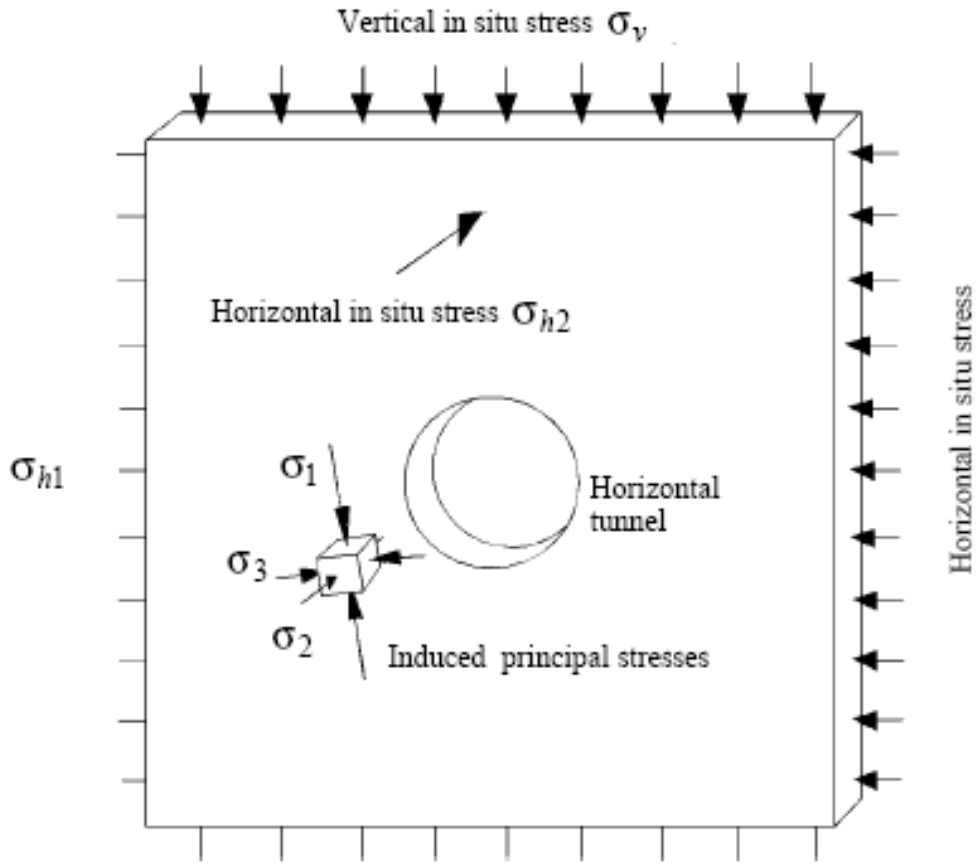
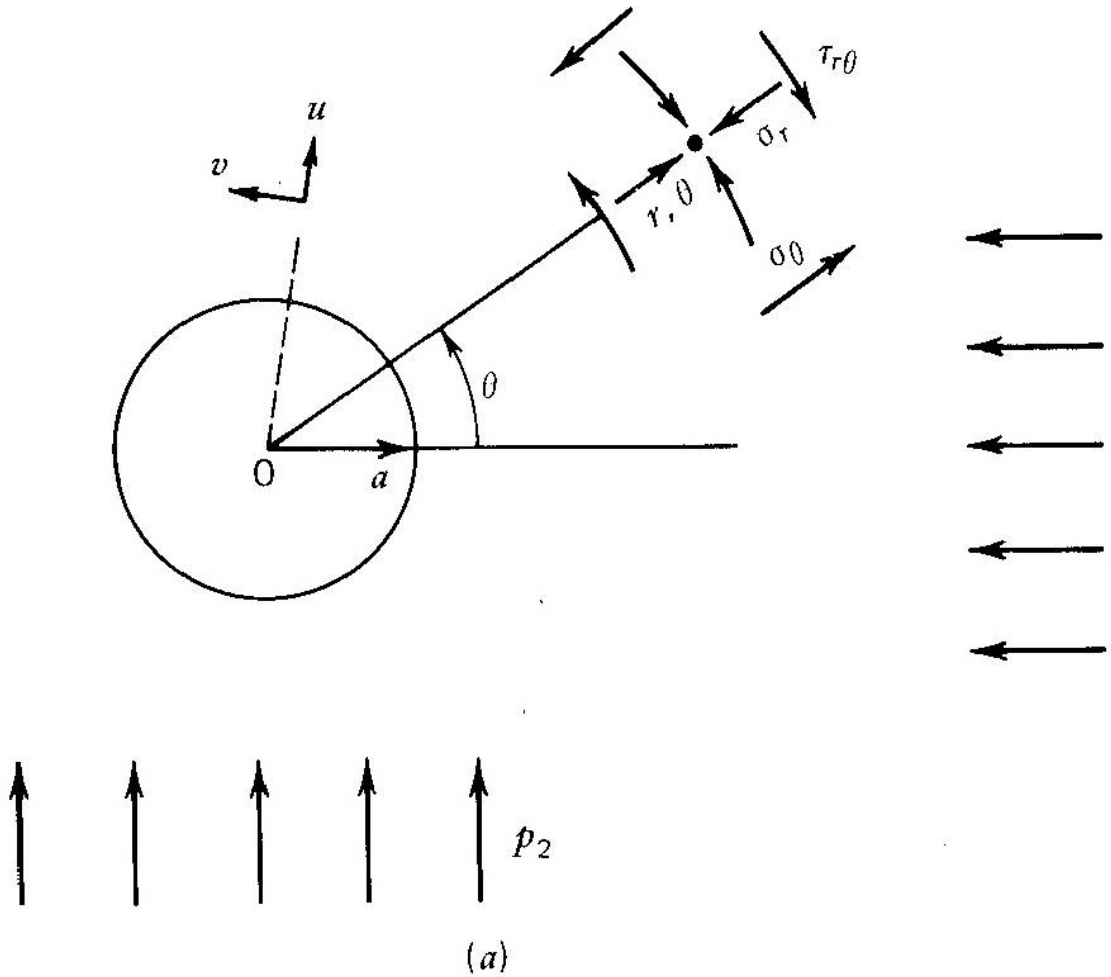
Tunneling in Rocks

Stress in circular opening



Stresses and deformation in polar coordinate



(a)

Stresses in single opening : Kirch solution (plane strain of hole in a Plate)

$$\sigma_r = \frac{S_h + S_v}{2}\left(1 - \frac{a^2}{r^2}\right) + \frac{S_h - S_v}{2}\left(1 - \frac{4a^2}{r^2} + \frac{3a^4}{r^4}\right)\cos 2\theta$$

$$\sigma_\theta = \frac{S_h + S_v}{2}\left(1 + \frac{a^2}{r^2}\right) - \frac{S_h - S_v}{2}\left(1 + \frac{3a^4}{r^4}\right)\cos 2\theta$$

$$\tau_{r\theta} = -\frac{S_h - S_v}{2}\left(1 + \frac{2a^2}{r^2} - \frac{3a^4}{r^4}\right)\sin 2\theta$$

Deformation in circular opening

$$u_r = \frac{(S_h + S_v)}{4G}\frac{a^2}{r} + \frac{(S_h - S_v)}{4G} + \frac{a^2}{r}\left[4(1-\upsilon) - \frac{a^2}{r^2}\right]\cos 2\theta$$

$$v_\theta = \frac{(S_h - S_v)}{4G}\frac{a^2}{r}\left[2(1-2\upsilon) + \frac{a^2}{r^2}\right]\sin 2\theta$$

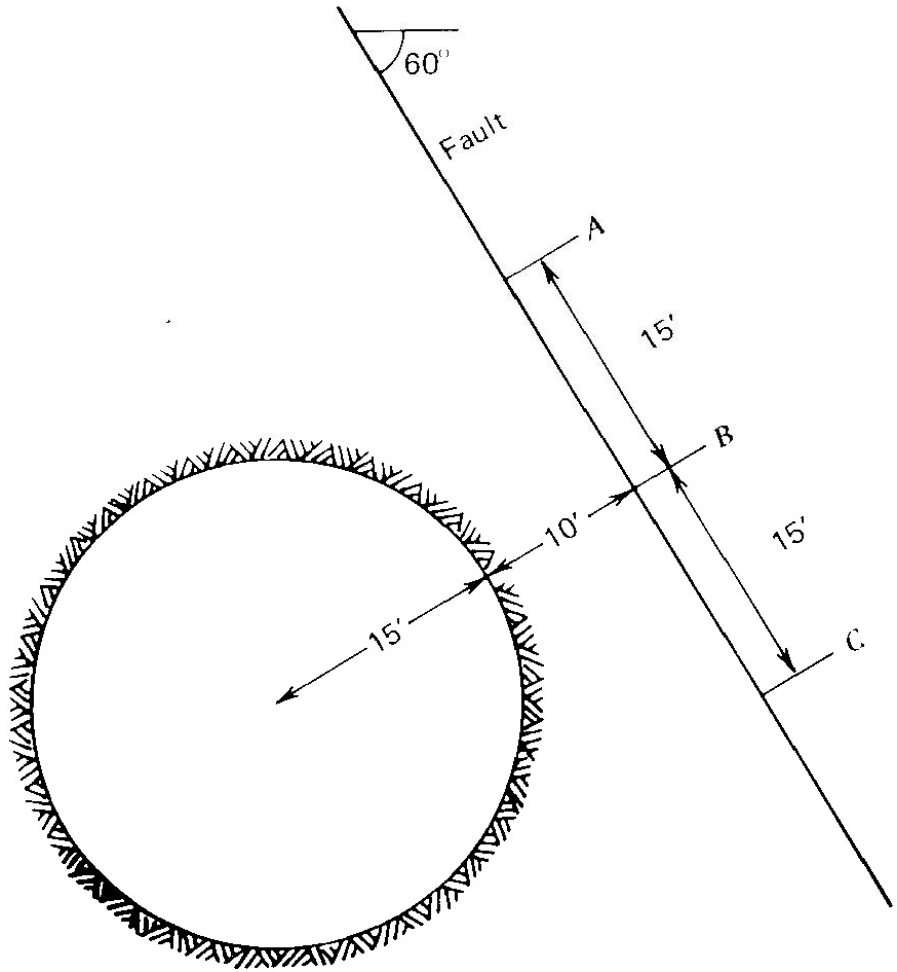
- ซึ่ง Sh,Sv= ความเค้นในแกนระดับ (ความเค้นล้อม) และความเค้นแนวดิ่ง
- a = รัศมีของอุโมงค์หรือช่องเปิด
- r = ระยะห่างจากจุดศูนย์กลางของอุโมงค์
- θ = ทิศทางของพิกัดวัดจากระนาบระดับ

