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PROJETO EXECUTIVO DA BARRAGEM MARCO,

EM MARCO, CEARA.

VOLUME 5: MEMORIA DESCRITIVA E JUSTIFICATIVA

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1. INTRODUCAO

A memória descritiva e justificativa é apresentada a seguir abordando os seguintes tópicos:

- Barragem
- Tomada d'Agua
- Vertedouro, Canal Rápido, Bacia de Dissipação e Canal de Retorno.

A memória descritiva e justificativa contêm além dos tópicos acima os seguintes anexos:

Anexo A - Memória de Cálculo

Anexo B - Desenhos

Anexo C - Listagem do Computador

2. BARRAGEM

O projeto executivo da barragem foi desenvolvido conforme a metodologia descrita e justificada a seguir, levando em conta os materiais disponíveis na região, bem como, as condições de fundação no local da barragem e do vertedouro.

Na elaboração do Projeto Executivo houve a participação do Professor Antonio Nunes de Miranda, que prestou consultoria na área de engenharia civil geotécnica.

Visando otimizar a aplicação dos materiais existentes na região, levando-se em conta o volume, a qualidade e a distância das ocorrências, foi concebida a seção tipo do maciço que é composta na zona de montante dos materiais oriundos das jazidas 1 e 3 e na zona de jusante de material proveniente do

corte do vertedouro. A jazida 2 (horizonte inferior) ficarà para ser utilizada num eventual complemento na parte de montante e fundação da barragem.

A seção tipo da barragem contèm, ainda, um sistema de drenagem interna que è composto de um filtro de areia vertical, um tapete drenante e um enrocamento de pè com dois metros de altura.

A cota do coroamento da barragem, 35,00 metros, foi determinada a partir da cota da soleira do vertedouro, fixada na cota 31,00 metros, correspondente ao armazenamento de um volume de 38.834.100 m3.

A camada final da barragem, com 0,30 m de espessura, serà executada com material utilizado em pavimentação primària de rodovias.

A fundação da barragem "Cut-Off" deve sempre atingir as profundidades definidas no projeto, ou ultrapassà-las a critèrio da Fiscalização, de forma que a trincheira de fundação fique assente sobre um maciço estàvel de solo ou rocha que possua permeabilidade compativel com o material empregado na fundação.

O topo do filtro vertical foi colocado na cota 33,00 metros aproximadamente a mesma cota da cheia màxima com a finalidade de interceptar as àguas de alguma camada mesmo acima da linha freàtica teòrica que por algum defeito de execução apresente um fluxo horizontal.

O filtro vertical e o tapete drenante serão executados com as areias dos areais 1 e 2, com 1,0 metro de espessura, entre as estacas 8 e 59 e 66 e 71.

O enrocamento será executado com pedra da pedreira P-2 entre as estacas 8 e 59 e 66 e 71, com 2,0 metros de altura.

Os taludes do maciço de terra foram estabelecidos de forma a ter segurança quanto á ruptura por cisalhamento perante as diversas hipóteses clássicas usualmente consideradas (Final de construção, rebaixamento ràpido e a longo prazo). Além da verificação da estabilidade quanto as hipóteses acima, foi, ainda, verificado a estabilidade com respeito ao abalo sísmico.

O cálculo da estabilidade foi feito pelo Mètodo de "Bishop Simplificado" em microcomputador IBM XT com 640 KB.

A geometria da barragem inicialmente testada tinha os seguintes taludes: Montante 1:2,5 (V:H) e Jusante 1:2 (V:H) com uma berma de 2,0 de largura na cota 25,00 m, dez metros abaixo do coroamento. Os coeficientes mínimos encontrados para a hipótese de final de construção foram inferiores a 1,3 mínimo recomendado.

Diante disto procedeu-se uma mudança no talude de jusante abaixo da cota 25,00 m passando de 1:2 (V:H) para 1:2,5 (V:H).

As anàlises efetuadas na nova geometria foram satisfatórias e são apresentadas no Anexo C contendo a listagem dos círculos testados, o desenho da barragem com indicação da grelha e a grelha ampliada com indicação do valor mínimo para cada centro.

Os parâmetros do solo foram retirados do ensaio de cisalhamento direto lento. A pressão neutra para a hipótese Final de Construção foi obtida pela expressão $U = \bar{B} . \sigma v$, onde:

U = pressão neutra;

σv = tensão vertical;

$\bar{B}$ = coeficiente de pressão neutra, adotou-se $\bar{B} = 0,20$.

A pressão neutra nas demais hipóteses de anàlise foi tomada como sendo a pressão hidrostàtica $U = \gamma w \times h$, onde:

U = pressão neutra;

w = peso especifico da água;

h = coluna d'àgua.

Os parâmetros adotados na anàlise são mostrados no quadro abaixo:

MATERIAIS	γs	γSAT	C'	ϕ'
Maciço	18,1	20,50	9	26,5
Filtro	17,0	20,00	-	30,0
Enrocamento	17,0	-	-	35,0
Fundação	18,1	20,50	-	32,0

onde:

γs = massa especifica aparente seca em KN/m3

γSAT = massa especifica aparente saturada em KN/m3

C' = coesão efetiva em KPa

ϕ' = angulo de atrito efetivo.

Na hipótese de esvaziamento ràpido, foi admitido

um rebaixamento do nivel d'água da cota 33,20 m para a cota 24,00 m sem alteração na rede de fluxo.

Na hipótese de abalo sismico, foram adotados os coeficientes horizontal e vertical igual a 0,10 da aceleração da gravidade para obter a força proveniente da onda mecânica.

Os coeficientes minimos de segurança permitidos nas diversas hipóteses foram os seguintes:

Final de Construção = 1,3

Reservatório Cheio = 1,5

Esvaziamento Rápido = 1,0

Abalo Sismico = 1,0

O resumo da anàlise efetuada é apresentado no quadro abaixo:

HIPOTESES	TALUDE ANALISADO	F.S MINIMO
Final de Construção	Jusante	1,43
A Longo Prazo	Jusante	1,71
Esvaziamento Ràpido	Montante	1,17
Abalo Sismico	Montante	1,01

A anàlise das tensões foi realizada pelo mètodo dos elementos finitos utilizando o Programa Soilstruct desenvolvido por G. W. Clough. Este programa assume uma relação linear entre as tensões e as deformações e utiliza uma Malha de elementos quadrilaterais para representar a geometria da

barragem. Os cálculos foram efetuados em um microcomputador IBM XT com 640 KB.

Os módulos de elasticidade dos materiais argilosos foram determinados dos ensaios de compressão simples e da areia do filtro do ensaio de compressão simples corrigida pela expressão:

$$E = \frac{(1 + \mu)(1 - 2\mu)}{1 - \mu} \times D$$

onde:

E = módulo de elasticidade em KPa;

μ = coeficiente Poissan = 0,3;

D = módulo confinado.

Os parâmetros utilizados foram os seguintes:

MATERIAIS	E	γ
Maciço	4.146	20,5
Filtro	28.200	20,0

onde:

E = módulo de elasticidade em KPa;

γ = massa especifica de compactação em KN/m3.

A análise foi realizada assumindo a barragem submetida somente ao seu peso próprio e construída em uma única

camada. Os resultados obtidos são apresentados no Anexo C. A simbologia adotada é a seguinte:

ELEM = número de ordem do elemento;

X = coordenada do centro do elemento na direção do eixo horizontal;

Y = coordenada do centro do elemento na direção do eixo vertical;

σ_x = tensão normal horizontal;

σ_y = tensão normal vertical;

τ_{xy} = tensão cisalhante;

τ_{max} = tensão cisalhante máxima;

σ_1 = tensão principal maior;

σ_3 = tensão principal menor;

θ = ângulo entre o plano onde atua σ_1 e o plano horizontal.

Examinando as tensões atuantes, verifica-se que a barragem não apresenta zonas de tração ou de plastificação.

E apresentado no Anexo B, desenho No. 01, os valores de tensão normal vertical e o peso de solo acima do ponto considerado ao longo da base da barragem è no desenho No. 02 os valores das tensões acima descritas ao longo de três verticais situadas nas proximidades do eixo do maciço. A comparação entre tensão vertical e o peso de solo mostra que a introdução do filtro vertical não criou uma condição desvantajosa de distribuição de tensões na barragem.

A proteção do talude de montante será feita

através de um "Rip-Rap" dimensionado para combater as ondas e composto de quatro camadas.

A proteção do talude de jusante será feita através de um plantio de grama e um sistema de calhas para coleta das águas superficiais.

A estanqueidade do maciço rochoso da fundação será garantida através da execução de uma cortina de injeção de cimento ao longo do eixo do "Cut-Off", composta, em principio, apenas por furos primários espaçados de 3,0 em 3,0 metros, no trecho entre as estacas 20 e 53, com profundidade de 12 metros abaixo do "Cut-Off" e com execução de ensaios de perda d' água "Lugeon". Deverão ser examinados os resultados dos ensaios de perda d'água, bem como analisados os consumos de calda de cimento, de modo que a Fiscalização poderá decidir sobre a necessidade de execução de furos secundários.

A memória justificativa dos cálculos elaborados é apresentada no Anexo A.

3. TOMADA D'AGUA

A tomada d' água dimensionada trata-se de uma galeria com tubulação de 800 mm de diâmetro, com comando a montante através de uma torre e com válvula dispersora a jusante. A tomada d'água foi posicionada na estaca 28 com o eixo da tubulação na cota 20,50 m. A cota do porão, 24,00 m, corresponde aproximadamente a 10% do volume armazenado, deverá ser observada durante a operação, com a tomada d'água sendo fechada ao atingir esta cota. A tubulação de aeração é de 150 mm e o By-Pass de

200mm. A válvula dispersora é de 625 mm.

A memória justificativa dos cálculos elaborados no dimensionamento da galeria, tubulação de aeração, By-pass e válvula dispersora é apresentada no Anexo A.

4. VERTEDOURO, CANAL RAPIDO, BACIA DE DISSIPAÇÃO E CANAL DE RETORNO

O vertedouro foi localizado entre as estacas 61 e 64+6,00 m por razões puramente topográficas uma vez que as investigações geotécnicas mostraram que não existe rocha sã a profundidade economicamente viável.

Foi projetado um vertedouro em perfil "Creeger" na cota 31,00 m com 66,00 m de largura e uma lâmina de 2,20 m na cheia milinar de 382 m3/s. As águas que atingem o vertedouro são conduzidas por um canal rápido de 66,00 m de largura até a cota 20,00 m inicio da bacia de dissipação com 18,00 m de comprimento.

A lâmina na entrada da bacia é de 0,37 m e a velocidade de 15,64 m/s e na saida da bacia a lâmina é de 4,11 e a velocidade de 1,41 m/s.

O retorno das águas á calha do rio é feito por um canal de seção trapezoidal inicialmente com 66,00 m na base menor e taludes de 1:2 (vertical : horizontal) e após 128,00 m de transição ficando com 122,00 m na base menor e taludes de 1:2 (vertical : horizontal). Os primeiros trinta metros do canal trapezoidal conterá um enrocamento. O canal de retorno terá declividade constante de 0,65%.

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ANEXO A:

Memória de Cálculo

- Capacidade do Reservatório:

A cota da soleira (31 m) foi fixada pelo DNOCS e corresponde a uma acumulação de 38.834.010 m3, conforme pode ser visto no gráfico Cota x Area x Volume apresentado no Desenho No. 02 (Volume 02).

- Escolha da Largura do Sangradouro:

A largura do sangradouro foi calculada para a cheia milenar, conforme mostrado a seguir

$$L = \frac{Qm}{1,77\ H\ \sqrt{H}}$$

onde:

L = largura do sangradouro = 66,00 m;

Qm = cheia milenar = 382 m3/s;

H = lâmina de sangria = 2,20 m.

- Folga da Barragem:

$$f = 1,02 + 0,0232\ .\ F - 0,0362\ .\ \sqrt[4]{F^3} + 0,482\ .\ \sqrt{F} - 0,354\ .\ \sqrt[4]{F}$$

onde:

f = folga da barragem em metros = 1,77 m, adotado f = 1,80 m;

F = fetch = 7,60 km (maior comprimento que pode ser obtido, ligando-se em linha

reta o eixo da barragem ao contorno da curva de nivel correspondente a cota màxima das àguas, isto è, a cota de sangria mais a lâmina d' àgua no sangradouro, cota 33,20 m, e è tirado na planta da bacia hidràulica da barragem).

- Revanche:

$$R = H + f$$

onde:

R = revanche = 4,00 m;
H = lâmina màxima de sangria = 2,20 m;
f = folga = 1,80 m.

- Cota do Coroamento:

$$Cc = Cs + R$$

onde:

Cc = cota do coroamento = 35,00 m;
Cs = cota da soleira = 31,00 m;
R = revanche = 4,00 m.

- Altura da Barragem:

$$H = Cc - Ct$$

onde:

H = altura da barragem = 18,35 m;

Cc = cota do coroamento = 35,00 m;

Ct = cota do talvegue = 16,65 m.

- Largura do Coroamento:

$$B = 1,1 \sqrt{H} + 0,9$$

onde:

B = largura do coroamento = 5,61 m, adotado B = 6,00 m;

H = altura da barragem = 18,35 m.

TOMADA D'AGUA

- Determinação da Cota do Porão:

Fixou-se a cota 24,00 metros como cota do porão, correspondente a aproximadamente a 10% do volume armazenado.

- Cota do Eixo da Tubulação:

A cota do eixo da tubulação foi determinada de forma que a velocidade seja de aproximadamente V = 2,0 m/s.

Para a vazão de projeto de Q = 1,05 m3/s, igual a três e meia vezes a vazão regularizada, obtido dos Estudos Hidrológicos, tem-se:

$$D = \sqrt{\frac{4 \times Q}{\pi \times V}} = 0,81 \text{ m}$$

Será adotado o diâmetro da galeria D = 0,80 m e portanto a velocidade será:

$$V = \frac{4Q}{\pi D2} = 2,08 \text{ m/s.}$$

A carga efetiva minima He foi obtida da expressão

$$V = Cd \sqrt{2g\ He}$$

onde:

V = velocidade em m/s;

Cd = coeficiente de descarga = 0,60;

g = aceleração da gravidade = 9,80 m/s2;

He = carga efetiva = (cota do porão - cota do eixo da tubulação - perda de carga).

$$He = \frac{V^2}{Cd^2 \times 2 \times g} = \frac{2,08^2}{0,60^2 \times 2 \times 9,8} = 0,62 \text{ m}$$

As perdas de cargas compreendem as perdas localizadas e as perdas por atrito na tubulação.

* Cálculo das perdas localizadas:

$$h_L = h_g + h_E + h_C + h_V + h_S$$

onde:

h_g = perda de carga na grade de entrada;

h_E = perda de carga na entrada;

h_C = perda de carga na comporta;

h_V = perda de carga na válvula dispersora;

h_S = perda de carga na saída.

Para V = 2,08 m/s e Kg = 0,98, Ke = 0,10 Kc - Desprezível (comporta na entrada), Kv = 5,6 e Ks = 1,0 temos:

$$h_L = (0,98 + 0,10 + 5,6 + 1,0) \times \frac{2,08^2}{2 \times 9,8} =$$

1,70 m.

* Cálculo das perdas por atrito:

Para:

V = velocidade = 2,08 m/s;

D = diâmetro da tubulação = 0,80;

ν = viscosidade cinemática a 24°C = $0,917 \times 10^{-6}$ m2/s;

K = rugosidade do tubo de aço novo = 5×10^{-5} m;

L = comprimento da tubulação = 80,00 m.

tem-se:

$$R = \text{número de Reynolds} = \frac{VD}{\nu} = 1{,}81 \times 10^{6}$$

$$D/K = \frac{0{,}8}{5 \times 10^{-5}} = 1{,}6 \times 10^{4}$$

Obtem-se do ábaco de Rouse para $R = 1{,}81 \times 10^{6}$ e $D/K = 1{,}6 \times 10^{4}$

f = coeficiente de atrito = 0,011

* A perda por atrito será:

$$ha = f \cdot \frac{L}{D} \times \frac{V^2}{2g} = \frac{0{,}011 \times 80 \times 2{,}08^2}{0{,}80 \times 2 \times 9{,}8} = 0{,}24 \text{ m}$$

* Cálculo da cota do eixo da tubulação:

Cota do Eixo = Cota do Porão - Altura Útil - Perdas de Carga.

Cota do Eixo = 24,00 - 0,62 - 1,94

Cota do Eixo = 21,44 = 21,50 m.

Conclusão: A tomada d'água será em galeria com controle a montante em tubulação de aço soldado e válvula dispersora a jusante.

- Cálculo das Curvas de Transição para a Entrada da Galeria:

A curva comumente usada é a elipse, que segundo o U. S. Bureau of Reclamation, para entrada circular, segue a seguinte fórmula:

$$\frac{X^2}{(0,5\ D)^2} + \frac{Y^2}{(0,15\ D)^2} = 1$$

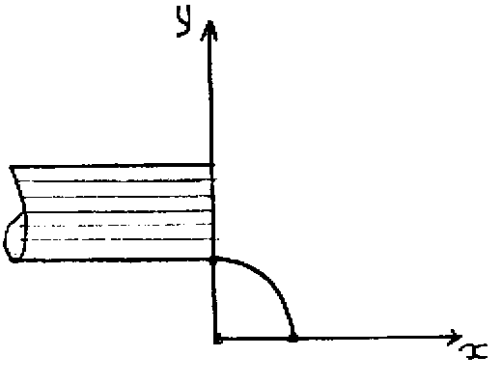
X = abcissa do eixo de coordenadas passando pela entrada da galeria;

Y = ordenada do eixo de coordenadas;

D = diâmetro da tubulação da galeria.

logo:

$$\frac{X^2}{0,16} + \frac{Y^2}{0,014} = 1$$



X	Y
0	0,12
0,10	0,11
0,20	0,10
0,30	0,08
0,40	0

- Tubo de Aeração:

O cálculo do diâmetro do tubo de aeração foi feito com base no roteiro do "Air Demand Design Critério".

* Cálculo da espessura da veia liquida:

$$e = 0,80 \times Cd \times D$$

onde:

e = espessura da veia liquida = 0,52 m;

D = diâmetro da tubulação da galeria = 0,80 m;

Cd = coeficiente de descarga para uma abertura de 80% da comporta = 0,805.

