

Scilab Textbook Companion for  
RCC Theory and Design  
by M. G. Shah and C. M. Kale<sup>1</sup>

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# Book Description

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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.

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# Chapter 1

## Singly Reinforced Sections

Scilab code Exa 1.1 Analysis of Singly Reinforced Section

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

---

Scilab code Exa 1.2 Analysis of Singly Reinforced Section

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

```

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

```

---

### Scilab code Exa 1.3 Analysis of Singly Reinforced Section

```

1 //assume d = 400 mm and b = 200 mm
2 b=200//in mm
3 d=400//in mm
4 sigma_cbc=5//in MPa
5 sigma_st=140//in MPa
6 m=18.66//modular ratio
7 Xc=d/(1+sigma_st/m/sigma_cbc)//in mm
8 z=d-Xc/3//in mm
9 Mr=b*Xc*sigma_cbc/2*z//in N-mm
10 Ast=b*Xc*sigma_cbc/2/sigma_st//in sq mm
11 pt=Ast*100/b/d//in %
12 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

```

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

```

---

#### Scilab code Exa 1.5 Analysis of Singly Reinforced Section

```

1 b=250//width, in mm
2 D=550//overall depth, in mm
3 Ast=1521//area of steel, in sq mm
4 cover=25//in mm
5 d=D-cover//effective depth, in mm
6 sigma_cbc=7//in MPa
7 sigma_st=140//in MPa
8 m=13.33//modular ratio
9 //to find critical depth of neutral axis
10 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
11 //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
12 p=b/2
13 q=m*Ast
14 r=-m*Ast*d
15 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
16 //x>Xc; hence beam is over-reinforced
17 Mr=b*x*sigma_cbc/2*(d-x/3)//in N-mm
18 mprintf("Moment of resistance of the beam=%f kN-m",
    Mr/10^6)

```

---

Scilab code Exa 1.6 Analysis of Singly Reinforced Section

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

---

Scilab code Exa 1.7 Analysis of Singly Reinforced Section

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

```

9 l=6//span, in m
10 w=25//unit weight of concrete, in kN/m^3
11 //to find critical depth of neutral axis
12 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
13 //to find actual depth of neutral axis using  $b(x^2)$ 
    /2= $mA_{st}(d-x)$ , which becomes of the form  $px^2+qx+r$ 
    =0
14 p=b/2
15 q=m*Ast
16 r=-m*Ast*d
17 //solving quadratic equation
18 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
19 //x<Xc, hence beam is under-reinforced
20 Mr=sigma_st*Ast*(d-x/3)//in N-mm
21 UDL=(Mr/10^6)*8/l^2//in kN/m
22 self_weight=w*b*D/10^6//in kN/m
23 net_weight=UDL-self_weight//in kN/m
24 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

```

1 b=250//width, in mm
2 D=500//overall depth, in mm
3 Ast=4*.785*22^2//four 22 mm dia bars, in sq mm
4 cover=25//in mm
5 d=D-cover//effective depth, in mm
6 l=5//effective span, in m
7 sigma_cbc=5//in MPa
8 sigma_st=190//in MPa
9 m=18.66//modular ratio
10 //to find critical depth of neutral axis
11 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
12 //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
13 p=b/2
14 q=m*Ast
15 r=-m*Ast*d
16 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
17 //as x>Xc, beam is over-reinforced
18 Mr=b*sigma_cbc*x/2*(d-x/3)//in N-mm
19 self_weight=25*(b/10^3)*(D/10^3)//in kN/m
20 M=Mr/10^6-self_weight*l^2/8//moment of resistance
    available for external load, in kN-m
21 W=4*M/l//in kN
22 mprintf("The concentrated load the beam can support
    at centre=%f kN",W)

```

---

### Scilab code Exa 1.9 Analysis of Singly Reinforced Section

```

1 d=120//effective depth of slab, in mm
2 //consider 1 m strip of slab
3 b=1000//in mm
4 s=80//spacing of 12mm dia bars centre-to-centre, in
    mm
5 Ast=1000*.785*12^2/s//in sq mm
6 l=3.2//span, in m
7 sigma_cbc=7//in MPa
8 sigma_st=140//in MPa
9 m=13.33//modular ratio
10 //to find critical depth of neutral axis
11 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
12 //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
13 p=b/2
14 q=m*Ast
15 r=-m*Ast*d

```



```

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

```

---

### Scilab code Exa 1.10 Analysis of Singly Reinforced Section

```

1 b=300//width, in mm
2 D=700//overall depth, in mm
3 Ast=4*.785*25^2//four 25mm dia bars, in sq mm
4 cover=30//in mm
5 d=D-cover//effective depth, in mm
6 M=130*10^6//bending moment, in N-mm
7 m=18.66//modular ratio
8 //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
9 p=b/2
10 q=m*Ast
11 r=-m*Ast*d
12 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
13 z=d-x/3//lever arm, in mm
14 //assuming under-reinforced section, Mr=Ast*sigma_st
  (d-x/3) and equating Mr to M
15 sigma_st=M/(Ast*z)//in MPa
16 sigma_st=116//round-off, in MPa
17 sigma_cbc=(sigma_st/m)*x/(d-x)//in MPa
18 sigma_cbc=5//round-off, in MPa
19 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

```
1 b=350//width, in mm
2 D=650//overall depth, in mm
3 Ast=4*.785*22^2//four 22mm dia bars, in sq mm
4 cover=25//in mm
5 d=D-cover//effective depth, in mm
6 W=20//UDL, in kN/m
7 l=7//span, in m
8 M=W*l^2/8*10^6//bending moment, in N-mm
9 m=13.33//modular ratio
10 //to find actual depth of neutral axis using  $b(x^2)$ 
    //  $=mAst(d-x)$ , which becomes of the form  $px^2+qx+r$ 
    // =0
11 p=b/2
12 q=m*Ast
13 r=-m*Ast*d
14 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
15 z=d-x/3//lever arm, in mm
16 //assuming under-reinforced section,  $M_r=Ast*\sigma_{st}$ 
    //(d-x/3) and equating  $M_r$  to M
17 sigma_st=M/(Ast*z)//in MPa
18 sigma_cbc=(sigma_st/m)*x/(d-x)//in MPa
19 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

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

```

5 M=75*10^6//bending moment, in N-mm
6 //critical depth of neutral axis,  $X_c=d/(1+\sigma_{st}/(m*\sigma_{cbc}))=a*d$ 
7 a=1/(1+sigma_st/(m*sigma_cbc))
8 d=(M/(b*sigma_cbc*a*(1-a/3)/2))^0.5//in mm
9 d=640//round-off, in mm
10 Xc=a*d//in mm
11 Ast=b*Xc*sigma_cbc/(2*sigma_st)//in sq mm
12 mprintf("Effective depth=%d mm\nArea of steel=%f mm
^2", round(d), Ast)

```

---

#### Scilab code Exa 1.13 Design of Singly Reinforced Section

```

1 //b=d/2 (given)
2 sigma_cbc=5//in MPa
3 sigma_st=140//in MPa
4 m=18.66//modular ratio
5 M=65*10^6//bending moment, in N-mm
6 //critical depth of neutral axis,  $X_c=d/(1+\sigma_{st}/(m*\sigma_{cbc}))=a*d$ 
7 a=1/(1+sigma_st/(m*sigma_cbc))
8 d=(M/(sigma_cbc*a*(1-a/3)/4))^(1/3)//in mm
9 d=530//round-off, in mm
10 Xc=a*d//in mm
11 b=d/2//in mm
12 Ast=M/sigma_st/0.87/d//in sq mm
13 Ast=1007//round-off, in sq mm
14 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

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

---

Scilab code Exa 2.2 Analysis of Doubly Reinforced Section

```

1 b=280//width, in mm
2 D=540//overall depth, in mm
3 Ast=5*0.785*22^2//five 22 mm dia bars on tension
   side, in sq mm
4 Asc=4*0.785*20^2//four 20 mm dia bars on compression
   side, in sq mm
5 bottom_cover=40//in mm
6 top_cover=30//in mm
7 sigma_cbc=5//in MPa
8 sigma_st=140//in MPa
9 m=18.66//modular ratio
10 d=D-bottom_cover//effective depth, in mm
11 //to find critical depth of neutral axis
12 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
13 //to find x using  $b(x^2)/2 + (1.5m-1)Asc(x-d') = mAst(d-x)$ , which becomes of the form  $px^2+qx+r=0$ 
14 p=b/2
15 q=(1.5*m-1)*Asc+m*Ast
16 r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
17 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
18 //as  $x < Xc$ , beam is under-reinforced
19 sigma_cbc=(sigma_st/m)*x/(d-x)//in MPa
20 sigma_cbc_dash=sigma_cbc*(x-top_cover)/x//in MPa
21 sigma_sc=1.5*m*sigma_cbc_dash//in MPa
22 //stress in compression steel is found to be less
   than its permissible limit of 130 N/mm2
23 Mr=b*x*sigma_cbc*(d-x/3)/2+(1.5*m-1)*Asc*
   sigma_cbc_dash*(d-top_cover)//in N-mm
24 mprintf("Moment of resistance of the beam=%f kN-m",
   Mr/10^6)

```

---

### Scilab code Exa 2.3 Analysis of Doubly Reinforced Section

```

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

```

```

3 Ast=1256//in sq mm
4 Asc=1256//in sq mm
5 top_cover=30//in mm
6 sigma_cbc=7//in MPa
7 sigma_st=190//in MPa
8 m=13.33//modular ratio
9 //using elastic theory method
10 //to find critical depth of neutral axis
11 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
12 //to find x using  $b(x^2)/2 + (1.5m-1)Asc(x-d') = mAst(d-x)$ , which becomes of the form  $px^2+qx+r=0$ 
13 p=b/2
14 q=(1.5*m-1)*Asc+m*Ast
15 r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
16 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
17 //as  $x < Xc$ , beam is under-reinforced
18 sigma_cbc=(sigma_st/m)*x/(d-x)//in MPa
19 sigma_cbc_dash=sigma_cbc*(x-top_cover)/x//in MPa
20 sigma_sc=1.5*m*sigma_cbc_dash//in MPa
21 //stress in compression steel is found to be less
    than its permissible limit of 130 N/mm2
22 Mr1=b*x*sigma_cbc*(d-x/3)/2+(1.5*m-1)*Asc*
    sigma_cbc_dash*(d-top_cover)//in N-mm
23 //using steel beam theory method
24 Mr2=Ast*sigma_st*(d-top_cover)//in N-mm
25 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

```

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

```

```

    side , in sq mm
4  Asc=3*0.785*22^2//three 22 mm dia bars on
    compression side , in sq mm
5  bottom_cover=50//in mm
6  top_cover=30//in mm
7  d=D-bottom_cover//effective depth , in mm
8  sigma_cbc=5//in MPa
9  sigma_st=140//in MPa
10 sigma_sc=130//in MPa
11 m=18.66//modular ratio
12 //to find critical depth of neutral axis
13 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
14 //to find x using  $b(x^2)/2 + (1.5m-1)Asc(x-d')=mAst(d-x)$ , which becomes of the form  $px^2+qx+r=0$ 
15 p=b/2
16 q=(1.5*m-1)*Asc+m*Ast
17 r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
18 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
19 //as  $x > Xc$ , beam is over-reinforced
20 sigma_cbc_dash=sigma_cbc*(x-top_cover)/x//in MPa
21 sigma_sc=1.5*m*sigma_cbc_dash//< 130 MPa, hence OK
22 //stress in compression steel is found to be less
    than its permissible limit of 130 N/mm2
23 Mr=b*x*sigma_cbc*(d-x/3)/2+(1.5*m-1)*Asc*
    sigma_cbc_dash*(d-top_cover)//in N-mm
24 mprintf("Moment of resistance of the beam=%f kN-m",
    Mr/10^6)

```

---

### Scilab code Exa 2.5 Analysis of Doubly Reinforced Section

```

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

```

```

5 top_cover=30//in mm
6 sigma_cbc=7//in MPa
7 sigma_st=140//in MPa
8 sigma_sc=130//in MPa
9 m=13.33//modular ratio
10 l=5.7//effective span, in m
11 //to find critical depth of neutral axis
12 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
13 //to find x using  $b(x^2)/2 + (1.5m-1)Asc(x-d')=mAst(d-x)$ , which becomes of the form  $px^2+qx+r=0$ 
14 p=b/2
15 q=(1.5*m-1)*Asc+m*Ast
16 r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
17 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
18 //as  $x < Xc$ , beam is under-reinforced
19 sigma_cbc=(sigma_st/m)*x/(d-x)//in MPa
20 sigma_cbc_dash=sigma_cbc*(x-top_cover)/x//in MPa
21 sigma_sc=1.5*m*sigma_cbc_dash//in MPa
22 //stress in compression steel is found to be less
    than its permissible limit of 130 N/mm2
23 Mr=b*x*sigma_cbc*(d-x/3)/2+(1.5*m-1)*Asc*
    sigma_cbc_dash*(d-top_cover)//in N-mm
24 W=(Mr/106)*8/12//in kN/m
25 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

```

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

```



```

6 top_cover=30//in mm
7 d=D-bottom_cover//effective depth, in mm
8 m=18.66//modular ratio
9 M=100*10^6//in N-mm
10 //to find x using  $b(x^2)/2 + (1.5m-1)Asc(x-d')=mAst(d-x)$ , which becomes of the form  $px^2+qx+r=0$ 
11 p=b/2
12 q=(1.5*m-1)*Asc+m*Ast
13 r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
14 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
15 //sigma_cbc_dash=sigma_cbc*(x-d')/x=a*sigma_cbc
16 a=(x-top_cover)/x
17 sigma_cbc=M/(b*x*(d-x/3)/2+(1.5*m-1)*Asc*a*(d-top_cover))//in MPa
18 sigma_st=m*sigma_cbc*(d-x)/x//in MPa
19 sigma_cbc_dash=a*sigma_cbc//in MPa
20 sigma_sc=1.5*m*sigma_cbc_dash//in MPa
21 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

```

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

```

```

11 r=-(1.5*m-1)*Asc*top_cover-m*Ast*d
12 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
13 //sigma_cbc_dash=sigma_cbc*(x-d')/x=a*sigma_cbc
14 a=(x-top_cover)/x
15 sigma_cbc=M/(b*x*(d-x/3)/2+(1.5*m-1)*Asc*a*(d-
    top_cover))//in MPa
16 sigma_st=m*sigma_cbc*(d-x)/x//in MPa
17 sigma_cbc_dash=a*sigma_cbc//in MPa
18 sigma_sc=1.5*m*sigma_cbc_dash//in MPa
19 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

```

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

```

```

20 Ast=Ast1+Ast2//in sq mm
21 //to find Asc
22 Asc=m*Ast2*(d-Xc)/((1.5*m-1)*(Xc-top_cover))//in sq
    mm
23 Asc=565//round-off, in sq mm
24 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

```

1 b=360//width, in mm
2 d=750//effective depth, in mm
3 top_cover=50//in mm
4 sigma_cbc=7//in MPa
5 sigma_st=190//in MPa
6 m=13.33//modular ratio
7 M=300*10^6//in N-mm
8 //to find critical depth of neutral axis
9 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
10 //to find Ast1
11 Ast1=b*Xc*sigma_cbc/(2*sigma_st)//in sq mm
12 Ast1=1638//round-off, in sq mm
13 Mr=b*Xc*sigma_cbc/2*(d-Xc/3)//moment of resistance
    of singly reinforced beam, in N-mm
14 M1=M-Mr//remaining bending moment, in N-mm
15 //to find Ast2
16 Ast2=M1/(sigma_st*(d-top_cover))//in sq mm
17 Ast=Ast1+Ast2//in sq mm
18 //to find Asc
19 Asc=m*Ast2*(d-Xc)/((1.5*m-1)*(Xc-top_cover))//in sq
    mm
20 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

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

---

Scilab code Exa 3.2 T beam

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

```

3 Df=100//thickness of flange , in mm
4 d=700//effective depth , in mm
5 m=18.66//modular ratio
6 Ast=8*0.785*25^2//eight 25 mm dia bars , in sq mm
7 //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  $px^2+qx+r=0$ 
8 p=Bf/2
9 q=m*Ast
10 r=-m*Ast*d
11 //solving quadratic equation
12 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
13 //x>Df; hence our assumption is incorrect; equating
  moments of area on compression and tension sides
  about N.A.
14 x=(m*Ast*d+Bf*Df^2/2)/(m*Ast+Bf*Df)//in mm
15 x=263//round-off , in mm
16 mprintf("Neutral axis depth=%d mm", x)

```

---

### Scilab code Exa 3.3 T beam

```

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

```

```

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

```

---

### Scilab code Exa 3.4 T beam

```

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

```

```

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

```

---

### Scilab code Exa 3.5 T beam

```

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

```

---

### Scilab code Exa 3.6 T beam

