=0.531 d
d=D-c
xu=0.531*d
Pu18=0//in kN
Mu18=0.149*fck*b*d^2/10^6//in kN-m

Pu=[Pu1 Pu2 Pu3 Pu4 Pu5 Pu6 Pu7 Pu8 Pu9 Pu10 Pu11
    Pu12 Pu13 Pu14 Pu15 Pu16 Pu17 Pu18]
Mu=[Mu1 Mu2 Mu3 Mu4 Mu5 Mu6 Mu7 Mu8 Mu9 Mu10 Mu11
    Mu12 Mu13 Mu14 Mu15 Mu16 Mu17 Mu18]
xtitle('P-M Interaction Diagram', 'Mu (kN-m)', 'Pu (
    kN)')
plot(Mu,Pu)
```

Scilab code Exa 18.8 Biaxial Bending

```
b=250//column width in mm
D=450//column depth in mm
Asc=2*1472//in sq mm
fck=15//in MPa
fy=250//in MPa
ex=200//in mm
ey=150//in mm
//from interaction curve
//for ex=200 mm on x-axis
Pum1=610//in kN
Muy1=120//in kN-m
//for ey=150 mm on y-axis
Pum2=720//in kN
Mux1=106//in kN-m
//(i)
Pu=300//in kN
Mux=Pu*ey/10^3//in kN-m
Muy=Pu*ex/10^3//in kN-m
Puz=(0.45*fck*(b*D-Asc)+0.75*fy*Asc)/10^3//in kN
```

```
a=Pu/Puz
an=1+1/0.6*(a-0.2)
b=(Mux/Mux1)^an+(Muy/Muy1)^an//<1
mprintf("The column can take a load of 300 kN with
   ex=200 mm and ey=150 mm\n")
//(ii)
Pu=500//in kN
Mux=Pu*ey/10^3//in kN-m
Muy=Pu*ex/10^3//in kN-m
a=Pu/Puz
an=1+1/0.6*(a-0.2)
b=(Mux/Mux1)^an+(Muy/Muy1)^an//>1
mprintf("The section is not suitable for a load of
   500 kN with ex=200 mm and ey=150 mm\n")
```

Scilab code Exa 18.9 Biaxial Bending

```
b=250//column width, in mm
D=500//column depth, in mm
lex=4//in m
ley=4//in m
Pu=300//in kN
Asc=1472//in sq mm
Ast=1472//in sq mm
fck=15//in MPa
fy=250//in MPa
c=50//cover, in mm
Max=Pu*10^3*D/2000*(lex/(D/10^3))^2/10^6//in kN-m
May=Pu*10^3*b/2000*(ley/(b/10^3))^2/10^6//in kN-m
Puz=(0.45*fck*(b*D-(Asc+Ast))+0.75*fy*(Asc+Ast))
   /10^3//in kN
//to find Pb
xu=(D-c)/(1+0.002/0.0035)//in mm
fsc=217.5//in MPa
fst=217.5//in MPa
```

```
Pb=(0.36*fck*b*xu+fsc*Asc-fst*Ast)/10^3//in kN
k=(Puz-Pu)/(Puz-Pb)//>1
k=1
Max=k*Max//in kN-m
May=k*May//in kN-m
mprintf("Additional Moments are:\nMax=%f kN/m\nMay=
   %f kN-m", Max,May)
```

Chapter 19

Designs by Limit State Method

Scilab code Exa 19.1 Design of One Way Slab

```
fck=15//in MPa
fy=250//in MPa
l=4//span, in m
MF=1.6
a=MF*20
D=l*10^3/a//in mm
W1=(D/10^3)*25//self-weight, in kN/m
W2=1//floor finish, in kN/m
W3=2//live load, in kN/m
W=W1+W2+W3//in kN/m
Wu=1.5*W//in kN/m
lef=4.125//in m
Mu=Wu*lef^2/8//in kN-m
d=sqrt(Mu*10^6/0.149/fck/10^3)//in mm
dia=12//assume 12 mm dia bars
D=d+dia/2+15//<125 mm (assumed value), hence OK
D=125//in mm
d=D-dia/2-15//in mm
//steel
//Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
a=0.87*fy/0.36/fck/10^3
```

```
//using Mu=0.87 fy Ast (d-0.416 Xu), we get a
    quadratic equation
p=0.87*fy*0.416*a
q=-0.87*fy*d
r=Mu*10^6
Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
s1=1000*0.785*dia^2/Ast//in mm
s1=105//in mm
pt=1000*0.785*dia^2/s1/10^3/d*100//in %
Ads=0.15/100*10^3*D//in sq mm
//provide 8 mm dia bars
s2=1000*0.785*8^2/Ads//in mm
s2=265//in mm
Vu=Wu*lef/2//in kN
Tv=Vu*10^3/10^3/d//in MPa
//for M15 and pt=1
Tc=0.6//in MPa
//for solid slabs
Tc=1.3*Tc//in MPa
//as Tc>Tv, no shear reinforcement required
mprintf("Summary of design:\nSlab thickness= %d mm\
    nCover = 15 mm\nMain steel = 12 mm dia @ %d mm c/
    c\nDistribution steel = 8 mm dia @ %d mm c/c",D,
    s1,s2)
```

Scilab code Exa 19.3 Design of One Way Slab

```
fck=15//in MPa
fy=415//in MPa
l=4.5//span, in m
MF=1.4
a=MF*20
D=l*10^3/a//in mm
D=160//in mm
W1=(D/10^3)*25//self-weight, in kN/m
```