* Velocidade da veia liquida:

$$V = \sqrt{2gH}$$

onde:

V = velocidade da veia liquida = 13,56 m/s;

g = aceleração da gravidade = 9,80 m/s2;

H = carga hidráulica máxima sobre a veia liquida = 31,0 - 21,5 + 0,40 - 0,52 = 9,38 m.

* Cálculo do número de Froude:

$$F = \frac{V}{\sqrt{ge}}$$

onde:

F = número de Froude = 6,00;

g = aceleração da gravidade = 9,8 m/s2;

e = espessura da veia liquida = 0,52 m;

V = velocidade da veia lquida = 13,56 m/s.

* Cálculo da demanda de água na tubulação:

Qw = A x V

onde:

Qw = demanda de água na tubulação = 4,61m3/s;

A = área transversal da veia liquida na tubulação = 0,34 m2;

V = velocidade da veia liquida = 13,56 m/s.

* Cálculo da demanda de ar na tubulação:

$Qa = Qw \times \beta$

onde:

Qa = demanda de ar na tubulação = 0,78 m3/s;

Qw = demanda de água na tubulação = 4,61m3/s;

β = relação entre a demanda de ar e a demanda de água = $\frac{Qa}{Qw} = 0,03\ (F-1)^{1,06}$ = 0,17.

* Determinação da área de vento:

$$Av = \frac{Qa}{V'}$$

onde:

Av = área de vento = 0,011 m2;

Qa = demanda de ar na tubulação = 0,78 m3/s;

V'= velocidade mèdia de ar permetida = 68,58 m/s.

* Diâmetro do tubo de areação:

$$D = \sqrt{\frac{4\ Av}{\pi}}$$

onde:

D = diâmetro do tubo de aeração = 118 mm adotado ϕ= 150 mm;

Av = área de vento = 0,011 m2.

- By-Passe:

O dimensionamento do By-Pass foi desenvolvido a partir de um tempo para o enchimento (te), e da velocidade màxima de enchimento.

* Cálculo da velocidade de enchimento:

$$Ve = \sqrt{2gH}$$

onde:

Ve = velocidade de enchimento = 13,64 m/s;

g = aceleração da gravidade = 9,8 m/s2;

H = carga máxima = 9,50 m.

* Cálculo da vazão necessária para enchimento:

$$Qe = \frac{Vt}{te} = 0,34 \text{ m3/s}$$

onde:

Qe = vazão necessária para enchimento =

Vt = volume da galeria = 40,21 m3;

te = 120 s (adotado).

* Cálculo da seção do By-Passe:

$$S = \frac{Qe}{Ve}$$

onde:

S = área do By-Passe = 0,024 m2;

Qe = vazão de enchimento = 0,34 m3/s;

Ve = velocidade de enchimento = 13,64 m/s.

* Cálculo do diâmetro do By-Passe:

$$D = \sqrt{\frac{4 \times S}{\pi}}$$

onde:

D = diâmetros do By-Pass = 174 mm adotado

ϕ = 200 mm;

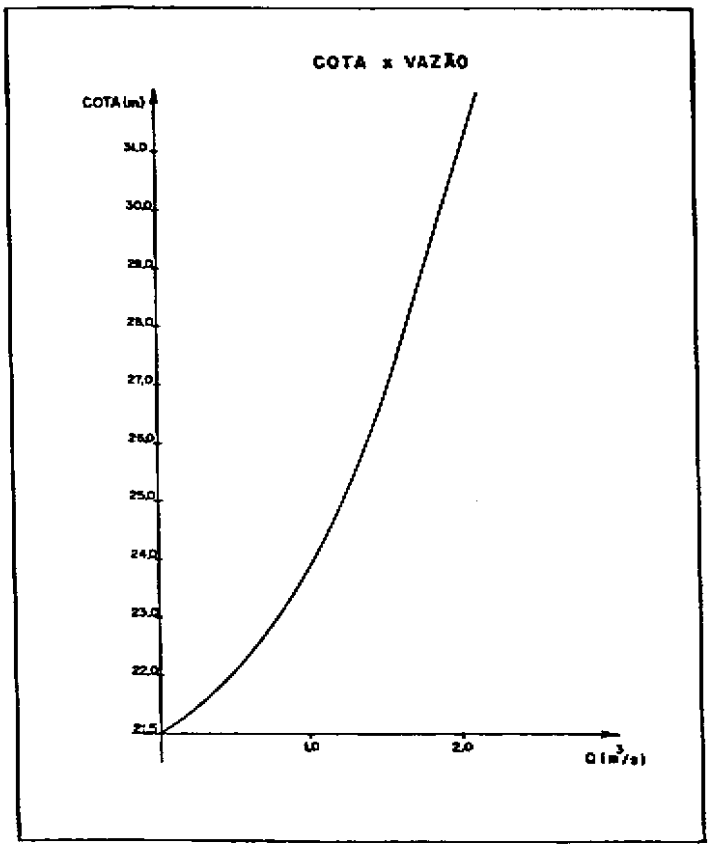
S = área = 0,024 m2.

- Curva de Descarga da Galeria:

Para obtenção da curva de descarga da galeria foi preparado a tabela a seguir:

Q (m3/s)	V (m/s)	$\frac{V^2}{2g}$	f	K f	K g	K E	K v	K s	$\sum K$	H'	H E	COTA (m)
0,5	1,00	0,051	0,011	1,10	0,98	0,10	5,6	1,0	8,78	0,45	0,14	22,09
1,0	1,99	0,202	0,011	1,10	0,98	0,10	5,6	1,0	8,78	1,77	0,55	23,82
1,5	2,98	0,453	0,011	1,10	0,98	0,10	5,6	1,0	8,78	3,98	1,24	26,72
2,0	3,97	0,804	0,011	1,10	0,98	0,10	5,6	1,0	8,78	7,06	2,21	30,77

A curva obtida é apresentada na figura abaixo:

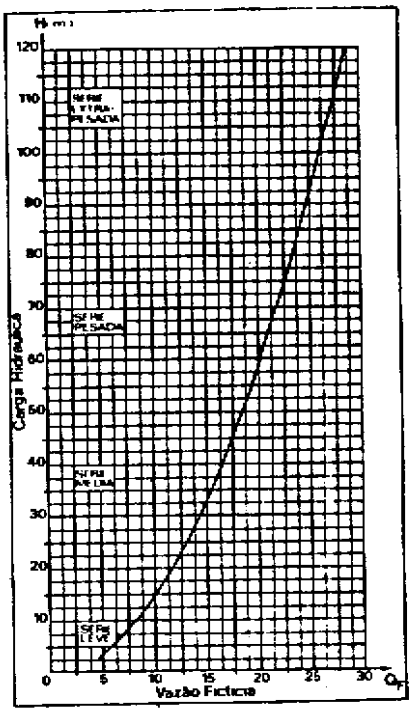


Sergio - Válvula Dispersora:

Os dados necessários foram os seguintes:

- vazão minima Q_1 = 1,05 m3/s;
- vazão máxima Q_2 = 2.05 m3/s;
- carga hidráulica minima = 2,5 m;
- carga hidráulica máxima = 9,5 m.

Da figura abaixo determina-se as vazões ficticias Q_{1F} = 4,38 e Q_{2F} = 7,92.

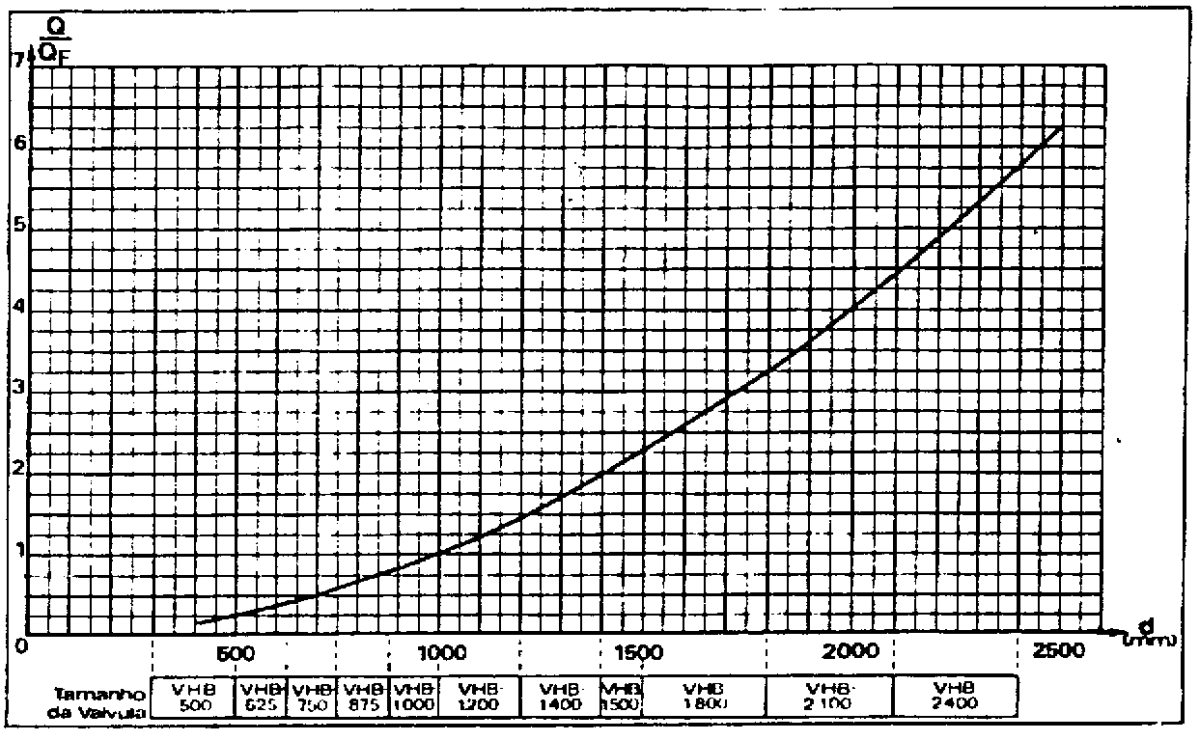


Para $\frac{Q_1}{Q_{1F}}$ = 0,24 verifica-se na figura a seguir que

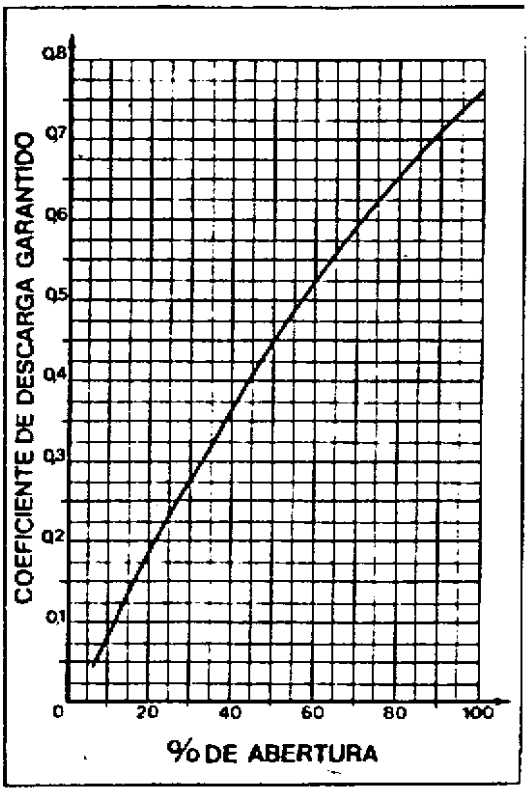
é necessária uma válvula de ϕ = 625 mm.

Para $\frac{Q_2}{Q_{2F}}$ = 0,26 verifica-se na mesma figura que é

necessária uma válvula de ϕ = 625 mm.



Logo a válvula necessária será de ø = 625 mm, cuja curva de desempenho é apresentada na figura abaixo.



- Canal Rápido, Perfil Vertedouro, Bacia de Dissipação e Canal de Retorno:

O canal rápido, bem como, o perfil vertedouro, a bacia de dissipação e o canal de retorno, foram dimensionados seguindo o "DESIGN OF SMALL DAMS" do "BUREAU OF RECLAMATION" do "UNITED STATES DEPARTMENT OF THE INTERIOR" conforme descrito a seguir.

* Determinação da carga total:

$$He = \left(\frac{Q}{C.L}\right)^{2/3}$$

onde:

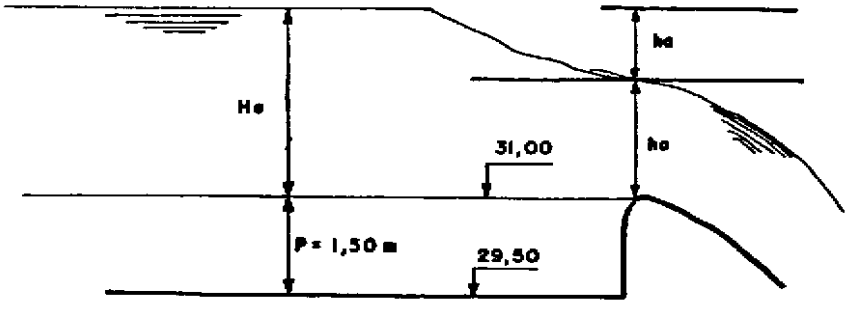
He = carga total sobre a crista, incluindo a carga de velocidade (m);

Q = descarga milenar = 382 m3/s;

C = coeficiente de descarga ($m^{0,5}/s$);

L = comprimento efetivo da crista = 66 m.

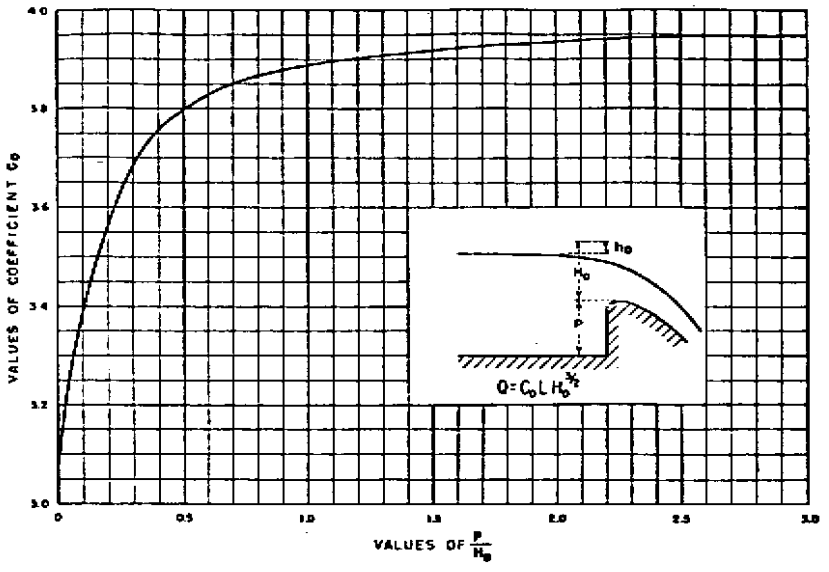
Para ilustrar o cálculo da lâmina de sangria segue a figura a seguir:



Adotando uma carga inicial Ho = 2,20 m e uma altura de aproximação P = 1,50 m, temos:

$$\frac{P}{Ho} = 0,68$$

Do gràfico abaixo extraido do "DESIGN OF SMALL DAMS", obtemos:

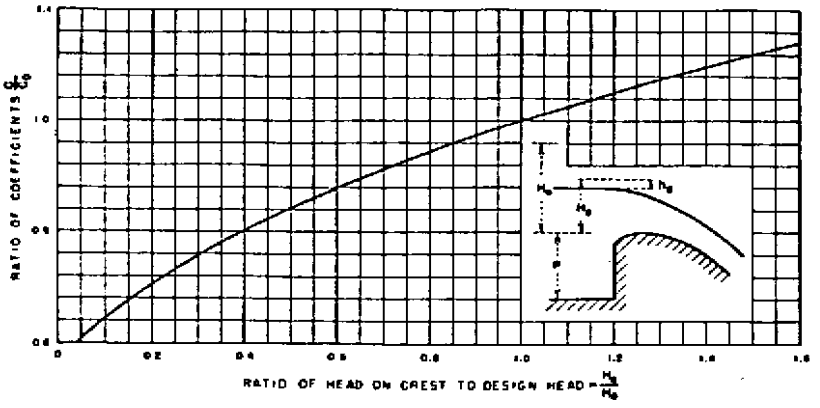


Fonte: Design of Small Dams

$$\frac{P}{Ho} = 0,68 \Rightarrow Co = 3,85 \text{ ft}^{0,5}/\text{s} = 2,126 \text{ m}^{0,5}/\text{s}$$

$$He = \left(\frac{Q}{CoL}\right)^{2/3} = \left(\frac{382}{2,126 \times 66}\right)^{2/3} = 1,95 \text{ m}$$

Como $\frac{He}{Ho} = 0,89$, obtemos do gràfico a seguir a relação $\frac{C}{Co}$:



Fonte: Design of Small Dams

$$\frac{C}{Co} = 0,985 \Rightarrow C = 0,985 \times 2,126 = 2,09$$

$$\text{Logo: } He = \left(\frac{Q}{CL}\right)^{2/3} = \left(\frac{382}{2,09 \times 66}\right)^{2/3} = 1,97 \text{ m}$$

* Cálculo da lâmina sobre o perfil vertedouro:

$$P + He = P + ho + ha$$

$$ha = \frac{Va^2}{2g}$$

onde:

Va = velocidade de aproximação;

g = aceleração da gravidade.