```

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

```

---

### Scilab code Exa 3.7 T beam

```

1 Bf=1200//width of flange , in mm
2 Bw=300//breadth of web, in mm
3 Df=120//thickness of flange , in mm
4 d=500//effective depth , in mm
5 sigma_cbc=7//in MPa
6 sigma_st=190//in MPa
7 m=13.33//modular ratio
8 Ast=5*0.785*20^2//five 20 mm dia bars , in sq mm
9 l=6//span , in m
10 //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  $px^2+qx+r=0$ 
11 p=Bf/2
12 q=m*Ast
13 r=-m*Ast*d
14 //solving quadratic equation
15 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
16 //x < Df; hence our assumption is correct
17 //to find critical depth of neutral axis
18 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
19 //as x<Xc, beam is under-reinforced
20 sigma_cbc=sigma_st/m*x/(d-x)//in MPa
21 //taking moments about tensile steel
22 Mr=Bf*x*sigma_cbc*(d-x/3)/2//in N-mm
23 W=(Mr/10^6)*8/1^2//in kN/m
24 printf("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

```

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

```

```

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

```

---

### Scilab code Exa 3.9 T beam

```

1 Bf=1250//width of flange , in mm
2 Df=120//thickness of flange , in mm
3 d=700//effective depth , in mm
4 m=13.33//modular ratio
5 Ast=5500//in sq mm
6 W=60//UDL including self-weight , in kN/m
7 l=8//span , in m
8 M=W*l^2/8*10^6//in N-mm
9 //Assume x>Df. Equating moments of area on
    compressiona and tension sides about N.A.
10 x=(m*Ast*d+Bf*Df^2/2)/(m*Ast+Bf*Df)//in mm
11 //let sigma_cbc_dash=a*sigma_cbc
12 a=(x-Df)/x
13 //to find lever arm
14 z=d-(1+2*a)/(1+a)*Df/3//in mm
15 sigma_cbc=2*M/(Bf*Df*(1+a)*z)//in MPa
16 sigma_st=m*sigma_cbc*(d-x)/x//in MPa
17 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

```

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

```

```

5 sigma_st=275//in MPa
6 m=18.66//modular ratio
7 Ast=1570//in sq mm
8 Asc=1256//in sq mm
9 top_cover=30//in mm
10 //to find critical depth of neutral axis
11 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
12 //assume x>Df; equating moments of area on
    compression and tension sides about N.A.
13 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
14 //as x<Xc, beam is under-reinforced
15 sigma_cbc=sigma_st/m*x/(d-x)//in MPa
16 sigma_cbc_dash=sigma_cbc*(x-top_cover)/x//stress in
    concrete at level of compression steel, in MPa
17 sigma_cbc_double_dash=sigma_cbc*(x-Df)/x//stress in
    concrete at the underside of the slab, in MPa
18 //to find lever arm
19 z=round(d-(sigma_cbc+2*sigma_cbc_double_dash)/(
    sigma_cbc+sigma_cbc_double_dash)*Df/3)//in mm
20 //taking moments about tensile steel
21 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
22 mprintf("Moment of resistance of the beam=%f kN-m",
    Mr/10^6)

```

---

### Scilab code Exa 3.11 T beam

```

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

```

```

8 Asc=1140//in sq mm
9 top_cover=50//in mm
10 //to find critical depth of neutral axis
11 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
12 //assume x>Df; equating moments of area on
    compression and tension sides about N.A.
13 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
14 //we find that x<Df, hence our assumption that x>Df
    is wrong
15 //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
16 p=Bf/2
17 q=m*Ast+(1.5*m-1)*Asc
18 r=-(m*Ast*d+(1.5*m-1)*Asc*top_cover)
19 //solving quadratic equation
20 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
21 //as x<Xc, beam is under-reinforced
22 sigma_cbc=sigma_st/m*x/(d-x)//in MPa
23 sigma_cbc_dash=sigma_cbc*(x-top_cover)/x//stress in
    concrete at level of compression steel, in MPa
24 //taking moments about tensile steel
25 Mr=Bf*x*sigma_cbc*(d-x/3)/2+(1.5*m-1)*Asc*
    sigma_cbc_dash*(d-top_cover)//in N-mm
26 mprintf("Moment of resistance of the beam=%f kN-m",
    Mr/10^6)
27 //answer given in textbook is incorrect

```

---

### Scilab code Exa 3.12 T beam

```

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

```

```

6 Asc=450//in sq mm
7 top_cover=30//in mm
8 M=200*10^6//in N-mm
9 //assume x>Df; equating moments of area on
    compression and tension sides about N.A.
10 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
11 //we find that x<Df, hence our assumption that x>Df
    is wrong
12 //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
13 p=Bf/2
14 q=m*Ast+(1.5*m-1)*Asc
15 r=-(m*Ast*d+(1.5*m-1)*Asc*top_cover)
16 //solving quadratic equation
17 x=(-q+sqrt(q^2-4*p*r))/(2*p)//in mm
18 //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
19 a=(x-top_cover)/x
20 //taking moments about tensile steel
21 sigma_cbc=M/(Bf*x*(d-x/3)/2+(1.5*m-1)*Asc*a*(d-
    top_cover))//in MPa
22 sigma_st=m*sigma_cbc*(d-x)/x//in MPa
23 sigma_sc=1.5*m*a*sigma_cbc//in MPa
24 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)
25 //answer in textbook is incorrect

```

---

### Scilab code Exa 3.13 L beam

```

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

```

```

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

```

---

#### Scilab code Exa 3.14 L beam

```

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

```

```

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

```

---

### Scilab code Exa 3.15 L beam

```

1 Df=120//thickness of flange, in mm
2 Bw=200//breadth of web, in mm
3 d=550//effective depth, in mm
4 l=6//span, in m
5 Bf=1*1000/12+Bw+3*Df//in mm
6 m=13.33//modular ratio
7 Ast=3200//in sq mm
8 M=190*10^6//in N-mm
9 //assume x>Df; equating moments of area on
   compression and tension sides about N.A.
10 x=(m*Ast*d+Bf*Df^2/2)/(m*Ast+Bf*Df)//in mm
11 //we find that x>Df, hence our assumption that x>Df
   is correct
12 //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
13 a=(x-Df)/x
14 //to find lever arm
15 z=d-(1+2*a)/(1+a)*Df/3//in mm
16 z=500//round-off, in mm
17 //taking moments about tensile steel
18 sigma_cbc=M/(Bf*Df*(1+a)*z/2)//in MPa
19 sigma_st=m*sigma_cbc*(d-x)/x//in MPa
20 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

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

---

### Scilab code Exa 4.2 Shear

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



```

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

```

---

#### Scilab code Exa 4.3 Shear

```

1 b=300//width , in mm
2 d=600//effective depth , in mm
3 W=100//UDL including self-weight , in kN/m
4 Pt=2//percentage tensile steel
5 l=7.2//span , in m
6 sigma_cbc=7//in MPa
7 sigma_st=190//in MPa
8 m=13.33//modular ratio
9 V=W*l/2//in kN
10 Tv=(V*10^3)/(b*d)//in MPa
11 Tcmax=1.8//in MPa
12 //as Tv>Tcmax, section is to be redesigned so that
    Tv becomes less than Tcmax
13 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

```

1 b=1000//consider 1 m width of slab
2 D=100//depth of slab , in mm
3 cover=20//in mm
4 d=D-cover//effective depth , in mm
5 W=7//uniformly distributed load , in kN/m^2
6 dia=10//in mm
7 s=100//spacing of 10 mm dia bars , in mm
8 l=4//span , in m
9 V=W*l/2//in kN
10 Pt=1000*.785*dia^2/(s*b*d)*100//in %
11 Tv=(V*10^3)/(b*d)//in MPa
12 //for given Pt and M15 grade concrete
13 Tc=0.37//in MPa
14 //and for solid slabs
15 k=1.3
16 Tc=k*Tc//in MPa
17 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

```

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

```

```

14 //for given Pt and for M15 grade concrete
15 Tc=0.34//in MPa
16 Vs=V-Tc*b*d/10^3//in kN
17 //providing 6 mm dia stirrups
18 dia=6//in mm
19 Asv=2*0.785*dia^2//in sq mm
20 Sv1=Asv*sigma_sv*d/(Vs*10^3)//in mm
21 Sv1=145//round-off , in mm
22 //Sv<0.75d or 450 mm, whichever is less; hence OK
23 //calculating minimum spacing of shear reinforcement
24 Sv2=Asv*Fy/(b*0.4)//in mm
25 Sv2=118//round-off , in mm
26 Sv=min(Sv1,Sv2)
27 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

```

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

```

```

17 //for given Pt and for M15 grade concrete
18 Tc=0.44//in MPa
19 Vs=V-Tc*b*d/10^3//in kN
20 //providing bent-up bars
21 Asv=0.785*22^2//in sq mm
22 Vs1=Asv*sigma_sv*sind(45)/10^3//in kN
23 //but shear taken up by bent-up bar is limited to Vs
    /2
24 Vs1=Vs/2//in kN
25 //providing 6 mm dia stirrups , which will take up
    remaining shear force
26 Vs2=Vs-Vs1//in kN
27 dia=6//in mm
28 Asv=2*0.785*dia^2//in sq mm
29 Sv=Asv*sigma_sv*d/(Vs2*10^3)//in mm
30 Sv1=105//round-off , in mm
31 //Sv<0.75d or 450 mm, whichever is less; hence OK
32 //calculating minimum spacing of shear reinforcement
33 Sv2=Asv*Fy/(b*0.4)//in mm
34 Sv2=260//round-off , in mm
35 //to calculate distance 'x' from support where shear
    stress in concrete is equal to Tc
36 x=Tc/Tv*1/2//in m
37 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,(1/2-x),
    Sv2)

```

---

#### Scilab code Exa 4.7 Development Length

```

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

```

```

6 cover=15//in mm
7 R=W*Lef/2//in kN
8 M=(R*s/2-W*s^2/2)*10^6//bending moment at face of
    wall, in N-mm
9 //10 mm dia bars at 145 mm c/c as main steel
10 dia=10//in mm
11 c=145//spacing of reinforcement, in mm
12 Ast=1000*0.785*dia^2/c//in sq mm
13 //as alternate bars are bent up
14 Ast=Ast/2//available steel reinforcement at face of
    wall, in sq mm
15 d=D-10/2-cover//in mm
16 //assuming balanced section
17 z=0.87*d//in mm
18 sigma_st=M/(Ast*z)//in MPa
19 Tbd=0.6//bond stress, in MPa
20 Ld=dia*sigma_st/(4*Tbd)//in mm
21 Ld=177//round-off, in mm
22 mprintf("Development length required from the face
    of the support = %d mm",Ld)
23 //answer given in textbook is incorrect

```

---

#### Scilab code Exa 4.8 Development Length

```

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

```

```

10 sigma_cbc=5//in MPa
11 sigma_st=230//in MPa
12 m=18.66//modular ratio
13 R=W*l/2//in kN
14 M=(R*s/2-W*s^2/2)*10^6//bending moment at face of
    wall, in N-mm
15 //assuming balanced section
16 z=0.87*d//in mm
17 sigma_st1=M/(Ast*z)//in MPa
18 Tbd=0.6*1.4//bond stress in MPa for deformed steel
    and M15
19 Ld1=dia*sigma_st1/(4*Tbd)//in mm
20 //to find critical depth of neutral axis
21 Xc=d/(1+sigma_st/(m*sigma_cbc))//in mm
22 Xc=144//round-off, in mm
23 //at face of support
24 sigma_cbc=sigma_st1/m*Xc/(d-Xc)//in MPa
25 sigma_sc=1.5*m*sigma_cbc//in MPa
26 Tbd=1.68//bond stress in MPa for M15 and deformed
    steel in compression
27 Ld2=dia*sigma_sc/(4*Tbd)//in mm
28 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

```

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

```

```

8  sigma_st=140//in MPa
9  m=18.66//modular ratio
10 W2=(D/10^3)*1*25//self load , in kN/m
11 W=W1+W2//in kN/m
12 M=W*1^2/2*10^6//bending moment at face of wall , in N
    -mm
13 //10 mm dia bars at 145 mm c/c as main steel
14 dia=10//in mm
15 d=D-dia/2-cover
16 c=100//spacing of reinforcement , in mm
17 Ast=1000*0.785*dia^2/c//in sq mm
18 //assuming balanced section
19 z=0.87*d//in mm
20 sigma_st=M/(Ast*z)//in MPa
21 Tbd=0.6//bond stress in MPa
22 Ld=dia*sigma_st/(4*Tbd)//in mm
23 Ld=412//round-off , in mm
24 mprintf("Development length required from the face
    of the support = %d mm",Ld)

```

---

# Chapter 5

## Columns

### Scilab code Exa 5.1 Short Column

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

---

### Scilab code Exa 5.2 Short Column

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



```

6 Ag=b*D//in sq mm
7 Ac=Ag-Asc//in sq mm
8 P=sigma_cc*Ac+sigma_sc*Asc//in N
9 mprintf("Permissible load on the column = %f kN\n",
    P/10^3)
10 //design of links
11 dia=20/4//in mm
12 //as this is less than 6
13 dia=6//in mm
14 //spacing of links
15 s1=b//in mm
16 s2=16*20//in mm
17 s3=48*dia//in mm
18 s=min(s1,s2,s3)
19 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)
20 Pc=Asc*100/(b*D)//percentage steel
21 mprintf("Percentage of steel is in between 0.8 to 4
    as prescribed by IS code")

```

---

### Scilab code Exa 5.3 Short Column

```

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

```

```

9 n=round(Asc/(0.785*25^2))
10 mprintf("Provide %d no. 25 mm dia bars\n", n)
11 //design of links
12 dia=20/4//in mm
13 //provide 8 mm dia links (available as per market
    size)
14 dia=8//in mm
15 //spacing of links
16 s1=b//in mm
17 s2=16*25//in mm
18 s3=48*dia//in mm
19 s=min(s1,s2,s3)
20 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

```

1 sigma_cc=4//in MPa
2 sigma_sc=130//in MPa
3 Asc=6*0.785*12^2//six 12 mm dia bars, in sq mm
4 D=200//dia of column, in mm
5 Ag=0.785*D^2//in sq mm
6 Ac=Ag-Asc//in sq mm
7 P=sigma_cc*Ac+sigma_sc*Asc//in N
8 dia=6//dia of links used, in mm
9 //spacing of links
10 s1=D//in mm
11 s2=16*12//in mm
12 s3=48*dia//in mm
13 s=min(s1,s2,s3)
14 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<sup>3</sup>, dia,D,16\*12, 48\*dia,s,s)

---

### Scilab code Exa 5.5 Short Column with Helical Bending

```

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

```

---

### Scilab code Exa 5.6 Long Column

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

---

### Scilab code Exa 5.7 Long Column

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

```

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

```

---

### Scilab code Exa 5.8 Design of column

```

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

```

```

28 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)
29 //Method II-same section
30 b=400//in mm
31 Ag=b^2//in sq mm
32 Cr=1.25-Lef*1000/(48*b)//reduction coefficient
33 sigma_cc=Cr*sigma_cc//in MPa
34 sigma_sc=Cr*sigma_sc//in MPa
35 Asc=(P*1000-sigma_cc*Ag)/(sigma_sc-sigma_cc)//in MPa
36 n=round(Asc/(%pi/4*20^2))//no. of bars
37 //design of links
38 dia=1/4*20//in mm
39 //as dia < 6 mm, provide 6 mm diameter links
40 dia=6//in mm
41 spacing=min(b,16*20,48*dia,300)//in mm
42 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

```

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

```

```

14 sigma_sc=Cr*sigma_sc//in MPa
15 Asc=(P*1000-sigma_cc*Ag)/(sigma_sc-sigma_cc)//in sq
    mm
16 //assume 18 mm dia bars
17 n=Asc/(%pi/4*18^2)//no. of bars
18 n=4//round-off
19 //design of links
20 dia=1/4*20//in mm
21 //as dia < 6 mm, provide 6 mm diameter links
22 dia=6//in mm
23 spacing=min(b,16*20,48*dia,300)//in mm
24 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

```

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