Home work

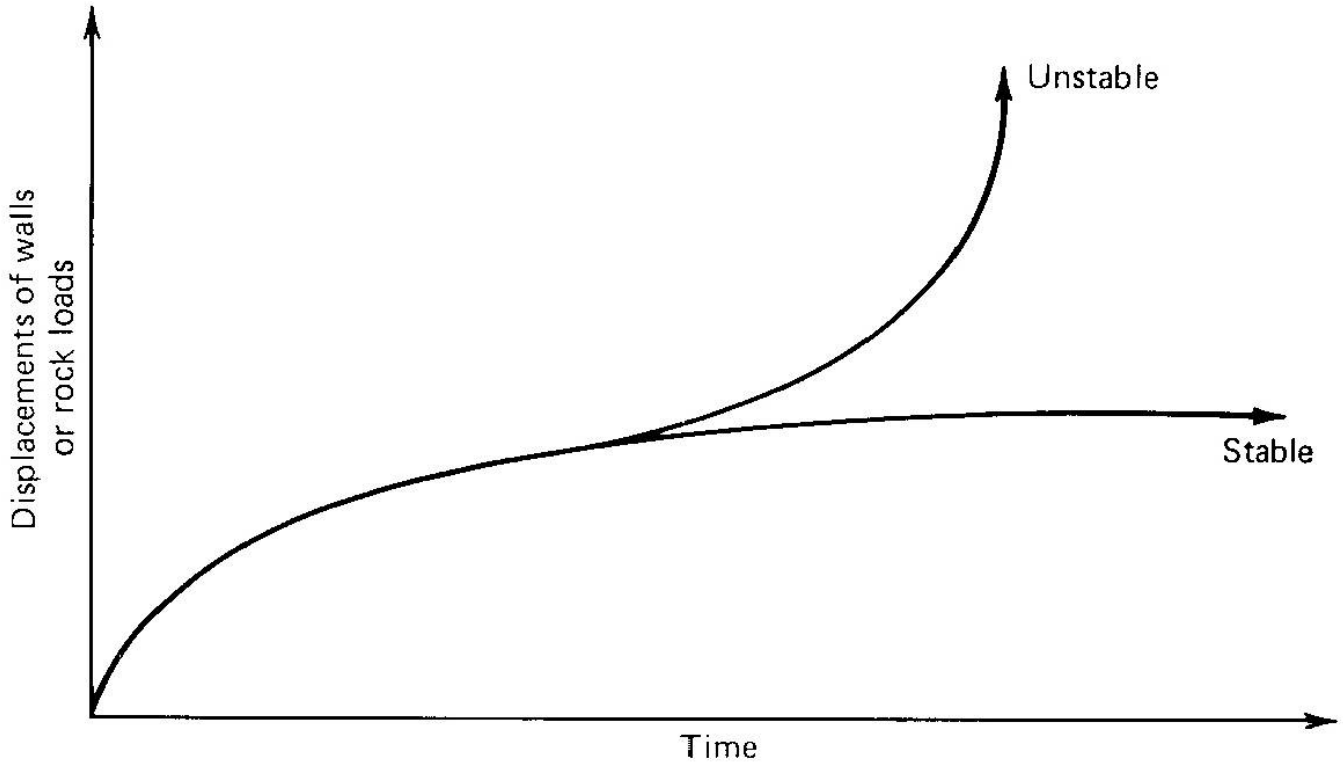
- Tunnel is driven at depth of 500 ft in granite, assume

  m =1,

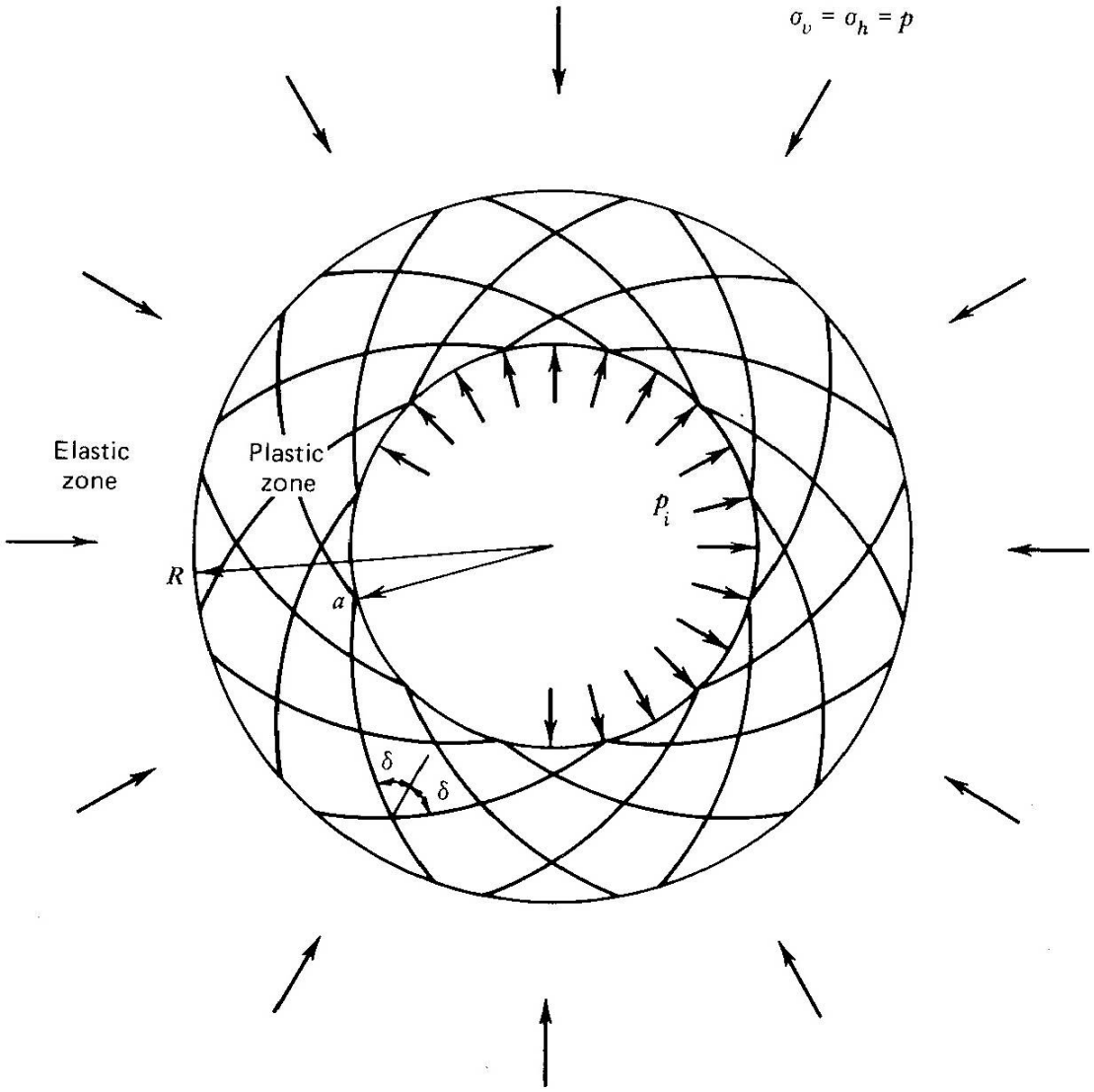
  γ=165 pcf
- Find normal and shear stresses in psi at A,B,C