$$Va = \frac{Q}{A} = \frac{Q}{L\,(P + ho)} = \frac{q}{P + ho}$$

onde:

$$q = \text{vazão por metro} = \frac{382}{66} = 5,79 \text{ m3/s.m};$$

$$ha = \frac{Va^2}{2g} = \frac{q^2}{(P + ho)^2 \times 2g};$$

$$P + He = P + ho + \frac{q^2}{(P + ho)^2 \times 2g}$$

$$1,5 + 1,97 = 1,5 + ho + \frac{5,79^2}{(1,5+ho)^2 \times 2 \times 9,81}$$

$$1,97 = ho + \frac{1,7087}{(1,5 + ho)^2}$$

Resolvendo a equação obtemos que ho = 1,81 m, então:

$$ha = He - ho = 1,97 - 1,81 = 0,16 \text{ m}$$

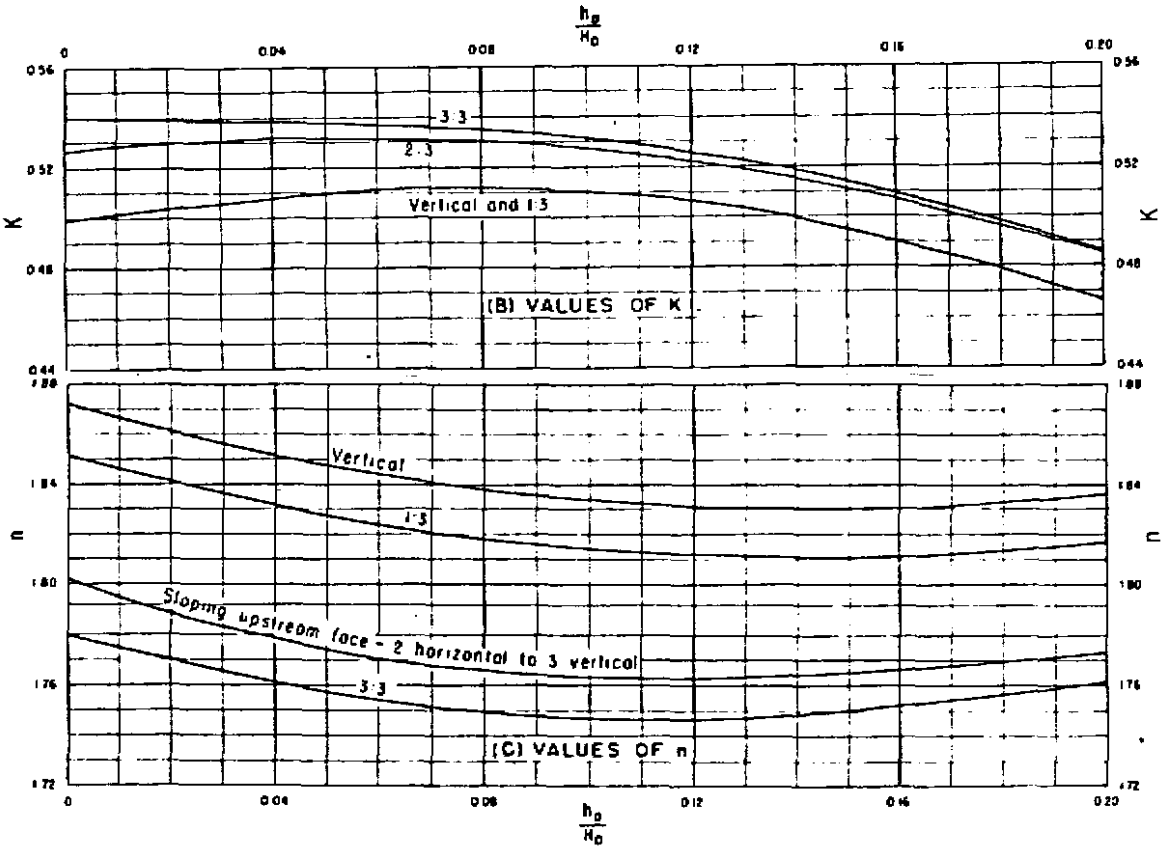
* Cálculo da velocidade de aproximação:

$$Va = \frac{Q}{L\ (P + ho)} = \frac{382}{66\ (1,5 + 1,81)} = 1,75 \text{ m/s}$$

* Obtenção da forma da soleira:

Para: $\frac{ha}{Ho} = \frac{0,16}{1,97} = 0,08$ encontramos os valores

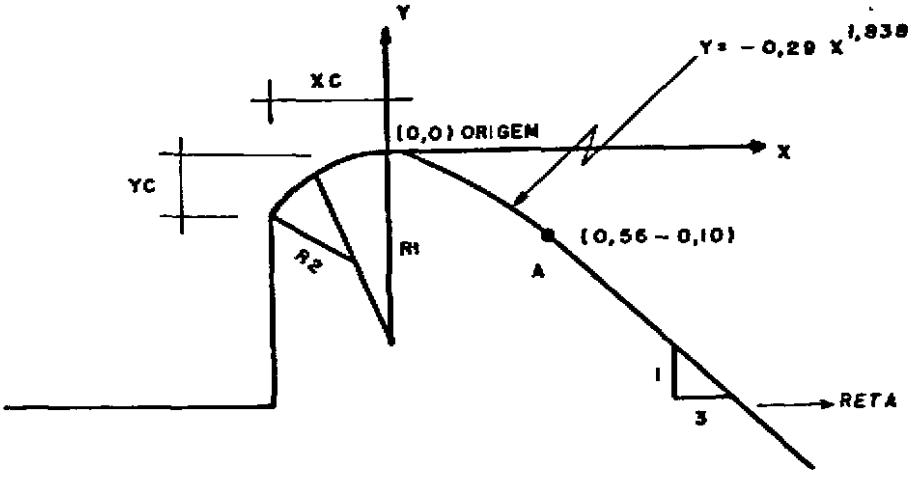
de n = 1,838 e K = 0,512 nos gráficos apresentados a seguir.



A equação da curva a jusante será portanto:

$$\frac{Y}{Ho} = -K\left(\frac{x}{Ho}\right)^{n}$$

$$\frac{Y}{1,97} = -0,512\left(\frac{x}{1,97}\right)^{1,838} \Rightarrow y = -0,29.X^{1,838}$$



A equação exponencial deverá concordar com a reta de coeficiente angular igual a - 0,33, o que equivale a uma inclinação de 1:3 (V:H), ou seja:

$$\frac{dy}{dx} = -0,33$$

$$\frac{dy}{dx} = -0,533.X^{0,838} = -0,33 \Rightarrow X = 0,56$$

Coordenadas do ponto de tangência (Ponto A):

$$x_A = 0,56$$

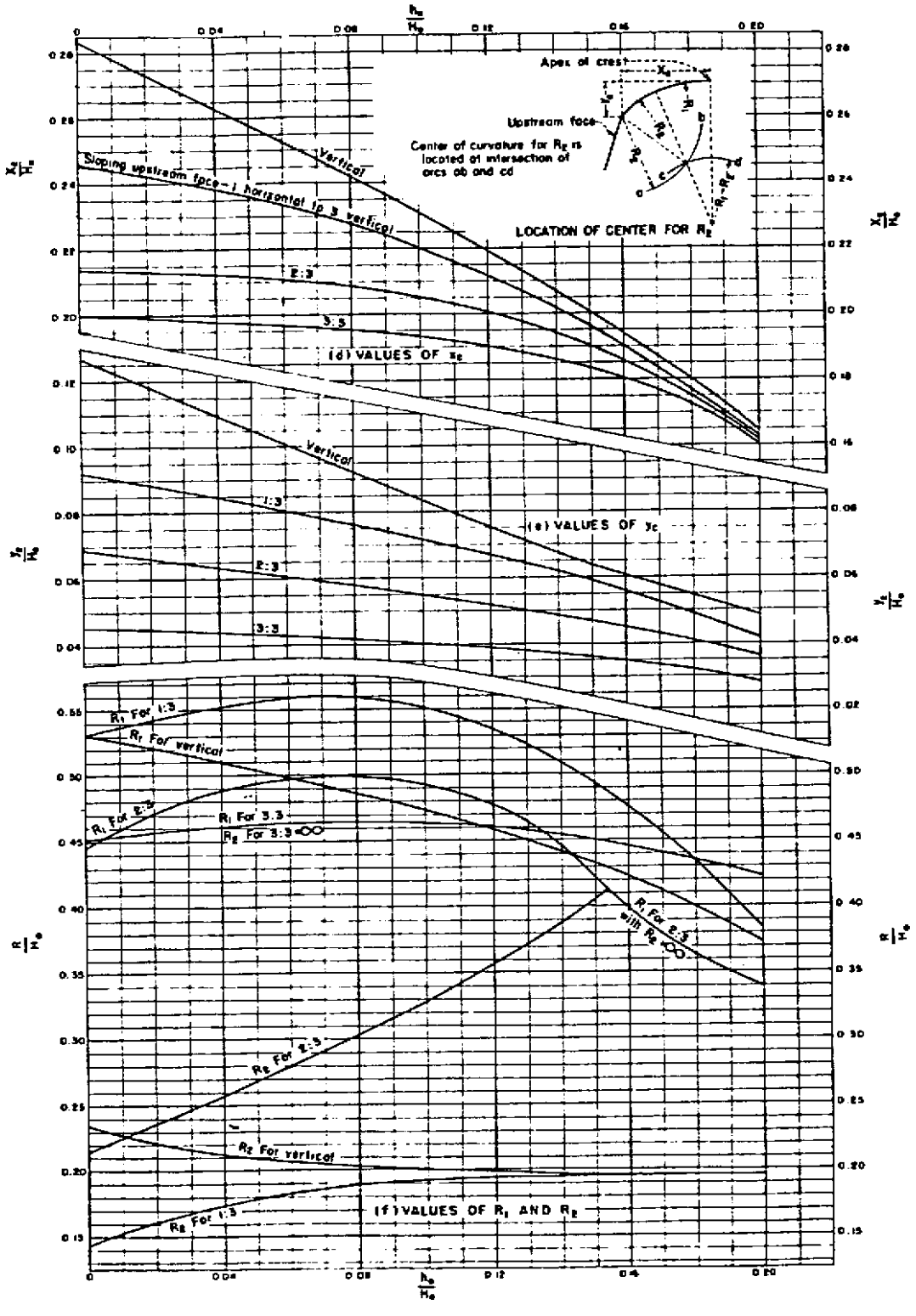
$$y_A = -0,10$$

Calcula-se, através da equaçao: $Y = -0,29.X^{1,838}$, as coordenadas do trecho de jusante da crista para diversos valores de X e Y, conforme quadro abaixo:

x	y
0,10	- 0,01
0,20	- 0,02
0,30	- 0,03
0,40	- 0,05
0,50	- 0,08
0,56	- 0,10 => Ponto A (Ponto de Tangência)

Os parâmetros que definem a forma do quadrante de montante foram obtidas dos ábacos abaixo a partir

de um valor de $\frac{ha}{Ho} = \frac{0,16}{1,97} = 0,08$:



$$\frac{Xc}{Ho} = 0,242 \Rightarrow Xc = 0,48 \text{ m}$$

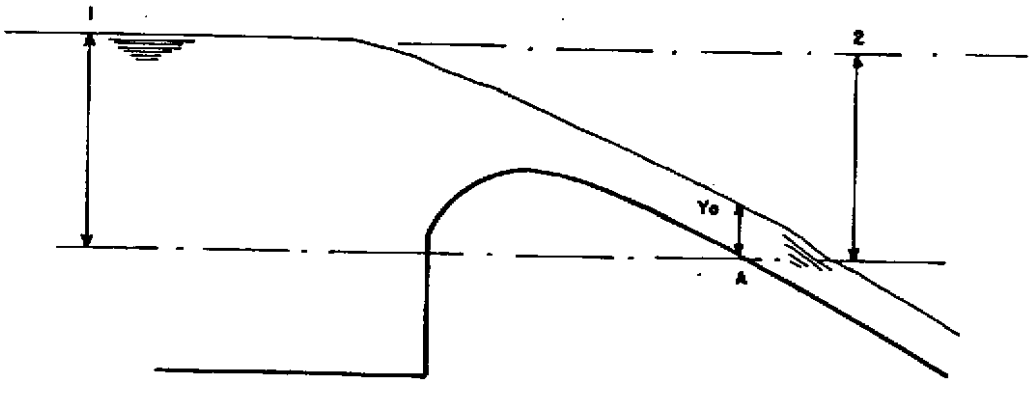
$$\frac{Yc}{Ho} = 0,092 \Rightarrow Yc = 0,18 \text{ m}$$

$$\frac{R1}{Ho} = 0,485 \Rightarrow R1 = 0,96 \text{ m}$$

$$\frac{R2}{Ho} = 0,22 \Rightarrow R2 = 0,43 \text{ m}$$

* Cálculo da lâmina na entrada do canal rápido (yo):

Desprezando as perdas por atrito no perfil, temos que:



$$E1 = E2$$

$$1,97 + 0,10 = yo + \frac{q^2}{yo^2 \times 2g}$$

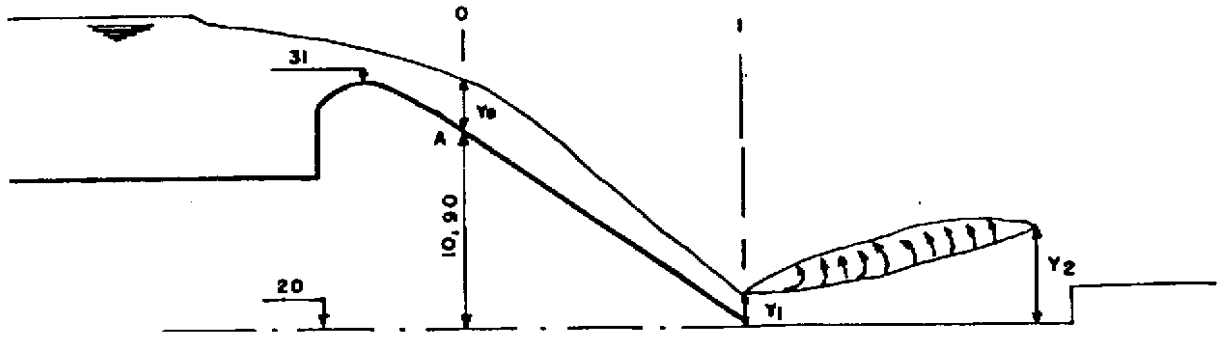
$$2,07 = yo + \frac{5,79^2}{yo^2 \times 2 \times 9,81} \Rightarrow 2,07 = yo + \frac{1,7087}{yo^2}$$

Resolvendo a equação obtemos: yo = 2,25 m.

* Cálculo da velocidade na entrada do canal rápido (Vo):

$$V = \frac{Q}{A} = \frac{382}{2,25 \times 66} = 2,6 \text{ m/s}$$

* Cálculo da lâmina na entrada da bacia (y1):



Admitindo-se inicialmente sem perda, temos:

$$Eo = E1$$

$$10,90 + 2,25 = y1' + \frac{1,7087}{y1'^2}$$

$$13,15 = y1' + \frac{1,7087}{y1'^2}$$

y1'= 0,366 m

V1'= 15,81 m/s

Calculando a perda de carga no canal usando a fórmula de Manning, temos:

$$I = \frac{(nV)^2}{RH^{4/3}} = \frac{(0,014 \times 15,81)^2}{0,362^{4/3}} = 0,19 \text{ m}$$

onde:

n = rugosidade = 0,014;

V = velocidade = 15,81 m/s;

RH = raio hidráulico = 0,362 m.

$E_1 = 13,15 - 0,19 = 12,96$ m

$$12,96 = y1 + \frac{1,7087}{y1^2}$$

y1 = 0,37 m

V1 = 15,64 m/s

* Cálculo da lâmina no final do ressalto hidráulico (y2):

$$y2 = \frac{-y1}{2} + \sqrt{\frac{y1^2}{4} + \frac{2.V1^2.y1}{g}}$$

$$y2 = \frac{-0,37}{2} + \sqrt{\frac{0,37^2}{4} + \frac{2 \times 15,64^2 \times 0,37}{9,81}}$$

$$y2 = 4,11 \text{ m}$$

* Cálculo do Número de Froude:

$$F^2 = \left(\frac{yc}{y1}\right)^3$$

onde:

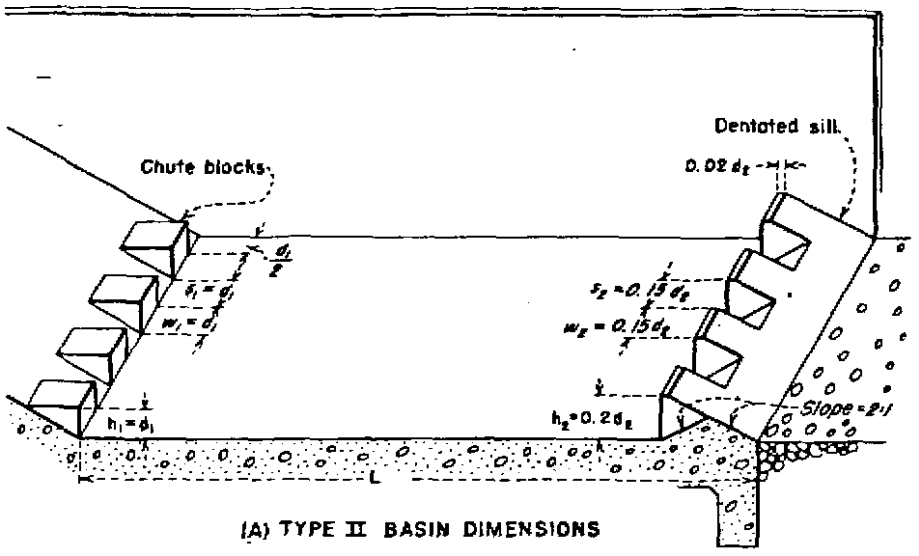
yc = altura critica

$$yc = \left(\frac{q^2}{g}\right)^{1/3} = \left(\frac{5,79^2}{9,81}\right)^{1/3} = 1,506 \text{ m}$$

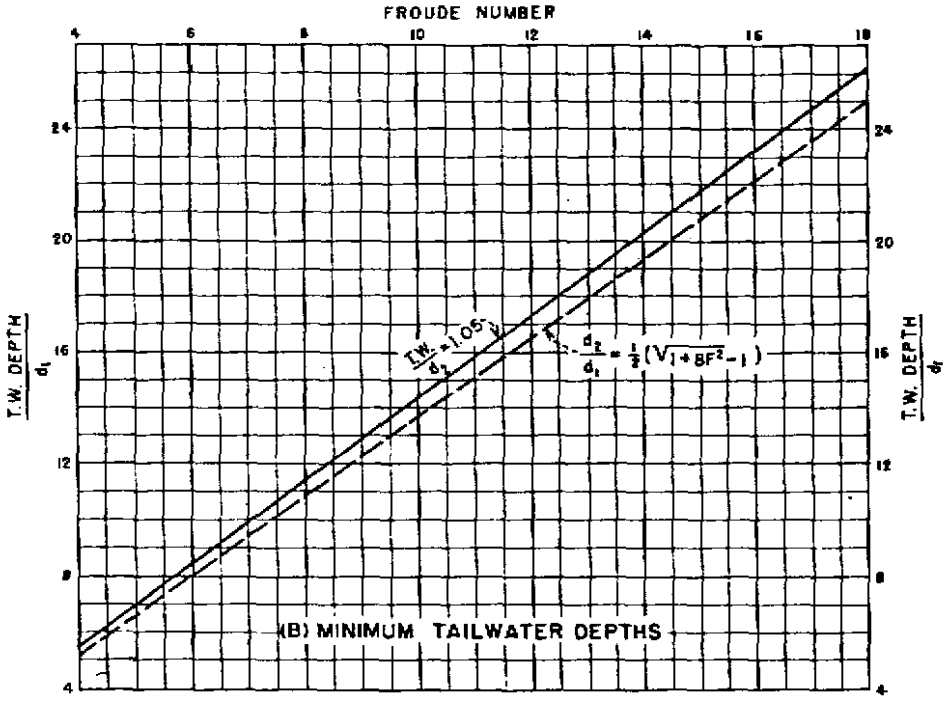
$$F = \sqrt{\left(\frac{1,506}{0,37}\right)^3} = 8,21$$

Como F > 4,5, teremos uma bacia de dissipação do tipo II, de acordo com o "BUREAU OF RECLAMATION".