```
W2=1//floor finish , in kN/m
W3=1//partitions , in kN/m
W4=4//live load , in kN/m
W=W1+W2+W3+W4//in kN/m
Wu=1.5*W//in kN/m
lef=l+0.16//in m
Mu=Wu*lef^2/8//in kN-m
d=sqrt(Mu*10^6/0.138/fck/10^3)//in mm
dia=12//assume 12 mm dia bars
D=d+dia/2+15//=160 mm(assumed value), approximately
D=160//in mm
d=140//in mm
//steel
//Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
a=0.87*fy/0.36/fck/10^3
//using Mu=0.87 fy Ast (d-0.416 Xu), we get a
   quadratic equation
p=0.87*fy*0.416*a
q=-0.87*fy*d
r=Mu*10^6
Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
s1=1000*0.785*dia^2/Ast//in mm
s1=112//in mm
pt=Ast/10^3/d*100//in %
Ads=0.12/100*10^3*D//in sq mm
//provide 8 mm dia bars
s2=1000*0.785*8^2/Ads//in mm
s2=260//in mm
Vu=Wu*lef/2//in kN
Tv=Vu*10^3/10^3/d//in MPa
//for M15 and pt=0.718
Tc=0.53//in MPa
//for solid slabs
Tc=1.25*Tc//in MPa
//as Tc>Tv, no shear reinforcement required
mprintf("Summary of design:\nSlab thickness= %d mm\
   nCover = 15 mm\nMain steel = 12 mm dia @ %d mm c/
   c\nDistribution steel = 8 mm dia @ %d mm c/c",D,
```

```
s1,s2)
```

Scilab code Exa 19.4 Design of Chajja

```
fck=15//in MPa
fy=415//in MPa
MF=1.4//modification factor
//let a be span to depth ratio
l=1//span, in m
a=MF*7
D=l*1000/a//in mm
D=105//assume, in mm
//to calculate loading
W1=25*(D/10^3)*1.5//self-weight, in kN/m
W2=0.5*1.5//finish, in kN/m
W3=0.75*1.5//live load, in kN/m
W=W1+W2+W3//in kN/m
Wu=1.5*W//in kN/m
lef=l+0.23/2//effective span, in m
Mu=Wu*lef/2//in kN-m
//check for depth
d=sqrt(Mu*10^6/(0.138*fck*1500))//in mm
dia=12//assume 12 mm dia bars
D=d+12/2+15//<105, hence OK
D=100//assume, in mm
d=D-dia/2-15//in mm
//steel
//Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
a=0.87*fy/0.36/fck/1.5/10^3
//using Mu=0.87 fy Ast (d-0.416 Xu), we get a quadratic equation
p=0.87*fy*0.416*a
q=-0.87*fy*d
r=Mu*10^6
Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
```

```
//provide 8 mm dia bars
dia=8//in mm
s1=1500*0.785*dia^2/Ast//>3d=3x79=237 mm
s1=235//in mm
Ads=0.12/100*1000*D//distribution steel, in sq mm
//assume 6 mm dia bars
s2=1000*0.785*6^2/Ads//in mm
s2=235//round-off, in mm
Tbd=1.6//in MPa
Ld=dia*0.87*fy/4/Tbd//in mm
Ld=452//in mm
Tv=Wu*10^3/1500/d//in MPa
Ast=1500*0.785*8^2/235//in sq mm
pt=Ast/1500/d*100//in %
//for M15 and pt=0.26
Tc=0.35//in MPa
//as Tc>Tv, no shear reinforcement required
mprintf("Summary of design\nThickness of slab = %d
    mm\nCover = 15 mm\nMain steel = 8 mm dia @ %d mm
    c/c\nDevelopment length = %d mm\nDistribution
    steel = 6 mm dia @ %d mm c/c",D,s1,Ld,s2)
```

Scilab code Exa 19.5 Design of Two Way Slab

```
lx=3.5//in m
ly=4//in m
fck=15//in MPa
fy=250//in MPa
D=lx*10^3/35//in mm
W1=(D/10^3)*25//self-weight, in kN/m
W2=1.5//live load, in kN/m
W=W1+W2//in kN/m
Wu=1.5*W//in kN/m
a=ly/lx
Ax=0.078
```

```
Ay=0.0602
Mx=Ax*Wu*lx^2//in kN-m
My=Ay*Wu*lx^2//in kN-m
d=sqrt(Mx*10^6/0.149/fck/10^3)//in mm
d=51//round-off, in mm
//assume 10 mm dia bars
dia=10//in mm
D=d+dia/2+15//<100 mm assumed value
D=100//in mm
d=D-dia/2-15//in mm
//steel - short span
//Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
a=0.87*fy/0.36/fck/10^3
//using Mu=0.87 fy Ast (d-0.416 Xu), we get a
    quadratic equation
p=0.87*fy*0.416*a
q=-0.87*fy*d
r=Mx*10^6
Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
s1=1000*0.785*dia^2/Ast//in mm
s1=220//round-off, in mm
//long span
d=d-dia/2-dia/2//in mm
//Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
a=0.87*fy/0.36/fck/10^3
//using Mu=0.87 fy Ast (d-0.416 Xu), we get a
    quadratic equation
p=0.87*fy*0.416*a
q=-0.87*fy*d
r=My*10^6
Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
s2=1000*0.785*dia^2/Ast//in mm
s2=250//round-off, in mm
mprintf("Summary of design\nSlab thickness=%d mm\
    nCover=15 mm\nSteel-\n(i)Short span = 10 mm dia @
     %d mm c/c\n(ii)Long span = 10 mm dia @ %d mm c/c
    ",D,s1,s2)
```

Scilab code Exa 19.6 Design of Rectangular Beam