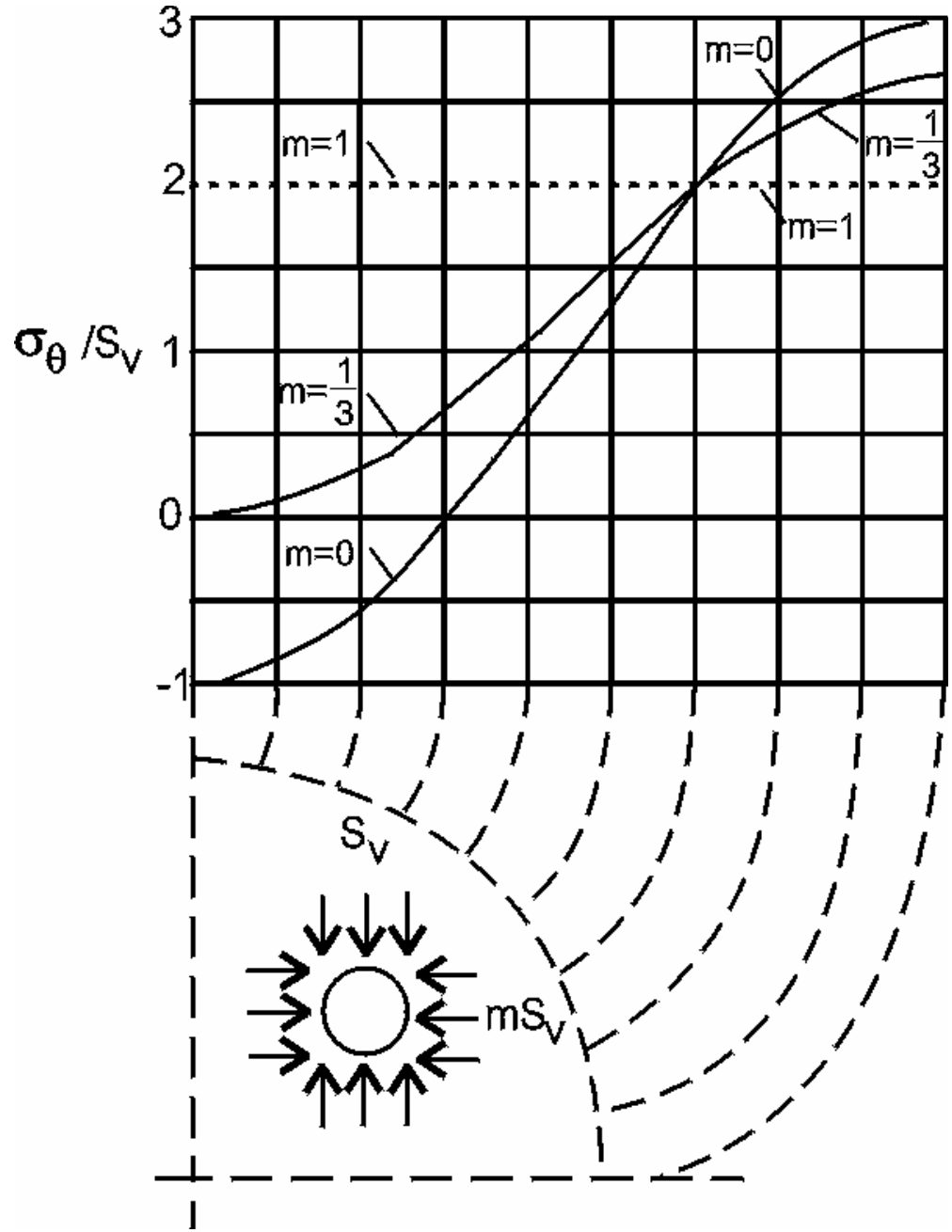


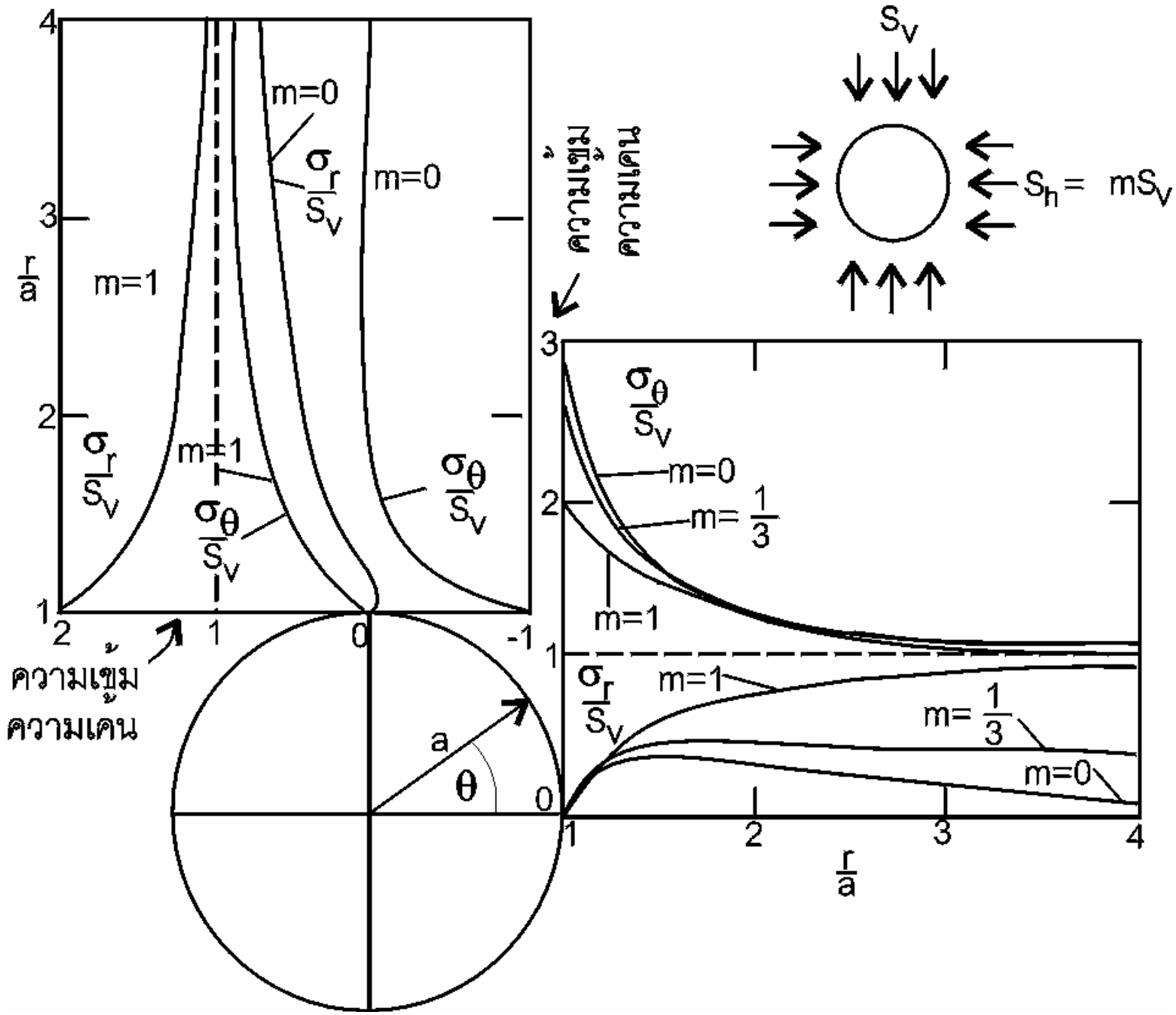
Convergence of wall (stability and instability)