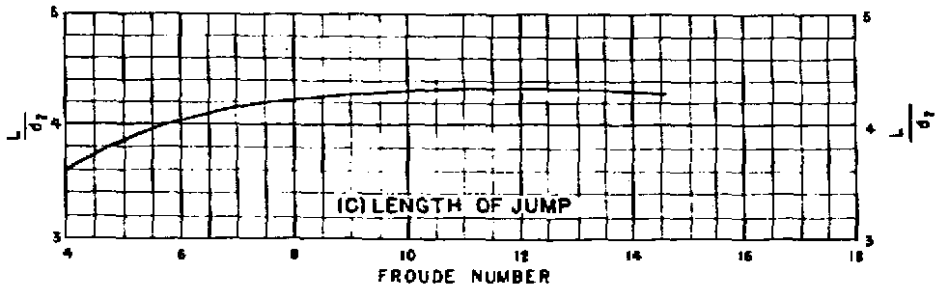
* Cálculo do comprimento da bacia:



(A) TYPE II BASIN DIMENSIONS



(B) MINIMUM TAILWATER DEPTHS



(C) LENGTH OF JUMP

Entrando no gráfico acima para F = 6,21, temos:

$$\frac{L}{y2} = 4,3 \Rightarrow L = 4,11 \times 4,3 = 17,67 \text{ m, adotado } L = 18,00 \text{ m.}$$

* Cálculo do bordo livre:

O bordo livre foi calculado pela seguinte fórmula empirica:

$$\text{Bordo livre} = 0,61 + 0,0372 \sqrt[3]{h} = 0,67 \text{ m}$$

onde:

h = altura em regime super critico = y2 = 4,11 m.

* Altura dos muros laterais da bacia:

H = Y2 + bordo livre = 4,11 + 0,67

H = 4,78 m => adotado H = 5,00 m.

- Canal de Retorno ao Leito do Rio:

Elementos hidráulicos na saida da bacia de dissipação:

Q = vazão = 382 m3/s;

V = velocidade = 1,41 m/s;

Y = lâmina = 4,11 m;

S = seção = 66,0 x 4,11 = 271,26 m2.

* Càlcula da altura critica:

$$Yc = \sqrt[3]{\frac{q^2}{g}}$$

onde

Yc = altura critica na seção retangular = 1,51 m;

q = vazão especifica = 5,78 m3/s x m;

g = aceleração da gravidade = 9,8 m3/s.

como:

Y > Yc temos regime subcritico.

* Elementos hidràulicos do canal de jusante:

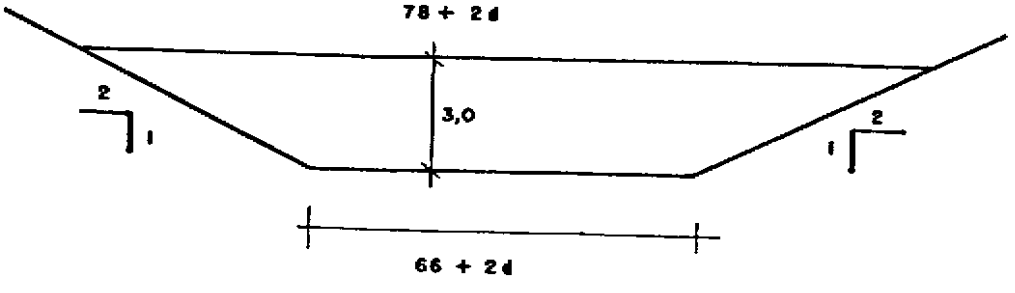
Q = vazão = 382 m3/s;

V = velocidade = 1,0 m/s;

Y = lâmina = 3,0 m;

S = seção molhada = 382 m2.

* Càlculo da seção de jusante:



onde:

d = acréscimo da semi-seção

tem-se:

$$S = \frac{66 + 2d + 78 + 2d}{2} \times 3 = 382 \text{ m}2$$

$d \cong 28$ m.

* Cálculo do comprimento de transição:

$$L = \frac{d}{\text{tg } 12^{\circ}\ 30'} \cong 127 \text{ m.}$$

DRENAGEM INTERNA

1. GRANULOMETRIA DOS MATERIAIS COMPONENTES DA DRENAGEM INTERNA

1.1 Granulometria da Areia:

D_{15A} = 0,001 mm (D_{15} do material argiloso).

D_{85A} = 1 mm (D_{85} do material argiloso).

D_{15B} = D_{15} da areia.

$$5 \times D_{15A} < D_{15B} < 5 \times D_{85A}$$

$$5 \times 0{,}001 < D_{15B} < 5 \times 1$$

$$0{,}005 \text{ mm} < D_{15B} < 5 \text{ mm}.$$

A areia dos Areais 1 e 2 estudados se enquadra dentro da faixa especificada e será utilizada na drenagem interna da barragem.

1.2 Granulometria da Brita "A":

D_{15B} = 0,4 mm (D_{15} da areia)

D_{85B} = 3 mm (D_{85} da areia)

D_{15C} = D_{15} da brita "A"

$$5 \times D_{15B} < D_{15C} < 5 \times D_{85B}$$

$$5 \times 0{,}4 < D_{15C} < 5 \times 3$$

$$2 \text{ mm} < D_{15C} < 15 \text{ mm}.$$

A brita "A" deverá ser confeccionada atendendo à especificação acima, ficando dentro da faixa mostrada na figura a seguir.

1.3 Granulometria da Brita "B":

D_{15C} = 5 mm (D_{15} da Brita "A")

D_{85C} = 19 mm (D_{85} da Brita "A")

$D_{15D} = D_{15}$ da brita "B"

$5 \times D_{15C} < D_{15D} < 5 \times D_{85C}$

$5 \times 5 < D_{15D} < 5 \times 19$

$25 \text{ mm} < D_{15D} < 95 \text{ mm}.$

A brita "B" deverá ser confeccionada atendendo à especificação acima, ficando dentro da faixa mostrada na figura a seguir.

1.3 Granulometria do Enrocamento:

$D_{15D} = 50$ mm (D_{15} da Brita "B")

$D_{85D} = 150$ mm (D_{85} da Brita "B")

$D_{15E} = D_{15}$ *do enrocamento*

$5 \times D_{15D} < D_{15E} < 5 \times D_{85D}$

$5 \times 50 < D_{15E} < 5 \times 150 \text{ mm}$

$250 \text{ mm} < D_{15E} < 450 \text{ mm}.$

O enrocamento deverá atender à especificação

acima, ficando dentro da faixa mostrada na figura a seguir.

2. RIP-RAP

2.1 Primeira Camada ou Camada Externa (Enrocamento):

- Altura da onda:

$$H = 0,75 + 0,34 \sqrt{F} - 0,26 \sqrt[4]{F}$$

onde:

H = altura da onda = 1,26 m;

F = fetch = 7,6 km.

- Velocidade da onda:

$$V = 1,5 + 2H$$

onde:

V = velocidade da onda = 4,02 m/s;

H = altura da onda = 1,26 m.

- Espessura da camada externa:

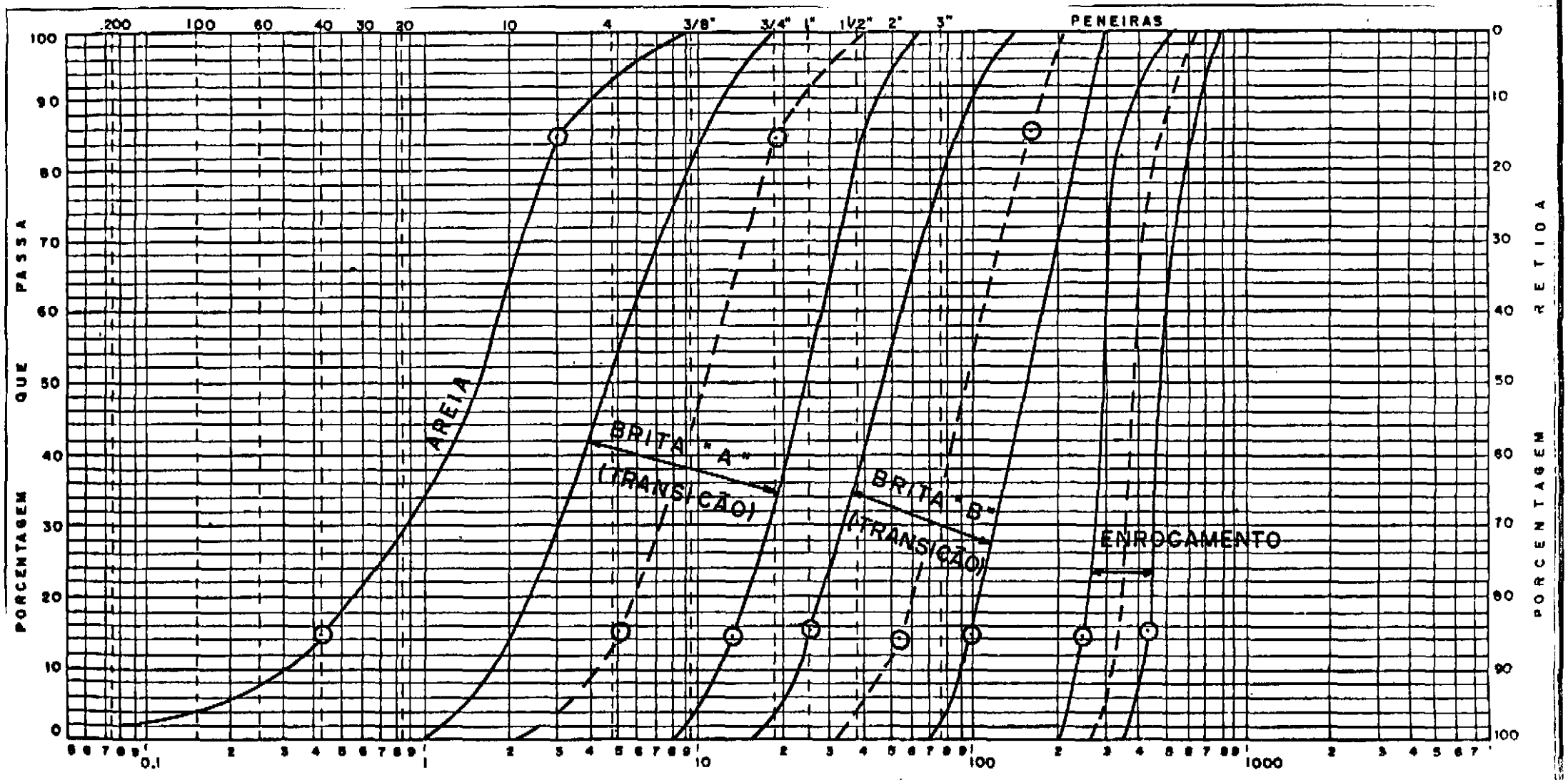
$$e_1 = C.V^2$$

onde:

e_1 = espessura da camada externa = 0,44 m;

adotado e_1 = 0,60 m;

GRANULOMETRIA DOS COMPONENTES DA DRENAGEM INTERNA



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C = 0,027 (parâmetro que depende da densidade da rocha a ser usada e da inclinação do talude);

V = velocidade das ondas = 4,02 m/s.

- Caracteristicas do material da camada externa:

$$P_{50} = 0,52 \times d \times e_1^3$$

onde:

P_{50} = 0,303 ton = 303 kg (50% da amostra deverá ter peso inferior a este valor);

d = densidade da rocha gnaisse = 2,7 ton/m3;

e_1 = espessura da camada = 0,60 m.

O "U. S. Army Carps Engineers" sugere que seja adotado um D_{50} = 0,40 m para uma altura da onda entre 1,20 e 1,80 m.

2.2 Camadas Internas:

- Espessuras adotadas:

e_2 = 0,30 m (Brita "B");

e_3 = 0,20 m (Brita "A");

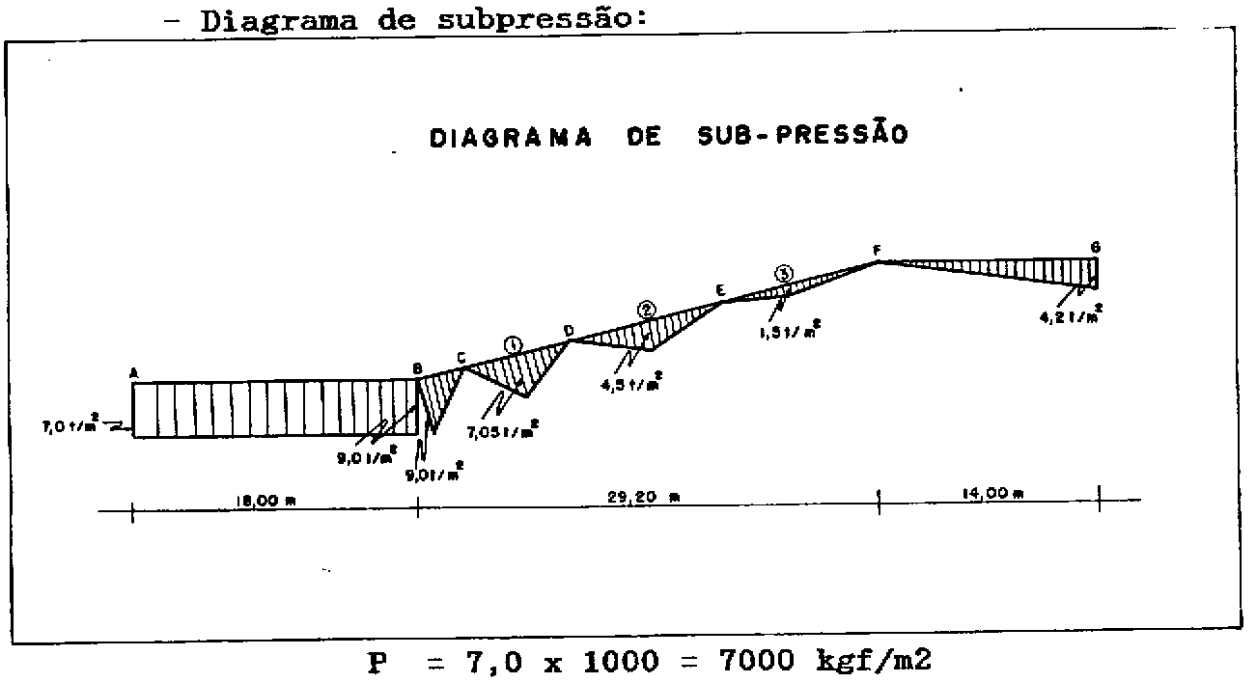
e_4 = 0,20 m (Areia).

- Granulometrias:

As granulometrias da Brita "B", Brita "A" e Areia são as mesmas especificadas anteriormente para o dreno de pé.

ANCORAGENS PASSIVAS, LAJES, VIGAS E MURO DE ARRIMO

- Diagrama de subpressão:



$P_A = 7,0 \times 1000 = 7000$ kgf/m2

$P_B = 9,0 \times 1000 = 9000$ kgf/m2

$P_C = P_D = P_E = P_F = 0$

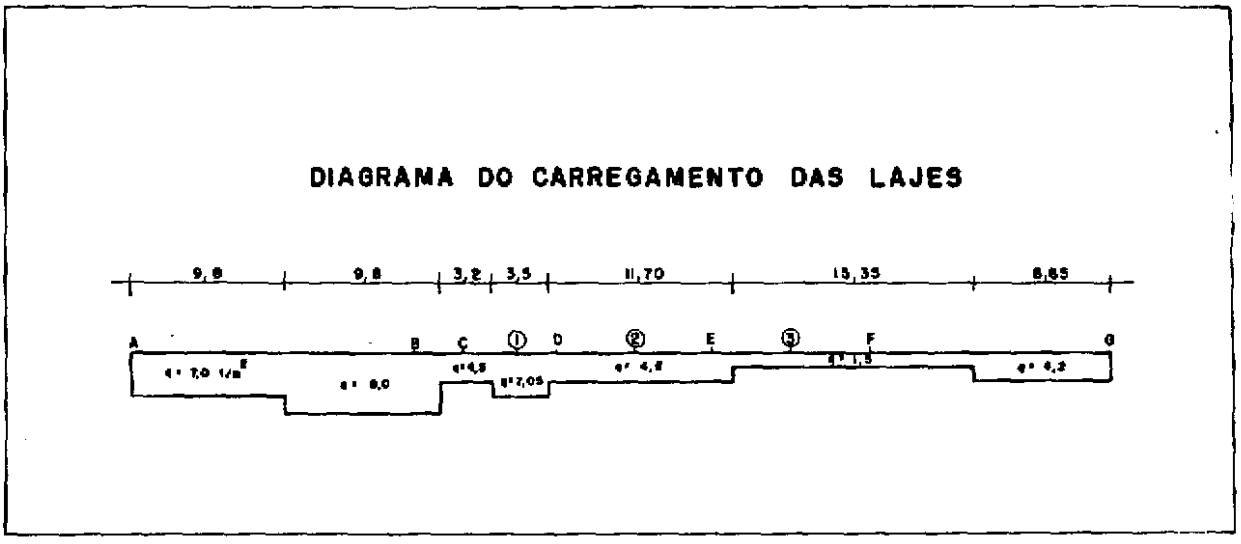
$P_G = 4,20 \times 1000 = 4200$ kgf/m2

$$P_1 = 9000 \times \frac{23,5}{30} = 7050 \text{ kgf/m2}$$

$$P_2 = 9000 \times \frac{15}{30} = 4500 \text{ kgf/m2}$$

$$P_3 = 9000 \times \frac{5}{30} = 1500 \text{ kgf/m2}$$

- Diagrama do carregamento nas lages:



* Cálculo dos esforços nas lajes:

Lages: 1 a 6

T = 7,0 x 9,0 x 10,67 = 673 ton.