```

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

---

### Scilab code Exa 5.11 Eccentrically Loaded Column

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

---



### Scilab code Exa 5.12 Cracked Section

```
1 b=450//width, in mm
2 D=900//depth, in mm
3 c=80//cover, in mm
4 d=D-c//in mm
5 Asc=4000//in sq mm
6 Ast=Asc//in sq mm
7 P=500//in kN
8 e=600//in mm
9 m=18.66
10 //equation for x is:  $x^2 + (k1 - k2 / \sigma_{cbc\_dash}) x - k3 = 0$ 
11 k1=2/b*((1.5*m-1)*Asc+m*Ast)
12 k2=2*P*10^3/b
13 k3=2/b*(c*(1.5*m-1)*Asc+d*m*Ast)
14 //equation for sigma_cbc_dash is:  $\sigma_{cbc\_dash} = \frac{Q1 x}{(Q2 x^2 (d - x/3) + Q3 (x - c))}$ 
15 Q1=P*10^3*(e+d-D/2)
16 Q2=b/2
17 Q3=(1.5*m-1)*(d-c)*Asc
18 sigma_cbc_dash=7//assume, in MPa
19 //solving equation for x
20 p=1
21 q=(k1-k2/sigma_cbc_dash)
22 r=-k3
23 x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
24 sigma_cbc_dash = Q1*x/(Q2*x^2*(d-x/3)+Q3*(x-c))//in
    MPa
25 //this process is repeated till convergence
26 //solving equation for x
27 p=1
28 q=(k1-k2/sigma_cbc_dash)
29 r=-k3
```

```

30 x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
31 sigma_cbc_dash = Q1*x/(Q2*x^2*(d-x/3)+Q3*(x-c))//in
    MPa
32 //solving equation for x
33 p=1
34 q=(k1-k2/sigma_cbc_dash)
35 r=-k3
36 x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
37 sigma_cbc_dash = Q1*x/(Q2*x^2*(d-x/3)+Q3*(x-c))//in
    MPa
38 //solving equation for x
39 p=1
40 q=(k1-k2/sigma_cbc_dash)
41 r=-k3
42 x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
43 sigma_cbc_dash = Q1*x/(Q2*x^2*(d-x/3)+Q3*(x-c))//in
    MPa
44 //solving equation for x
45 p=1
46 q=(k1-k2/sigma_cbc_dash)
47 r=-k3
48 x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
49 sigma_cbc_dash = Q1*x/(Q2*x^2*(d-x/3)+Q3*(x-c))//in
    MPa
50 //solving equation for x
51 p=1
52 q=(k1-k2/sigma_cbc_dash)
53 r=-k3
54 x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
55 sigma_sc=m*sigma_cbc_dash*(x-c)/x//in MPa
56 sigma_st=m*sigma_cbc_dash*x/(d-x)//in MPa
57 //answer in textbook is incorrect

```

---

# Chapter 7

## Slab Design One Way

Scilab code Exa 7.1 Design of One Way Simply Supported Slab

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

```

21 self_weight=25*(D/10^3)//in kN/m
22 finish=1//in kN/m
23 live_load=2//in kN/m
24 W=self_weight+finish+live_load//total load, in kN/m
25 lef=l+D/1000//in m
26 M=W*lef^2/8//in kN-m
27 //check for depth
28 d=round((M*10^6/(0.87*1000))^0.5)//in mm
29 D=d+12/2+15//in mm
30 Ast=round(M*10^6/(sigma_st*0.87*d))//in sq mm
31 s1=1000*0.785*12^2/Ast//which is less than 3d= 387
    mm
32 s1=120//approximately, in mm
33 Ads=0.15/100*1000*D//distribution steel, in sq mm
34 //assume 8 mm dia bars
35 s2=1000*0.785*8^2/Ads//which is less than 5d= 645 mm
36 s2=220//approximately, in mm
37 //to calculate development length
38 w=0.345//support width, in m
39 lef=l+w//in m
40 R=W*lef/2//reaction at support, in kN
41 M1=R*w/2-W*w^2/2//bending moment at the face of wall
    , in kN-m
42 sigma_st=M1*10^6/(Ast/2*0.87*d)//in MPa
43 Tbd=0.6//in MPa
44 Ld=12*sigma_st/(4*Tbd)//in mm
45 La=w*1000-25//available length for bar over wall,
    which is greater than development length
46 //check for shear
47 V=W*4.15/2//in kN
48 Tv=V*10^3/(1000*d)//in MPa
49 Tc=0.33//permissible shear in concrete for p=0.71
    and M15, in MPa
50 Tc=1.3*Tc//permissible shear for slabs, in MPa
51 //Tc>Tv; hence no shear reinforcement is required
52 printf("Summary of design\nSlab thickness=%d mm\n
    nCover=15 mm\nMain steel = 12 mm dia @ %d mm c/c\n
    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

```

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

```

```

28 W=self_weight+finish+partitions+live_load//total
    load , in kN/m
29 lef=l+D/1000//in m
30 M=W*lef^2/8//in kN-m
31 //check for depth
32 d=round((M*10^6/(0.9*sigma_cbc/2*0.29*1000))^0.5)//
    in mm
33 D=d+12/2+15//in mm
34 D=250//approximately , in mm
35 Ast=round(M*10^6/(sigma_st*0.9*d))//in sq mm
36 s1=1000*0.785*12^2/Ast//which is less than 3d= 690
    mm
37 s1=155//approximately , in mm
38 pt=Ast/1000/d*100//in %
39 Ads=0.12/100*1000*D//distribution steel , in sq mm
40 //assume 8 mm dia bars
41 s2=1000*0.785*8^2/Ads//which is less than 5d= 1150
    mm
42 s2=165//approximately , in mm
43 //to calculate development length
44 w=0.23//support width , in m
45 l=1+w//in m
46 R=W*l/2//reaction at support , in kN
47 M1=R*w/2-W*w^2/2//bending moment at the face of wall
    , in kN-m
48 sigma_st=M1*10^6/(Ast/2*0.9*d)//in MPa
49 Tbd=0.6//in MPa
50 Ld=12*sigma_st/(4*Tbd)//in mm
51 La=w*1000-25//available length for bar over wall ,
    which is greater than development length
52 //check for shear
53 V=W*lef/2//in kN
54 Tv=V*10^3/(1000*d)//in MPa
55 Tc=0.2212//permissible shear in concrete for p=0.315
    and M15, in MPa
56 Tc=1.15*Tc//permissible shear for slabs , in MPa
57 //Tc>Tv; hence no shear reinforcement is required
58 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

```

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

```

```

27 M1=Wd*lef^2/12+Wl*lef^2/10//bending moment at mid-
    span , in kN-m
28 M2=Wd*lef^2/10+Wl*lef^2/9//bending moment at support
    next to end support , in kN-m
29 //check for depth
30 d=round((M2*10^6/(0.9*sigma_cbc/2*0.29*1000))^0.5)//
    in mm
31 D=d+12/2+15//<210, hence OK
32 D=200//assume, in mm
33 d=D-dia/2-15//in mm
34 //main steel at mid-span
35 Ast1=round(M1*10^6/(sigma_st*0.91*d))//in sq mm
36 s1=1000*0.785*12^2/Ast1//in mm
37 s1=175//approximately, in mm
38 //main steel at support
39 Ast2=round(M2*10^6/(sigma_st*0.91*d))//in sq mm
40 //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
41 Ast2=Ast2-Ast1//which is nominal, hence no separate
    steel is required
42 Ads=0.12/100*1000*D//distribution steel, in sq mm
43 //assume 8 mm dia bars
44 s2=1000*0.785*8^2/Ads//in mm
45 s2=200//approximately, in mm
46 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)
47 //answer given in textbook is incorrect

```

---

#### Scilab code Exa 7.4 Design of Cantilever Chajja

```

1 sigma_cbc=5//in MPa

```



```

2  sigma_st=230//in MPa
3  MF=1.4//modification factor
4  //let a be span to depth ratio
5  l=1//span, in m
6  a=MF*7
7  D=l*1000/a//in mm
8  D=105//assume, in mm
9  //to calculate loading
10 self_weight=25*(D/10^3)*1.5//in kN/m
11 finish=0.5*1.5//in kN/m
12 live_load=0.75*1.5//in kN/m
13 W=self_weight+finish+live_load//in kN/m
14 lef=l+0.23/2//effective span, in m
15 M=W*lef/2//in kN-m
16 //check for depth
17 d=(M*10^6/(0.65*1500))^0.5//in mm
18 dia=12//assume 12 mm dia bars
19 D=d+12/2+15//<105, hence OK
20 D=100//assume, in mm
21 d=D-dia/2-15//in mm
22 //main steel at mid-span
23 Ast=M*10^6/(sigma_st*0.9*d)//in sq mm
24 s1=1500*0.785*12^2/Ast//>3d = 237 mm
25 s1=235//assume, in mm
26 Ads=0.12/100*1000*D//distribution steel, in sq mm
27 //assume 6 mm dia bars
28 s2=1000*0.785*6^2/Ads//in mm
29 s2=235//assume, in mm
30 Tbd=0.84//in MPa
31 Ld=dia*sigma_st/4/Tbd// in mm
32 Ld=821//round-off, in mm
33 Tv=W*10^3/1500/d//in MPa
34 As=1500*0.785*12^2/235//in sq mm
35 pt=As/1500/d*100//in %
36 Tc=0.316//in MPa
37 //as Tc>Tv, no shear reinforcement required
38 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

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

```

20 d=D-dia/2-15//in mm
21 //steel - short span
22 z=0.87*d//in mm
23 Ast=Mx*10^6/sigma_st/z//in sq mm
24 s1=1000*0.785*dia^2/Ast//in mm
25 s1=200//assume, in mm
26 //long span
27 d=d-dia/2-dia/2//in mm
28 Ast=My*10^6/sigma_st/0.87/d//in sq mm
29 s2=1000*0.785*dia^2/Ast//>3d = 210 mm
30 s2=210//assume, in mm
31 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 1/7 from support
in both directions",D,s1,s2)

```

---

### Scilab code Exa 8.2 Design of Two Way Continuous Slab

```

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

```

```

16 Ay=0.043
17 Mx1=Ax*W*lx^2//in kN-m
18 My1=Ay*W*lx^2//in kN-m
19 //at support
20 Ay=0.057
21 Ms=Ay*W*lx^2//in kN-m
22 //for panel II
23 //at mid-span
24 Ax=0.0403
25 Ay=0.035
26 Mx2=Ax*W*lx^2//in kN-m
27 My2=Ay*W*lx^2//in kN-m
28 //at support
29 Ay=0.045//<0.057, hence not considered
30 d=sqrt(Ms*10^6/0.65/10^3)//in mm
31 d=80//assume, in mm
32 //assume 10 mm dia bars
33 dia=10//in mm
34 D=d+dia/2+15
35 //steel at centre
36 //for panels I and III
37 //short span
38 z=0.9*d//in mm
39 Ast=Mx1*10^6/sigma_st/z//in sq mm
40 s1=1000*0.785*dia^2/Ast//>3d
41 //long span
42 Ast=My1*10^6/sigma_st/z//in sq mm
43 s2=1000*0.785*dia^2/Ast//>3d
44 //for panel II
45 //short span
46 Ast=Mx2*10^6/sigma_st/z//in sq mm
47 s3=1000*0.785*dia^2/Ast//>3d
48 //long span
49 Ast=My2*10^6/sigma_st/z//in sq mm
50 s3=1000*0.785*dia^2/Ast//>3d
51 //steel at support
52 Ast=Ms*10^6/sigma_st/z//in sq mm
53 s4=1000*0.785*dia^2/Ast//>3d

```

```

54 s=3*d//maximum spacing of bars in both directions as
    per IS 456, in mm
55 Ast=1000*0.785*dia^2/s//in sq mm
56 pt=Ast/10^3/d*100//in %
57 //steel for torsion, provide 6 mm dia bars
58 //(i)at outer corner of slab
59 At1=3/4*Ast//in sq mm
60 l=lx/5//in m
61 s5=750*0.785*6^2/At1//in mm
62 s5=85//assume, in mm
63 //(ii)at continuous support
64 At2=At1/2//in sq mm
65 s6=750*0.785*6^2/At2//in mm
66 s6=170//assume, in mm
67 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

```

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

```

```

12 a=ly/lx
13 //panels I, II, V and VI belong to case 4 and panels
    III and IV belong to case 3
14 //for panels I, II, V and VI
15 //at mid-span
16 Ax=0.043
17 Ay=0.035
18 Mxm1=Ax*W*lx^2//in kN-m
19 Mym1=Ay*W*lx^2//in kN-m
20 //at support
21 Ax=0.058
22 Ay=0.047
23 Mxs1=Ax*W*lx^2//in kN-m
24 Mys1=Ay*W*lx^2//in kN-m
25 //for panels III and IV
26 //at mid-span
27 Ax=0.036
28 Ay=0.028
29 Mxm2=Ax*W*lx^2//in kN-m
30 Mym2=Ay*W*lx^2//in kN-m
31 //at support
32 Ax=0.047
33 Ay=0.037//<0.047, hence will not be considered
34 Mxs2=Ax*W*lx^2//in kN-m
35 //check for depth
36 M=max(Mxm1,Mym1,Mxs1,Mys1,Mxm2,Mym2,Mxs2)//in kN-m
37 d=sqrt(M*10^6/0.81/10^3)//in mm
38 d=170//assume, in mm
39 //assume 10 mm dia bars
40 dia=10//in mm
41 D=d+dia/2+15//>180 mm assumed value
42 D=190//in mm
43 d=D-dia/2-15//in mm
44 //main steel-short span
45 //for panels I, II, V and VI-at mid-span
46 z=0.92*d//in mm
47 Astm=Mxm1*10^6/sigma_st/z//in sq mm
48 s1=1000*0.785*dia^2/Astm//in mm

```

```

49 s1=195//assume, in mm
50 //at support
51 Ast=Mxs1*10^6/sigma_st/z//in sq mm
52 Astr=Ast-Astm//balance steel required at support, in
    sq mm
53 s2=1000*0.785*dia^2/Astr//in mm
54 s2=565//assume, in mm
55 //for panels III and IV-at mid-span
56 Astm=Mxm2*10^6/sigma_st/z//in sq mm
57 s3=1000*0.785*dia^2/Astm//in mm
58 s3=235//assume, in mm
59 //at support
60 Ast=Mxs2*10^6/sigma_st/z//in sq mm
61 Astr=Ast-Astm//balance steel required at support, in
    sq mm
62 s4=1000*0.785*dia^2/Astr//in mm
63 s4=775//assume, in mm
64 //long span
65 //at mid-span
66 //for panels I, II, V and VI
67 Astm1=Mym1*10^6/sigma_st/z//in sq mm
68 s5=1000*0.785*dia^2/Astm1//in mm
69 s5=240//assume, in mm
70 //for panels III and IV
71 Astm2=Mym2*10^6/sigma_st/z//in sq mm
72 s6=1000*0.785*dia^2/Astm2//in mm
73 s6=300//assume, in mm
74 //at support
75 //for panels I, II, V and VI
76 Ast=Mys1*10^6/sigma_st/z//in sq mm
77 Astr=Ast-Astm1/2-Astm2/2//balance steel required at
    support, in sq mm
78 s7=1000*0.785*dia^2/Astr//in mm
79 s7=550//assume, in mm
80 //steel for torsion, provide 6 mm dia bars
81 //(i)at outside corners of slab
82 Ast=Mxm1*10^6/sigma_st/z//in sq mm
83 At1=3/4*Ast//in sq mm

```



```

84 l=lx/5//in m
85 s8=1*10^3*0.785*6^2/At1//in mm
86 s8=110//assume, in mm
87 //(ii)at continuous support
88 At2=At1/2//in sq mm
89 s9=1*10^3*0.785*6^2/At2//in mm
90 s9=225//assume, in mm
91 mprintf("Summary of design\nSlab thickness=%d mm\n
    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\n
    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)
92 //answer in textbook is incorrect

```

---

# Chapter 9

## Beam Design

Scilab code Exa 9.1 Design of Lintel Beam

```
1 l=3//span, in m
2 b=225//wall thickness, in mm
3 Dm=19.2//weight of masonry, in kN/cu m
4 sigma_cbc=5//in MPa
5 sigma_st=230//in MPa
6 fy=415//in MPa
7 //area of triangle of brick masonry
8 A=sqrt(3)/4*l^2//in sq m
9 V=A*(b/10^3)//volume of triangle of masonry, in cu m
10 W=V*Dm//weight of masonry, in kN
11 M1=W*l/6//in kN-m
12 D=1*10^3/12//in mm
13 D=300//approximately, in mm
14 self_weight=25*(D/10^3)*(b/10^3)//in kN/m
15 M2=self_weight*l^2/8//in kN-m
16 M=M1+M2//in kN-m
17 //check for depth
18 d=sqrt(M*10^6/0.65/b)//in mm
19 d=265//approximately, in mm
20 dia=10//in mm
21 D=d+dia/2+25//<300 mm, hence OK
```

```

22 D=300 //in mm
23 Ast=M*10^6/sigma_st/0.9/d//in sq mm
24 n=Ast/0.785/10^2//no. of 10 mm dia bars required
25 //provide 2-10 mm dia + 1-8 mm dia bars
26 Ast=2*0.785*10^2+0.785*8^2//in sq mm
27 pt=Ast/b/d*100//pt=0.35, approximately
28 W=W+self_weight*1//in kN
29 V=W/2//in kN
30 Tv=V*10^3/b/d//in MPa
31 //for M15 grade concrete and pt=0.35
32 Tc=0.248//in MPa
33 //as Tc>Tv, no shear reinforcement required; provide
    nominal stirrups
34 //provide 6 mm dia bars
35 Asv=2*0.785*6^2//in sq mm
36 Sv=Asv*fy/0.4/b//in mm
37 Sv=260//approximately, in mm
38 Svmax=0.75*d//in mm
39 Svmax=200//approximately, in mm
40 Sv=min(Sv,Svmax)//in mm
41 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