```
b=225//width in mm
D=300//depth in mm
fck=15//in MPa
fy=415//in MPa
l=4.2//span, in m
W1=(b/10^3)*(D/10^3)*25//self-weight, in kN/m
W2=6//live load, in kN/m
W=W1+W2//in kN/m
Wu=1.5*W//in kN/m
Mu=Wu*l^2/8//in kN-m
d=270//assume, in mm
Mulim=0.138*fck*b*d^2/10^6//in kN-m
//as Mulim > Mu, it will be a singly reinforced beam
//Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
a=0.87*fy/0.36/fck/b
//using Mu=0.87 fy Ast (d-0.416 Xu), we get a
    quadratic equation
p=0.87*fy*0.416*a
q=-0.87*fy*d
r=Mu*10^6
Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
//provide 12 mm dia bars
n=Ast/0.785/12^2
n=3//assume
Ast=n*0.785*12^2//in sq mm
Vu=Wu*l/2//in kN
Tv=Vu*10^3/b/d//in MPa
pt=Ast/b/d*100//pt=0.56
//for M15 and pt=0.56
Tc=0.46//in MPa
//as Tc>Tv, no shear reinforcement required
//provide nominal stirrups and provide 6 mm stirrups
```

```
Asv=2*0.785*6^2//in sq mm
Sv=Asv*fy/0.4/b//in mm
Sv=260//assume, in mm
Svmax=0.75*d//in mm
Svmax=200//round-off, in mm
Sv=min(Sv,Svmax)//in mm
mprintf("Summary of design:\nBeam size - %d x %d mm\nCover - 25 mm\nSteel - %d-12 mm dia bars\nStirrups - 6 mm dia @ %d mm c/c",b,D,n,Sv)
//deflection check
Ec=5700*sqrt(fck)//in MPa
Es=2*10^5//in MPa
m=Es/Ec
fcr=0.7*sqrt(fck)//in MPa
//using b x x/2 = m Ast (d-x), we get a quadratic equation
//solving the quadratic equation
p=b/2
q=m*Ast
r=-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
z=d-x/3//in mm
Ir=b*x^3/12+b*x*(x/2)^2+m*Ast*(d-x)^2//in mm^4
Igr=b*D^3/12//in mm^4
yt=D/2//in mm
Mr=fcr*Igr/yt//in N-mm
M=W*l^2/8*10^6//in N-mm
Ieff=Ir/(1.2-Mr/M*z/d*(1-x/d)*b/b)//in mm^4
//Ir<Ieff<Igr, hence OK
W1=W*l//in kN
u1=5/384*(W1*10^3)*(l*10^3)^3/Ec/Ieff//short-term deflection, in mm
//long-term deflection
//(i) deflection due to shrinkage
k3=0.125//for simply supported beam
pt=0.56//in %
pc=0//in %
k4=0.72*(pt-pc)/sqrt(pt)
```

```
phi=k4*0.0003/D
u2=k3*phi*(l*10^3)^2//in mm
//(ii) deflection due to creep
Ecc=Ec/(1+1.6)//in MPa
//assuming a permanent load of 60%
W2=0.6*W*l//in kN
u3=5/384*(W2*10^3)*(l*10^3)^3/Ecc/Ieff//in mm
u4=5/384*(W2*10^3)*(l*10^3)^3/Ec/Ieff//in mm
u5=u3-u4//in mm
u=u1+u2+u5//total deflection, in mm
v1=l*10^3/250//permissible deflection, in mm
v2=l*10^3/350//in mm
//assuming half the shrinkage strain occurs within
    the first 28 days, the deflection occurring after
     this time
v3=u2/2+u5//< permissible value, hence OK
```

Scilab code Exa 19.7 Design of Rectangular Beam

```
l=7//span, in m
fck=15//in MPa
fy=250//in MPa
b=300//assume, in mm
W=35//live load, in kN/m
Wu=1.5*W//in kN/m
Mu=Wu*l^2/8//in kN-m
d=(Mu*10^6/0.149/fck/b)^0.5//in mm
d=1.1*d//increase depth by 10% for self-weight
d=750//assume, in mm
c=50//cover, in mm
D=d+c//in mm
W1=(b/10^3)*(D/10^3)*25//self-weight, in kN/m
W2=35//live load, in kN/m
W=W1+W2//in kN/m
Wu=1.5*W//in kN/m
```