Lages: 7 a 12

T = 7,0 x 0,8 x 10,67 + 9,0 x 8,2 x 10,67 = 848 ton.

Lages: 13 a 18

T = 9,0 x 1,6 x 10,67 + 4,5 x 3,2 x 10,67 + 7,05 x 3,5 x 10,67 + 4,5 x 1,7 x 10,67 = 652 ton.

Lages: 19 a 24

T = 4,5 x 10 x 10,67 = 481 ton.

Lages: 25 a 30

T = 1,5 x 10 x 10,67 = 161 ton.

Lages: 31 a 36

T = 1,5 x 5,0 x 10,67 = 80 ton.

Lages: 37 a 42

T = 1,5 x 0,35 x 10,67 + 4,2 x 8,65 x 10,67

= 394 ton.

- Dimensionamento das Ancoragens Passivas:

  * Aço ST-85/105 de ϕ = 32 mm da Protendidos Dywidag.

  * Furos ϕ = NX = 73,31 mm.

  * Parâmetros do Solo:

    ϕ' = 28°

    C' = 1,0 ton/m2

    γ_{SAT} = 2,1 ton/m3.

  * A resistência da ancoragem/solo é dada por:

    $Z = \pi \times d \times h \times \overline{\sigma}$

    onde:

    Z = resistência em ton;

    d = diâmetro da ancoragem = 73,31 mm;

    $\overline{\sigma}$ = resistência média ao cisalhamento em ton/m2;

    h = comprimento da ancoragem.

$$\overline{\sigma}(h) = C' + \sigma_e \, tg\phi'$$

onde:

σ_e = tensão efetiva = K (σ_{tv} - U);

σ_{tv} = tensão total = γ_{SAT}.h;

U = tensão neutra = γ_w.h;

K = coeficiente de Empuxo = 2,0;

γ_{SAT} = peso especifico saturado = 2,1 ton/m3;

γ_w = peso especifico da água = 1,0 ton/m3.

$$\overline{\overline{\sigma}} = \frac{\int_o^h \overline{\sigma}(h)dh}{h}$$

$$\overline{\overline{\sigma}} = \frac{\int_o^h 1,0dh + \int_o^h 2,0 \times (2,1-1,0)xhx0,53xdh}{h}$$

$$\overline{\overline{\sigma}}(h) = \frac{2h + 1,17h^2}{2h} = \frac{2 + 1,17h}{2}$$

$$\overline{\overline{\sigma}}(h) = \frac{2 + 1,17h}{2} \quad ton/m2$$

$$Z = 0,23 \, h \left(\frac{2 + 1,17h}{2}\right)$$

$$Z = o,23\ h + 0,14\ h^2$$

h (m)	Z (ton)
5	4,65
10	16,30
15	34,95
20	60,60
25	92,50
30	132,90

- Cálculo do Espaçamento e Comprimento das Ancoragens:

Lages: 1 a 6

T = 673 ton A = 96,03 m2

$$\frac{T}{A} = 7,0 \text{ ton/m2}$$

Adotando a área de influência Ai = 4,0 m2 tem-se que o esforço para ancoragem será:

E = 7,0 x 4 = 28 ton.

Será usado ancoragem com 20,0 m espaçadas de 2,0 em 2,0 metros.

Lages: 7 a 12

T = 848 ton A = 96,03 m2

$$\frac{T}{A} = 8,83 \text{ ton/m2}$$

Mesma solução do grupo anterior.

Lages: 13 a 18

T = 652 ton A = 106,70 m2

$$\frac{T}{A} = 6,11 \text{ ton/m2}$$

Adotando a área de influência Ai = 9,0 m2 tem-se o seguinte esforço por ancoragem:

E = 6,11 x 9,0 = 54,99 ton.

Será usado ancoragem com 25,0 m espaçadas de 3,0 em 3,0 metros.

Lages: 19 a 24

T = 481 ton A = 106,70 m2

$$\frac{T}{A} = 4,50 \text{ ton/m2}$$

Adotando a área de influência Ai = 9,0 m2 tem-se o seguinte esforço por ancoragem:

E = 4,50 X 9,0 = 40,50 ton.

Será usado ancoragem com 20,0 m espaçadas de 3,0 em 3,0 metros.

Lages: 25 a 30

T = 161 ton A = 106,70 m2

$$\frac{T}{A} = 1,51 \text{ ton/m2}$$

Adotando Ai = 9,0 m2 tem-se:

E = 1,51 X 9,0 = 13,59 ton.

Será adotado ancoragens com 15,00 m espaçadas de 3,0 em 3,0 metros.

Lages: 31 a 36

T = 80 ton A = 53,35 m2

$$\frac{T}{A} = 1,50 \text{ ton/m2}$$

Adotando Ai = 9,0 m2 tem-se:

E = 1,50 X 9,0 = 13,50 ton.

Será adotado ancoragem com 15,00 m espaçadas de 3,0 em 3,0 metros.

Lages: 37 a 42

T = 394 ton A = 96,03 m2

$$\frac{T}{A} = 4,10 \text{ ton/m2}$$

Adotando Ai = 9,0 m2 tem-se:

$$E = 4,10 \times 9,0 = 36,90 \text{ ton.}$$

Será adotado ancoragens com 20,00 m espaçadas de 3,0 em 3,0 metros.

- Cálculo dos Esforços nas Lages e Dimensionamento:

As lajes são consideradas apoiadas em vigas continuas virtuais apoiadas nas ancoragens.

As lajes serão dimensionadas para os momentos máximos positivos funcionando como simplesmente apoiadas e máximos negativos funcionando como perfeitamente engastada nas vigas.

Lajes: 1 a 6

$q = 7,0$ ton/m2 $\quad lx = ly = 2,0$

$\lambda = 1,0 \quad Kx = 0,5 \quad mx = my = 27,43$

$nx = ny = 24,00$

$qx = Kx.q = 3,5$ ton/m2

$$Mx = My = \frac{qlx^2}{m} = 1,02 \text{ ton x m.}$$

$$Xx = Xy = \frac{qlx^2}{n} = 1,17 \text{ ton x m.}$$

Lajes: 7 a 12

q = 9,0 ton/m2 lx = ly = 2,0

λ = 1,0 Kx = 0,5 mx = my = 27,43

nx = ny = 24,00

qx = Kx.q = 4,5 ton/m2

$$Mx = My = \frac{qlx^2}{m} = 1,32 \text{ ton x m.}$$

$$Xx = Xy = \frac{qlx^2}{n} = 1,50 \text{ ton x m.}$$

Lajes: 13 a 18

q = 6,11 ton/m2 lx = ly = 3,0

λ = 1,0 Kx = 0,5 mx = my = 27,43

nx = ny = 24,00

qx = Kxq = 3,01 ton/m2

$$Mx = My = \frac{qlx^2}{m} = 2,00 \text{ ton x m.}$$

$$Xx = Xy = \frac{qlx^2}{n} = 2,30 \text{ ton x m.}$$

Lajes: 19 a 24

q = 4,50 ton/m2 lx = ly = 3,0

λ = 1,0 Kx = 0,5 mx = my = 27,43

nx = ny = 24,00

qx = Kx.q = 2,25 ton/m2

$$Mx = My = \frac{qlx^2}{m} = 1,48 \text{ ton x m.}$$

$$Xx = Xy = \frac{qlx^2}{n} = 1,69 \text{ ton x m.}$$

Lajes: 25 a 30

q = 1,51 ton/m2 lx = ly = 3,0

λ = 1,0 Kx = 0,5 mx = my = 27,43

nx = ny = 24,00

qx = Kx.q = 0,76 ton/m2

$$Mx = My = \frac{qlx^2}{m} = 0,50 \text{ ton x m.}$$

$$Xx = Xy = \frac{qlx^2}{n} = 0,57 \text{ ton x m.}$$

Lajes: 31 a 36

q = 1,50 ton/m2 lx = ly = 3,0

λ = 1,0 Kx = 0,5 mx = my = 27,43

nx = ny = 24,00

$qx = Kx.q = 0,75$ ton/m2

$$Mx = My = \frac{qlx^2}{m} = 0,50 \text{ ton x m.}$$

$$Xx = Xy = \frac{qlx^2}{n} = 0,57 \text{ ton x m.}$$

Lajes: 37 a 42

$q = 4,10$ ton/m2 $lx = ly = 3,0$

$\lambda = 1,0$ $Kx = 0,5$ $mx = my = 27,43$

$nx = ny = 24,00$

$qx = Kx.q = 2,05$ ton/m2

$$Mx = My = \frac{qlx^2}{m} = 1,35 \text{ ton x m.}$$

$$Xx = Xy = \frac{qlx^2}{n} = 1,54 \text{ ton x m.}$$

- Dimensionamento das Lajes:

Adotando as lajes com h = 0,30 m, d = 0,28 m, fck = 140 kg/cm2 e aço CA-50A.

Lajes: 1 a 6

M = 1010 kg x m

X = 1170 kg x m.

vão

$$d_{min} = 0,209 \sqrt{\frac{1020}{1,0}} = 6,7 < 28 \text{ cm}$$

$$r_o = \frac{28}{\sqrt{\frac{1020}{1,0}}} = 0,876 \Rightarrow \alpha_o = 28,91$$

$$A'_s = \frac{1020}{28,91 \times 28} = 1,26 \text{ cm2} \Rightarrow 5 \phi 3/8" \text{ c/20cm}$$

Apoio

$$d_{min} = 0,209 \sqrt{\frac{1170}{1,0}} = 7,15 < 28 \text{ cm}$$

$$r_o = \frac{28}{\sqrt{\frac{1170}{1,0}}} = 0,818 \Rightarrow \alpha_o = 28,91$$

$$A'_s = \frac{1170}{28,91 \times 28} = 1,45 \text{ cm2} \Rightarrow 5 \phi 3/8" \text{ c/20cm}$$

Lajes: 7 a 12

M = 1320 kg x m

X = 1500 kg x m.

Vão $\equiv$ Apoio

$$d_{min} = 0,209 \sqrt{\frac{1500}{1,0}} = 8,09 < 28 \text{ cm}$$

$$r_o = \frac{28}{\sqrt{\frac{1500}{1,0}}} = 0,722 \Rightarrow \alpha_o = 28,91$$

$$A'_s = \frac{1500}{28,91 \times 28} = 1,85 \text{ cm2} \Rightarrow 5 \phi 3/8" \text{ c/20cm}$$

Lajes: 13 a 18

M = 2000 kg x m

X = 2300 kg x m.

Vão $\tilde{=}$ Apoio

$$d_{min} = 0,209 \sqrt{\frac{2300}{1,0}} = 10 < 28 \text{ cm}$$

$$r_o = \frac{28}{\sqrt{\frac{2300}{1,0}}} = 0,583 \Rightarrow \alpha_o = 28,91$$

$$A'_s = \frac{2300}{28,91 \times 28} = 2,85 \text{ cm2} \Rightarrow 5 \phi 3/8" \text{ c/20cm}$$

Lajes: 19 a 24

M = 1480 kg x m

X = 1690 kg x m.

Vão $\tilde{=}$ Apoio

$$d_{min} = 0,209 \sqrt{\frac{1690}{1,0}} = 8,6 < 28 \text{ cm}$$

$$r_o = \frac{28}{\sqrt{\frac{1690}{1,0}}} = 0,681 \Rightarrow \alpha_o = 28,91$$

$$A_s' = \frac{1690}{28,91 \times 28} = 2,08 \text{ cm2} \Rightarrow 5\ \phi\ 3/8" \text{ c/20cm}$$

Lajes: 25 a 36

M = 500 kg x m

X = 570 kg x m.

Vão = Apoio

$$d_{min} = 0,209 \sqrt{\frac{570}{1,0}} = 4,9 < 28 \text{ cm}$$

$$r_o = \frac{28}{\sqrt{\frac{570}{1,0}}} = 1,172 \Rightarrow \alpha_o = 28,91$$

$$A_s = \frac{570}{28,91 \times 28} = 0,70 \text{ cm2} \Rightarrow 5\ \phi\ 3/8" \text{ c/25cm}$$

Lajes: 37 a 42

M = 1350 kg x m

X = 1540 kg x m.

Vão $\tilde{=}$ Apoio

$$d_{min} = 0,209 \sqrt{\frac{1540}{1,0}} = 8,2 < 28 \text{ cm}$$

$$r_o = \frac{28}{\sqrt{\frac{1540}{1,0}}} = 0,713 \Rightarrow \alpha_o = 28,91$$

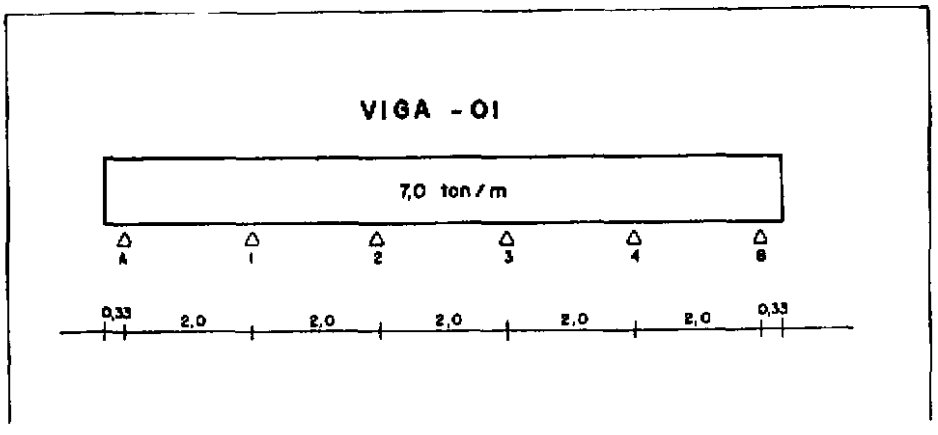
$$A_s = \frac{1540}{28,91 \times 28} = 1,90 \text{ cm2} \Rightarrow 5 \phi 3/8" \text{ c/20cm}$$

- Cálculo dos Esforços nas Vigas Virtuais:

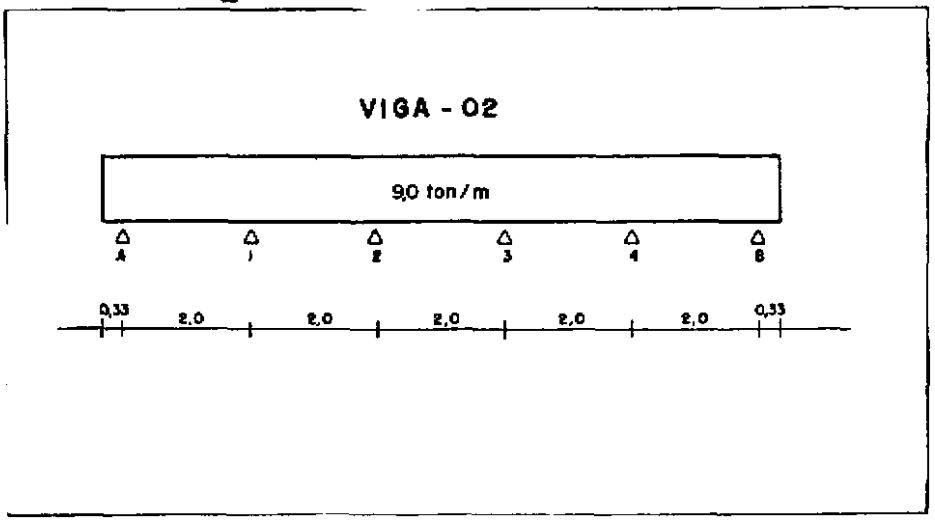
As vigas virtuais terão seção de 30 x 30.

Serão determinados os esforços nas vigas normais ao fluxo.