```

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

```

```

9 W2=6//load on beam, in kN/m
10 W=W1+W2//in kN/m
11 M=W*1^2/8//in kN-m
12 dia=12//in mm
13 d=D-dia/2-25//in mm
14 Xc=0.29*d//in mm
15 Mr=0.65*b*d^2/10^6//Mr, hence doubly reinforced
    beam
16 Ast1=round(Mr*10^6/sigma_st/0.9/d)//steel required
    for singly reinforced beam, in sq mm
17 M1=M-Mr//balance of moment, in kN-m
18 d1=25//top cover, in mm
19 Ast2=round(M1*10^6/sigma_st/(d-d1))//in sq mm
20 Ast=Ast1+Ast2//in sq mm
21 n1=Ast/0.785/12^2//no. of 12 mm dia bars on tension
    side
22 n1=3//assume
23 Asc=m*Ast2*(d-Xc)/(1.5*m-1)/(Xc-d1)//in sq mm
24 n2=Asc/0.785/12^2//no. of 12 mm dia bars on
    compression side
25 n2=3//assume
26 V=W*1/2//in kN
27 Tv=V*10^3/b/d//in MPa
28 pt=n1*0.785*12^2/b/d*100//pt=0.56, approximately
29 //for M15 grade concrete and pt=0.56
30 Tc=0.302//in MPa
31 //as Tc>Tv, no shear reinforcement required; provide
    nominal stirrups
32 //provide 6 mm dia bars
33 Asv=2*0.785*6^2//in sq mm
34 Sv=Asv*fy/0.4/b//in mm
35 Sv=260//approximately, in mm
36 Svmax=0.75*d//in mm
37 Svmax=200//approximately, in mm
38 Sv=min(Sv, Svmax)//in mm
39 printf("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

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

```

28 s=1000*0.785*6^2/Asf//in mm
29 s=188//assume, in mm
30 V=W*l/2//in kN
31 Tv=V*10^3/b/d//<Tcmax=1.6 MPa, hence OK
32 //for M15 grade concrete and pt=0.7
33 Tc=0.33//in MPa
34 //as Tv>Tc, shear reinforcement required
35 Vs=V-Tc*b*d/10^3//in kN
36 //provide 6 mm dia bars
37 Asv=2*0.785*6^2//in sq mm
38 sigma_sv=140//in MPa
39 Sv=Asv*sigma_sv*d/Vs/10^3//in mm
40 Sv=155//approximately, in mm
41 Svmin=Asv*fy/0.4/b//in mm
42 Svmin=117//approximately, in mm
43 Sv=min(Sv,Svmin)//in mm
44 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

```

1 l=10//span, in m
2 sigma_cbc=5//in MPa
3 sigma_st=140//in MPa
4 fy=250//in MPa
5 m=18.66//modular ratio
6 Df=100//slab thickness, in mm
7 D=1*10^3/12//in mm
8 D=850//approximately, in mm
9 d=D-100//cover=100 mm
10 bw=300//in mm
11 bf=1*10^3/6+bw+6*Df//>2500 mm c/c distance of beams

```

```

12 bf=2500 //in mm
13 W1=(bw/10^3)*(d-Df)/10^3*25 //in kN/m
14 W2=(Df/10^3)*(bf/10^3)*25 //in kN/m
15 W3=(bf/10^3)*5 //imposed load , in kN/m
16 W=W1+W2+W3 //in kN/m
17 W=24 //approximately , in kN/m
18 M=W*1^2/8 //in kN-m
19 V=W*1/2 //in kN
20 Ast=round(M*10^6/sigma_st/0.87/d) //in sq mm
21 //provide 4-25 mm dia bars + 4-20 mm dia bars
22 Ast=4*0.785*25^2+4*0.785*20^2 //in sq mm
23 //verification of trial section
24 //assume x>Df
25 x=(m*Ast*d+bf*Df^2/2)/(bf*Df+m*Ast) //in mm
26 //sigma_cbc'=sigma_cbc (x-Df)/x
27 a=(x-Df)/x
28 z=d-(1+2*a)/(1+a)*Df/3 //in mm
29 sigma_st=M*10^6/Ast/z //<140 MPa, hence OK
30 sigma_cbc=sigma_st/m*x/(d-x) //<5 MPa, hence OK
31 Tv=V*10^3/bw/d //in MPa
32 pt=Ast*100/(bw*d+(2500-300)*100) //pt=0.72,
    approximately
33 //for M15 grade concrete and pt=0.72
34 Tc=0.33 //in MPa
35 //as Tv>Tc, shear reinforcement required
36 Vs=V-Tc*bw*d/10^3 //in kN
37 //provide 6 mm dia bars
38 Asv=2*0.785*6^2 //in sq mm
39 sigma_sv=140 //in MPa
40 Sv=Asv*sigma_sv*d/Vs/10^3 //in mm
41 Sv=130 //approximately , in mm
42 Svmin=Asv*fy/0.4/bw //in mm
43 Svmin=117 //approximately , in mm
44 Sv=min(Sv, Svmin) //in mm
45 printf("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

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

```

21 Ast=M*10^6/sigma_st/z//in sq mm
22 n=Ast/0.785/8^2
23 n=4//assume
24 Ads=0.15/100*D*t*10^3//distribution steel , in sq mm
25 //provide 6 mm dia bars
26 s=1000*0.785*6^2/Ads//>5d=415 mm
27 s=415//in mm
28 Tbd=0.6//in MPa
29 Ld=dia*sigma_st/4/Tbd//in mm
30 Ld=470//assume , in mm
31 fprintf("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

```

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

```

```

17 dia=10//in mm
18 D=d+dia/2+25//which is equal to assumed value , hence
    OK
19 z=0.9*d//in mm
20 Ast=M*10^6/sigma_st/z//in mm
21 s1=1000*0.785*dia^2/Ast//spacing of 10 mm dia bars
22 s1=150//assume , in mm
23 Ads=0.12/100*D*10^3//distribution steel , in sq mm
24 //provide 8 mm dia bars
25 s2=1000*0.785*8^2/Ads//in mm
26 s2=210//in mm
27 //let span-to-depth ratio be 'a'
28 a=1*10^3/D
29 //for Fe415 grade steel and pt=.32
30 MF=1.2
31 b=20*MF//permissible span-to-depth ratio
32 //as a<b, hence OK
33 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

```

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

```

```

11 W=W1+W2+W3//in kN/m
12 M=W*l^2/8//in kN-m
13 d=sqrt(M*10^6/0.81/1.5/10^3)//in mm
14 d=177//in mm
15 //assume 10 mm dia bars
16 dia=10//in mm
17 D=d+dia/2+25//which is slightly more than assumed
    value, hence OK
18 D=200//in mm
19 d=D-dia/2-25//in mm
20 z=0.92*d//in mm
21 Ast=M*10^6/sigma_st/z//in sq mm
22 s1=1500*0.785*dia^2/Ast//spacing of 10 mm dia bars,
    in mm
23 s1=130//assume, in mm
24 Ads=0.12/100*D*1.5*10^3//distribution steel, in sq
    mm
25 //provide 8 mm dia bars
26 s2=1000*0.785*8^2/Ads//in mm
27 s2=140//in mm
28 //let span-to-depth ratio be 'a'
29 a=1*10^3/D
30 pt=Ast/1500/D*100//pt=0.3
31 //for Fe500 grade steel and pt=.3
32 MF=1.2
33 b=20*MF//permissible span-to-depth ratio
34 //as a<b, hence OK
35 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

```

1 R=0.15//rise, in m

```

```

2 t=0.3//tread , in m
3 sigma_cbc=5//in MPa
4 sigma_st=230//in MPa
5 l1=1.8+1.5//span for flight AB, in m
6 l2=1.2+1.5+1.5//span for flight BC, in m
7 l3=1.8+1.5//span for flight CD, in m
8 //assuming 50 mm slab thickness per 1 m of span
9 D=50*12//slab thickness , in mm
10 W1=D/10^3*25*1.5*sqrt(R^2+t^2)/t//slab load on plan ,
    in kN/m
11 W2=1/2*R*t*1.5*25/t//load of step per metre , in kN/m
12 W3=1.5*5//live load , in kN/m
13 W=W1+W2+W3//in kN/m
14 //bending moment
15 //(a) flight AB and CD, refer Fig. 10.9
16 Rb=(W/2*1.5*(1.8+1.5/2)+W*1.8^2/2)/(1.5+1.8)//in kN
17 Ra=W/2*1.5+W*1.8-Rb//in kN
18 x=Ra/Rb//point of zero shear force from Ra, in m
19 M1=Ra*x-W*x^2/2//maximum bending moment, in kN-m
20 //(b) flight BC, refer Fig. 10.10
21 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
22 Rc=Rb//in kN
23 //maximum bending moment will be at centre
24 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
25 M=max(M1,M2)//in kN/m
26 d=sqrt(M*10^6/0.65/1.5/10^3)//in mm
27 //assume 10 mm dia bars
28 dia=10//in mm
29 D=d+dia/2+25//< 210 mm (assumed value)
30 D=210//in mm
31 d=D-dia/2-25//in mm
32 //steel
33 //flight AB and CD
34 z=0.9*d//in mm
35 Ast=M1*10^6/sigma_st/z//in sq mm
36 s1=1500*0.785*dia^2/Ast//spacing of 10 mm dia bars ,

```

```

    in mm
37 s1=210//round-off, in mm
38 Ads=0.12/100*D*1.5*10^3//distribution steel, in sq
    mm
39 //provide 6 mm dia bars
40 s2=1000*0.785*6^2/Ads//in mm
41 s2=70//round-off, in mm
42 //flight BC
43 Ast=M2*10^6/sigma_st/z//in sq mm
44 s3=1500*0.785*dia^2/Ast//spacing of 10 mm dia bars,
    in mm
45 s3=130//round-off, in mm
46 //distribution steel is same as flights AB and CD
47 //let span-to-depth ratio be 'a'
48 a=12*10^3/D
49 //for Fe415 grade steel and pt=.32
50 MF=1.2//modification factor
51 b=20*MF//permissible span-to-depth ratio
52 //as a < b, hence OK
53 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)
54 //answer in textbook is incorrect

```

---

# Chapter 11

## Column Footing Design

Scilab code Exa 11.1 Design of Column Footing

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

```

    in Fig. 11.3 of textbook
22 d1=L*(L-b)/2*p/(Tc*L+L*p)//in m
23 //case II: refer Fig. 11.4 of textbook; we get a
    quadratic equation of the form e d^2 + f d + g =
    0
24 e=p+4*Tc
25 f=b*p+D*p+2*(b+D)*Tc
26 g=-(L^2-b*D)*p
27 d2=(-f+sqrt(f^2-4*e*g))/2/e//in m
28 d2=0.362//assume, in m
29 //bending moment consideration, refer Fig. 11.5 of
    textbook
30 Mx=1*((L-b)/2)^2/2*p//in kN-m
31 My=1*((L-D)/2)^2/2*p//in kN-m
32 d3=sqrt(Mx*10^6/0.65/10^3)//<362 mm, hence OK
33 z=0.9*d2*10^3//lever arm, in mm
34 Ast1=(Mx*10^6/sigma_st/z)//in sq mm
35 Ast=L*Ast1//steel required for full width of 2.1 m,
    in sq mm
36 //provide 12 mm dia bars
37 dia=12//in mm
38 n=Ast/0.785/dia^2//no. of 12 mm dia bars
39 n=16//assume
40 Tbd=0.84//in MPa
41 Ld=dia*sigma_st/4/Tbd//in mm
42 Ld=825//assume, in mm
43 c=50//side cover, in mm
44 La=(L-D)/2*10^3-c//>Ld, hence OK
45 D=d2*10^3+dia/2+100//in mm
46 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



```

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

```

```

35 Ast=L*Ast1//steel required for full width of 2.3 m,
    in sq mm
36 //provide 18 mm dia bars
37 dia=18//in mm
38 n=Ast/0.785/dia^2//no. of 18 mm dia bars
39 n=15//assume
40 Tbd=0.6//in MPa
41 Ld=dia*sigma_st/4/Tbd//in mm
42 c=50//side cover, in mm
43 La=(L-D)/2*10^3-c//in mm
44 //providing hook at ends
45 La=La+16*dia//>Ld, hence OK
46 D=d2*10^3+dia/2+100//in mm
47 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

```

1 B=0.5//column diameter, in m
2 fck=20//in MPa
3 sigma_cbc=7//in MPa
4 sigma_st=230//in MPa
5 P1=1600//load on column, in kN
6 P2=0.05*P1//weight of footing, in kN
7 P=P1+P2//in kN
8 q=300//bearing capacity of soil, in kN/sq m
9 A=P/q//in sq m
10 L=sqrt(A)//assuming footing to be square
11 L=2.4//assume, in m
12 p=P1/L^2//soil pressure, in kN/sq m
13 p=278//assume, in kN/sq m
14 bc=1
15 ks=0.5+bc//>1
16 ks=1

```

```

17 Tc=0.16*sqrt(fck)*10^3//in kN/sq m
18 Tv=Tc
19 //let d be the depth of footing in metres
20 //case I: refer Fig. 11.11 of textbook
21 d1=L*(L-B)/2*p/(Tc*L+L*p)//in m
22 //case II: refer Fig. 11.12 of textbook; we get a
    quadratic equation of the form e d^2 + f d + g =
    0
23 e=%pi/4*p+%pi*Tc
24 f=2*%pi/4*B*p+%pi*B*Tc
25 g=-(L^2-%pi/4*B^2)*p
26 d2=(-f+sqrt(f^2-4*e*g))/2/e//in m
27 d2=0.57//assume, in m
28 d=max(d1,d2)//in m
29 //bending moment consideration, refer Fig. 11.13 of
    textbook
30 M=1*((L-B)/2)^2/2*p//in kN-m
31 d3=sqrt(M*10^6/0.88/10^3)//<570 mm, hence OK
32 z=0.9*d*10^3//lever arm, in mm
33 Ast1=(M*10^6/sigma_st/z)//in sq mm
34 Ast=L*Ast1//steel required for full width of 2.4 m
35 //provide 20 mm dia bars
36 dia=20//in mm
37 n=Ast/0.785/dia^2//no. of 20 mm dia bars
38 n=9//assume
39 Tbd=1.12//in MPa
40 Ld=dia*sigma_st/4/Tbd//in mm
41 Ld=1030//assume, in mm
42 c=50//side cover, in mm
43 La=(L-B)/2*10^3-c//in mm
44 //bend bar at right angle and provide length, l
45 l=Ld-La//in mm
46 D=d*10^3+dia/2+100//in mm
47 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)
48 //answer in textbook is incorrect

```

### Scilab code Exa 11.4 Design of Rectangular Column Footing

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

```

31 d3=0.47//assume, in m
32 d=max(d1,d2,d3)//in m
33 //bending moment consideration, refer Fig. 11.17 of
    textbook
34 Mx=1*((L1-b)/2)^2/2*p//in kN-m
35 My=1*((L2-c1)/2)^2/2*p//in kN-m
36 d4=sqrt(My*10^6/0.8/10^3)//in mm
37 d4=480//>470 mm (provided for shear)
38 d=d4//in mm
39 z=0.92*d//lever arm, in mm
40 //short direction
41 Ast1=(Mx*10^6/sigma_st/z)//in sq mm
42 Ast=L2*Ast1//steel required for full width of 3.2 m,
    in sq mm
43 b1=L1//central band width, in m
44 beta=L2/L1
45 Astc=L1/(beta+1)*Ast//in sq mm
46 //provide 12 mm dia bars
47 dia=12//in mm
48 n1=Astc/0.785/dia^2//no. of 12 mm dia bars
49 n1=13//assume
50 Astr=Ast-Astc//steel in remaining width, in sq mm
51 n2=Astr/0.785/dia^2
52 n2=4//assume
53 n2=n2/2//on each side
54 Tbd=1.12//in MPa
55 Ld=dia*sigma_st/4/Tbd//in mm
56 c=50//side cover, in mm
57 La=(L1-b)/2*10^3-c//>Ld, hence OK
58 //long direction
59 Ast1=(My*10^6/sigma_st/z)//in sq mm
60 Ast=L1*Ast1//steel required for full width of 2 m,
    in sq mm
61 //provide 18 mm dia bars
62 dia=18//in mm
63 n=Ast/0.785/dia^2//no. of 18 mm dia bars
64 n=12//assume
65 Ld=dia*sigma_st/4/Tbd//in mm

```