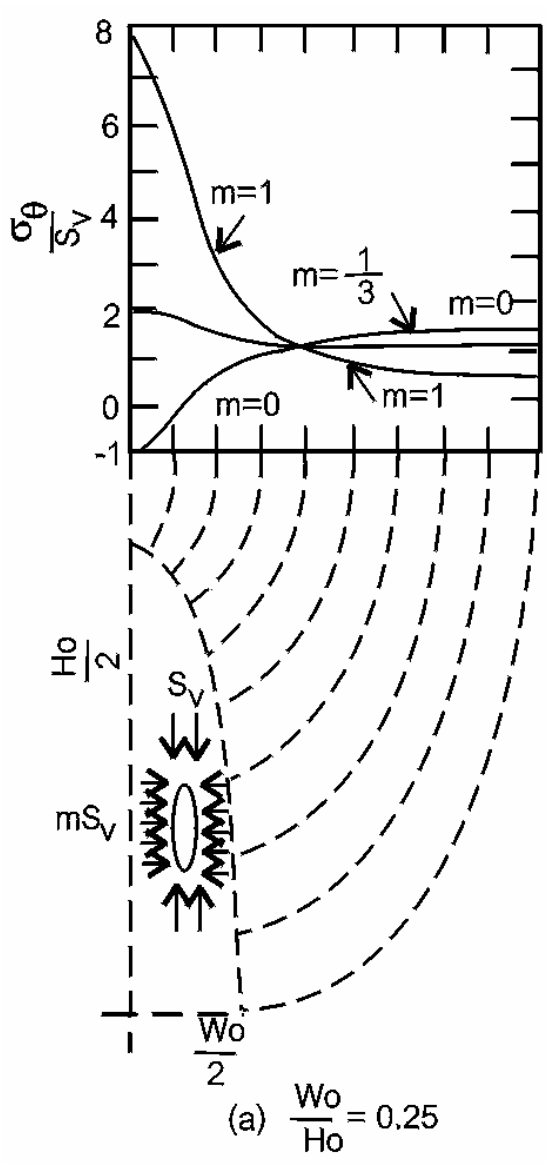


Bray's Elastic –plastic solution

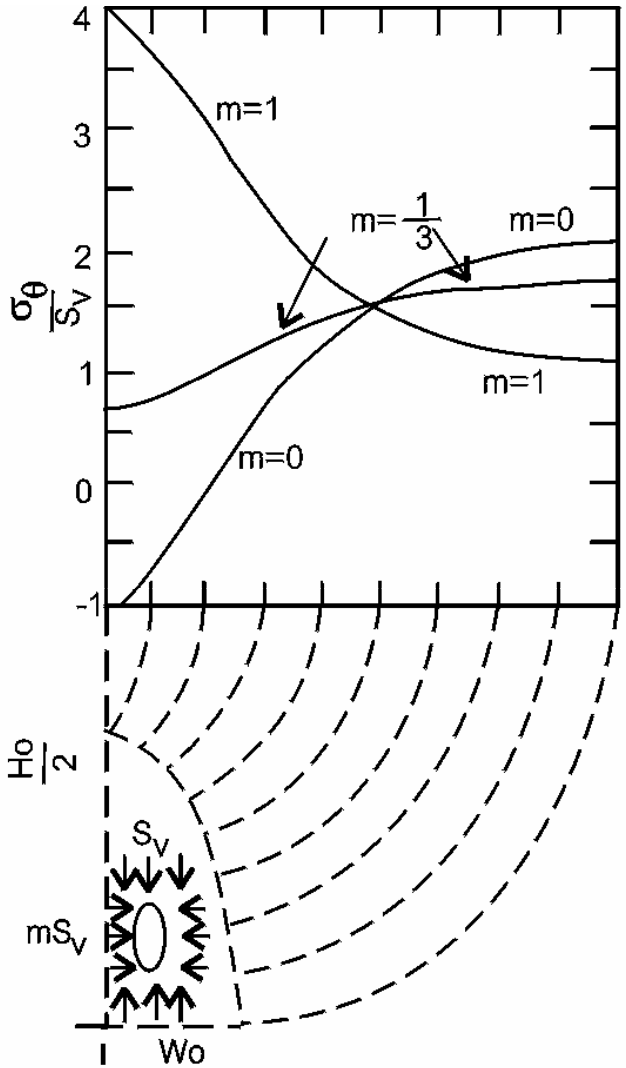



3
2
1
0
-1
σ_θ / S_V
m=0
m=1
m=1/3
m=1
m=1/3
m=0
S_V
mS_V

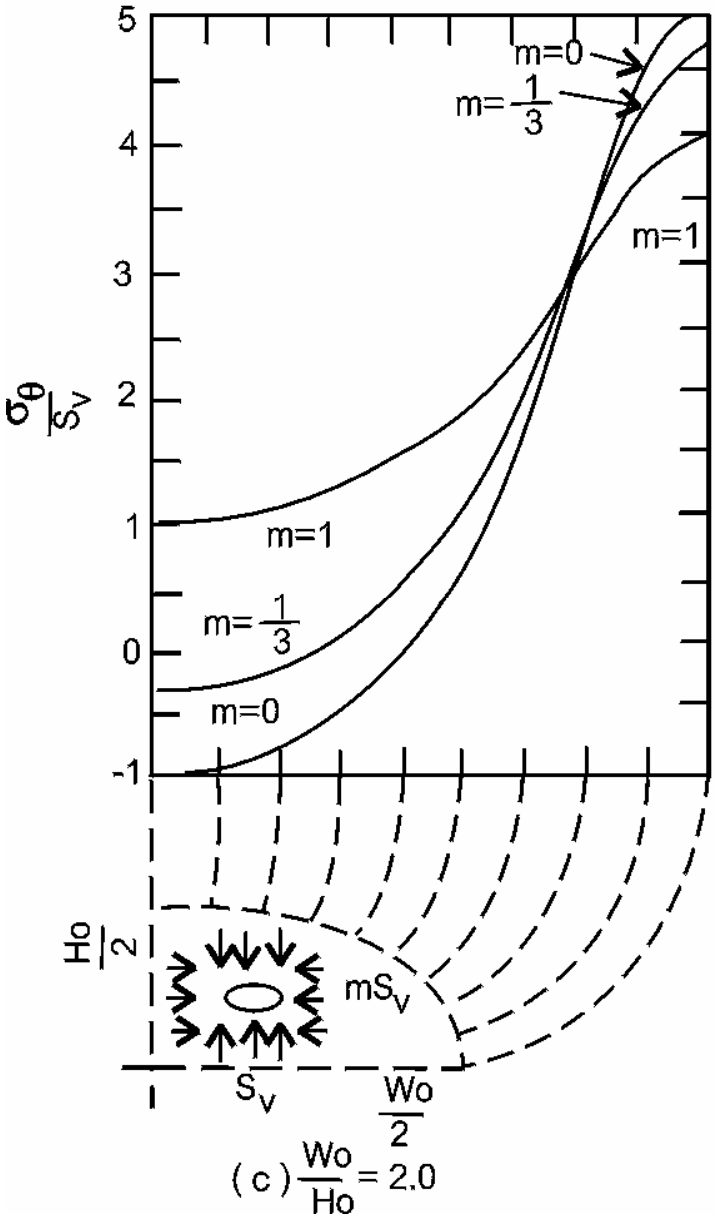

S_v
$S_h = mS_v$
m=0
m=0
m=1
m=±1
$\frac{\sigma_r}{S_v}$
$\frac{\sigma_\theta}{S_v}$
$\frac{r}{a}$
ความเข้ม
ความเค้น
a
θ
0
-1
1
2
3
4
$\frac{\sigma_\theta}{S_v}$
m=0
m= $\frac{1}{3}$
m=1
$\frac{\sigma_r}{S_v}$
m=1
m= $\frac{1}{3}$
m=0
$\frac{r}{a}$