Lages: 1 a 6

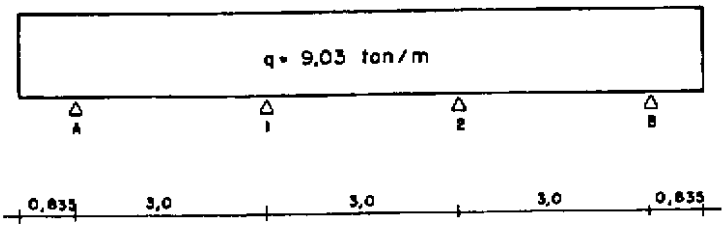


Lages: 7 a 12



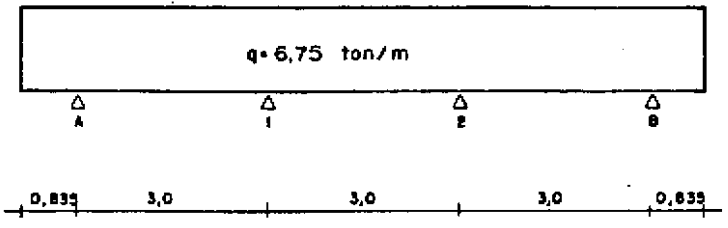
Lages: 13 a 18

VIGA - 03



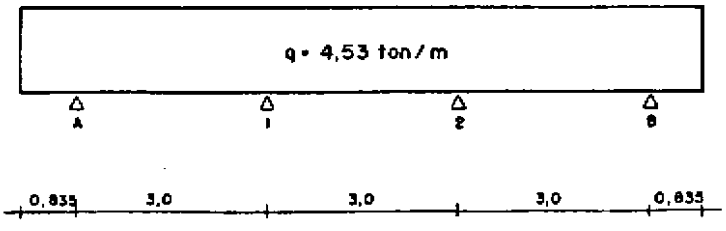
Lages: 19 a 24

VIGA - 04

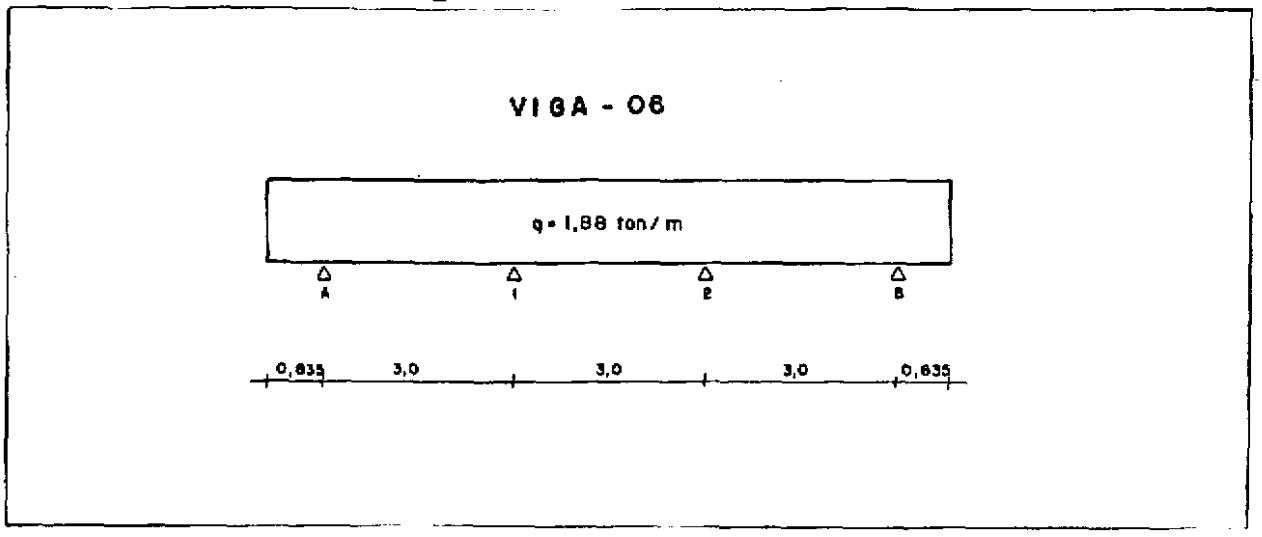


Lages: 25 a 30

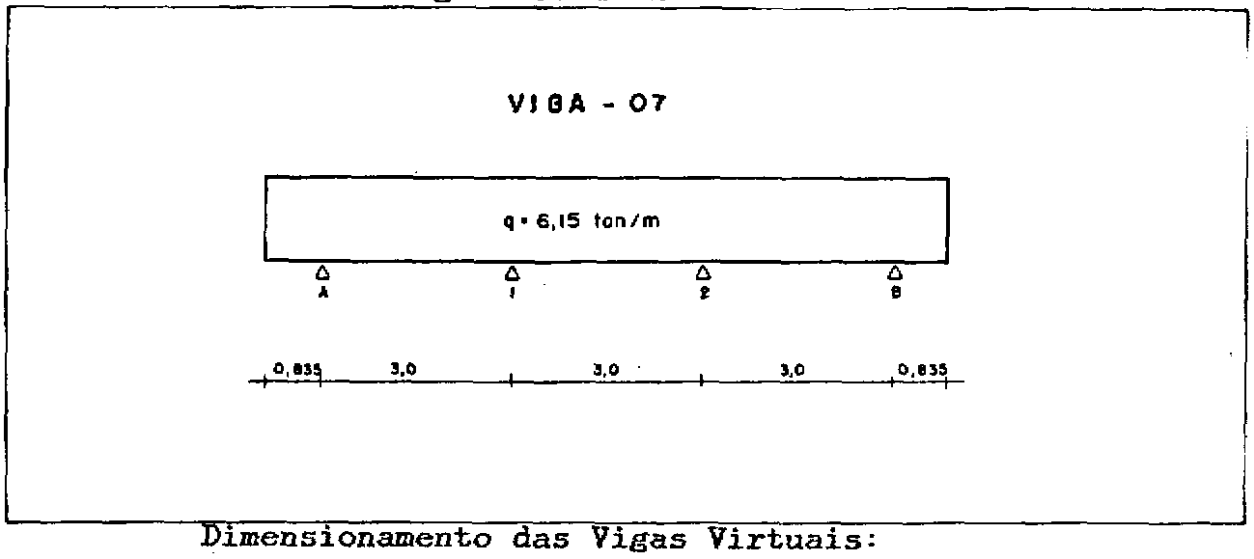
VIGA - 05



Lages: 31 a 36



Lages: 37 a 42



Dimensionamento das Vigas Virtuais:

Viga: V-1 e V-2

M = 1300 kg x m

X = 5700 kg x m

vão

$$d_{min} = 0,209 \sqrt{\frac{1300}{0,30}} = 13,75 < 28 \text{ cm}$$

$$r_o = \frac{28}{\sqrt{\frac{1300}{0,30}}} = 0,425 \Rightarrow \alpha_o = 28,91$$

$$A_s = \frac{1300}{28,91 \times 28} = 1,61 \text{ cm2} \Rightarrow 3 \phi 3/8"$$

Apoio

$$d_{min} = 0,209 \sqrt{\frac{5700}{0,30}} = 28,8 < 28$$

Armadura dupla.

$$M_1 = \mu_o.b.d^2.fcd = 0,229 \times 0,30 \times 28^2 \times 100 =$$

5.387 kg x m

$$M_2 = 5700 - 5387 = 313 \text{ kg x m}$$

$$M_{1d} = 1,4 \times 5387 = 7542 \text{ kg x m}$$

$$M_{2d} = 1,4 \times 313 = 439 \text{ kg x m}$$

$$A_s = \frac{7542}{0,749 \times 4200 \times 0,28} + \frac{439}{0,26 \times 4348}$$

$$A_s = 8,57 + 0,39 = 8,96 \text{ cm2} \Rightarrow 7 \phi 1/2"$$

$$A'_s = \frac{439}{0,26 \times 4200} = 0,40 \text{ cm2} \Rightarrow 2 \phi 1/4"$$

Esforço cortante màximo.

$$V = 9000 + \frac{5000}{2} = 11.500 \text{ kg}$$

Tensão de cisalhamento convencional.

$$\overline{\sigma}_{wd} = \frac{16.100}{30 \times 28} = 19,2 \text{ kg/cm2} < 0,20 \text{ fcd}$$

Armadura de cisalhamento

$$A_{ci} = \frac{16100}{0,87 \times 0,28 \times 4348} = 15,20 \text{ cm2/m} \Rightarrow$$

Estribos de 5/16" C 6,5

Viga: V-3

$M = 4000 \text{ kg x m}$

$X = 9400 \text{ kg x m}$

vão

$$d_{min} = 0,177 \sqrt{\frac{1,4 \times 4000}{0,30}} = 24,18 < 28$$

$$r = \frac{28}{\sqrt{\frac{1,4 \times 4000}{0,30}}} = 0,204 \Rightarrow \alpha_o = 36,09$$

$$A_s = \frac{1,4 \times 4000}{36,09 \times 28} = 5,54 \text{ cm2} \Rightarrow 3 \phi 1/2"$$

Apoio

$$d_{min} = 0,177 \sqrt{\frac{1,4 \times 9400}{0,30}} = 37,07 > 28 \text{ cm}$$

Armadura dupla.

$$M_{1d} = 0,320 \times 0,30 \times 28^2 \times 100 = 7527$$

$$M_{2d} = 13160 - 7527 = 5633$$

$$A_s = \frac{7527}{0,749 \times 4200 \times 0,28} + \frac{5633}{0,26 \times 4348}$$

$$A_s = 13,53 \text{ cm2} \Rightarrow 11 \phi 1/2"$$

$$A'_s = \frac{5633}{0,26 \times 4348} = 4,99 \text{ cm2} \Rightarrow 4 \phi 1/2"$$

Esforço cortante máximo.

$$V = 9030 + \frac{6200}{3} = 11.097 \text{ kg}$$

Tensão de cisalhamento convencional.

$$\tau_{wd} = \frac{15.536}{30 \times 28} = 18,5 < 0,20 \text{ fcd}$$

Armadura de cisalhamento

$$A_{ci} = \frac{15536}{0,87 \times 0,28 \times 4348} = 14,67 \text{ cm2/m} \Rightarrow$$

Estribos de 5/16" C 7,0

Vigas: V-4 e V-7

$M = 2910 \text{ kg x m}$

$X = 7020 \text{ kg x m}$

vão

$$d_{min} = 0,177 \sqrt{\frac{1,4 \times 2910}{0,30}} = 20,6 < 28$$

$$r_o = \frac{28}{\frac{1,4 \times 2910}{0,30}} = 0,240 \Rightarrow \alpha_o = 38,48$$

$$A_s = \frac{4074}{38,48 \times 28} = 3,79 \text{ cm2} \Rightarrow 3 \phi 1/2"$$

Apoio

$$d_{min} = 0,177 \sqrt{\frac{1,4 \times 7020}{0,30}} = 32 > 28 \text{ cm}$$

Armadura dupla.

$$M_{1d} = 0,320 \times 0,30 \times 28^2 \times 100 = 7527 \text{ kg x m}$$

$$M_{2d} = 9828 - 7527 = 2301 \text{ kg x m}$$

$$A_s = \frac{7527}{0,749 \times 4200 \times 0,28} + \frac{2301}{0,26 \times 4348}$$

$$A_s = 10,59 \text{ cm2} \Rightarrow 9 \phi 1/2"$$

$$A_s = \frac{2301}{0,26 \times 4200} = 2,10 \text{ cm2} \Rightarrow 3 \phi 1/2"$$

Esforço cortante màximo.

$$V = 9300 + \frac{4110}{3} = 10.670 \text{ kg}$$

Tensão de cisalhamento convencional.

$$\tau_{wd} = \frac{14.938}{30 \times 28} = 17,8 < 0,20 \text{ fcd}$$

Armadura de cisalhamento

$$A_{ci} = \frac{14.938}{0,87 \times 0,28 \times 4348} = 14,10 \text{ cm2/m} \Rightarrow$$

Estribos de 5/16" C 7,0

Viga: V-5

M = 2000 kg x m

X = 4720 kg x m

vão

$$d_{min} = 0,177 \quad \frac{1,4 \times 2000}{0,30} = 17,1 < 28$$

$$r = \frac{28}{\sqrt{\frac{2800}{0,30}}} = 0,289 \Rightarrow \alpha = 40$$

$$A_s = \frac{2800}{40 \times 28} = 2,5 \text{ cm2} \Rightarrow 2 \phi 1/2"$$

Apoio

$$d_{min} = 0,177 \sqrt{\frac{6608}{0,30}} = 26,3 < 28 \text{ cm}$$

$$r = \frac{28}{\sqrt{\frac{6608}{0,30}}} = 0,188 \Rightarrow \alpha = 3413$$

$$A_s = \frac{6608}{34,13 \times 28} = 6,92 \text{ cm2} \Rightarrow 6 \phi 1/2"$$

Esforço cortante máximo.

$$V = 6525 + 1573 = 8098 \text{ kg}$$

Tensão de cisalhamento convencional.

$$\tau_{wd} = \frac{11.338}{30 \times 28} = 13,5 < 0,20 \text{ fcd}$$

Armadura de cisalhamento

$$A_{ci} = \frac{11.338}{0,87 \times 0,28 \times 4348} = 10,70 \text{ cm2/m} \Rightarrow$$

Estribos de 5/16" C 9,0

Viga: V-6

M = 810 kg x m

X = 1960 kg x m

vão $\cong$ apoio

$$d_{min} = 0,177 \sqrt{\frac{1,4 \times 1960}{0,30}} = 16,9 < 28$$

$$r = \frac{28}{\frac{2744}{0,30}} = 0,292 \Rightarrow \alpha = 40,22$$

$$A_s = \frac{2744}{40,22 \times 28} = 2,44 \text{ cm2} \Rightarrow 2 \phi 1/2"$$

Esforço cortante máximo.

V = 2820 + 435 = 3255 kg

Armadura de cisalhamento.

$$A_{ci} = \frac{4.557}{30 \times 28} = 5,43 \text{ cm2/m} \Rightarrow$$ Estribos de 5/16" C 18,0

Analise da estabilidade do muro lateral do canal ràpido e bacia de dissipação.

Analisado pela teoria de Rankine.

Empuxo ativo $\gamma_{sat} = 2,1$ ton/m2

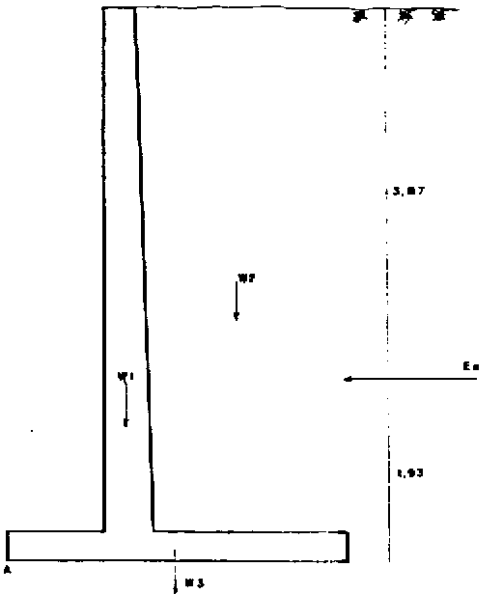
$\Phi' = 28$

$$Ea = \frac{1}{2} \times \gamma \times h^2 \times Ka$$

$$Ka = tg^2 (45 - \frac{\Phi'}{2}) = 0,36$$

$$Ea = \frac{1}{2} \times 2,1 \times 5,8^2 \times 0,36$$

Ea = 12,72 ton/m



$$W_1 = \frac{0,30 + 0,50}{2} \times 5,5 \times 2,5 = 5,5 \text{ ton/m}$$

$$W_2 = \frac{2,00 + 2,20}{2} \times 5,5 \times 2,10 = 24,25 \text{ ton/m}$$

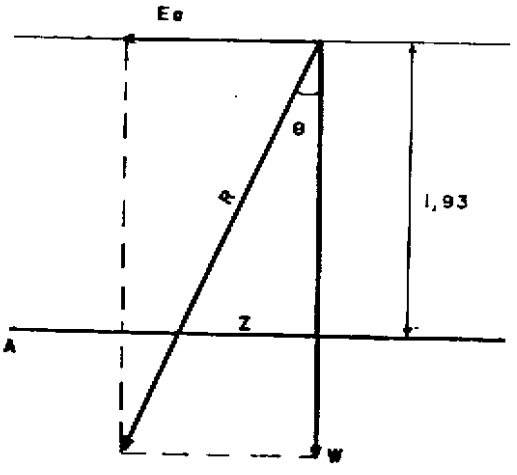
$$W_3 = 0,30 \times 3,5 \times 2,5 = 2,62 \text{ ton/m}$$

* Abscissa da resultante vertical em relação ao ponto A:

$$W.X = 1{,}15\ W_1 + 2{,}50\ W_2 + 1{,}75 \times W_3$$

$$X = \frac{6{,}33 + 60{,}63 + 4{,}59}{32{,}37} = 2{,}21\ m$$

* Abscissa da resultante total em relação ao Ponto A:



$$tg\theta = \frac{Ea}{W} = 0{,}393$$

$$Z = 1{,}93 \times 0{,}393$$

$$Z = 0{,}76 \qquad X_A = 2{,}21 - 0{,}76$$

$$X_A = 1{,}45 > 1{,}0$$

Logo a resultante passa no terço central.

- Verificação ao tombamento, em torno do Ponto A:

Momento tombador = Ea x 1,93 = 24,55 ton x m/m

Momento resistente = W x 2,21 = 71,54 ton x m/m

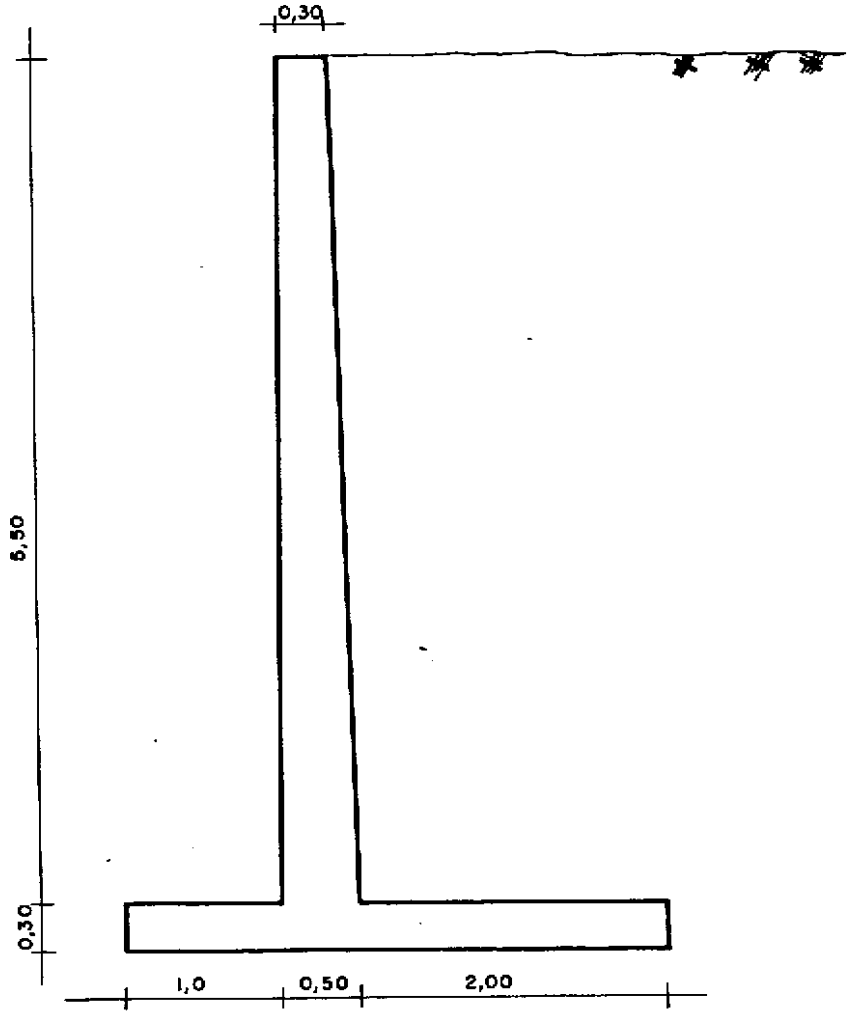
$$\text{Coeficiente de segurança} = \frac{71{,}54}{24{,}55} = 2{,}91 > 1{,}5 \text{ O.K!}$$

- Verificação contra o escorregamento:

$$\frac{W\ tg\phi'}{Ea} > 1{,}2$$

$$\frac{17,01}{12,72} = 1,35 \text{ O.K!}$$

- Cálculo Estrutural do Muro do Canal Rápido e da Bacia de Dissipação:



A laje vertical será calculada supondo engastado na laje horizontal.

A laje de fundação será calculada com dois consolos.