```

66 c=50//side cover , in mm
67 La=(L2-c1)/2*10^3-c//>Ld, hence OK
68 D=d+dia/2+100//in mm
69 D=590//assume, in mm
70 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

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

```

22 D3=D2+(D1-D2)*h/H//in mm
23 d3=sqrt(M2*10^6/0.65/1000)//in mm
24 D3=d3+dia/2+25//< 325 mm (provided), hence OK
25 D3=325//in mm
26 d3=D3-dia/2-25//in mm
27 //main steel
28 //(a) 5 m below the top
29 Ast=M1*10^6/sigma_st/0.9/d//in sq mm
30 //provide 20 mm dia bars
31 s1=1000*0.785*20^2/Ast//in mm
32 s1=240//assume, in mm
33 //(b) 2.5 m below the top
34 Ast=M2*10^6/sigma_st/0.9/d3//in sq mm
35 Astmin=0.12/100*10^3*D3//in sq mm
36 Ast=max(Ast,Astmin)//in sq mm
37 //provide 12 mm dia bars
38 s2=1000*0.785*12^2/Ast//in mm
39 s2=290//assume, in mm
40 //distribution steel
41 Ads=0.12/100*10^3*D3//in sq mm
42 //provide 8 mm dia bars
43 s3=1000*0.785*8^2/Ads//in mm
44 s3=125//assume, in mm
45 //check for shear
46 V=P//in kN
47 Tv=V*10^3/10^3/d//in MPa
48 //for M15 grade concrete and pt=0.31
49 Tc=0.22//in MPa
50 //as Tc > Tv, no shear reinforcement required
51 //development length
52 //(a) At the base of stem
53 dia=20//in mm
54 Tbd=0.84//in MPa
55 Ld=dia*sigma_st/4/Tbd//in mm
56 Ld=1370//assume, in mm
57 //(b) At 2.5 m below the top
58 dia=12//in mm
59 Ld=dia*sigma_st/4/Tbd//in mm

```



```

60 Ld=825//assume, in mm
61 //check for stability
62 D4=500//thickness of base, in mm (assume)
63 V1=1/2*(D1-D2)/10^3*H*25//in kN
64 V2=(D2/10^3)*H*25//in kN
65 V3=(D4/10^3)*B*25//weight of base, in kN
66 V4=(B-T-D1/10^3)*H*W//weight of soil, in kN
67 V=V1+V2+V3+V4//in kN
68 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
69 x=M/V//in m
70 x=1.8//assume, in m
71 //factor of safety
72 //for overturning
73 F1=V*x/P/(H/3)//> 1.5, hence OK
74 mu=0.5
75 //for sliding
76 F2=mu*V/P//> 1.5, hence OK
77 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

```

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

```

```

11 //bending moment at 3 m below the top
12 h=3//in m
13 M2=W*h^2/2*(1-sind(phi))/(1+sind(phi))*h/3//in kN-m
14 M2=22//in kN-m
15 //thickness of stem (at the base)
16 d=sqrt(M1*10^6/0.87/1000)//in mm
17 d=450//in mm
18 dia=20//assume 20 mm dia bars
19 D1=d+dia/2+25//in mm
20 D2=200//thickness at top, in mm
21 D3=D2+(D1-D2)*h/H//in mm
22 d3=sqrt(M2*10^6/0.87/1000)//in mm
23 D3=d3+dia/2+25//< 342.5 mm (provided), hence OK
24 D3=342.5//in mm
25 d3=D3-dia/2-25//in mm
26 //main steel
27 //(a) 6 m below the top
28 Ast=M1*10^6/sigma_st/0.87/d//in sq mm
29 //provide 20 mm dia bars
30 s1=1000*0.785*20^2/Ast//in mm
31 s1=95//assume, in mm
32 //(b) 3 m below the top
33 Ast=M2*10^6/sigma_st/0.87/d3//in sq mm
34 //provide 10 mm dia bars
35 s2=1000*0.785*10^2/Ast//in mm
36 s2=130//assume, in mm
37 //distribution steel
38 Ads=0.15/100*10^3*D3//in sq mm
39 //provide 10 mm dia bars
40 s3=1000*0.785*10^2/Ads//in mm
41 s3=150//assume, in mm
42 //check for shear
43 V=P//in kN
44 Tv=V*10^3/10^3/d//in MPa
45 //for M15 grade concrete and pt=0.71
46 Tc=0.34//in MPa
47 //as Tc > Tv, no shear reinforcement required
48 //development length

```

```

49 //(a) At the base of stem
50 dia=20//in mm
51 Tbd=0.6//in MPa
52 Ld=dia*sigma_st/4/Tbd//in mm
53 Ld=1170//assume, in mm
54 //(b) At 3 m below the top
55 dia=10//in mm
56 Ld=dia*sigma_st/4/Tbd//in mm
57 Ld=590//assume, in mm
58 //check for stability
59 D4=500//thickness of base, in mm (assume)
60 V1=1/2*(D1-D2)/10^3*H*25//in kN
61 V2=(D2/10^3)*H*25//in kN
62 V3=(D4/10^3)*B*25//weight of base, in kN
63 V4=(B-T-D1/10^3)*H*W//in kN
64 V=V1+V2+V3+V4//in kN
65 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
66 x=M/V//in m
67 //factor of safety
68 //for overturning
69 F1=V*x/P/(H/3)//> 1.5, hence OK
70 mu=0.5
71 //for sliding
72 F2=mu*V/P//< 1.5, hence it is not safe against
    sliding
73 mprintf("Summary of design:\nThickness of stem (at
    base) = %d mm\nThickness of stem at top = %d mm\n
    Refer Fig. 12.7 of textbook for reinforcement
    details",D1,D2)
74 //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

```

1  sigma_cbc=5//in MPa
2  sigma_st=230//in MPa
3  phi=30//angle of repose , in degrees
4  H=5//height of wall , in m
5  B=0.6*H//assume , in m
6  T=B/4//assume toe to base ratio as 1:4
7  t=450//thickness of wall , in mm
8  W=16//density of retained earth , in kN/cu m
9  P=W*H^2/2*(1-sind(phi))/(1+sind(phi))//in kN
10 P=67//assume , in kN
11 y=1.8//in m
12 P=67//in kN
13 Wt=223//in kN
14 D=0.5//thickness of base , in m
15 x=1.8-P*(H/3+D/10^3)/Wt//in m
16 x=1.15//in m
17 e=B/2-x//in m
18 q1=Wt/B+Wt*e/(1*B^2/6)//maximum pressure , in kN/sq m
19 q2=Wt/B-Wt*e/(1*B^2/6)//minimum pressure , in kN/sq m
20 Pa=q1-(q1-q2)/B*T//pressure at A, in kN/sq m
21 Pa=100//assume , in kN/sq m
22 Pb=q1-(q1-q2)/B*(T+t/10^3)//pressure at B, in kN/sq
   m
23 Pb=85//assume , in kN/sq m
24 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
25 Ma=30//round-off , in kN-m
26 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
27 Mb=80//in kN-m
28 //design of toe
29 d=sqrt(Ma*10^6/0.65/10^3)//in mm
30 D=d+10/2+70//<500 mm (provided) , hence OK
31 D=500//in mm
32 d=D-70//in mm
33 Ast=Ma*10^6/sigma_st/0.9/d//in sq mm
34 Astmin=0.12/100*10^3*D//in sq mm

```

```

35 Ast=max(Ast,Astmin)//in sq mm
36 s1=1000*0.785*10^2/Ast//in mm
37 s1=130//assume, in mm
38 //distribution steel is same as above
39 //check for shear
40 V=(q1+Pa)/2*T//in kN
41 Tv=V*10^3/10^3/d//in MPa
42 //for M15 grade concrete and pt=0.32
43 Tc=0.2368//in MPa
44 //as Tc > Tv, no shear reinforcement required
45 //development length
46 dia=10//in mm
47 Tbd=0.84//in MPa
48 Ld=dia*sigma_st/4/Tbd//in mm
49 Ld=685//assume, in mm
50 //design of heel
51 d=sqrt(Mb*10^6/0.65/10^3)//< 430 mm (provided),
    hence OK
52 d=430//in mm
53 Ast=Mb*10^6/sigma_st/0.9/d//in sq mm
54 s2=1000*0.785*10^2/Ast//in mm
55 s2=85//assume, in mm
56 //distribution steel: 0.12% of Ag, hence provide 10
    mm dia bars @ 130 mm c/c
57 V=(B-T-t/10^3)*H*W-(Pb+q2)/2*(B-T-t/10^3)//in kN
58 Tv=V*10^3/10^3/d//in MPa
59 //for M15 grade concrete and pt=0.32
60 Tc=0.2368//in MPa
61 //as Tc > Tv, no shear reinforcement required
62 //development length
63 dia=10//in mm
64 Tbd=0.84//in MPa
65 Ld=dia*sigma_st/4/Tbd//in mm
66 Ld=685//assume, in mm
67 mprintf("Summary of design:\nThickness of base slab=
    %d mm. Refer to Fig. 12.11 of textbook for
    reinforcement details.",D)
68 //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

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

```

22 Ast=T*10^3/sigma_st//in sq mm
23 s2=10^3*0.785*16^2/Ast//in mm
24 s2=260//assume, in mm
25 Ads=0.3/100*t*10^3//vertical steel as distribution
    steel, in sq mm
26 s3=1000*0.785*10^2/Ads//in mm
27 s3=235//in mm
28 //design of tank floor
29 D=150//in mm
30 Ast=0.3/100*D*1000//in sq mm
31 s4=1000*0.785*10^2/Ast//in mm
32 s4=170//in mm
33 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)
34 //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

```

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

```



```

12 w=10//unit weight of water , in kN/cu m
13 T=w*H*B/2//hoop tension , in kN
14 Ast=T*10^3/sigma_st//in sq mm
15 s1=10^3*0.785*12^2/Ast//in mm
16 s1=80//assume , in mm
17 t=(T*10^3/sigma_ct-(m-1)*Ast)/1000//in mm
18 t=175//assume , in mm
19 //steel at 2 m below top of wall
20 h=2//in m
21 T=w*h*B/2//in kN
22 Ast=T*10^3/sigma_st//in sq mm
23 s2=10^3*0.785*12^2/Ast//in mm
24 s2=145//assume , in mm
25 Ads=0.3/100*t*10^3//vertical steel as distribution
    steel , in sq mm
26 s3=1000*0.785*10^2/Ads//in mm
27 s3=150//assume , in mm
28 //design of tank floor
29 D=190//in mm
30 Ast=0.3/100*D*1000//in sq mm
31 s4=1000*0.785*10^2/Ast//in mm
32 s4=135//assume , in mm
33 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

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

---

Scilab code Exa 14.2 Analysis of Singly Reinforced Section

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

```

5 Xc=0.456*d//in mm
6 Mu=0.36*fck*b*Xc*(d-0.416*Xc)/10^6//in kN-m
7 Ast=round(0.36*fck*b*Xc/0.87/fy)//in sq mm
8 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

```

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

```

---

### Scilab code Exa 14.4 Analysis of Singly Reinforced Section

```

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

```

```

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

```

---

#### Scilab code Exa 14.5 Analysis of Singly Reinforced Section

```

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

```

---

#### Scilab code Exa 14.6 Design of Singly Reinforced Section

```

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

```

```

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

```

---

#### Scilab code Exa 14.7 Design of Singly Reinforced Section

```

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

```

---

# Chapter 15

## Doubly Reinforced Sections

Scilab code Exa 15.1 Analysis of Doubly Reinforced Section

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

---

Scilab code Exa 15.2 Analysis of Doubly Reinforced Section

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

```

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

```

---

### Scilab code Exa 15.3 Analysis of Doubly Reinforced Section

```

1 b=250//width , in mm
2 d=550//effective depth , in mm
3 fck=15//in MPa
4 fy=250//in MPa
5 M=95//in kN-m
6 Mu=1.5*M//factored moment, in kN-m
7 Mulim=0.149*fck*b*d^2/10^6//in kN-m
8 //as Mu<Mulim, no steel required on compression side
9 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

```

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

```

```

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

```

---

#### Scilab code Exa 15.5 Design of Doubly Reinforced Section

```

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

```

---



### Scilab code Exa 15.6 Design of Doubly Reinforced Section

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

---

### Scilab code Exa 15.7 Design of Doubly Reinforced Section

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

```
10 M1=Mu-Mulim//in kN-m
11 fcc=0.446*fck//in MPa
12 //for d'/d=30/200=0.15 and Fe500 grade steel ,
13 fsc=395//in MPa
14 Asc=round(M1*10^6/(fsc-fcc)/(d-top_cover))//in sq mm
15 Ast2=round((fsc-fcc)*Asc/0.87/fy)//in sq mm
16 Ast=Ast1+Ast2//in sq mm
17 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

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

---

Scilab code Exa 16.2 Analysis of T beam

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

```

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

```

---

### Scilab code Exa 16.3 Analysis of T beam

```

1 Df=100//in mm
2 bf=1500//in mm
3 bw=300//in mm
4 d=700//in mm
5 Ast=4510//in sq mm
6 fy=250//in MPa
7 fck=15//in MPa
8 Asf=round(0.36*fck*bf*Df/0.87/fy)//area of steel
    required for flange , in sq mm
9 //as Ast>Asf, Xu>Df
10 Xu=round((0.87*fy*Ast-0.446*fck*(bf-bw)*Df)/0.36/fck
    /bw)//in mm
11 Xc=0.531*d//Xc>Xu; hence OK
12 a=0.43*Xu//as Df>0.43 Xu, stress in flange is not
    uniform
13 yf=0.15*Xu+0.65*Df//in mm

```

```

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

```

---

#### Scilab code Exa 16.4 Analysis of T beam

```

1 Df=100//in mm
2 bf=1250//in mm
3 bw=250//in mm
4 d=650//in mm
5 Ast=2800//in sq mm
6 fy=415//in MPa
7 fck=20//in MPa
8 Asf=round(0.36*fck*bf*Df/0.87/fy)//area of steel
    required for flange , in sq mm
9 //as Ast>Asf, Xu>Df
10 Xu=round((0.87*fy*Ast-0.446*fck*(bf-bw)*Df)/0.36/fck
    /bw)//in mm
11 //but Xu<Df; this indicates that stress in the
    flange is not uniform, hence replace Df by yf
12 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
13 Xc=0.479*d//Xc>Xu; hence OK
14 a=0.43*Xu//as Df>0.43 Xu, stress in flange is not
    uniform
15 yf=0.15*Xu+0.65*Df//in mm
16 Mu=(0.36*fck*bw*Xu*(d-0.416*Xu)+0.446*fck*(bf-bw)*yf
    *(d-yf/2))/10^6//in kN-m
17 mprintf("Moment of resistance of T-beam=%f kN-m", Mu)
18 //answer in textbook is incorrect

```

---

#### Scilab code Exa 16.5 Analysis of T beam

```

1 Df=100//in mm
2 bf=1250//in mm
3 bw=250//in mm
4 d=660//in mm
5 fy=250//in MPa
6 fck=15//in MPa
7 Xc=0.531*d//in mm
8 a=0.43*Xc//Df<0.43 Xu, stress in entire flange is
   uniform
9 Mu=(0.36*fck*bw*Xc*(d-0.416*Xc)+0.446*fck*(bf-bw)*Df
   *(d-Df/2))/10^6//in kN-m
10 Ast=(0.36*fck*bw*Xc+0.446*fck*(bf-bw)*Df)/0.87/fy//
   in sq mm
11 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

```

1 Df=100//in mm
2 bf=1250//in mm
3 bw=250//in mm
4 d=550//in mm
5 Mu=400//in kN-m
6 fy=415//in MPa
7 fck=15//in MPa
8 Asf=0.446*fck*(bf-bw)*Df/0.87/fy//in sq mm
9 Muf=0.446*fck*(bf-bw)*Df*(d-Df/2)/10^6//in kN-m
10 Muw=Mu-Muf//in kN-m
11 //using Cu=Tu, 0.36 fck bw Xu = 0.87 fy Ast, Xu = a
   Asw
12 a=0.87*fy/0.36/fck/bw
13 //Muw=0.87 fy Asw (d-0.416 Xu)
14 p=0.87*fy*0.416*a
15 q=-0.87*fy*d
16 r=Muw*10^6

```

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

---

# Chapter 17

## Shear and Development Length

Scilab code Exa 17.1 Shear Design

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

---

Scilab code Exa 17.2 Shear Design