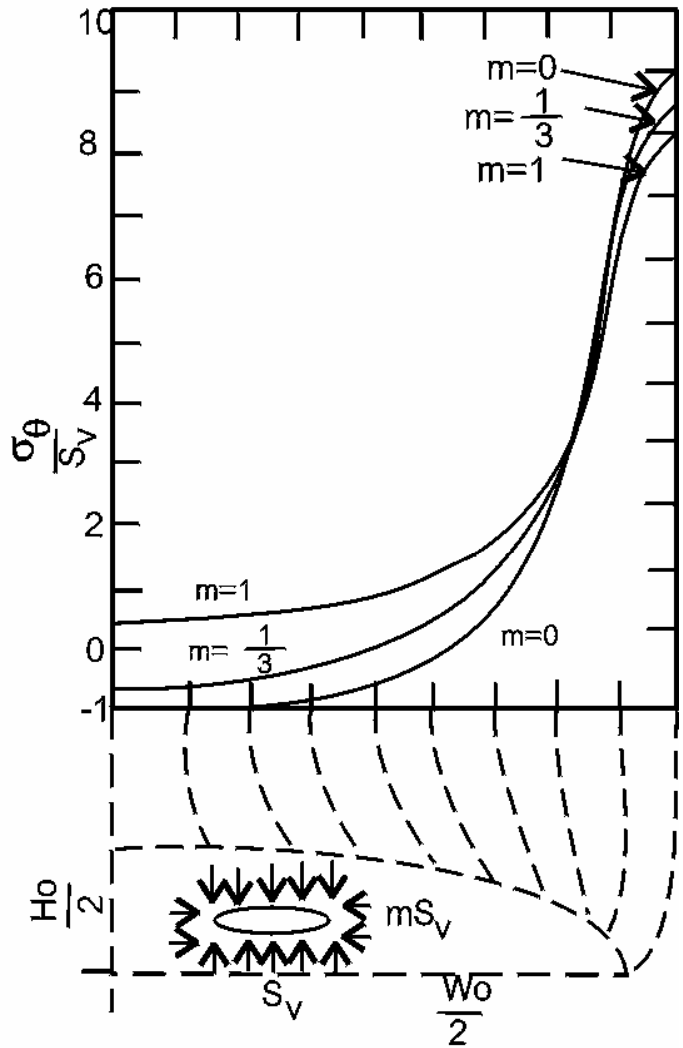
(a) $\frac{Wo}{Ho} = 0.25$



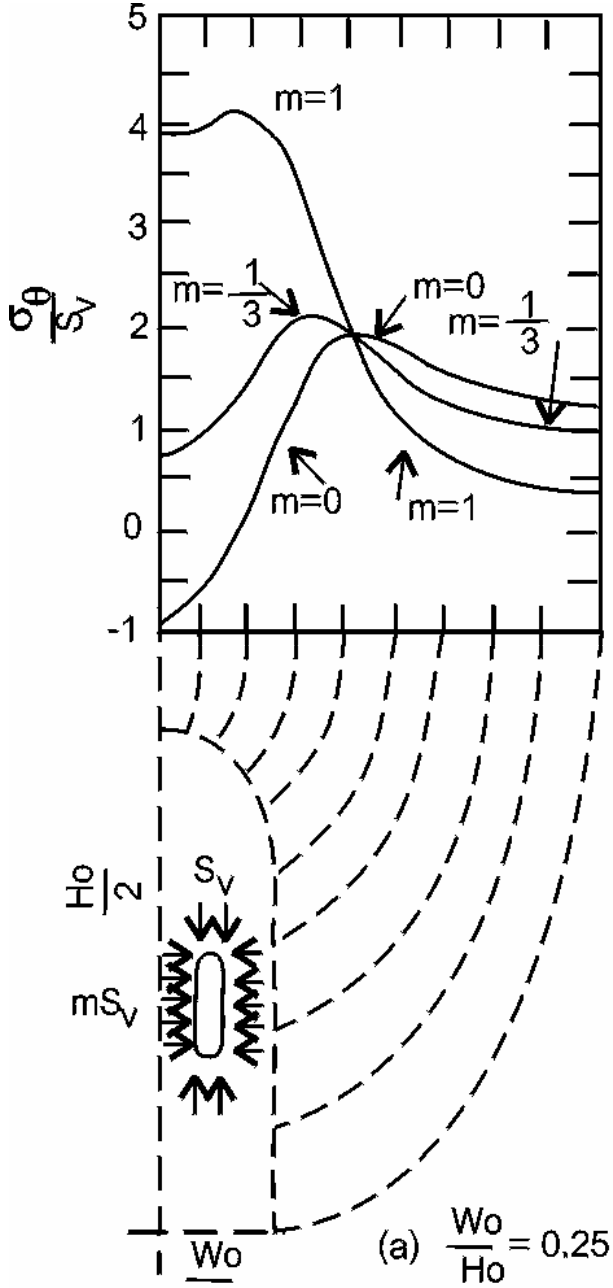
(b) $\frac{Wo}{Ho} = 0.5$

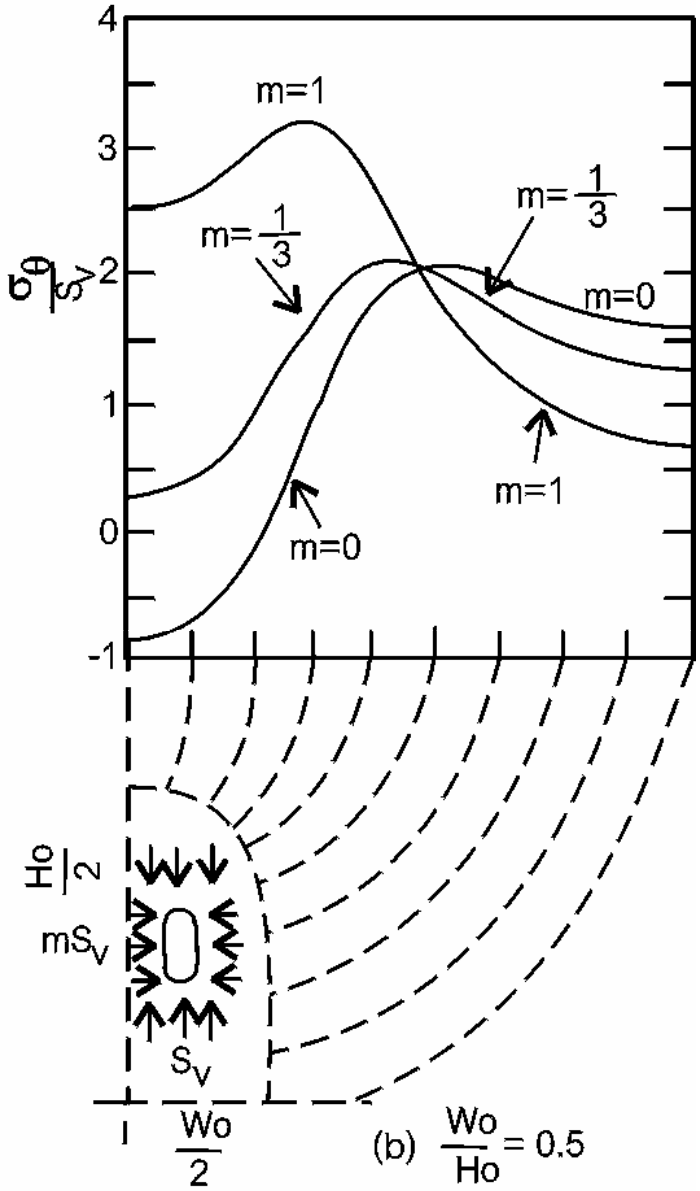


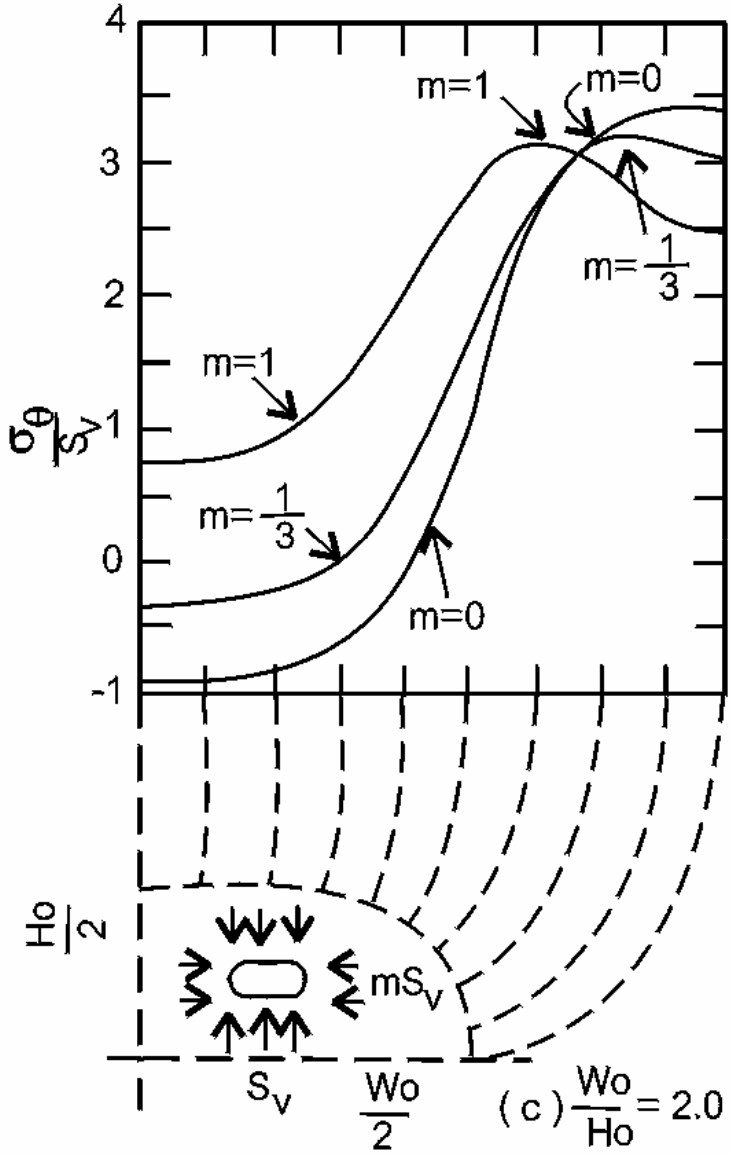
(c) $\frac{Wo}{Ho} = 2.0$

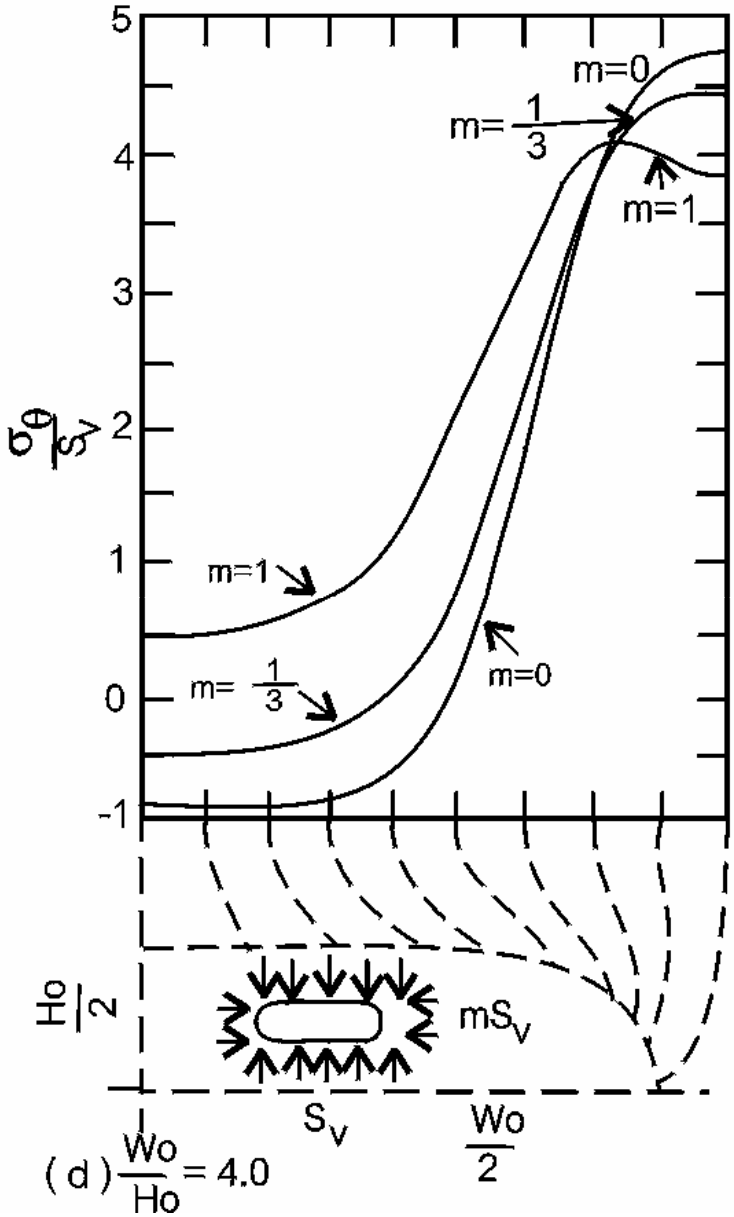


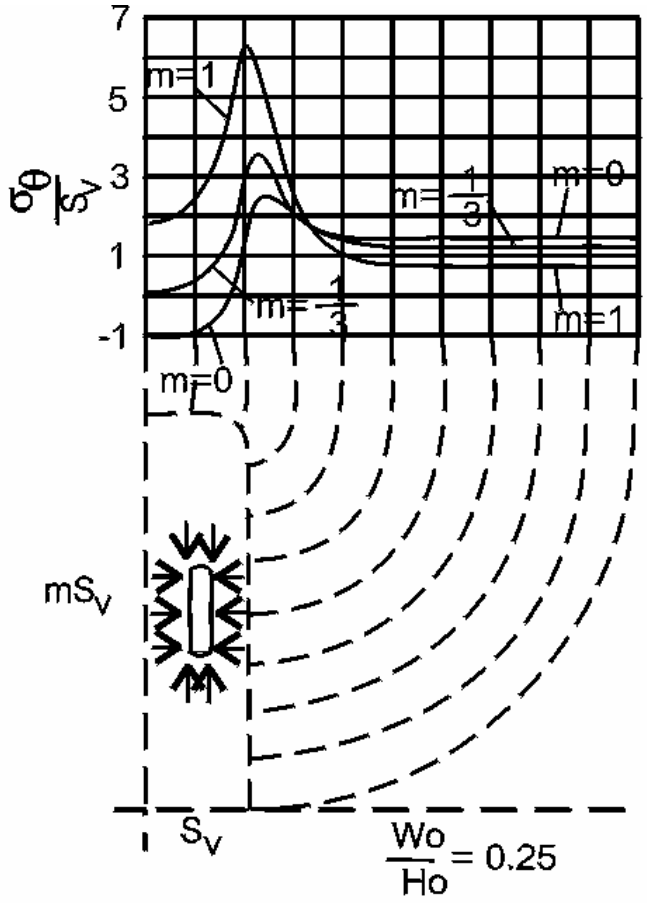
(d) $\frac{Wo}{Ho} = 4.0$


5
4
3
2
1
0
-1
m=1
m=1/3
m=0
m=1/3
m=0
m=1
σθ/sv
Ho/2
Sv
mSv
Wo
(a) Wo/Ho = 0.25

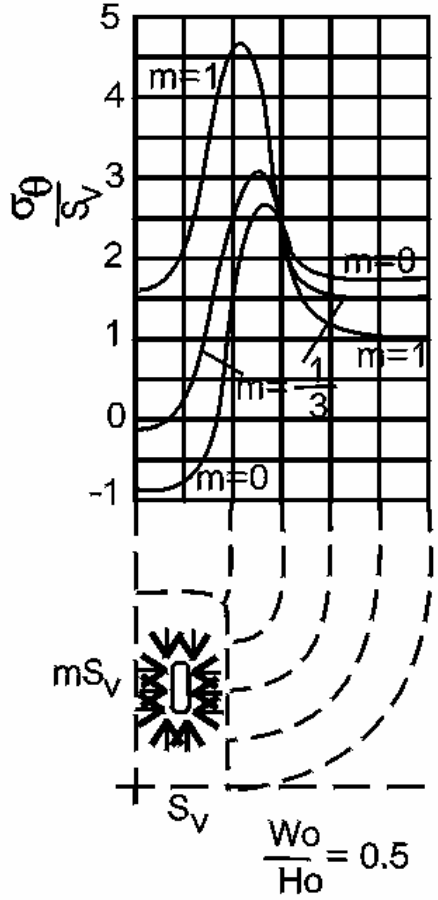

4
3
2
1
0
-1
m=1
m=1/3
m=1/3
m=0
m=0
m=1
σθ/sv
Ho/2
mSv
Sv
Wo/2
(b) Wo/Ho = 0.5


4
3
2
1
0
-1
m=1
m=0
m=1/3
m=1
m=1/3
m=0
σθ/Sv
Ho/2
mSv
Sv
Wo/2
(c) Wo/Ho = 2.0

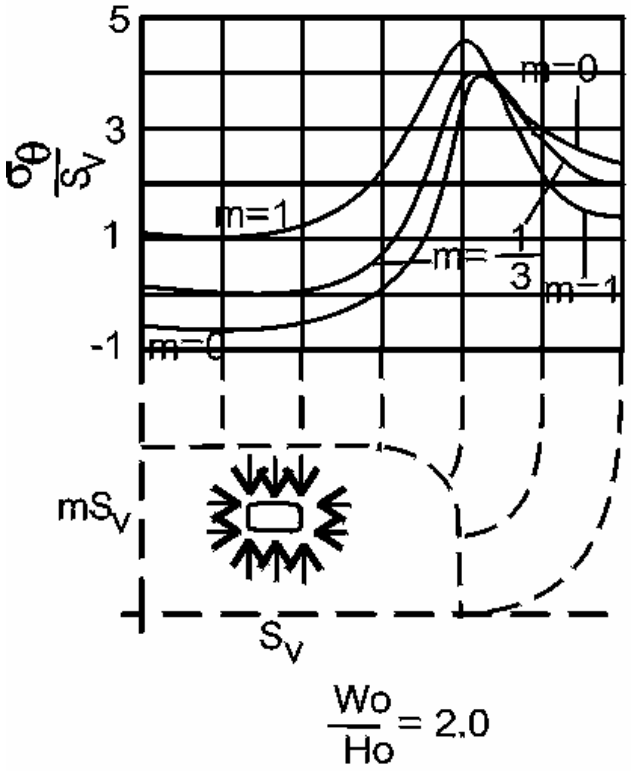

5
4
3
2
1
0
-1
m=0
m=1/3
m=1
m=1
m=1/3
m=0
σθ/Sv
Ho/2
mSv
Sv
Wo/2
(d) Wo/Ho = 4.0