Laje vertical

Momento de engastamento

$M = Ea \times 1,93 \cong 24.600 \text{ ton x m/m}$

Dimensionamento da seção de engastamento:

$M = 24.600 \text{ kg x m}$

$b = 1,0 \text{ m} \quad h = 50 \text{ cm} \quad d = 48 \text{ cm}$

$$d_{min} = 0,177 \sqrt{\frac{34.400}{1,0}} = 32,8 < 48$$

$$r = \frac{48}{\sqrt{\frac{34.440}{1,0}}} = 0,258 \Rightarrow \propto = 39,13$$

$$A_s = \frac{34.440}{39,13 \times 48} = 18,34 \Rightarrow 15 \phi 1/2" \text{ C } 6,6$$

A face comprimida será dimensionada para o momento causado pelo empuxo da água.

$$E_w = \frac{1}{2} \times 1,0 \times 5,0^2 = 12.500 \text{ kg x m}$$

Momento do empuxo da água

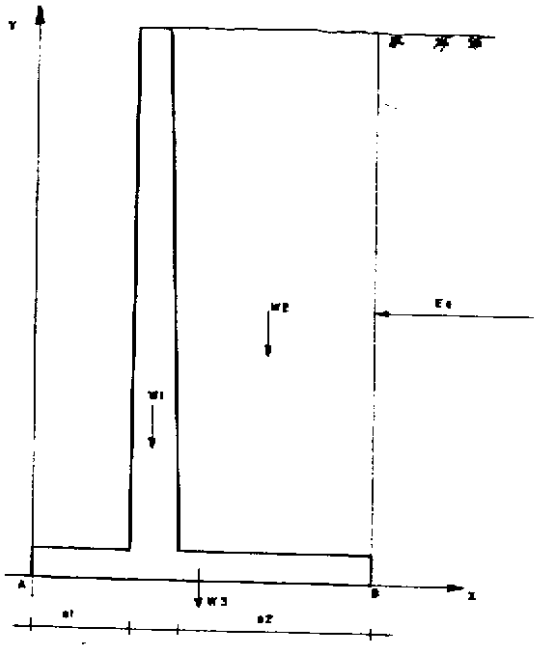
$$M_w = \frac{12.500 \times 5,0}{3} = 20834 \text{ kg x m}$$

$$d_{min} = 0,177 \sqrt{\frac{29.168}{1,0}} = 30,22 < 48$$

$$r = \frac{48}{\sqrt{\frac{29.168}{1,0}}} = 0,281 \Rightarrow \alpha = 40$$

$$A_s = \frac{29.168}{40 \times 48} = 15,19 \text{ cm2} \Rightarrow 12 \phi 1/2" \text{ C } 8,3$$

Lage horizontal



A resultante do sistema de forças mostrado intercepta o eixo das abscissa no ponto X = 1,23 m y = 0 e $R = \sqrt{12,72^2 + 32,37^2} = 34,77$ ton

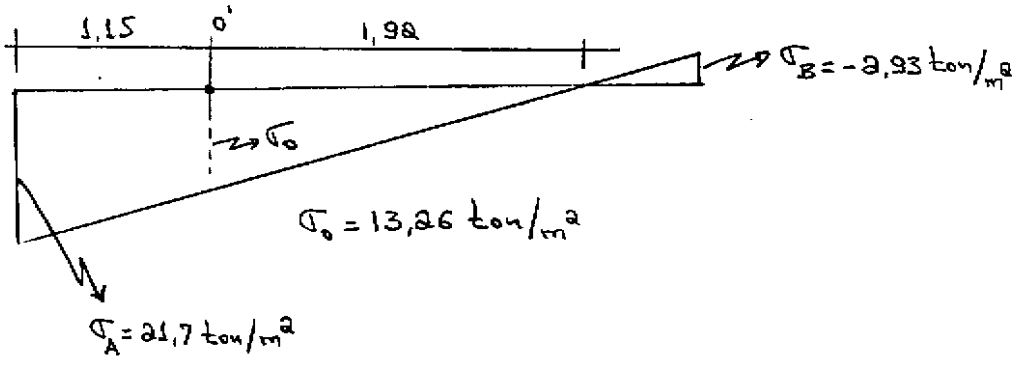
Rx = 12,72 ton e Ry = 34,77 ton.

As tensões do terreno (reação) na base AB terá distribuição trapezoidal e os extremos são:

$$\sigma_A = \frac{32,37}{1,0 \times 3,5}\left(1 + \frac{6 \times 0,77}{3,5}\right) = 21,4 \text{ ton/m2}$$

$$\sigma_B = \frac{32,37}{1,0 \times 3,5}\left(1 - \frac{6 \times 0,77}{3,5}\right) = -2,95 \text{ ton/m2}$$

Cálculo do momento de engaste do consolo mais desfavorável na seção 00'= 100 x 30 m.



$$M_{00'} = 13,26 \times \frac{1,15^2}{2} + \frac{7,94 \times 1,15}{2} \times 0,76$$

$$M_{00'} = 12,24 \text{ ton x m.}$$

Dimensionamento:

$$d_{min} = 0,177 \sqrt{\frac{17.136}{1,0}} = 23,17 < 28$$

$$r = \frac{28}{\sqrt{\frac{17.136}{1,0}}} = 0,214 \Rightarrow \alpha = 36,74$$

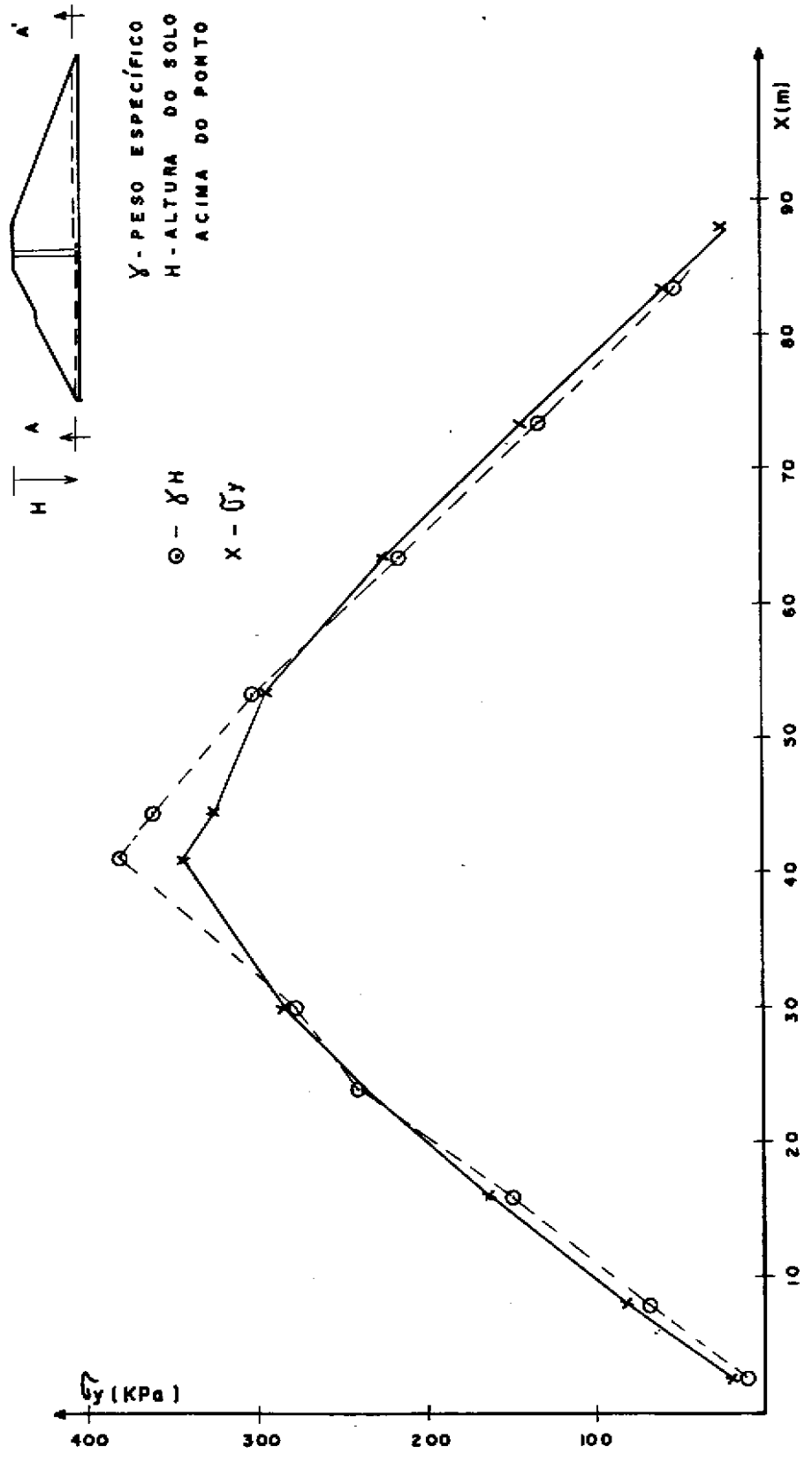
$$A_s = \frac{17.136}{36,74 \times 48} = 16,66 \text{ cm2} \Rightarrow 14 \phi 1/2" \text{ C } 7$$

rmms./fsn.

Geonorte

ANEXO B:

Desenhos

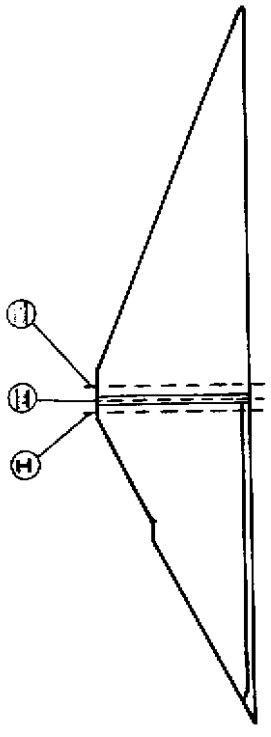


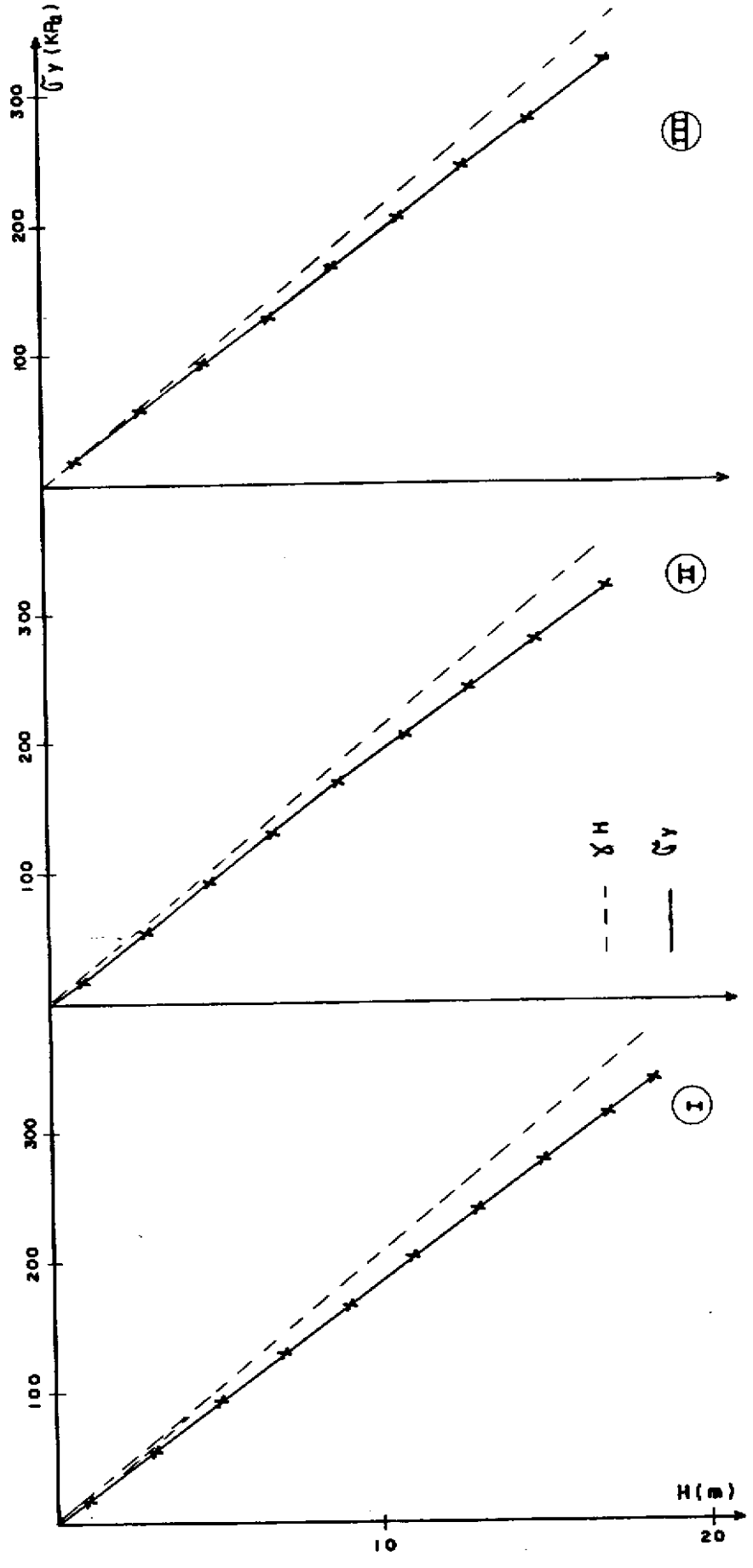
000080

DNOCS - DEPARTAMENTO NACIONAL DE OBRAS CONTRA AS SECAS.			
DATA. JUN./88	DES.	VISTO.	Geonorte
ESC. —	APROV.		
TENSÃO VERTICAL E PESO DO SOLO X HORIZONTE AA'			T-101/88 DES. 01

γ – PESO ESPECÍFICO DO SOLO

H – ALTURA DO SOLO ACIMA DO PONTO





000081

DNOCS – DEPARTAMENTO NACIONAL DE OBRAS CONTRA AS SECAS.			
DATA. JUN./88	DES.	VISTO.	Geonorte
ESC. —	APROV.		
TENSÃO VERTICAL E PESO DO SOLO X SEÇÕES I, II, III.			T-101/88 DES. 02

AANEXO C:

Listagem do Computador

Geonorte

ANALISE DAS TENSOES

Geonorte

Elem	X	Y	σ_x	σ_y	τ_{xy}	τ_{max}	σ_1	σ_3	θ
SIZE OF SN =		9515							
1	2.67	0.67 E	9.057D+00	2.113D+01	8.994D+00	1.083D+01	2.593+01	4.263D+00	61.9
2	5.00	0.75 E	2.625D+01	3.957D+01	1.612D+01	1.744D+01	5.035+01	1.547D+01	56.2
3	8.00	0.50 E	3.878D+01	8.426D+01	2.400D+01	3.306D+01	9.458+01	2.846D+01	66.7
4	12.00	0.50 E	5.532D+01	1.253D+02	2.998D+01	4.607D+01	1.364+02	4.423D+01	69.7
5	16.00	0.50 E	7.170D+01	1.649D+02	3.362D+01	5.747D+01	1.758+02	6.084D+01	72.1
6	20.00	0.50 E	8.697D+01	2.025D+02	3.523D+01	6.766D+01	2.124+02	7.707D+01	74.3
7	24.00	0.50 E	1.016D+02	2.380D+02	3.487D+01	7.657D+01	2.464+02	9.321D+01	76.5
8	27.00	0.50 E	1.117D+02	2.628D+02	3.358D+01	8.267D+01	2.699+02	1.046D+02	78.0
9	30.00	0.50 E	1.207D+02	2.853D+02	3.071D+01	8.784D+01	2.909+02	1.152D+02	79.8
10	34.00	0.50 E	1.311D+02	3.118D+02	2.470D+01	9.371D+01	3.152+02	1.277D+02	82.4
11	38.00	0.50 E	1.385D+02	3.311D+02	1.598D+01	9.763D+01	3.325+02	1.372D+02	85.3
12	41.25	0.50 E	1.424D+02	3.405D+02	7.145D+00	9.929D+01	3.407+02	1.422D+02	87.9
13	5.33	2.00 E	2.101D+01	2.295D+01	1.228D+01	1.232D+01	3.430+01	9.658D+00	47.3
14	8.00	2.00 E	3.246D+01	4.898D+01	1.804D+01	1.984D+01	6.058+01	2.087D+01	57.3
15	12.00	2.00 E	4.706D+01	9.321D+01	2.420D+01	3.344D+01	1.038+02	3.670D+01	66.8
16	16.00	2.00 E	6.092D+01	1.329D+02	2.811D+01	4.568D+01	1.428+02	5.125D+01	71.0
17	20.00	2.00 E	7.496D+01	1.716D+02	2.983D+01	5.677D+01	1.800+02	6.650D+01	74.2
18	24.00	2.00 E	8.781D+01	2.074D+02	2.999D+01	6.691D+01	2.145+02	8.071D+01	76.7
19	27.00	2.00 E	9.693D+01	2.329D+02	2.901D+01	7.392D+01	2.389+02	9.100D+01	78.4
20	30.00	2.00 E	1.044D+02	2.561D+02	2.685D+01	8.048D+01	2.608+02	9.979D+01	80.3
21	34.00	2.00 E	1.125D+02	2.836D+02	2.174D+01	8.825D+01	2.863+02	1.098D+02	82.9
22	38.00	2.00 E	1.181D+02	3.039D+02	1.409D+01	9.392D+01	3.049+02	1.171D+02	85.7
23	41.00	2.00 E	1.204D+02	3.133D+02	7.189D+00	9.671D+01	3.138+02	1.202D+02	87.9
24	42.50	1.75 E	1.255D+02	3.214D+02	1.749D+00	9.795D+01	3.214+02	1.255D+02	89.5
25	44.50	1.50 E	1.291D+02	3.249D+02	-1.772D+00	9.792D+01	3.249+02	1.290D+02	-89.5
26	48.50	1.50 E	1.266D+02	3.158D+02	-1.156D+01	9.534D+01	3.169+02	1.259D+02	-86.5
27	53.50	1.50 E	1.196D+02	2.934D+02	-2.146D+01	8.953D+01	2.960+02	1.170D+02	-83.1
28	58.50	1.50 E	1.087D+02	2.606D+02	-2.745D+01	8.074D+01	2.654+02	1.039D+02	-80.1
29	63.50	1.50 E	9.498D+01	2.221D+02	-2.956D+01	7.011D+01	2.283+02	8.845D+01	-77.5
30	68.50	1.50 E	7.985D+01	1.819D+02	-2.857D+01	5.847D+01	1.893+02	7.239D+01	-75.4
31	73.50	1.50 E	6.372D+01	1.411D+02	-2.559D+01	4.641D+01	1.488+02	5.603D+01	-73.3
32	78.50	1.50 E	4.762D+01	1.005D+02	-2.103D+01	3.380D+01	1.079+02	4.029D+01	-70.8
33	83.50	1.50 E	3.056D+01	5.550D+01	-1.532D+01	1.975D+01	6.278+01	2.328D+01	-64.6
34	87.87	1.50 E	1.125D+01	2.624D+01	-6.961D+00	1.023D+01	2.893+01	8.512D+00	-68.6
35	8.67	3.67 E	2.731D+01	2.267D+01	1.292D+01	1.313D+01	3.813+01	1.186D+01	39.9
36	12.00	4.00 E	3.501D+01	4.747D+01	1.770D+01	1.877D+01	6.008+01	2.247D+01	54.7
37	16.00	4.00 E	4.793D+01	9.126D+01	2.142D+01	3.046D+01	1.003+02	3.913D+01	67.7
38	20.00	4.00 E	5.919D+01	1.297D+02	2.369D+01	4.249D+01	1.368+02	5.197D+01	73.1
39	24.00	4.00 E	7.072D+01	1.667D+02	2.412D+01	5.370D+01	1.728+02	6.500D+01	76.7
40	27.00	4.00 E	7.830D+01	1.925D+02	2.395D+01	6.193D+01	1.978+02	7.548D+01	78.6
41	30.00	4.00 E	8.431D+01	2.168D+02	2.275D+01	7.002D+01	2.208+02	8.651D+01	80.5
42	34.00	4.00 E	9.012D+01	2.455D+02	1.892D+01	7.997D+01	2.478+02	8.785D+01	82.2
43	38.00	4.00 E	9.376D+01	2.668D+02	1.236D+01	8.741D+01	2.678+02	9.268D+01	85.9
44	41.00	4.00 E	9.579D+01	2.777D+02	5.901D+00	9.115D+01	2.778+02	9.560D+01	86.1
45	42.50	4.00 E	9.578D+01	2.798D+02	3.123D+00	9.206D+01	2.798+02	9.577D+01	89.0
46	44.50	4.00 E	9.569D+01	2.790D+02	-1.842D+00	9.168D+01	2.798+02	9.567D+01	-87.4
47	48.50	4.00 E	9.471D+01	2.699D+02	-9.878D+00	8.814D+01	2.708+02	9.416D+01	-86.8
48	53.50	4.00 E	9.094D+01	2.458D+02	-1.781D+01	7.947D+01	2.478+02	8.892D+01	-83.5
9	58.50	4.00 E	8.368D+01	2.110D+02	-2.216D+01	6.740D+01	2.148+02	7.793D+01	-80.4
50	63.50	4.00 E	7.351D+01	1.710D+02	-2.290D+01	5.386D+01	1.768+02	6.840D+01	-77.4
	68.50	4.00 E	6.042D+01	1.292D+02	-2.126D+01	4.044D+01	1.358+02	5.438D+01	74.1
52	73.50	4.00 E	4.686D+01	8.862D+01	-1.790D+01	2.750D+01	9.528+01	4.324D+01	-69.7
53	3.50	4.00 E	3.175D+01	4.444D+01	-1.311D+01	1.457D+01	5.268+01	2.752D+01	-57.9
54	82.67	3.67 E	2.176D+01	1.917D+01	-8.762D+00	8.857D+00	2.938+01	1.141D+01	-46.8
55	12.67	5.67 E	2.793D+01	2.234D+01	1.257D+01	1.288D+01	3.808+01	1.226D+01	78.7