```

1 b=300//width, in mm
2 d=1010//effective depth, in mm
3 l=7//span, in m
4 Ast=round(6*0.785*22^2)//six 22 mm dia bars, in sq
   mm
5 fck=15//in MPa
6 fy=250//in MPa
7 W=45//in kN/m
8 Wu=1.5*W//factored load, in kN/m
9 Vu=Wu*l/2//in kN
10 Tv=Vu*10^3/b/d//in MPa
11 //Tv<Tcmax, hence OK
12 p=Ast/b/d*100//p=0.75, approximately
13 //for p=0.75 and M15 grade concrete
14 Tc=0.54//in MPa
15 //Tv>Tc, hence shear reinforcement required
16 Vus=Vu-Tc*b*d/10^3//in kN
17 //provide 6 mm dia stirrups
18 Sv=0.87*fy*2*0.785*6^2*d/Vus/10^3//in mm
19 Sv=171//approximately, in mm
20 Svmin=2*0.785*6^2*fy/b/0.4//in mm
21 Svmin=118//approximately, in mm
22 Sv=min(Sv,Svmin)//in mm
23 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

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

---

Scilab code Exa 18.2 Design of Short Axially Loaded Column

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

```

4 l=2.75//unsupported length , in m
5 //assume 1% steel
6 Ag=Pu*10^3/(0.4*fck*0.99+0.67*fy*0.01)//in sq mm
7 L1=225//assuming a square column
8 L2=Ag/L1//in mm
9 L2=880//in mm
10 Asc=0.01*L1*L2//in sq mm
11 e1=1*10^3/500+L1/30//in mm
12 e2=1*10^3/500+L2/30//in mm
13 ep1=0.05*L1//<e1
14 ep2=0.05*L2//>e2, hence Ok
15 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

```

1 b=225//in mm
2 D=500//in mm
3 c=45//cover , in mm
4 Asc=2463//in sq mm
5 Ast=Asc
6 fck=15//in MPa
7 fy=250//in MPa
8 fcc=0.446*fck//in MPa
9 //(i)
10 xu=1.1*D//in mm
11 m=0.43*D//in mm
12 esc1=0.002*(xu-c)/(xu-m)
13 esc2=0.002*(xu-D+c)/(xu-m)
14 //by interpolation
15 fsc1=217.5//in MPa
16 fsc2=217.5*esc2/0.0010875//in MPa
17 //stress block parameters for xu / D = 1.1

```

```

18 n=0.384
19 l=0.443
20 A=n*fck*D//area of stress block
21 r=l*D//distance of c.g., in mm
22 Pu=(A*b+Asc*(fsc1-fcc)+Ast*fsc2)/10^3
23 Mu=(A*b*(D/2-r)+Asc*(fsc1-fcc)*(D/2-c)-Ast*fsc2*(D
    /2-c))/10^6
24 mprintf("(i) For xu = 1.1 D\nP=%f kN\nMu=%f kN-m\n",
    Pu, Mu)
25 //answer in textbook is incorrect
26 //(ii)
27 xu=330//in mm
28 esc=0.0035*(xu-c)/xu
29 est=0.0035*(D-c-xu)/xu
30 //by interpolation
31 fsc=217.5//in MPa
32 fst=217.5//in MPa
33 Pu=(0.36*fck*b*xu+Asc*(fsc-fcc)-Ast*fst)/10^3//in kN
34 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
35 mprintf("(ii) For xu = 330 mm\nP=%f kN\nMu=%f kN-m",
    Pu, Mu)

```

---

#### Scilab code Exa 18.4 Uniaxial Bending

```

1 b=300//in mm
2 D=400//in mm
3 c=30//cover, in mm
4 Asc=452//in sq mm
5 Ast=Asc
6 fck=15//in MPa
7 fy=415//in MPa
8 fcc=0.446*fck//in MPa
9 //(i)
10 xu=1.4*D//in mm

```

```

11 m=0.43*D//in mm
12 esc1=0.002*(xu-c)/(xu-m)
13 esc2=0.002*(xu-D+c)/(xu-m)
14 //by interpolation
15 fsc1=356.8//in MPa
16 fsc2=238.68//in MPa
17 //stress block parameters for xu / D = 1.4
18 n=0.417
19 l=0.475
20 A=n*fck*D//area of stress block
21 r=l*D//distance of c.g., in mm
22 Pu=(A*b+Asc*(fsc1-fcc)+Ast*fsc2)/10^3//in kN
23 Mu=(A*b*(D/2-r)+Asc*(fsc1-fcc)*(D/2-c)-Ast*fsc2*(D
    /2-c))/10^6//in kN-m
24 printf("(i) For xu = 1.4 D\nP=%f kN\nMu=%f kN-m\n",
    Pu,Mu)
25 //(ii)
26 xu=370//in mm
27 esc=0.0035*(xu-c)/xu
28 est=0.0035*(D-c-xu)/xu
29 //by interpolation
30 fsc=355.8//in MPa
31 Pu=(0.36*fck*b*xu+Asc*(fsc-fcc))/10^3//in kN
32 Mu=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*(fsc-fcc)*(D/2-
    c))/10^6//in kN-m
33 printf("(ii) For xu = 370 mm\nP=%f kN\nMu=%f kN-m",
    Pu,Mu)

```

---

### Scilab code Exa 18.5 Uniaxial Bending

```

1 b=225//in mm
2 D=500//in mm
3 c=50//cover, in mm
4 Asc=1520//in sq mm
5 Ast=Asc

```

```

6 fck=20//in MPa
7 fy=500//in MPa
8 fcc=0.446*fck//in MPa
9 //(i)
10 xu=1.3*D//in mm
11 m=0.43*D//in mm
12 esc1=0.002*(xu-c)/(xu-m)
13 esc2=0.002*(xu-D+c)/(xu-m)
14 //by interpolation
15 fsc1=412.515//in MPa
16 fsc2=183.794//in MPa
17 //stress block parameters for xu / D = 1.3
18 n=0.409
19 l=0.468
20 A=n*fck*D//area of stress block
21 r=l*D//distance of c.g., in mm
22 Pu=(A*b+Asc*(fsc1-fcc)+Ast*fsc2)/10^3//in kN
23 Mu=(A*b*(D/2-r)+Asc*(fsc1-fcc)*(D/2-c)-Ast*fsc2*(D
    /2-c))/10^6//in kN-m
24 mprintf("(i) For xu = 1.3 D\nP=%f kN\nMu=%f kN-m\n",
    Pu, Mu)
25 //(ii)
26 xu=400//in mm
27 esc=0.0035*(xu-c)/xu
28 est=0.0035*(D-c-xu)/xu
29 //by interpolation
30 fsc=422.11//in MPa
31 fst=87.45//in MPa
32 Pu=(0.36*fck*b*xu+Asc*(fsc-fcc)-Ast*fst)/10^3//in kN
33 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
34 mprintf("(ii) For xu = 400 mm\nP=%f kN\nMu=%f kN-m",
    Pu, Mu)
35 //answer in textbook for Mu in (ii) is incorrect

```

---

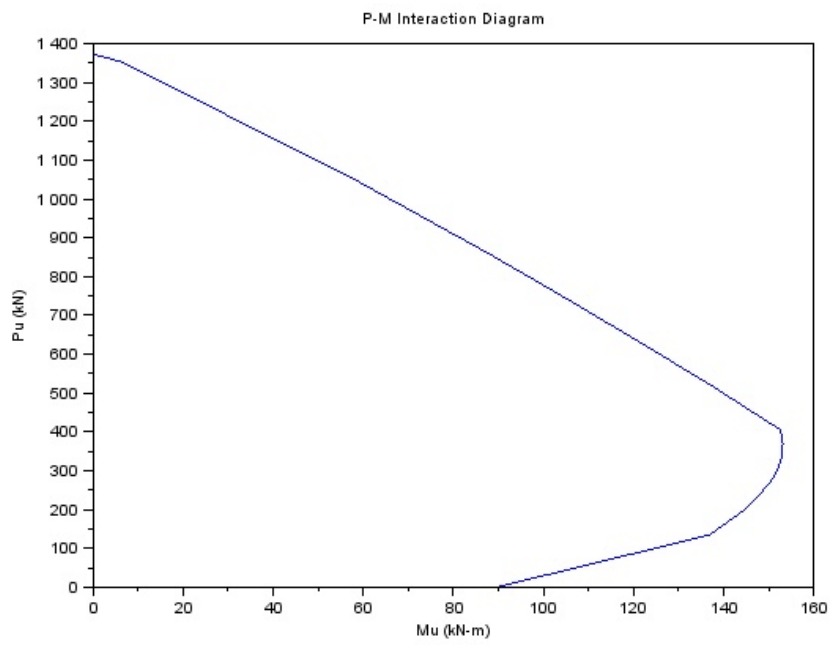


Figure 18.1: Interaction diagram

### Scilab code Exa 18.6 Interaction diagram

```
1 b=250//width, in mm
2 D=450//depth, in mm
3 c=50//cover, in mm
4 Asc=1472//in sq mm
5 Ast=Asc
6 fck=15//in MPa
7 fcc=0.446*fck//in MPa
8 fy=250//in MPa
9 Es=2*10^5//in MPa
10 ey=0.87*fy/Es//strain in mild steel at yield point
11 fs=0.87*fy//stress in mild steel at yield point, in
    MPa
12
13 //xu=infinity
14 Pu1=(0.446*fck*(b*D-Asc-Ast)+(Asc+Ast)*fs)/10^3//in
    kN
15 Mu1=0//in kN-m
16
17 //xu=1.5 D
18 xu=1.5*D//in mm
19 m=0.43*D//in mm
20 esc1=0.002*(xu-c)/(xu-m)
21 if(esc1<=ey)
22     fsc1=esc1/ey*fs
23 else
24     fsc1=fs
25 end
26 esc2=0.002*(xu-D+c)/(xu-m)//>ey
27 if(esc2<=ey)
28     fsc2=esc2/ey*fs
29 else
30     fsc2=fs
```



```

31 end
32 //stress block parameters for xu / D = 1.5
33 n=0.422
34 l=0.48
35 A=n*fck*D//area of stress block
36 r=l*D//distance of c.g.
37 Pu2=(A*b+Asc*fsc1+Ast*fsc2)/10^3//in kN
38 Mu2=(A*b*(D/2-r)+Asc*fsc1*(D/2-c)-Ast*fsc2*(D/2-c))
    /10^6//in kN-m
39
40 //xu=1.3 D
41 xu=1.3*D//in mm
42 m=0.43*D//in mm
43 esc1=0.002*(xu-c)/(xu-m)
44 if(esc1<=ey)
45     fsc1=esc1/ey*fs
46 else
47     fsc1=fs
48 end
49 esc2=0.002*(xu-D+c)/(xu-m)//>ey
50 if(esc2<=ey)
51     fsc2=esc2/ey*fs
52 else
53     fsc2=fs
54 end
55 //stress block parameters for xu / D = 1.3
56 n=0.409
57 l=0.468
58 A=n*fck*D//area of stress block
59 r=l*D//distance of c.g.
60 Pu3=(A*b+Asc*fsc1+Ast*fsc2)/10^3//in kN
61 Mu3=(A*b*(D/2-r)+Asc*fsc1*(D/2-c)-Ast*fsc2*(D/2-c))
    /10^6//in kN-m
62
63 //xu=1.2 D
64 xu=1.2*D//in mm
65 m=0.43*D//in mm
66 esc1=0.002*(xu-c)/(xu-m)

```

```

67  if(esc1<=ey)
68      fsc1=esc1/ey*fs
69  else
70      fsc1=fs
71  end
72  esc2=0.002*(xu-D+c)/(xu-m) //>ey
73  if(esc2<=ey)
74      fsc2=esc2/ey*fs
75  else
76      fsc2=fs
77  end
78  //stress block parameters for xu / D = 1.2
79  n=0.399
80  l=0.458
81  A=n*fck*D//area of stress block
82  r=l*D//distance of c.g.
83  Pu4=(A*b+Asc*fsc1+Ast*fsc2)/10^3//in kN
84  Mu4=(A*b*(D/2-r)+Asc*fsc1*(D/2-c)-Ast*fsc2*(D/2-c))
      /10^6//in kN-m
85
86  //xu=1.1 D
87  xu=1.1*D//in mm
88  m=0.43*D//in mm
89  esc1=0.002*(xu-c)/(xu-m)
90  if(esc1<=ey)
91      fsc1=esc1/ey*fs
92  else
93      fsc1=fs
94  end
95  esc2=0.002*(xu-D+c)/(xu-m) //>ey
96  if(esc2<=ey)
97      fsc2=esc2/ey*fs
98  else
99      fsc2=fs
100 end
101 //stress block parameters for xu / D = 1.1
102 n=0.384
103 l=0.443

```

```

104 A=n*fck*D//area of stress block
105 r=l*D//distance of c.g.
106 Pu5=(A*b+Asc*fsc1+Ast*fsc2)/10^3//in kN
107 Mu5=(A*b*(D/2-r)+Asc*fsc1*(D/2-c)-Ast*fsc2*(D/2-c))
    /10^6//in kN-m
108
109 //xu = D
110 xu=D//in mm
111 m=0.43*D//in mm
112 esc1=0.002*(xu-c)/(xu-m)
113 if(esc1<=ey)
114     fsc1=esc1/ey*fs
115 else
116     fsc1=fs
117 end
118 esc2=0.002*(xu-D+c)/(xu-m)//>ey
119 if(esc2<=ey)
120     fsc2=esc2/ey*fs
121 else
122     fsc2=fs
123 end
124 //stress block parameters for xu / D = 1
125 n=0.361
126 l=0.416
127 A=n*fck*D//area of stress block
128 r=l*D//distance of c.g.
129 Pu6=(A*b+Asc*fsc1+Ast*fsc2)/10^3//in kN
130 Mu6=(A*b*(D/2-r)+Asc*fsc1*(D/2-c)-Ast*fsc2*(D/2-c))
    /10^6//in kN-m
131
132 //xu=400 mm
133 xu=400//in mm
134 esc=0.0035*(xu-c)/xu
135 if(esc<=ey)
136     fsc=esc/ey*fs
137 else
138     fsc=fs
139 end

```

```

140 est=0.0035*(D-xu-c)/xu
141 if(est<=ey)
142     fst=est/ey*fs
143 else
144     fst=fs
145 end
146 Pu7=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
147 Mu7=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
        Ast*fst*(D/2-c))/10^6
148
149 //xu=375 mm
150 xu=375//in mm
151 esc=0.0035*(xu-c)/xu
152 if(esc<=ey)
153     fsc=esc/ey*fs
154 else
155     fsc=fs
156 end
157 est=0.0035*(D-xu-c)/xu
158 if(est<=ey)
159     fst=est/ey*fs
160 else
161     fst=fs
162 end
163 Pu8=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
164 Mu8=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
        Ast*fst*(D/2-c))/10^6
165
166 //xu=350 mm
167 xu=350//in mm
168 esc=0.0035*(xu-c)/xu
169 if(esc<=ey)
170     fsc=esc/ey*fs
171 else
172     fsc=fs
173 end
174 est=0.0035*(D-xu-c)/xu
175 if(est<=ey)

```

```

176     fst=est/ey*fs
177 else
178     fst=fs
179 end
180 Pu9=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
181 Mu9=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
      Ast*fst*(D/2-c))/10^6
182
183 //xu=325 mm
184 xu=325//in mm
185 esc=0.0035*(xu-c)/xu
186 if(esc<=ey)
187     fsc=esc/ey*fs
188 else
189     fsc=fs
190 end
191 est=0.0035*(D-xu-c)/xu
192 if(est<=ey)
193     fst=est/ey*fs
194 else
195     fst=fs
196 end
197 Pu10=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
198 Mu10=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
      Ast*fst*(D/2-c))/10^6
199
200 //xu=300 mm
201 xu=300//in mm
202 esc=0.0035*(xu-c)/xu
203 if(esc<=ey)
204     fsc=esc/ey*fs
205 else
206     fsc=fs
207 end
208 est=0.0035*(D-xu-c)/xu
209 if(est<=ey)
210     fst=est/ey*fs
211 else

```

```

212     fst=fs
213 end
214 Pu11=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
215 Mu11=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
      Ast*fst*(D/2-c))/10^6
216
217 //xu=275 mm
218 xu=275//in mm
219 esc=0.0035*(xu-c)/xu
220 if(esc<=ey)
221     fsc=esc/ey*fs
222 else
223     fsc=fs
224 end
225 est=0.0035*(D-xu-c)/xu
226 if(est<=ey)
227     fst=est/ey*fs
228 else
229     fst=fs
230 end
231 Pu12=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
232 Mu12=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
      Ast*fst*(D/2-c))/10^6
233
234 //xu=250 mm
235 xu=250//in mm
236 esc=0.0035*(xu-c)/xu
237 if(esc<=ey)
238     fsc=esc/ey*fs
239 else
240     fsc=fs
241 end
242 est=0.0035*(D-xu-c)/xu
243 if(est<=ey)
244     fst=est/ey*fs
245 else
246     fst=fs
247 end

```