```
Mu=Wu*l^2/8//in kN-m
d=(Mu*10^6/0.149/fck/b)^0.5//<750 mm, hence OK
d=750//in mm
//steel
//Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
a=0.87*fy/0.36/fck/b
//using Mu=0.87 fy Ast (d-0.416 Xu), we get a quadratic equation
p=0.87*fy*0.416*a
q=-0.87*fy*d
r=Mu*10^6
Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
//provide 20 mm dia bars
n=Ast/0.785/20^2
//provide 8-20 mm + 2-18 mm dia bars
Ast=8*0.785*20^2+2*0.785*18^2//in sq mm
pt=Ast/b/d*100//pt=1.34
Vu=Wu*l/2//in kN
Tv=Vu*10^3/b/d//in MPa
//for M15 and pt=1.34
Tc=0.65//in MPa
//as Tv>Tc, shear reinforcement required
//provide 6 mm stirrups
Vus=Vu-Tc*b*d/10^3//in kN
Asv=2*0.785*6^2//in sq mm
Sv=Asv*0.87*fy*d/Vus/10^3//in mm
Sv=130//assume, in mm
Svmin=Asv*fy/0.4/b//in mm
Svmin=115//assume, in mm
Sv=min(Sv,Svmin)//in mm
mprintf("Summary of design:\nBeam size - %d x %d mm\nCover - 50 mm\nSteel - 8-20 mm + 2-18 mm dia bars\nStirrups - 6 mm dia @ %d mm c/c",b,D,Sv)
//deflection check
Ec=5700*sqrt(fck)//in MPa
Es=2*10^5//in MPa
m=Es/Ec
fcr=0.7*sqrt(fck)//in MPa
```

```
//using b x x/2 = m Ast (d-x), we get a quadratic equation
//solving the quadratic equation
p=b/2
q=m*Ast
r=-m*Ast*d
x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
x=290//assume, in mm
z=d-x/3//in mm
Ir=b*x^3/12+b*x*(x/2)^2+m*Ast*(d-x)^2//in mm^4
Igr=b*D^3/12//in mm^4
yt=D/2//in mm
Mr=fcr*Igr/yt//in N-mm
M=W*l^2/8*10^6//in N-mm
Ieff=Ir/(1.2-Mr/M*z/d*(1-x/d)*b/b)//in mm^4
//Ir>Ieff
Ieff=Ir//in mm^4
W1=W*l//in kN
u1=5/384*(W1*10^3)*(l*10^3)^3/Ec/Ieff//short-term deflection, in mm
//long-term deflection
//(i) deflection due to shrinkage
k3=0.125//for simply supported beam
pt=1.34//in %
pc=0//in %
k4=0.65*(pt-pc)/sqrt(pt)
phi=k4*0.0003/D
u2=k3*phi*(l*10^3)^2//in mm
//(ii) deflection due to creep
Ecc=Ec/(1+1.6)//in MPa
//assuming a permanent load of 60%
W2=0.6*W*l//in kN
u3=5/384*(W2*10^3)*(l*10^3)^3/Ecc/Ieff//in mm
u4=5/384*(W2*10^3)*(l*10^3)^3/Ec/Ieff//in mm
u5=u3-u4//in mm
u=u1+u2+u5//total deflection, in mm
v1=l*10^3/250//permissible deflection, in mm
v2=l*10^3/350//in mm
```

```
//assuming half the shrinkage strain occurs within the first 28 days, the deflection occurring after this time
v3=u2/2+u5//< permissible value, hence OK
```

Scilab code Exa 19.8 Design of T beam

```
l=10//span, in m
fck=15//in MPa
fy=250//in MPa
Df=100//slab thickness, in mm
D=l*10^3/15//depth of beam, in mm
D=600//assume, in mm
d=D-50//cover=50 mm
bw=300//beam width, in mm
bf=l*10^3/6+bw+6*Df//>2500 mm c/c distance of beams
bf=2500//in mm
W1=(bw/10^3)*(D-Df)/10^3*25//web, in kN/m
W2=(Df/10^3)*(bf/10^3)*25//slab, in kN/m
W3=(bf/10^3)*5//imposed load, in kN/m
W=W1+W2+W3//in kN/m
Wu=1.5*W//in kN/m
Mu=Wu*l^2/8//in kN-m
Vu=Wu*l/2//in kN
Asf=0.36*fck*bf*Df/0.87/fy//steel required only for flange, in sq mm
Asf=6210//round-off, in sq mm
//verification of trial section
xu=100//assume, in mm
Ast=Asf//in sq mm
Mulim=0.87*fy*Ast*(d-0.416*xu)/10^6//in kN-m
//Mulim > Mu, hence OK
//keeping the assumed trial section, work out the steel required
//Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
```

```
a=0.87*fy/0.36/fck/bf
//using Mu=0.87 fy Ast (d-0.416 Xu), we get a quadratic equation
p=0.87*fy*0.416*a
q=-0.87*fy*d
r=Mu*10^6
Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
//provide 5-25 mm dia + 3-22 mm dia bars
pt=Ast*100/(bw*d+(bf-bw)*Df)//pt=1%, approximately
//check for shear
Tv=Vu*10^3/bw/d//in MPa
//for M15 grade concrete and pt=1%
Tc=0.6//in MPa
//as Tv > Tc, shear reinforcement required
Vus=Vu-Tc*bw*d/10^3//in kN
//provide 6 mm dia stirrups
Asv=2*0.785*6^2//in sq mm
Sv=Asv*0.87*fy*d/Vus/10^3//in mm
Sv=90//round-off, in mm
mprintf("T beam:bf=%d mm\nDf=%d mm\nd=%d mm\nD=%d mm\nCover = 50 mm\nSteel= 5-25 mm dia + 3-22 mm dia bars\nStirrups = 6 mm dia @ %d mm c/c throughout",bf,Df,d,D,Sv)
//answer in textbook for spacing of stirrups is incorrect
//deflection check
Ec=5700*sqrt(fck)//in MPa
Es=2*10^5//in MPa
m=Es/Ec//modular ratio
fcr=0.7*sqrt(fck)//in MPa
//using bf Df (x-Df/2) = m Ast (d-x), we get a quadratic equation
x=(m*Ast*d+bf*Df^2/2)/(bf*Df+m*Ast)//in mm
z=0.87*d//assume, in mm
//refer Fig. 19.5 of textbook
Ir=bf*x^3/12+bf*Df*(x/2)^2+m*Ast*(d-x)^2//in mm^4
y=(bf*Df*Df/2+(D-Df)*bw*((D-Df)/2+Df))/(bf*Df+(D-Df)*bw)//c.g. from top, in mm (neglecting steel)
```