7
5
3
1
-1
m=1
m=0
m=1/3
m=1/3
m=0
m=1
σ_θ/S_V
mS_V
S_V
$\frac{Wo}{Ho} = 0.25$

(a)

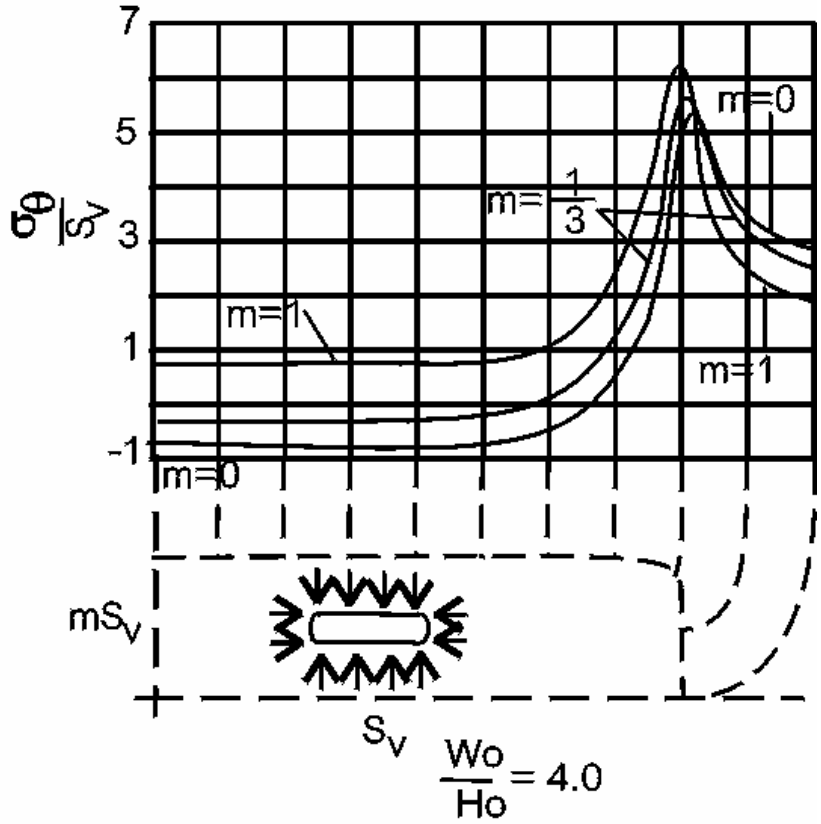

5
4
3
2
1
0
-1
m=1
m=0
m=1
m=1/3
m=0
σ_θ/S_V
mS_V
S_V
$\frac{Wo}{Ho} = 0.5$

(b)



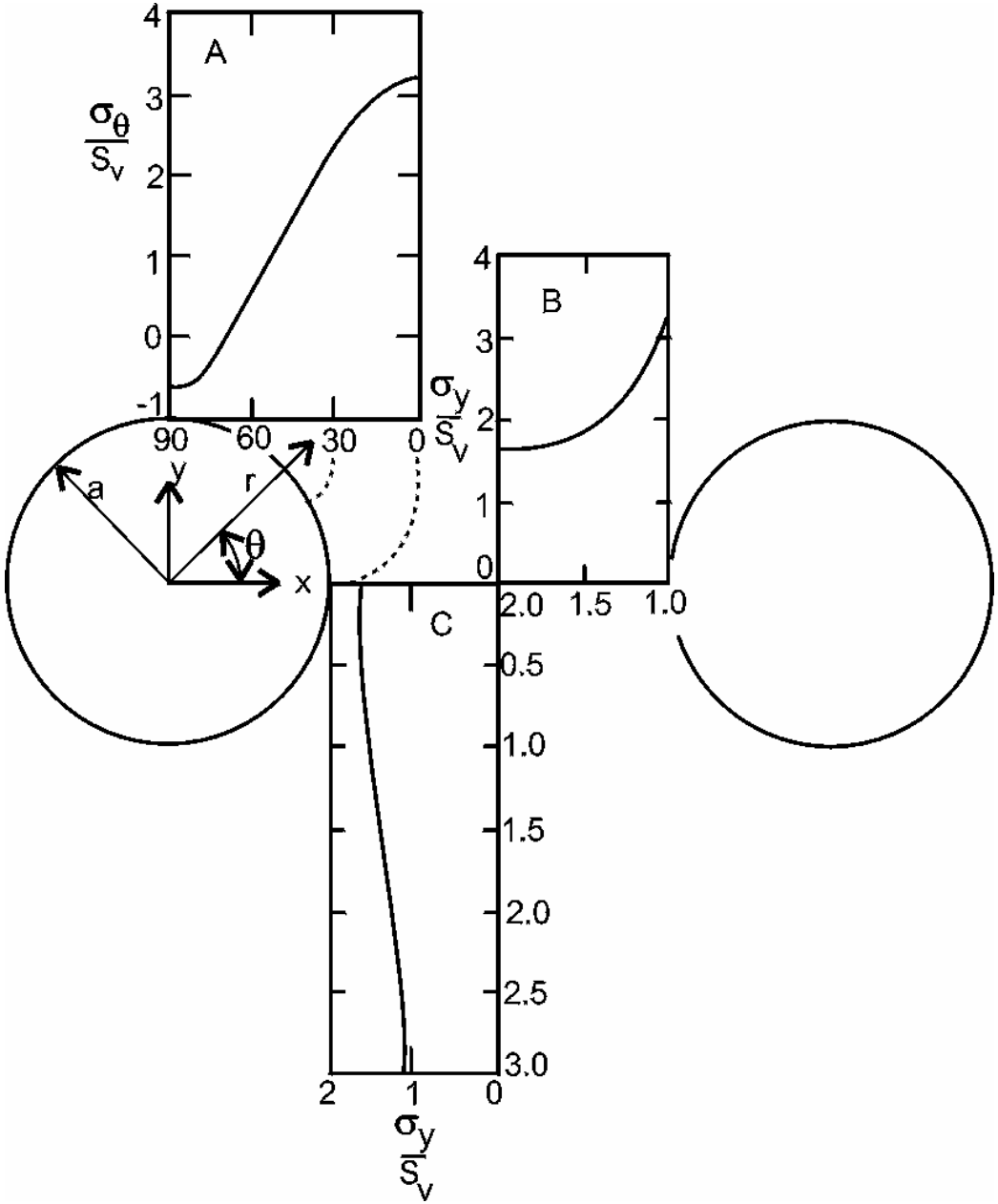
$\frac{Wo}{Ho} = 2.0$

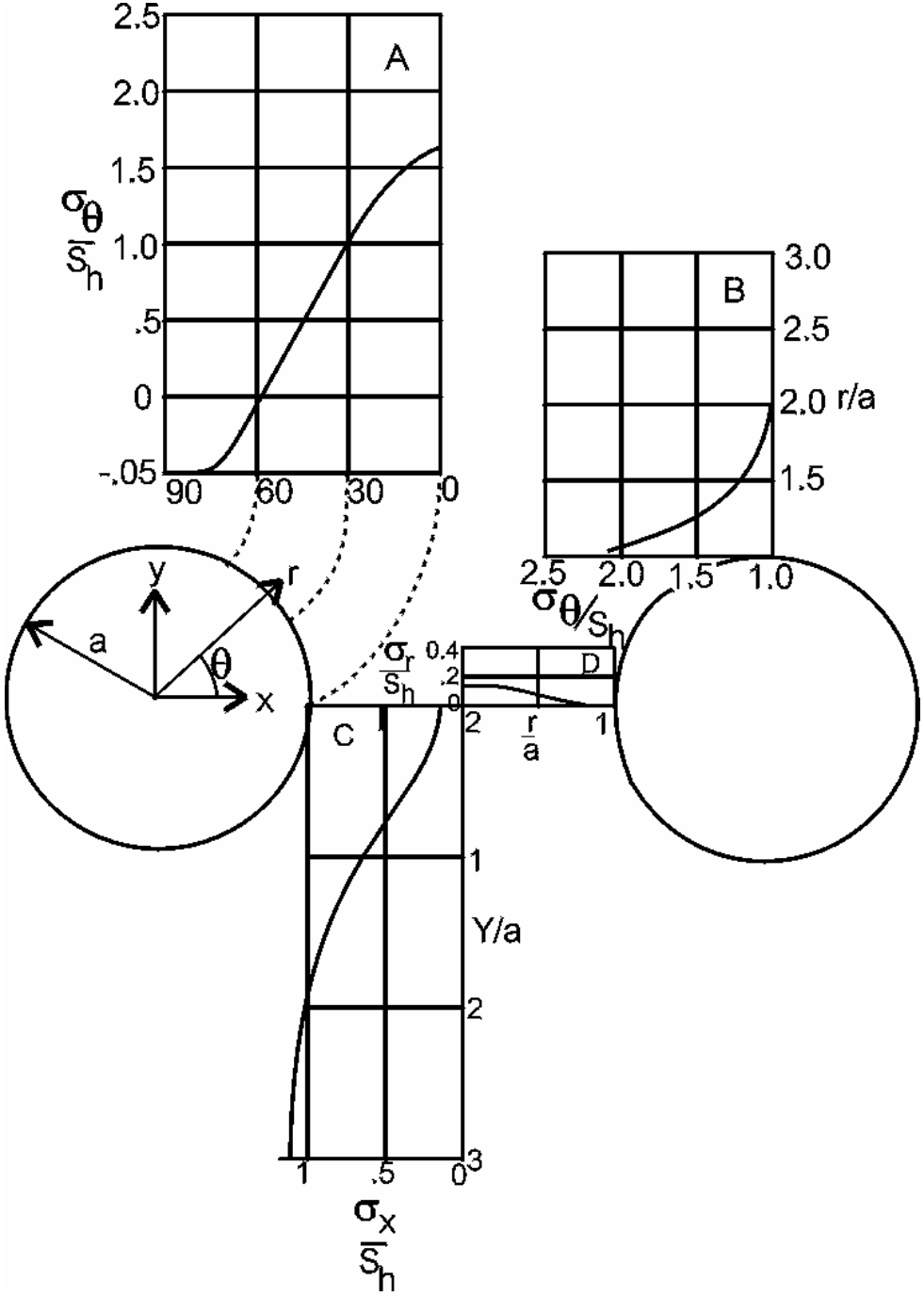
(c)