```

248 Pu13=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
249 Mu13=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
      Ast*fst*(D/2-c))/10^6
250
251 //xu=225 mm
252 xu=225//in mm
253 esc=0.0035*(xu-c)/xu
254 if(esc<=ey)
255     fsc=esc/ey*fs
256 else
257     fsc=fs
258 end
259 est=0.0035*(D-xu-c)/xu
260 if(est<=ey)
261     fst=est/ey*fs
262 else
263     fst=fs
264 end
265 Pu14=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
266 Mu14=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
      Ast*fst*(D/2-c))/10^6
267
268 //xu=200 mm
269 xu=200//in mm
270 esc=0.0035*(xu-c)/xu
271 if(esc<=ey)
272     fsc=esc/ey*fs
273 else
274     fsc=fs
275 end
276 est=0.0035*(D-xu-c)/xu
277 if(est<=ey)
278     fst=est/ey*fs
279 else
280     fst=fs
281 end
282 Pu15=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
283 Mu15=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+

```

```

        Ast*fst*(D/2-c))/10^6
284
285 //xu=150 mm
286 xu=150//in mm
287 esc=0.0035*(xu-c)/xu
288 if(esc<=ey)
289     fsc=esc/ey*fs
290 else
291     fsc=fs
292 end
293 est=0.0035*(D-xu-c)/xu
294 if(est<=ey)
295     fst=est/ey*fs
296 else
297     fst=fs
298 end
299 Pu16=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
300 Mu16=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
        Ast*fst*(D/2-c))/10^6
301
302 //xu=100 mm
303 xu=100//in mm
304 esc=0.0035*(xu-c)/xu
305 if(esc<=ey)
306     fsc=esc/ey*fs
307 else
308     fsc=fs
309 end
310 est=0.0035*(D-xu-c)/xu
311 if(est<=ey)
312     fst=est/ey*fs
313 else
314     fst=fs
315 end
316 Pu17=(0.36*fck*b*xu+Asc*fsc-Ast*fst)/10^3
317 Mu17=(0.36*fck*b*xu*(D/2-0.416*xu)+Asc*fsc*(D/2-c)+
        Ast*fst*(D/2-c))/10^6
318

```



```

319 //xu=0.531 d
320 d=D-c
321 xu=0.531*d
322 Pu18=0//in kN
323 Mu18=0.149*fck*b*d^2/10^6//in kN-m
324
325 Pu=[Pu1 Pu2 Pu3 Pu4 Pu5 Pu6 Pu7 Pu8 Pu9 Pu10 Pu11
      Pu12 Pu13 Pu14 Pu15 Pu16 Pu17 Pu18]
326 Mu=[Mu1 Mu2 Mu3 Mu4 Mu5 Mu6 Mu7 Mu8 Mu9 Mu10 Mu11
      Mu12 Mu13 Mu14 Mu15 Mu16 Mu17 Mu18]
327 xtitle('P-M Interaction Diagram', 'Mu (kN-m)', 'Pu (
      kN)')
328 plot(Mu,Pu)

```

---

### Scilab code Exa 18.8 Biaxial Bending

```

1 b=250//column width in mm
2 D=450//column depth in mm
3 Asc=2*1472//in sq mm
4 fck=15//in MPa
5 fy=250//in MPa
6 ex=200//in mm
7 ey=150//in mm
8 //from interaction curve
9 //for ex=200 mm on x-axis
10 Pum1=610//in kN
11 Muy1=120//in kN-m
12 //for ey=150 mm on y-axis
13 Pum2=720//in kN
14 Mux1=106//in kN-m
15 //(i)
16 Pu=300//in kN
17 Mux=Pu*ey/10^3//in kN-m
18 Muy=Pu*ex/10^3//in kN-m
19 Puz=(0.45*fck*(b*D-Asc)+0.75*fy*Asc)/10^3//in kN

```

```

20 a=Pu/Puz
21 an=1+1/0.6*(a-0.2)
22 b=(Mux/Mux1)^an+(Muy/Muy1)^an//<1
23 mprintf("The column can take a load of 300 kN with
           ex=200 mm and ey=150 mm\n")
24 //(ii)
25 Pu=500//in kN
26 Mux=Pu*ey/10^3//in kN-m
27 Muy=Pu*ex/10^3//in kN-m
28 a=Pu/Puz
29 an=1+1/0.6*(a-0.2)
30 b=(Mux/Mux1)^an+(Muy/Muy1)^an//>1
31 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

```

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

```

```
18 Pb=(0.36*fck*b*xu+fsc*Asc-fst*Ast)/10^3 //in kN
19 k=(Puz-Pu)/(Puz-Pb) //>1
20 k=1
21 Max=k*Max //in kN-m
22 May=k*May //in kN-m
23 fprintf("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

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

```

22 //using Mu=0.87 fy Ast (d-0.416 Xu), we get a
    quadratic equation
23 p=0.87*fy*0.416*a
24 q=-0.87*fy*d
25 r=Mu*10^6
26 Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
27 s1=1000*0.785*dia^2/Ast//in mm
28 s1=105//in mm
29 pt=1000*0.785*dia^2/s1/10^3/d*100//in %
30 Ads=0.15/100*10^3*D//in sq mm
31 //provide 8 mm dia bars
32 s2=1000*0.785*8^2/Ads//in mm
33 s2=265//in mm
34 Vu=Wu*lef/2//in kN
35 Tv=Vu*10^3/10^3/d//in MPa
36 //for M15 and pt=1
37 Tc=0.6//in MPa
38 //for solid slabs
39 Tc=1.3*Tc//in MPa
40 //as Tc>Tv, no shear reinforcement required
41 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

```

1 fck=15//in MPa
2 fy=415//in MPa
3 l=4.5//span, in m
4 MF=1.4
5 a=MF*20
6 D=1*10^3/a//in mm
7 D=160//in mm
8 W1=(D/10^3)*25//self-weight, in kN/m

```

```

9 W2=1//floor finish , in kN/m
10 W3=1//partitions , in kN/m
11 W4=4//live load , in kN/m
12 W=W1+W2+W3+W4//in kN/m
13 Wu=1.5*W//in kN/m
14 lef=1+0.16//in m
15 Mu=Wu*lef^2/8//in kN-m
16 d=sqrt(Mu*10^6/0.138/fck/10^3)//in mm
17 dia=12//assume 12 mm dia bars
18 D=d+dia/2+15//=160 mm(assumed value) , approximately
19 D=160//in mm
20 d=140//in mm
21 //steel
22 //Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
23 a=0.87*fy/0.36/fck/10^3
24 //using Mu=0.87 fy Ast (d-0.416 Xu) , we get a
    quadratic equation
25 p=0.87*fy*0.416*a
26 q=-0.87*fy*d
27 r=Mu*10^6
28 Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
29 s1=1000*0.785*dia^2/Ast//in mm
30 s1=112//in mm
31 pt=Ast/10^3/d*100//in %
32 Ads=0.12/100*10^3*D//in sq mm
33 //provide 8 mm dia bars
34 s2=1000*0.785*8^2/Ads//in mm
35 s2=260//in mm
36 Vu=Wu*lef/2//in kN
37 Tv=Vu*10^3/10^3/d//in MPa
38 //for M15 and pt=0.718
39 Tc=0.53//in MPa
40 //for solid slabs
41 Tc=1.25*Tc//in MPa
42 //as Tc>Tv, no shear reinforcement required
43 printf("Summary of design:\nSlab thickness= %d mm\n
    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

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

```

31 //provide 8 mm dia bars
32 dia=8//in mm
33 s1=1500*0.785*dia^2/Ast//>3d=3x79=237 mm
34 s1=235//in mm
35 Ads=0.12/100*1000*D//distribution steel, in sq mm
36 //assume 6 mm dia bars
37 s2=1000*0.785*6^2/Ads//in mm
38 s2=235//round-off, in mm
39 Tbd=1.6//in MPa
40 Ld=dia*0.87*fy/4/Tbd//in mm
41 Ld=452//in mm
42 Tv=Wu*10^3/1500/d//in MPa
43 Ast=1500*0.785*8^2/235//in sq mm
44 pt=Ast/1500/d*100//in %
45 //for M15 and pt=0.26
46 Tc=0.35//in MPa
47 //as Tc>Tv, no shear reinforcement required
48 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

```

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

```



```

12 Ay=0.0602
13 Mx=Ax*Wu*lx^2//in kN-m
14 My=Ay*Wu*lx^2//in kN-m
15 d=sqrt(Mx*10^6/0.149/fck/10^3)//in mm
16 d=51//round-off, in mm
17 //assume 10 mm dia bars
18 dia=10//in mm
19 D=d+dia/2+15//<100 mm assumed value
20 D=100//in mm
21 d=D-dia/2-15//in mm
22 //steel - short span
23 //Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
24 a=0.87*fy/0.36/fck/10^3
25 //using Mu=0.87 fy Ast (d-0.416 Xu), we get a
    quadratic equation
26 p=0.87*fy*0.416*a
27 q=-0.87*fy*d
28 r=Mx*10^6
29 Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
30 s1=1000*0.785*dia^2/Ast//in mm
31 s1=220//round-off, in mm
32 //long span
33 d=d-dia/2-dia/2//in mm
34 //Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
35 a=0.87*fy/0.36/fck/10^3
36 //using Mu=0.87 fy Ast (d-0.416 Xu), we get a
    quadratic equation
37 p=0.87*fy*0.416*a
38 q=-0.87*fy*d
39 r=My*10^6
40 Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
41 s2=1000*0.785*dia^2/Ast//in mm
42 s2=250//round-off, in mm
43 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

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

```

32 Asv=2*0.785*6^2//in sq mm
33 Sv=Asv*fy/0.4/b//in mm
34 Sv=260//assume, in mm
35 Svmax=0.75*d//in mm
36 Svmax=200//round-off, in mm
37 Sv=min(Sv,Svmax)//in mm
38 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)
39 //deflection check
40 Ec=5700*sqrt(fck)//in MPa
41 Es=2*10^5//in MPa
42 m=Es/Ec
43 fcr=0.7*sqrt(fck)//in MPa
44 //using  $b x x/2 = m Ast (d-x)$ , we get a quadratic
        equation
45 //solving the quadratic equation
46 p=b/2
47 q=m*Ast
48 r=-m*Ast*d
49 x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
50 z=d-x/3//in mm
51 Ir=b*x^3/12+b*x*(x/2)^2+m*Ast*(d-x)^2//in mm^4
52 Igr=b*D^3/12//in mm^4
53 yt=D/2//in mm
54 Mr=fcr*Igr/yt//in N-mm
55 M=W*l^2/8*10^6//in N-mm
56 Ieff=Ir/(1.2-Mr/M*z/d*(1-x/d)*b/b)//in mm^4
57 //Ir<Ieff<Igr, hence OK
58 W1=W*1//in kN
59 u1=5/384*(W1*10^3)*(1*10^3)^3/Ec/Ieff//short-term
        deflection, in mm
60 //long-term deflection
61 //(i) deflection due to shrinkage
62 k3=0.125//for simply supported beam
63 pt=0.56//in %
64 pc=0//in %
65 k4=0.72*(pt-pc)/sqrt(pt)

```

```

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

```

---

### Scilab code Exa 19.7 Design of Rectangular Beam

```

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

```

```

17 Mu=Wu*1^2/8//in kN-m
18 d=(Mu*10^6/0.149/fck/b)^0.5//<750 mm, hence OK
19 d=750//in mm
20 //steel
21 //Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
22 a=0.87*fy/0.36/fck/b
23 //using Mu=0.87 fy Ast (d-0.416 Xu), we get a
    quadratic equation
24 p=0.87*fy*0.416*a
25 q=-0.87*fy*d
26 r=Mu*10^6
27 Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
28 //provide 20 mm dia bars
29 n=Ast/0.785/20^2
30 //provide 8-20 mm + 2-18 mm dia bars
31 Ast=8*0.785*20^2+2*0.785*18^2//in sq mm
32 pt=Ast/b/d*100//pt=1.34
33 Vu=Wu*1/2//in kN
34 Tv=Vu*10^3/b/d//in MPa
35 //for M15 and pt=1.34
36 Tc=0.65//in MPa
37 //as Tv>Tc, shear reinforcement required
38 //provide 6 mm stirrups
39 Vus=Vu-Tc*b*d/10^3//in kN
40 Asv=2*0.785*6^2//in sq mm
41 Sv=Asv*0.87*fy*d/Vus/10^3//in mm
42 Sv=130//assume, in mm
43 Svmin=Asv*fy/0.4/b//in mm
44 Svmin=115//assume, in mm
45 Sv=min(Sv,Svmin)//in mm
46 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)
47 //deflection check
48 Ec=5700*sqrt(fck)//in MPa
49 Es=2*10^5//in MPa
50 m=Es/Ec
51 fcr=0.7*sqrt(fck)//in MPa

```

```

52 //using  $b x x/2 = m A_{st} (d-x)$ , we get a quadratic
    equation
53 //solving the quadratic equation
54 p=b/2
55 q=m*Ast
56 r=-m*Ast*d
57 x=(-q+sqrt(q^2-4*p*r))/2/p//in mm
58 x=290//assume, in mm
59 z=d-x/3//in mm
60 Ir=b*x^3/12+b*x*(x/2)^2+m*Ast*(d-x)^2//in mm^4
61 Igr=b*D^3/12//in mm^4
62 yt=D/2//in mm
63 Mr=fcr*Igr/yt//in N-mm
64 M=W*l^2/8*10^6//in N-mm
65 Ieff=Ir/(1.2-Mr/M*z/d*(1-x/d)*b/b)//in mm^4
66 //Ir>Ieff
67 Ieff=Ir//in mm^4
68 W1=W*1//in kN
69 u1=5/384*(W1*10^3)*(1*10^3)^3/Ec/Ieff//short-term
    deflection, in mm
70 //long-term deflection
71 //(i) deflection due to shrinkage
72 k3=0.125//for simply supported beam
73 pt=1.34//in %
74 pc=0//in %
75 k4=0.65*(pt-pc)/sqrt(pt)
76 phi=k4*0.0003/D
77 u2=k3*phi*(1*10^3)^2//in mm
78 //(ii) deflection due to creep
79 Ecc=Ec/(1+1.6)//in MPa
80 //assuming a permanent load of 60%
81 W2=0.6*W*1//in kN
82 u3=5/384*(W2*10^3)*(1*10^3)^3/Ecc/Ieff//in mm
83 u4=5/384*(W2*10^3)*(1*10^3)^3/Ec/Ieff//in mm
84 u5=u3-u4//in mm
85 u=u1+u2+u5//total deflection, in mm
86 v1=1*10^3/250//permissible deflection, in mm
87 v2=1*10^3/350//in mm

```

```

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

```

---

### Scilab code Exa 19.8 Design of T beam

```

1 l=10//span , in m
2 fck=15//in MPa
3 fy=250//in MPa
4 Df=100//slab thickness , in mm
5 D=1*10^3/15//depth of beam, in mm
6 D=600//assume, in mm
7 d=D-50//cover=50 mm
8 bw=300//beam width , in mm
9 bf=1*10^3/6+bw+6*Df//>2500 mm c/c distance of beams
10 bf=2500//in mm
11 W1=(bw/10^3)*(D-Df)/10^3*25//web, in kN/m
12 W2=(Df/10^3)*(bf/10^3)*25//slab , in kN/m
13 W3=(bf/10^3)*5//imposed load , in kN/m
14 W=W1+W2+W3//in kN/m
15 Wu=1.5*W//in kN/m
16 Mu=Wu*l^2/8//in kN-m
17 Vu=Wu*l/2//in kN
18 Asf=0.36*fck*bf*Df/0.87/fy//steel required only for
    flange , in sq mm
19 Asf=6210//round-off , in sq mm
20 //verification of trial section
21 xu=100//assume, in mm
22 Ast=Asf//in sq mm
23 Mulim=0.87*fy*Ast*(d-0.416*xu)/10^6//in kN-m
24 //Mulim > Mu, hence OK
25 //keeping the assumed trial section , work out the
    steel required
26 //Xu=0.87*fy*Ast/0.36/fck/b = a*Ast

```