```
Igr=bf*Df^3/12+bf*Df*(Df/2-y)^2+bw*(D-Df)^3/12+bw*(D
   -Df)*((D-Df)/2+Df-y)^2//in mm^4
yt=d/2//in mm
Mr=fcr*Igr/yt//in N-mm
M=W*l^2/8*10^6//in N-mm
Ieff=Ir/(1.2-Mr/M*z/d*(1-x/d)*bw/bf)//in mm^4
//Ir > Ieff
Ieff=Ir//in mm^4
W1=W*l//in kN
u1=5/384*(W1*10^3)*(l*10^3)^3/Ec/Ieff//short term
   deflection , in mm
//deflection due to shrinkage
k3=0.125//for simply supported beam
pt=1//in %
pc=0//in %
k4=0.65*(pt-pc)/sqrt(pt)
phi=k4*0.0003/D
u2=k3*phi*(l*10^3)^2//in mm
//deflection due to creep
Ecc=Ec/(1+1.6)//in MPa
//assuming a permanent load of 60%
W2=0.6*W*l//in kN
u3=5/384*(W2*10^3)*(l*10^3)^3/Ecc/Ieff//in mm
u4=5/384*(W2*10^3)*(l*10^3)^3/Ec/Ieff//in mm
u5=u3-u4//in mm
u=u1+u2+u5//total deflection , in mm
v1=l*10^3/250//permissible deflection , in mm
v2=l*10^3/350//>20 mm
v2=20//in mm
//assuming half the shrinkage strain occurs within
   the first 28 days, the deflection occurring after
    this time
v3=u2/2+u5//< permissible value , hence OK
```

Scilab code Exa 19.9 Design of Staircase

```
l=2.7+1//span, in m
R=0.15//rise, in m
t=0.27//tread, in m
fck=15//in MPa
fy=415//in MPa
D=200//assume, in mm
W1=D/10^3*25*sqrt(R^2+t^2)/t//slab load on plan, in kN/m
W2=1/2*R*t*25/t//load of step per metre, in kN/m
W3=3//live load, in kN/m
W=W1+W2+W3//in kN/m
Wu=1.5*W//in kN/m
Mu=Wu*l^2/8//in kN-m
d=sqrt(Mu*10^6/0.138/fck/10^3)//in mm
d=115//round-off, in mm
//assume 10 mm dia bars
dia=10//in mm
D=d+dia/2+25//< 200 mm, hence OK
D=l*10^3/24//depth required for deflection, in mm
D=155//round-off, in mm
d=D-dia/2-25//in mm
//steel
//Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
a=0.87*fy/0.36/fck/10^3
//using Mu=0.87 fy Ast (d-0.416 Xu), we get a quadratic equation
p=0.87*fy*0.416*a
q=-0.87*fy*d
r=Mu*10^6
Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
s1=1000*0.785*dia^2/Ast//spacing of 10 mm dia bars
s1=110//round-off, in mm
Ads=0.12/100*D*10^3//distribution steel, in sq mm
//provide 8 mm dia bars
s2=1000*0.785*8^2/Ads//in mm
s2=270//round-off, in mm
mprintf("Summary of design\nSlab thickness=%d mm\nCover = 25 mm\nMain steel = 10 mm dia bars @ %d
```

```
mm c/c\nDistribution steel = 8 mm dia @ %d mm c/c",D,s1,s2)
//answer in textbook for spacing of 10 mm dia bars is incorrect
```

Scilab code Exa 19.10 Design of Column Footing

```
b=0.2//column width, in m
D=0.3//column depth, in m
fck=15//in MPa
fy=415//in MPa
P1=600//load on column, in kN
P2=0.05*P1//weight of footing, in kN
P=P1+P2//in kN
Pu=1.5*P//in kN
q=150//bearing capacity of soil, in kN/sq m
qu=2*q//ultimate bearing capacity of soil, in kN/sq m
A=Pu/qu//in sq m
L=sqrt(A)//assuming footing to be square, in m
L=1.8//round-off, in m
p=P1*1.5/L^2//soil pressure, in kN/sq m
p=277.8//round-off, in kN/sq m
bc=b/D
ks=0.5+bc//>1
ks=1
Tc=0.25*sqrt(fck)*10^3//in kN/sq m
Tv=Tc
//let d be the depth of footing in metres
//case I: consider greater width of shaded portion in Fig. 19.6 of textbook
d1=L*(L-b)/2*p/(Tc*L+L*p)//in m
//case II: refer Fig. 19.7 of textbook; we get a quadratic equation of the form e d^2 + f d + g = 0
```