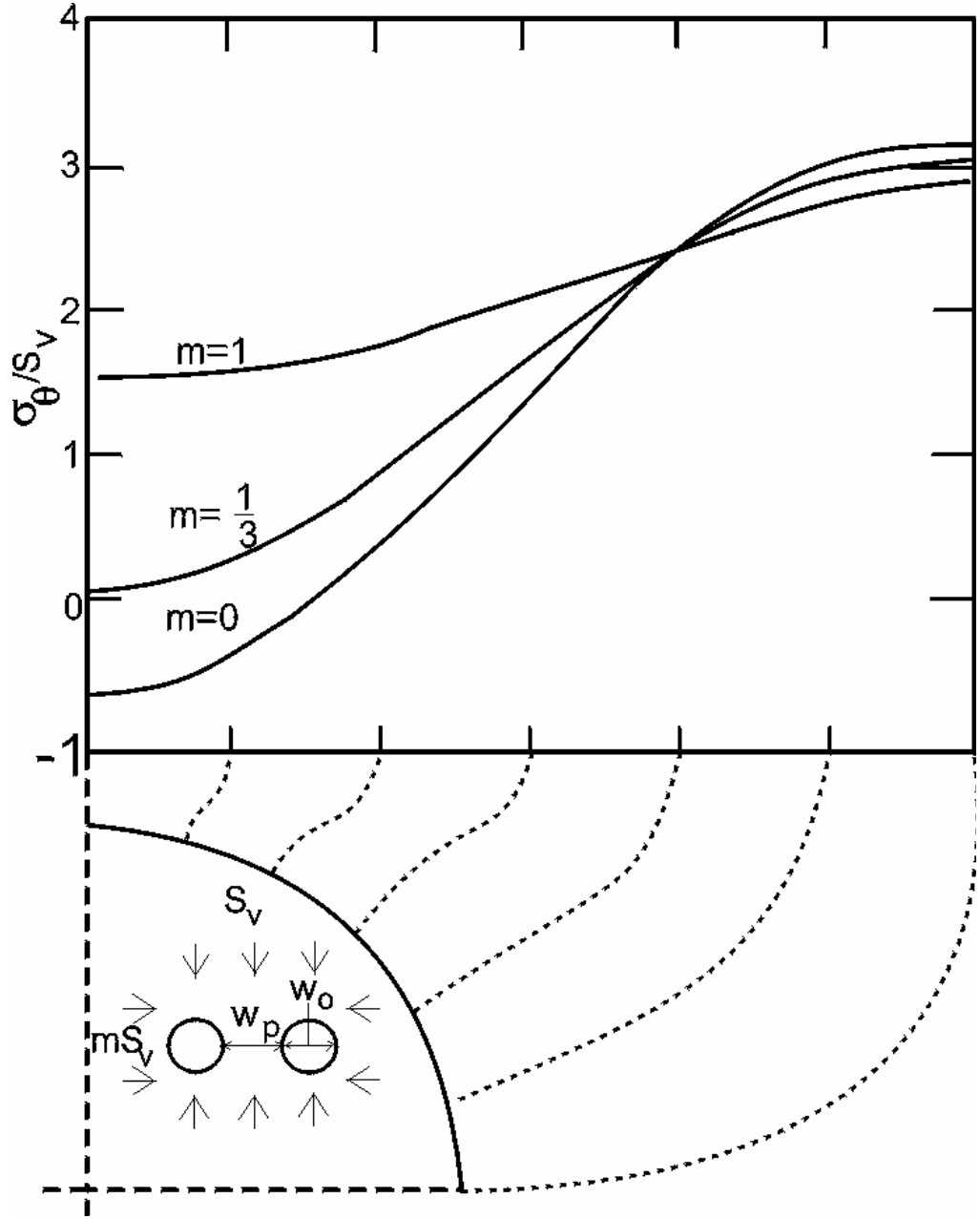


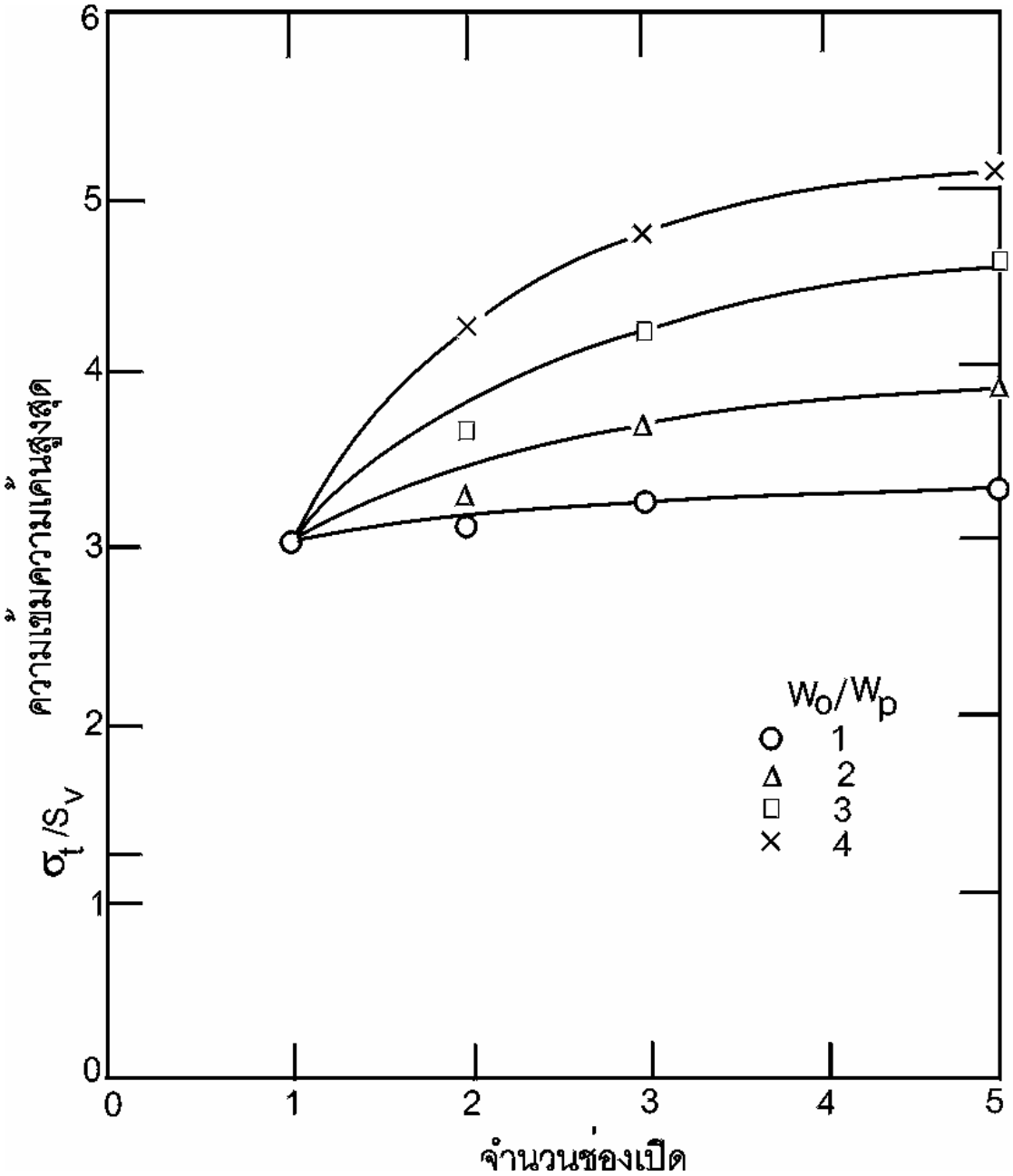
$\frac{Wo}{Ho} = 4.0$

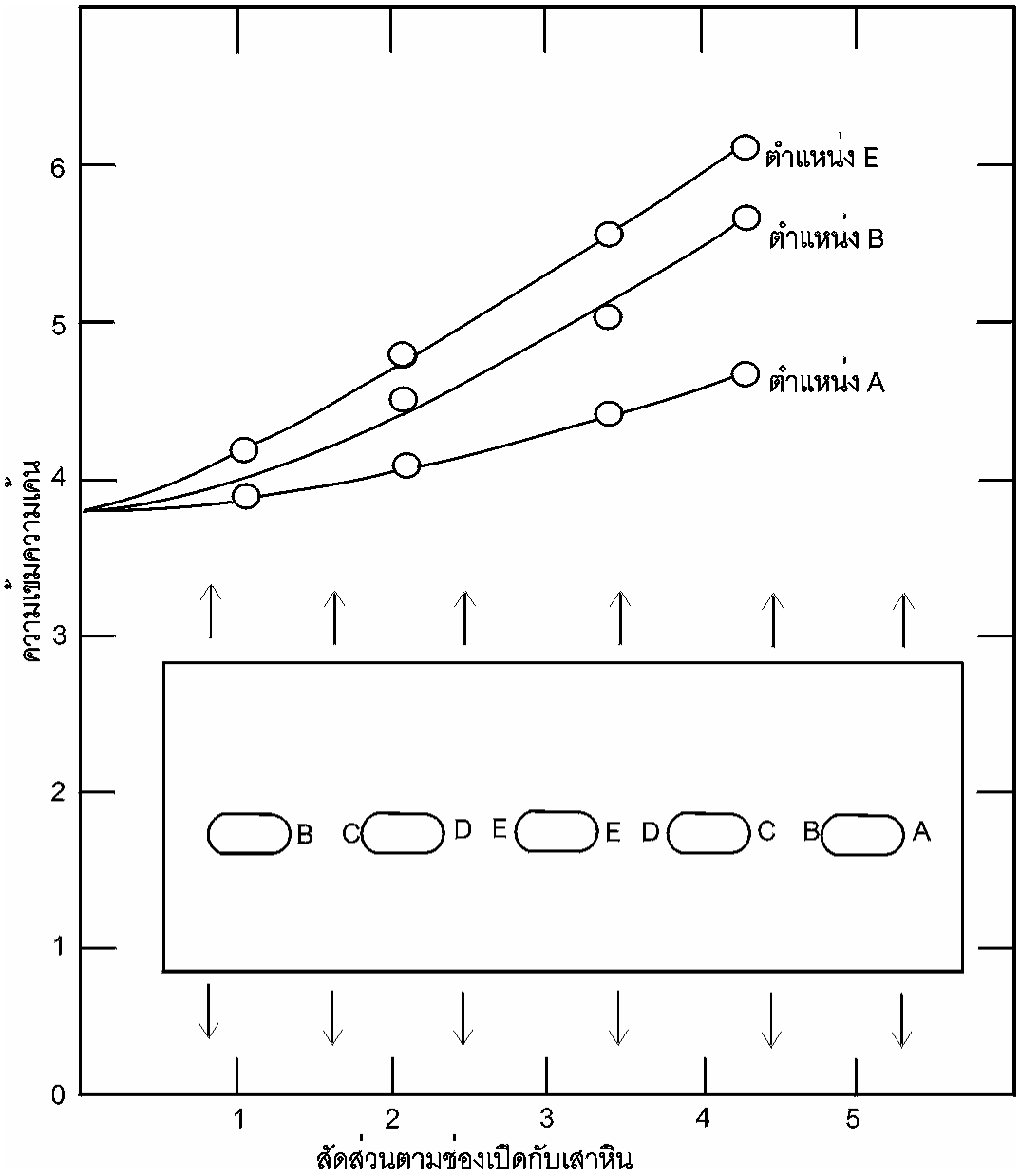
(d)