```

27 a=0.87*fy/0.36/fck/bf
28 //using Mu=0.87 fy Ast (d-0.416 Xu), we get a
    quadratic equation
29 p=0.87*fy*0.416*a
30 q=-0.87*fy*d
31 r=Mu*10^6
32 Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
33 //provide 5-25 mm dia + 3-22 mm dia bars
34 pt=Ast*100/(bw*d+(bf-bw)*Df)//pt=1%, approximately
35 //check for shear
36 Tv=Vu*10^3/bw/d//in MPa
37 //for M15 grade concrete and pt=1%
38 Tc=0.6//in MPa
39 //as Tv > Tc, shear reinforcement required
40 Vus=Vu-Tc*bw*d/10^3//in kN
41 //provide 6 mm dia stirrups
42 Asv=2*0.785*6^2//in sq mm
43 Sv=Asv*0.87*fy*d/Vus/10^3//in mm
44 Sv=90//round-off, in mm
45 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)
46 //answer in textbook for spacing of stirrups is
    incorrect
47 //deflection check
48 Ec=5700*sqrt(fck)//in MPa
49 Es=2*10^5//in MPa
50 m=Es/Ec//modular ratio
51 fcr=0.7*sqrt(fck)//in MPa
52 //using bf Df (x-Df/2) = m Ast (d-x), we get a
    quadratic equation
53 x=(m*Ast*d+bf*Df^2/2)/(bf*Df+m*Ast)//in mm
54 z=0.87*d//assume, in mm
55 //refer Fig. 19.5 of textbook
56 Ir=bf*x^3/12+bf*Df*(x/2)^2+m*Ast*(d-x)^2//in mm^4
57 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)

```



```

58 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
59 yt=d/2//in mm
60 Mr=fcr*Igr/yt//in N-mm
61 M=W*l^2/8*10^6//in N-mm
62 Ieff=Ir/(1.2-Mr/M*z/d*(1-x/d)*bw/bf)//in mm^4
63 //Ir > Ieff
64 Ieff=Ir//in mm^4
65 W1=W*l//in kN
66 u1=5/384*(W1*10^3)*(1*10^3)^3/Ec/Ieff//short term
    deflection , in mm
67 //deflection due to shrinkage
68 k3=0.125//for simply supported beam
69 pt=1//in %
70 pc=0//in %
71 k4=0.65*(pt-pc)/sqrt(pt)
72 phi=k4*0.0003/D
73 u2=k3*phi*(1*10^3)^2//in mm
74 //deflection due to creep
75 Ecc=Ec/(1+1.6)//in MPa
76 //assuming a permanent load of 60%
77 W2=0.6*W*l//in kN
78 u3=5/384*(W2*10^3)*(1*10^3)^3/Ecc/Ieff//in mm
79 u4=5/384*(W2*10^3)*(1*10^3)^3/Ec/Ieff//in mm
80 u5=u3-u4//in mm
81 u=u1+u2+u5//total deflection , in mm
82 v1=1*10^3/250//permissible deflection , in mm
83 v2=1*10^3/350//>20 mm
84 v2=20//in mm
85 //assuming half the shrinkage strain occurs within
    the first 28 days, the deflection occurring after
    this time
86 v3=u2/2+u5//< permissible value , hence OK

```

---

Scilab code Exa 19.9 Design of Staircase

```

1 l=2.7+1//span , in m
2 R=0.15//rise , in m
3 t=0.27//tread , in m
4 fck=15//in MPa
5 fy=415//in MPa
6 D=200//assume , in mm
7 W1=D/10^3*25*sqrt(R^2+t^2)/t//slab load on plan , in
  kN/m
8 W2=1/2*R*t*25/t//load of step per metre , in kN/m
9 W3=3//live load , in kN/m
10 W=W1+W2+W3//in kN/m
11 Wu=1.5*W//in kN/m
12 Mu=Wu*l^2/8//in kN-m
13 d=sqrt(Mu*10^6/0.138/fck/10^3)//in mm
14 d=115//round-off , in mm
15 //assume 10 mm dia bars
16 dia=10//in mm
17 D=d+dia/2+25//< 200 mm, hence OK
18 D=1*10^3/24//depth required for deflection , in mm
19 D=155//round-off , in mm
20 d=D-dia/2-25//in mm
21 //steel
22 //Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
23 a=0.87*fy/0.36/fck/10^3
24 //using Mu=0.87 fy Ast (d-0.416 Xu), we get a
  quadratic equation
25 p=0.87*fy*0.416*a
26 q=-0.87*fy*d
27 r=Mu*10^6
28 Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
29 s1=1000*0.785*dia^2/Ast//spacing of 10 mm dia bars
30 s1=110//round-off , in mm
31 Ads=0.12/100*D*10^3//distribution steel , in sq mm
32 //provide 8 mm dia bars
33 s2=1000*0.785*8^2/Ads//in mm
34 s2=270//round-off , in mm
35 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)
36 //answer in textbook for spacing of 10 mm dia bars
    is incorrect

```

---

### Scilab code Exa 19.10 Design of Column Footing

```

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

```

```

25 e=p+4*Tc
26 f=b*p+D*p+2*(b+D)*Tc
27 g=-(L^2-b*D)*p
28 d2=(-f+sqrt(f^2-4*e*g))/2/e//in m
29 d2=0.35//round-off, in m
30 //bending moment consideration, refer Fig. 19.8 of
    textbook
31 Mx=1*((L-b)/2)^2/2*p//in kN-m
32 My=1*((L-D)/2)^2/2*p//in kN-m
33 d3=sqrt(Mx*10^6/0.138/fck/10^3)//<350 mm, hence OK
34 //steel
35 //Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
36 a=0.87*fy/0.36/fck/10^3
37 //using Mu=0.87 fy Ast (d-0.416 Xu), we get a
    quadratic equation
38 p=0.87*fy*0.416*a
39 q=-0.87*fy*d2*10^3
40 r=Mx*10^6
41 Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
42 Ast=L*Ast//steel required for full width of 1.8 m
43 //provide 12 mm dia bars
44 dia=12//in mm
45 n=Ast/0.785/dia^2//no. of 12 mm dia bars
46 n=12//round-off
47 Tbd=1.6//in MPa
48 Ld=dia*0.87*fy/4/Tbd//in mm
49 Ld=677//assume, in mm
50 //this length is available from the face of the
    column in both directions
51 D=d2*10^3+dia/2+100//in mm
52 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

```

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

```

```

37 //provide 20 mm dia bars
38 s1=1000*0.785*20^2/Ast//in mm
39 s1=155//round-off, in mm
40 //(b) 2.5 m below the top
41 //Xu=0.87*fy*Ast/0.36/fck/b = a*Ast
42 a=0.87*fy/0.36/fck/10^3
43 //using Mu=0.87 fy Ast (d-0.416 Xu), we get a
    quadratic equation
44 p=0.87*fy*0.416*a
45 q=-0.87*fy*d3
46 r=M2*10^6
47 Ast=(-q-sqrt(q^2-4*p*r))/2/p//in sq mm
48 Astmin=0.12/100*10^3*D3//in sq mm
49 Ast=max(Ast,Astmin)//in sq mm
50 //provide 12 mm dia bars
51 s2=1000*0.785*12^2/Ast//in mm
52 s2=360//round-off, in mm
53 //distribution steel
54 Ads=0.12/100*10^3*D3//in sq mm
55 //provide 8 mm dia bars
56 s3=1000*0.785*8^2/Ads//in mm
57 s3=160//round-off, in mm
58 //check for shear
59 Vu=P//in kN
60 Tv=Vu*10^3/10^3/d//in MPa
61 //for M15 grade concrete and pt=0.71
62 Tc=0.54//in MPa
63 //as Tc > Tv, no shear reinforcement required
64 //development length
65 //(a) At the base of stem
66 dia=20//in mm
67 Tbd=1.6//in MPa
68 Ld=dia*0.87*fy/4/Tbd//in mm
69 Ld=1130//round-off, in mm
70 //(b) At 2.5 m below the top
71 dia=12//in mm
72 Ld=dia*0.87*fy/4/Tbd//in mm
73 Ld=680//round-off, in mm

```

```

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

```

---

#### Scilab code Exa 19.12 Design of Axially Loaded Short Column

```

1 P=1000//in kN
2 Pu=1.5*P//in kN
3 fck=15//in MPa
4 fy=415//in MPa
5 l=3.5//unsupported length, in m
6 //assume 1% steel
7 Ag=Pu*10^3/(0.4*fck*0.99+0.67*fy*0.01)//in sq mm
8 L=sqrt(Ag)//assuming a square column
9 L=420//in mm
10 emin=1*10^3/500+L/30//in mm
11 ep=0.05*L//=emin, hence OK
12 Asc=0.01*L^2//in sq mm
13 //provide 6-20 mm dia bars
14 Asc=6*0.785*20^2//in sq mm
15 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

```

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

```

```

8 L=sqrt(Ag)//assuming a square column
9 L=315//in mm
10 emin=1*10^3/500+L/30//<20
11 emin=20//in mm
12 ep=0.05*L//<emin, hence the column is to be checked
    for bending
13 Mu=Pu*10^3*emin//in N-mm
14 a=Pu*10^3/fck/L/L
15 b=Mu/fck/L/L^2//b=0.032
16 d1=40//cover(assume), in mm
17 c=d1/L//c=d'/D
18 //for d'/D = 0.15
19 p=0.07*fck//in %
20 Asc=p/100*L^2//in sq mm
21 //provide 4-20 mm dia bars
22 Asc=4*0.785*20^2//in sq mm
23 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

```

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

```



```

        considered in this direction
14  emin2=1*10^3/500+b/30//in direction of X axis, in mm
    , < 20 mm
15  emin2=20//in mm
16  ep2=0.05*b//<emin, hence moment in this direction
    needs to be considered
17  //interaction diagram
18  b=400//in mm
19  D=250//in mm
20  Mu=Pu*10^3*emin2//in N-mm
21  m=Pu*10^3/fck/b/D
22  n=Mu/fck/b/D^2//b=0.032
23  d1=40//cover(assume), in mm
24  c=d1/D//c=d'/D
25  //referring to Fig. 19.12
26  p=0.08*fck//in %
27  Asc=p/100*b*D//in sq mm
28  //provide 6-16 dia bars
29  Asc=6*0.785*16^2//in sq mm
30  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

```

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

```

```

12 //hence the column is slender on both the axes
13 Max=Pu*10^3*L/2000*(lex/(L/10^3))^2/10^6 //in kN-m
14 May=Max
15 Puz=(0.45*fck*(L^2-Asc)+0.75*fy*Asc)/10^3 //in kN
16 c=40 //cover, in mm
17 //to find Pb
18 xu=(L-c)/(1+0.002/0.0035) //in mm
19 Pb=0.36*fck*L*xu/10^3 //in kN
20 k=(Puz-Pu)/(Puz-Pb) //>1
21 Max=k*Max //in kN-m
22 Mu=15 //in kN-m
23 Mu=Mu+Max //in kN-m
24 a=Pu*10^3/fck/L/L
25 b=Mu*10^6/fck/L/L^2 //b=0.047
26 d1=c/L //d1=d'/D
27 //for d'/D = 0.1
28 p=0.095*fck //in %
29 Asc=p/100*L^2 //in sq mm
30 //provide 4-18 mm + 4-12 mm dia bars
31 Asc=4*0.785*18^2+4*0.785*12^2 //in sq mm
32 printf("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

```

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

```

```

10 L=400 //in mm
11 m=Pu*10^3/fck/L/L
12 n=p/fck
13 c=50 //cover (assume), in mm
14 d1=c/L //d1=d'/D
15 //from Fig. 19.21, for d'/D = 0.15 and Pu / fck b D
    = 0.625
16 f=0.046
17 Mux1=f*fck*L*L^2/10^6 //in kN-m
18 Muy1=Mux1
19 Puz=(0.45*fck*(1-p/100)*L^2+0.75*fy*p/100*L^2)/10^3
    //in kN
20 a=Pu/Puz // >0.8
21 an=2
22 b=(Mux/Mux1)^an+(Muy/Muy1)^an // >1
23 //assume 2.5% steel
24 p=2.5 //in %
25 n=p/fck
26 //from Fig. 19.21, for d'/D = 0.15 and Pu / fck b D
    = 0.625
27 f=0.08
28 Mux1=f*fck*L*L^2/10^6 //in kN-m
29 Muy1=Mux1
30 Puz=(0.45*fck*(1-p/100)*L^2+0.75*fy*p/100*L^2)/10^3
    //in kN
31 a=Pu/Puz // <0.8
32 an=1+1/0.6*(a-0.2)
33 b=(Mux/Mux1)^an+(Muy/Muy1)^an // <1, hence OK
34 Asc=p/100*L^2 //in sq mm
35 //provide 12-22 mm dia bars
36 Asc=12*0.785*22^2 //in sq mm
37 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

```

1 b=400 //in mm
2 D=500 //in mm
3 Pu=1600 //in kN
4 Mux=90 //in kN-m
5 Muy=50 //in kN-m
6 fck=15 //in MPa
7 fy=415 //in MPa
8 p=1.5 //assume 1.5% steel , placed on four sides
9 m=p/fck
10 c=50 //cover (assume), in mm
11 //to find Mux1
12 n=c/D //n=d'/D
13 l=Pu*10^3/fck/b/D
14 //referring to Fig.19.20 , for Pu/ fck/ b/ D = 0.53
    and p/ fck = 0.1
15 f=0.09
16 Mux1=f*fck*b*D^2/10^6 //in kN-m
17 //to find Muy1
18 b=500 //in mm
19 D=400 //in mm
20 n=c/D //n=d'/D
21 l=Pu*10^3/fck/b/D
22 //referring to Fig.19.21 , for Pu/ fck/ b/ D = 0.53
    and p/ fck = 0.1
23 f=0.08
24 Muy1=f*fck*b*D^2/10^6 //in kN-m
25 Puz=(0.45*fck*(1-p/100)*b*D+0.75*fy*p/100*b*D)/10^3
    //in kN
26 a=Pu/Puz // <0.8
27 an=1+1/0.6*(a-0.2)
28 r=(Mux/Mux1)^an+(Muy/Muy1)^an // <1
29 Asc=p/100*b*D //in sq mm
30 //provide 6-16 mm + 6-20 mm dia bars
31 Asc=6*0.785*16^2+6*0.785*20^2 //in sq mm
32 mprintf("Summary of design:\nColumn size - %d x %d
    mm\nSteel-main = 6-16 mm + 6-20 mm dia bars",D,b)

```

33 //answer in textbook is incorrect

---

**Scilab code Exa 19.18 Design of Column with Biaxial Bending**

```
1 b=300 //in mm
2 Pu=1500 //in kN
3 Mux=100 //in kN-m
4 Muy=70 //in kN-m
5 fck=15 //in MPa
6 fy=250 //in MPa
7 p=1.5 //assume 1.5% steel , placed on four sides
8 Ag=Pu*10^3/(0.4*fck*(1-p/100)+0.67*fy*p/100) //in sq
   mm
9 D=Ag/b //in mm
10 D=600 //assume , in mm
11 m=p/fck
12 c=60 //cover (assume) , in mm
13 //to find Mux1
14 n=c/D //n=d'/D
15 l=Pu*10^3/fck/b/D
16 //referring to Fig.19.17 , for Pu/ fck/ b/ D = 0.56
   and p/ fck = 0.1
17 f=0.038
18 Mux1=f*fck*b*D^2/10^6 //in kN-m
19 //to find Muy1
20 b=600 //in mm
21 D=300 //in mm
22 n=c/D //n=d'/D
23 l=Pu*10^3/fck/b/D
24 //referring to Fig.19.19 , for Pu/ fck/ b/ D = 0.56
   and p/ fck = 0.1
25 f=0.038
26 Muy1=f*fck*b*D^2/10^6 //in kN-m
27 Puz=(0.45*fck*(1-p/100)*b*D+0.75*fy*p/100*b*D)/10^3
   //in kN
```

```

28 a=Pu/Puz//>0.8
29 an=2
30 r=(Mux/Mux1)^an+(Muy/Muy1)^an//>1
31 p=4//assume 4% steel , second trial
32 m=p/fck
33 //to find Mux1
34 b=300//in mm
35 D=600//in mm
36 //referring to Fig.19.17, for Pu/ fck/ b/ D = 0.56
    and p/ fck = 0.26
37 f=0.15
38 Mux1=f*fck*b*D^2/10^6//in kN-m
39 //to find Muy1
40 b=600//in mm
41 D=300//in mm
42 n=c/D//n=d'/D
43 //referring to Fig.19.19, for Pu/ fck/ b/ D = 0.56
    and p/ fck = 0.26
44 f=0.15
45 Muy1=f*fck*b*D^2/10^6//in kN-m
46 Puz=(0.45*fck*(1-p/100)*b*D+0.75*fy*p/100*b*D)/10^3
    //in kN
47 a=Pu/Puz//<0.8
48 an=1+1/0.6*(a-0.2)
49 r=(Mux/Mux1)^an+(Muy/Muy1)^an//<1, hence OK
50 //but steel can be reduced
51 p=3//assume 3% steel , second trial
52 m=p/fck
53 //to find Mux1
54 b=300//in mm
55 D=600//in mm
56 //referring to Fig.19.17, for Pu/ fck/ b/ D = 0.56
    and p/ fck = 0.2
57 f=0.12
58 Mux1=f*fck*b*D^2/10^6//in kN-m
59 //to find Muy1
60 b=600//in mm
61 D=300//in mm

```

```

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

```

---