```
e=p+4*Tc
f=b*p+D*p+2*(b+D)*Tc
g=-(L^2-b*D)*p
d2=(-f+sqrt(f^2-4*e*g))/2/e//in m
d2=0.35//round-off , in m
//bending moment consideration , refer Fig. 19.8 of
   textbook
Mx=1*((L-b)/2)^2/2*p//in kN-m
My=1*((L-D)/2)^2/2*p//in kN-m
d3=sqrt(Mx*10^6/0.138/fck/10^3)//<350 mm, hence OK
//steel
//Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
a=0.87*fy/0.36/fck/10^3
//using Mu=0.87 fy Ast (d-0.416 Xu), we get a
   quadratic equation
p=0.87*fy*0.416*a
q=-0.87*fy*d2*10^3
r=Mx*10^6
Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
Ast=L*Ast//steel required for full width of 1.8 m
//provide 12 mm dia bars
dia=12//in mm
n=Ast/0.785/dia^2//no. of 12 mm dia bars
n=12//round-off
Tbd=1.6//in MPa
Ld=dia*0.87*fy/4/Tbd//in mm
Ld=677//assume, in mm
//this length is available from the face of the
   column in both directions
D=d2*10^3+dia/2+100//in mm
mprintf("Summary of design:\nOverall depth of
   footing=%d mm\nCover=100 mm\nSteel-%d bars of 12
   mm dia both ways",D,n)
```

Scilab code Exa 19.11 Design of Retaining Wall

```
fck=15//in MPa
fy=415//in MPa
phi=30//angle of repose, in degrees
H=5//height of wall, in m
B=0.6*H//assume, in m
T=B/4//assume toe to base ratio as 1:4, in m
W=16//density of retained earth, in kN/cu m
Wu=1.5*W//factored load, in kN/cu m
P=Wu*H^2/2*(1-sind(phi))/(1+sind(phi))//in kN
M1=P*H/3//in kN-m
M1=167//round-off, in kN-m
//bending moment at 2.5 m below the top
h=2.5//in m
M2=Wu*h^2/2*(1-sind(phi))/(1+sind(phi))*h/3//in kN-m
M2=21//round-off, in kN-m
//thickness of stem (at the base)
d=sqrt(M1*10^6/0.138/fck/1000)//in mm
d=285//round-off, in mm
dia=20//assume 20 mm dia bars
D1=d+dia/2+25//in mm
D2=200//thickness at top, in mm
D3=D2+(D1-D2)*h/H//thickness at 2.5 m below top, in mm
d3=sqrt(M2*10^6/0.138/fck/1000)//in mm
D3=d3+dia/2+25//< 260 mm (provided), hence OK
D3=260//in mm
d3=D3-dia/2-25//in mm
//main steel
//(a) 5 m below the top
//Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
a=0.87*fy/0.36/fck/10^3
//using Mu=0.87 fy Ast (d-0.416 Xu), we get a quadratic equation
p=0.87*fy*0.416*a
q=-0.87*fy*d
r=M1*10^6
Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
pt=Ast/1000/d*100//in %
```

```
//provide 20 mm dia bars
s1=1000*0.785*20^2/Ast//in mm
s1=155//round-off, in mm
//(b) 2.5 m below the top
//Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
a=0.87*fy/0.36/fck/10^3
//using Mu=0.87 fy Ast (d-0.416 Xu), we get a
    quadratic equation
p=0.87*fy*0.416*a
q=-0.87*fy*d3
r=M2*10^6
Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
Astmin=0.12/100*10^3*D3//in sq mm
Ast=max(Ast,Astmin)//in sq mm
//provide 12 mm dia bars
s2=1000*0.785*12^2/Ast//in mm
s2=360//round-off, in mm
//distribution steel
Ads=0.12/100*10^3*D3//in sq mm
//provide 8 mm dia bars
s3=1000*0.785*8^2/Ads//in mm
s3=160//round-off, in mm
//check for shear
Vu=P//in kN
Tv=Vu*10^3/10^3/d//in MPa
//for M15 grade concrete and pt=0.71
Tc=0.54//in MPa
//as Tc > Tv, no shear reinforcement required
//development length
//(a) At the base of stem
dia=20//in mm
Tbd=1.6//in MPa
Ld=dia*0.87*fy/4/Tbd//in mm
Ld=1130//round-off, in mm
//(b) At 2.5 m below the top
dia=12//in mm
Ld=dia*0.87*fy/4/Tbd//in mm
Ld=680//round-off, in mm
```

```
mprintf("Summary of design:\nThickness of stem (at base) = %d mm\nThickness of stem at top = %d mm\nRefer Fig. 19.10 of textbook for reinforcement details",D1,D2)
```

Scilab code Exa 19.12 Design of Axially Loaded Short Column

```
P=1000//in kN
Pu=1.5*P//in kN
fck=15//in MPa
fy=415//in MPa
l=3.5//unsupported length, in m
//assume 1% steel
Ag=Pu*10^3/(0.4*fck*0.99+0.67*fy*0.01)//in sq mm
L=sqrt(Ag)//assuming a square column
L=420//in mm
emin=l*10^3/500+L/30//in mm
ep=0.05*L//=emin, hence OK
Asc=0.01*L^2//in sq mm
//provide 6-20 mm dia bars
Asc=6*0.785*20^2//in sq mm
mprintf("Summary of design:\nColumn size - %d x %d mm\nSteel-main = 6-20 mm dia bars",L,L)
```

Scilab code Exa 19.13 Design of Short Column with Uniaxial Bending

```
P=500//in kN
Pu=1.5*P//in kN
fck=15//in MPa
fy=250//in MPa
l=3//unsupported length, in m
//assume 1% steel
Ag=Pu*10^3/(0.4*fck*0.99+0.67*fy*0.01)//in sq mm
```