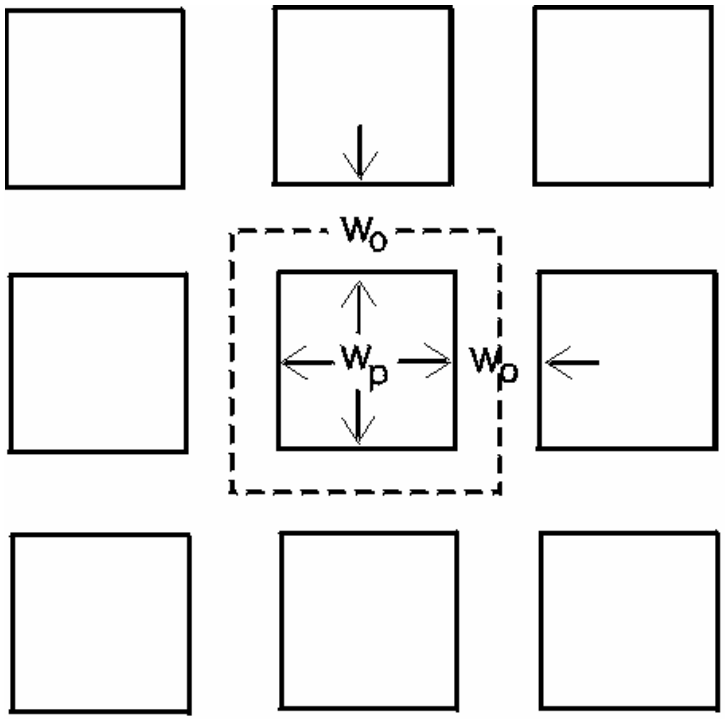

A
B
C
$\frac{\sigma_\theta}{S_v}$
$\frac{\sigma_y}{S_v}$
$\frac{\sigma_y}{S_v}$
4
3
2
1
0
-1
90
60
30
0
2.0
1.5
1.0
0.5
1.0
1.5
2.0
2.5
3.0
2
1
0
a
y
r
θ
x

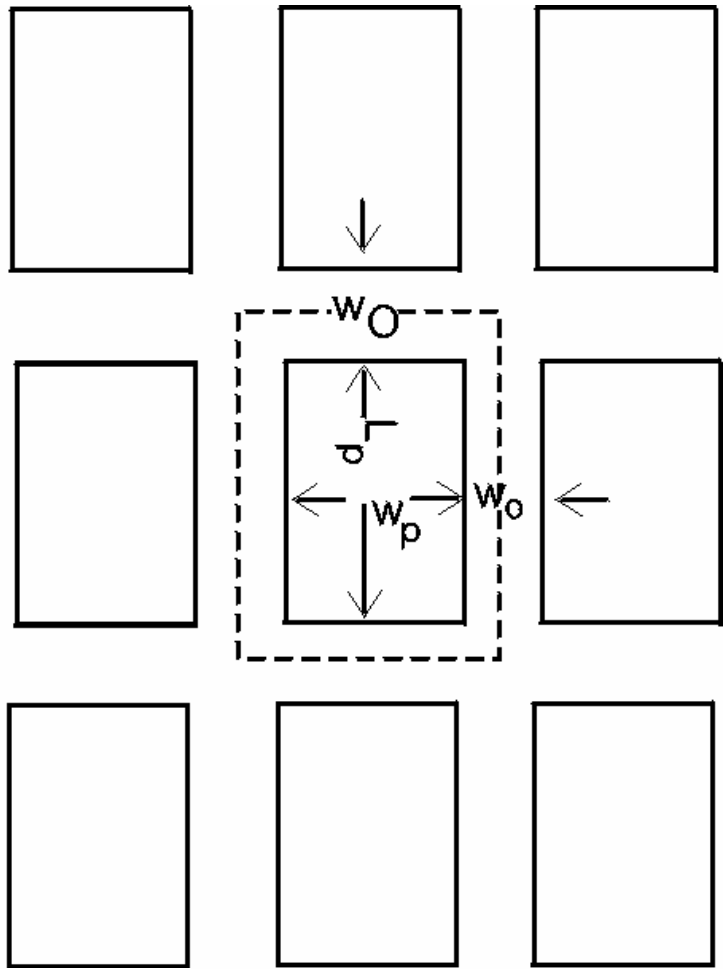

A
B
C
D
2.5
2.0
1.5
1.0
.5
0
-.05
90
60
30
0
σθ/Sh
3.0
2.5
2.0 r/a
1.5
2.5 2.0 1.5 1.0
σθ/Sh
y
r
a
θ
x
σr/Sh
0.4
.2
0
2
r/a
1
1
Y/a
2
3
1 .5 0
σx/Sh


4
3
2
1
0
-1
σ_θ/S_v
m=1
m= 1/3
m=0
S_v
w_o
w_p
mS_v


6
5
4
3
2
1
0
0
1
2
3
4
5
ความเข้มความเค้นสูงสุด
σ_t / S_V
จำนวนช่องเปิด
W_o/W_p
1
2
3
4


ตำแหน่ง E
ตำแหน่ง B
ตำแหน่ง A
ความเข้มความเค้น
0
1
2
3
4
5
6
B C D E E D C B A
1
2
3
4
5
สัดส่วนตามช่องเปิดกับเสาหิน


w_o
w_p
w_o

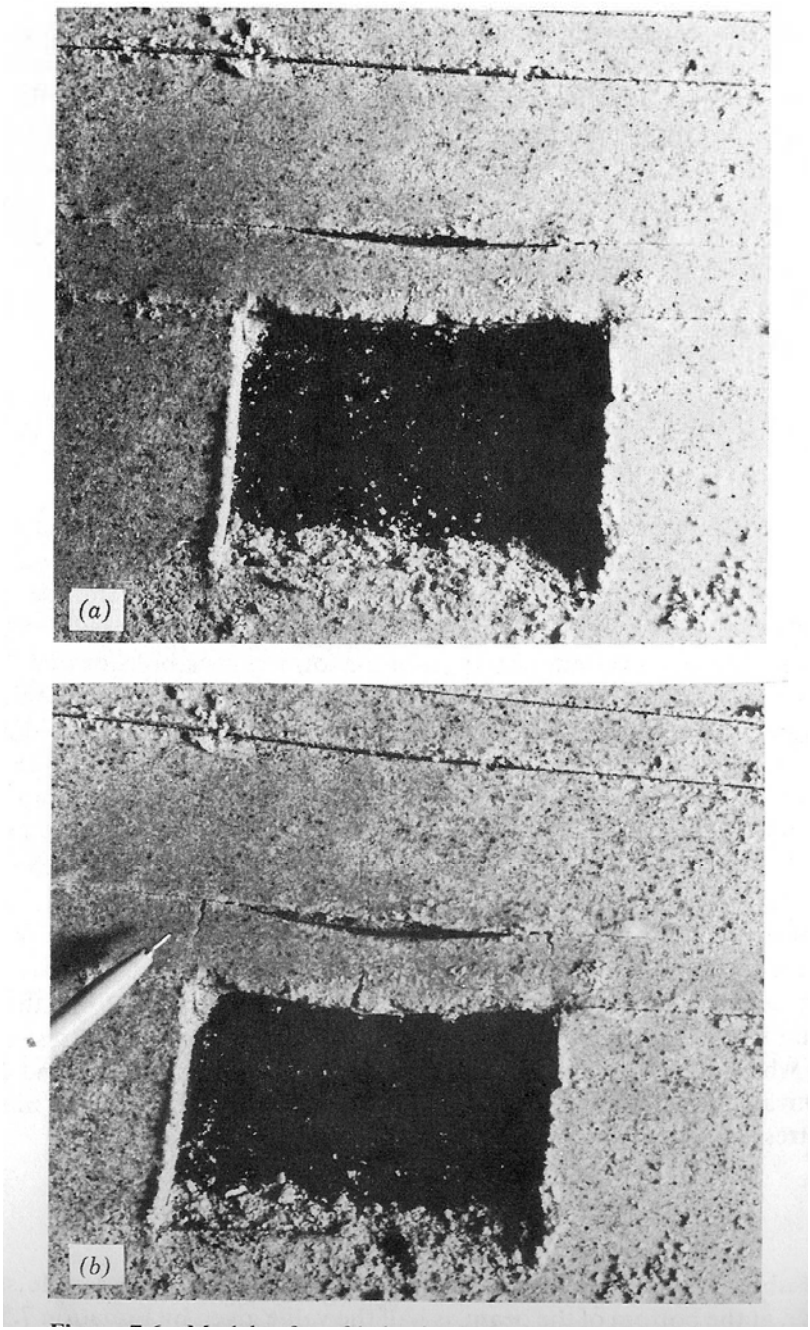

w_o
L_p
w_p
w_o

Pillar stress : tributary area

$$\sigma'_p = \frac{A_t}{A_p} \cdot \sigma_v$$

- $\sigma'p$ = ความเค้นประสิทธิผลกระทำบนเสาหิน
- At = พื้นที่ที่เสาหินจะต้องรับน้ำหนัก
- Ap = พื้นที่หน้าตัดของเสาหิน
- σv = ความเค้นดิ่งที่ระดับเพดานช่องเปิด

Thinner beam beneath thicker bed



- Thicker beam beneath thinnerbed