```
L=sqrt(Ag)//assuming a square column
L=315//in mm
emin=l*10^3/500+L/30//<20
emin=20//in mm
ep=0.05*L//<emin, hence the column is to be checked
   for bending
Mu=Pu*10^3*emin//in N-mm
a=Pu*10^3/fck/L/L
b=Mu/fck/L/L^2//b=0.032
d1=40//cover(assume), in mm
c=d1/L//c=d'/D
//for d'/D = 0.15
p=0.07*fck//in %
Asc=p/100*L^2//in sq mm
//provide 4-20 mm dia bars
Asc=4*0.785*20^2//in sq mm
mprintf("Summary of design:\nColumn size - %d x %d
   mm\nSteel-main = 4-20 mm dia bars",L,L)
```

Scilab code Exa 19.14 Design of Short Column with Uniaxial Bending

```
P=500//in kN
Pu=1.5*P//in kN
fck=15//in MPa
fy=250//in MPa
l=3//unsupported length, in m
//assume 1% steel
Ag=Pu*10^3/(0.4*fck*0.99+0.67*fy*0.01)//in sq mm
b=250//in mm
D=Ag/b//in mm
D=400//round-off, in mm
emin1=l*10^3/500+D/30//in direction of Y axis, in mm
   , < 20 mm
emin1=20//in mm
ep1=0.05*D//=emin, hence no moment is required to be
```

```
considered in this direction
emin2=l*10^3/500+b/30//in direction of X axis, in mm, < 20 mm
emin2=20//in mm
ep2=0.05*b//<emin, hence moment in this direction needs to be considered
//interaction diagram
b=400//in mm
D=250//in mm
Mu=Pu*10^3*emin2//in N-mm
m=Pu*10^3/fck/b/D
n=Mu/fck/b/D^2//b=0.032
d1=40//cover(assume), in mm
c=d1/D//c=d'/D
//referring to Fig. 19.12
p=0.08*fck//in %
Asc=p/100*b*D//in sq mm
//provide 6-16 dia bars
Asc=6*0.785*16^2//in sq mm
mprintf("Summary of design:\nColumn size - %d x %d mm\nSteel-main = 6-16 mm dia bars",D,b)
```

Scilab code Exa 19.15 Design of Long Column

```
P=500//in kN
Pu=1.5*P//in kN
fck=15//in MPa
fy=250//in MPa
l=5//effective length, in m
lex=5//in m
ley=5//in m
L=315//column dimension in mm (square column)
Asc=1256//in sq mm
m=lex*10^3/L//>12
n=ley*10^3/L//>12
```

```
//hence the column is slender on both the axes
Max=Pu*10^3*L/2000*(lex/(L/10^3))^2/10^6//in kN-m
May=Max
Puz=(0.45*fck*(L^2-Asc)+0.75*fy*Asc)/10^3//in kN
c=40//cover, in mm
//to find Pb
xu=(L-c)/(1+0.002/0.0035)//in mm
Pb=0.36*fck*L*xu/10^3//in kN
k=(Puz-Pu)/(Puz-Pb)//>1
Max=k*Max//in kN-m
Mu=15//in kN-m
Mu=Mu+Max//in kN-m
a=Pu*10^3/fck/L/L
b=Mu*10^6/fck/L/L^2//b=0.047
d1=c/L//d1=d'/D
//for d'/D = 0.1
p=0.095*fck//in %
Asc=p/100*L^2//in sq mm
//provide 4-18 mm + 4-12 mm dia bars
Asc=4*0.785*18^2+4*0.785*12^2//in sq mm
mprintf("Summary of design:\nColumn size - %d x %d
   mm\nSteel-main = 4-18 mm + 4-12 mm dia bars",L,L)
```

Scilab code Exa 19.16 Design of Column with Biaxial Bending

```
Pu=2000//in kN
Mux=50//in kN-m
Muy=Mux
fck=20//in MPa
fy=415//in MPa
//assume 2% steel
p=2//in %
Ag=Pu*10^3/(0.4*fck*(1-p/100)+0.67*fy*p/100)//in sq
   mm
L=sqrt(Ag)//assuming a square column
```

```
L=400//in mm
m=Pu*10^3/fck/L/L
n=p/fck
c=50//cover (assume), in mm
d1=c/L//d1=d'/D
//from Fig. 19.21, for d'/D = 0.15 and Pu / fck b D
  = 0.625
f=0.046
Mux1=f*fck*L*L^2/10^6//in kN-m
Muy1=Mux1
Puz=(0.45*fck*(1-p/100)*L^2+0.75*fy*p/100*L^2)/10^3
  //in kN
a=Pu/Puz// >0.8
an=2
b=(Mux/Mux1)^an+(Muy/Muy1)^an//>1
//assume 2.5% steel
p=2.5//in %
n=p/fck
//from Fig. 19.21, for d'/D = 0.15 and Pu / fck b D
  = 0.625
f=0.08
Mux1=f*fck*L*L^2/10^6//in kN-m
Muy1=Mux1
Puz=(0.45*fck*(1-p/100)*L^2+0.75*fy*p/100*L^2)/10^3
  //in kN
a=Pu/Puz// <0.8
an=1+1/0.6*(a-0.2)
b=(Mux/Mux1)^an+(Muy/Muy1)^an//<1, hence OK
Asc=p/100*L^2//in sq mm
//provide 12-22 mm dia bars
Asc=12*0.785*22^2//in sq mm
mprintf("Summary of design:\nColumn size - %d x %d
  mm\nSteel-main = 12-22 mm dia bars placed equally
   on four faces of the column",L,L)
```

Scilab code Exa 19.17 Design of Column with Biaxial Bending

```
b=400//in mm
D=500//in mm
Pu=1600//in kN
Mux=90//in kN-m
Muy=50//in kN-m
fck=15//in MPa
fy=415//in MPa
p=1.5//assume 1.5% steel, placed on four sides
m=p/fck
c=50//cover (assume), in mm
//to find Mux1
n=c/D//n=d'/D
l=Pu*10^3/fck/b/D
//referring to Fig.19.20, for Pu/ fck/ b/ D = 0.53
    and p/ fck = 0.1
f=0.09
Mux1=f*fck*b*D^2/10^6//in kN-m
//to find Muy1
b=500//in mm
D=400//in mm
n=c/D//n=d'/D
l=Pu*10^3/fck/b/D
//referring to Fig.19.21, for Pu/ fck/ b/ D = 0.53
    and p/ fck = 0.1
f=0.08
Muy1=f*fck*b*D^2/10^6//in kN-m
Puz=(0.45*fck*(1-p/100)*b*D+0.75*fy*p/100*b*D)/10^3
    //in kN
a=Pu/Puz//<0.8
an=1+1/0.6*(a-0.2)
r=(Mux/Mux1)^an+(Muy/Muy1)^an//<1
Asc=p/100*b*D//in sq mm
//provide 6-16 mm + 6-20 mm dia bars
Asc=6*0.785*16^2+6*0.785*20^2//in sq mm
mprintf("Summary of design:\nColumn size - %d x %d
    mm\nSteel-main = 6-16 mm + 6-20 mm dia bars",D,b)
```

```
//answer in textbook is incorrect
```

Scilab code Exa 19.18 Design of Column with Biaxial Bending

```
b=300//in mm
Pu=1500//in kN
Mux=100//in kN-m
Muy=70//in kN-m
fck=15//in MPa
fy=250//in MPa
p=1.5//assume 1.5% steel , placed on four sides
Ag=Pu*10^3/(0.4*fck*(1-p/100)+0.67*fy*p/100)//in sq mm
D=Ag/b//in mm
D=600//assume , in mm
m=p/fck
c=60//cover (assume) , in mm
//to find Mux1
n=c/D//n=d'/D
l=Pu*10^3/fck/b/D
//referring to Fig.19.17 , for Pu/ fck/ b/ D = 0.56 and p/ fck = 0.1
f=0.038
Mux1=f*fck*b*D^2/10^6//in kN-m
//to find Muy1
b=600//in mm
D=300//in mm
n=c/D//n=d'/D
l=Pu*10^3/fck/b/D
//referring to Fig.19.19 , for Pu/ fck/ b/ D = 0.56 and p/ fck = 0.1
f=0.038
Muy1=f*fck*b*D^2/10^6//in kN-m
Puz=(0.45*fck*(1-p/100)*b*D+0.75*fy*p/100*b*D)/10^3//in kN
```

```
a=Pu/Puz//>0.8
an=2
r=(Mux/Mux1)^an+(Muy/Muy1)^an//>1
p=4//assume 4% steel , second trial
m=p/fck
//to find Mux1
b=300//in mm
D=600//in mm
//referring to Fig.19.17, for Pu/ fck/ b/ D = 0.56 and p/ fck = 0.26
f=0.15
Mux1=f*fck*b*D^2/10^6//in kN-m
//to find Muy1
b=600//in mm
D=300//in mm
n=c/D//n=d'/D
//referring to Fig.19.19, for Pu/ fck/ b/ D = 0.56 and p/ fck = 0.26
f=0.15
Muy1=f*fck*b*D^2/10^6//in kN-m
Puz=(0.45*fck*(1-p/100)*b*D+0.75*fy*p/100*b*D)/10^3 //in kN
a=Pu/Puz//<0.8
an=1+1/0.6*(a-0.2)
r=(Mux/Mux1)^an+(Muy/Muy1)^an//<1, hence OK
//but steel can be reduced
p=3//assume 3% steel , second trial
m=p/fck
//to find Mux1
b=300//in mm
D=600//in mm
//referring to Fig.19.17, for Pu/ fck/ b/ D = 0.56 and p/ fck = 0.2
f=0.12
Mux1=f*fck*b*D^2/10^6//in kN-m
//to find Muy1
b=600//in mm
D=300//in mm
```

```
n=c/D//n=d'/D
//referring to Fig.19.19, for Pu/ fck/ b/ D = 0.56 and p/ fck = 0.2
f=0.12
Muy1=f*fck*b*D^2/10^6//in kN-m
Puz=(0.45*fck*(1-p/100)*b*D+0.75*fy*p/100*b*D)/10^3 //in kN
a=Pu/Puz//<0.8
an=1+1/0.6*(a-0.2)
r=(Mux/Mux1)^an+(Muy/Muy1)^an//<1, hence OK
Asc=p/100*b*D//in sq mm
//provide 12-25 dia bars
Asc=12*0.785*25^2//in sq mm
mprintf("Summary of design:\nColumn size - %d x %d mm\nSteel-main = 12-25 mm dia bars",D,b)
```