56	16.00	6.00	E	3.391D+01	4.629D+01	1.614D+01	1.728D+01	5.738D+01	2.282D+01	55.5
57	20.00	6.00	E	4.522D+01	8.889D+01	1.803D+01	2.832D+01	9.537D+01	3.873D+01	70.2
58	24.00	6.00	E	5.455D+01	1.252D+02	1.915D+01	4.018D+01	1.301D+02	4.970D+01	75.8
59	27.00	6.00	E	6.186D+01	1.518D+02	1.948D+01	4.899D+01	1.558D+02	5.782D+01	78.3
60	30.00	6.00	E	6.647D+01	1.766D+02	1.962D+01	5.843D+01	1.799D+02	6.308D+01	80.2
61	34.00	6.00	E	7.072D+01	2.069D+02	1.709D+01	7.019D+01	2.090D+02	6.861D+01	83.0
62	38.00	6.00	E	7.297D+01	2.296D+02	1.125D+01	7.912D+01	2.304D+02	7.217D+01	85.9
63	41.00	6.00	E	7.385D+01	2.406D+02	5.528D+00	8.355D+01	2.408D+02	7.367D+01	88.1
64	42.50	6.00	E	7.429D+01	2.431D+02	2.493D+00	8.445D+01	2.432D+02	7.426D+01	89.2
65	44.50	6.00	E	7.448D+01	2.425D+02	-1.758D+00	8.401D+01	2.4[illegible]D+02	7.446D+01	89.4
66	48.50	6.00	E	7.391D+01	2.324D+02	-9.249D+00	7.976D+01	2.329D+02	7.308D+01	-86.7
67	53.50	6.00	E	7.147D+01	2.070D+02	-1.604D+01	6.964D+01	2.089D+02	6.960D+01	-83.7
68	58.50	6.00	E	6.618D+01	1.708D+02	-1.890D+01	5.563D+01	1.741D+02	6.287D+01	-80.1
69	63.50	6.00	E	5.698D+01	1.292D+02	-1.857D+01	4.062D+01	1.337D+02	5.249D+01	-76.4
70	68.50	6.00	E	4.599D+01	8.791D+01	-1.586D+01	2.628D+01	9.323D+01	4.067D+01	-71.4
71	73.50	6.00	E	3.200D+01	4.356D+01	-1.244D+01	1.372D+01	5.150D+01	2.407D+01	-57.5
72	77.67	5.67	E	2.466D+01	1.941D+01	-8.848D+00	9.229D+00	3.126D+01	1.281D+01	-36.7
73	16.67	7.67	E	2.567D+01	2.172D+01	1.120D+01	1.137D+01	3.507D+01	1.232D+01	40.0
74	20.00	8.00	E	3.039D+01	4.476D+01	1.373D+01	1.550D+01	5.308D+01	2.208D+01	58.8
75	24.00	8.00	E	4.045D+01	8.450D+01	1.414D+01	2.618D+01	8.865D+01	3.670D+01	73.6
76	27.00	8.00	E	4.644D+01	1.095D+02	1.570D+01	3.520D-01	1.131D+02	4.275D+01	76.8
77	30.00	8.00	E	5.117D+01	1.357D+02	1.708D+01	4.557D+01	1.390D+02	4.785D+01	79.0
78	34.00	8.00	E	5.416D+01	1.677D+02	1.597D+01	5.900D+01	1.699D+02	5.196D+01	82.1
79	38.00	8.00	E	5.551D+01	1.920D+02	1.064D+01	6.909D+01	1.929D+02	5.469D+01	85.6
80	41.00	8.00	E	5.618D+01	2.036D+02	5.122D+00	7.388D+01	2.038D+02	5.600D+01	88.0
81	42.50	8.00	E	5.643D+01	2.062D+02	2.085D+00	7.493D+01	2.062D+02	5.640D+01	89.2
82	44.50	8.00	E	5.664D+01	2.055D+02	-1.860D+00	7.445D+01	2.055D+02	5.662D+01	-89.3
83	48.50	8.00	E	5.654D+01	1.945D+02	-8.983D+00	6.957D+01	1.951D+02	5.596D+01	-86.3
84	53.50	8.00	E	5.503D+01	1.678D+02	-1.468D+01	5.829D+01	1.697D+02	5.315D+01	-82.7
85	58.50	8.00	E	5.012D+01	1.296D+02	-1.635D+01	4.299D+01	1.329D+02	4.689D+01	-78.8
86	63.50	8.00	E	4.233D+01	8.816D+01	-1.420D+01	2.696D+01	9.220D+01	3.829D+01	-74.1
87	68.50	8.00	E	2.991D+01	4.306D+01	-1.119D+01	1.298D+01	4.946D+01	2.350D+01	-60.2
88	72.67	7.67	E	2.347D+01	1.891D+01	-7.906D+00	8.227D+00	2.942D+01	1.296D+01	-37.0
89	20.67	9.67	E	2.186D+01	2.102D+01	9.556D+00	9.565D+00	3.100D+01	1.187D+01	43.7
90	24.00	10.00	E	2.553D+01	4.093D+01	1.008D+01	1.268D+01	4.592D+01	2.055D+01	67.7
91	27.00	10.00	E	3.402D+01	6.798D+01	1.056D+01	1.999D+01	7.099D+01	3.101D+01	78.1
92	30.00	10.00	E	3.788D+01	9.316D+01	1.513D+01	3.151D+01	9.702D+01	3.491D+01	75.7
93	34.00	10.00	E	4.055D+01	1.284D+02	1.518D+01	4.648D+01	1.310D+02	3.801D+01	80.5
94	38.00	10.00	E	4.158D+01	1.543D+02	1.026D+01	5.730D+01	1.553D+02	4.066D+01	84.8
95	41.00	10.00	E	4.201D+01	1.666D+02	4.829D+00	6.246D+01	1.667D+02	4.182D+01	87.8
96	42.50	10.00	E	4.215D+01	1.673D+02	1.812D+00	6.359D+01	1.693D+02	4.212D+01	89.2
97	44.50	10.00	E	4.248D+01	1.683D+02	-2.134D+00	6.296D+01	1.684D+02	4.245D+01	89.0
98	48.50	10.00	E	4.261D+01	1.566D+02	-8.801D+00	5.766D+01	1.573D+02	4.193D+01	-85.6
99	53.50	10.00	E	4.119D+01	1.278D+02	-1.380D+01	4.544D+01	1.299D+02	3.704D+01	81.2
100	58.50	10.00	E	3.676D+01	8.893D+01	-1.339D+01	2.932D+01	9.234D+01	3.[illegible]	-71.4
101	63.50	10.00	E	2.677D+01	4.331D+01	-1.042D+01	1.330D+01	4.835D+01	2.[illegible]	-47.7
102	67.67	9.67	E	2.040D+01	1.831D+01	-6.321D+00	6.406D+00	2.576D+01	[illegible]	41.3
103	24.67	11.67	E	1.623D+01	1.617D+01	5.922D+00	5.922D+00	2.212D+01	1.[illegible]	14.3
104	27.00	12.00	E	1.879D+01	2.110D+01	4.330D+00	6.481D+00	2.443D+01	1.347D+01	51.5
105	30.00	12.00	E	2.713D+01	4.957D+01	1.296D+01	1.714D+01	5.549D+01	2.121D+01	65.4
106	34.00	12.00	E	3.934D+01	8.876D+01	1.441D+01	3.257D+01	8.212D+01	3.593D+01	79.9
107	38.00	12.00	E	4.129D+01	1.165D+02	1.004D+01	4.379D+01	1.172D+02	4.112D+01	87.4
108	41.00	12.00	E	4.147D+01	1.295D+02	4.596D+00	4.923D+01	1.297D+02	4.262D+01	87.1
109	42.50	12.00	E	4.181D+01	1.324D+02	1.601D+00	5.022D+01	1.324D+02	4.173D+01	88
110	44.50	12.00	E	3.183D+01	1.312D+02	-2.394D+00	4.973D+01	1.311D+02	[illegible]	8
111	48.50	12.00	E	3.224D+01	1.182D+02	-8.850D+00	4.396D+01	1.159D+02	[illegible]	74.1
112	53.50	12.00	E	3.057D+01	8.805D+01	-1.250D+01	3.134D+01	9.049D+01	[illegible]	-75.2
113	58.50	12.00	E	2.449D+01	4.439D+01	-1.064D+01	1.457D+01	4.903D+01	[illegible]	61.5
114	62.67	11.67	E	1.750D+01	1.822D+01	-5.506D+00	5.518D+00	2.039D+01	[illegible]	44.5

115	30.67	13.67	E	2.058D+01	2.282D+01	1.002D+01	1.008D+01	3.178I+01	1.162D+01	48.2
116	34.00	14.00	E	2.460D+01	4.654D+01	1.370D+01	1.755D+01	5.312I+01	1.801D+01	64.3
117	38.00	14.00	E	2.460D+01	7.909D+01	9.914D+00	2.899D+01	8.083I+01	2.286D+01	80.0
118	41.00	14.00	E	2.515D+01	9.251D+01	4.412D+00	3.397D+01	9.280I+01	2.486D+01	86.3
119	42.50	14.00	E	2.475D+01	9.531D+01	1.295D+00	3.531D+01	9.534I+01	2.472D+01	88.9
120	44.50	14.00	E	2.555D+01	9.398D+01	-2.516D+00	3.431D+01	9.407I+01	2.546D+01	-87.9
121	48.50	14.00	E	2.503D+01	8.001D+01	-8.927D+00	2.890D+01	8.142I+01	2.361D+01	-81.0
122	53.50	14.00	E	2.385D+01	4.492D+01	-1.099D+01	1.523D+01	4.961I+01	1.916D+01	-66.9
123	57.67	13.67	E	1.755D+01	1.938D+01	-6.994D+00	7.053D+00	2.552I+01	1.141D+01	-48.7
124	34.67	15.67	E	2.310D+01	2.435D+01	1.468D+01	1.469D+01	3.842I+01	9.035D+00	46.2
125	38.00	16.00	E	2.357D+01	3.939D+01	9.418D+00	1.230D+01	4.378I+01	1.918D+01	65.0
126	41.00	16.00	E	2.196D+01	5.589D+01	4.969D+00	1.768D+01	5.661I+01	2.125D+01	81.8
127	42.50	16.00	E	2.268D+01	5.902D+01	1.473D+00	1.823D+01	5.908I+01	2.262D+01	87.7
128	44.50	16.00	E	2.180D+01	5.718D+01	-3.361D+00	1.800D+01	5.750I+01	2.149D+01	-84.6
129	48.50	16.00	E	2.348D+01	3.929D+01	-8.100D+00	1.132D+01	4.270I+01	2.007D+01	-67.1
130	52.67	15.67	E	2.152D+01	2.177D+01	-1.114D+01	1.115D+01	3.279I+01	1.050D+01	-45.3
131	38.67	17.67	E	2.405D+01	1.597D+01	1.251D+01	1.314D+01	3.315I+01	6.863D+00	36.0
132	41.00	18.00	E	2.539D+01	1.826D+01	1.788D+00	3.989D+00	2.582I+01	1.734D+01	13.3
133	42.50	18.00	E	2.756D+01	2.132D+01	4.651D-01	3.157D+00	2.760I+01	2.128D+01	4.2
134	44.50	18.00	E	2.629D+01	1.877D+01	-4.524D-01	3.785D+00	2.631I+01	1.874D+01	-3.4
135	47.67	17.67	E	2.397D+01	1.537D+01	-1.108D+01	1.189D+01	3.156I+01	7.786D+00	-34.4

Geonorte

ANALISE DE ESTABILIDADE

000087

Geonorte

Final de Construção

000088

MARCO1 - Final de Construcao
GRID SEARCH ANALYSIS
Approximately 16 slices selected

Xmin=	80.0	Xmax=	100.0	Increment=	2.0
Ymin=	40.0	Ymax=	50.0	Increment=	2.0
Rmin=	25.0	Rmax=	40.0	Increment=	3.0

Circle center at X= 80.0, Y= 40.0
FS= 2.097 at R= 25.0
FS= 2.372 at R= 28.0
FS= 2.581 at R= 31.0
FS= 2.879 at R= 34.0
FS= 3.171 at R= 37.0
FS= 3.477 at R= 40.0
Minimum FS for center = 2.097 at R= 25.0

Circle center at X= 82.0, Y= 40.0
FS= 1.987 at R= 25.0
FS= 2.195 at R= 28.0
FS= 2.416 at R= 31.0
FS= 2.638 at R= 34.0
FS= 2.928 at R= 37.0
FS= 3.239 at R= 40.0
Minimum FS for center = 1.987 at R= 25.0

Circle center at X= 84.0, Y= 40.0
FS= 1.876 at R= 25.0
FS= 2.058 at R= 28.0
FS= 2.276 at R= 31.0
FS= 2.448 at R= 34.0
FS= 2.728 at R= 37.0
FS= 3.053 at R= 40.0
Minimum FS for center = 1.876 at R= 25.0

Circle center at X= 86.0, Y= 40.0
FS= 1.820 at R= 25.0
FS= 1.958 at R= 28.0
FS= 2.135 at R= 31.0
FS= 2.346 at R= 34.0
FS= 2.575 at R= 37.0
FS= 2.914 at R= 40.0
Minimum FS for center = 1.820 at R= 25.0

Circle center at X= 88.0, Y= 40.0
FS= 1.796 at R= 25.0
FS= 1.871 at R= 28.0
FS= 2.047 at R= 31.0
FS= 2.249 at R= 34.0
FS= 2.477 at R= 37.0
FS= 2.789 at R= 40.0
Minimum FS for center = 1.796 at R= 25.0

```
Circle center at X=  90.0, Y=  40.0
FS= 1.773 at R=  25.0
FS= 1.834 at R=  28.0
FS= 1.966 at R=  31.0
FS= 2.173 at R=  34.0
FS= 2.445 at R=  37.0
FS= 2.710 at R=  40.0
Minimum FS for center = 1.773 at R=  25.0

Circle center at X=  92.0, Y=  40.0
FS= 1.742 at R=  25.0
FS= 1.817 at R=  28.0
FS= 1.934 at R=  31.0
FS= 2.149 at R=  34.0
FS= 2.403 at R=  37.0
FS= 2.676 at R=  40.0
Minimum FS for center = 1.742 at R=  25.0

Circle center at X=  94.0, Y=  40.0
FS= 1.725 at R=  25.0
FS= 1.793 at R=  28.0
FS= 1.945 at R=  31.0
FS= 2.136 at R=  34.0
FS= 2.405 at R=  37.0
FS= 2.684 at R=  40.0
Minimum FS for center = 1.725 at R=  25.0

Circle center at X=  96.0, Y=  40.0
FS= 1.711 at R=  25.0
FS= 1.784 at R=  28.0
FS= 1.976 at R=  31.0
FS= 2.179 at R=  34.0
FS= 2.412 at R=  37.0
FS= 2.689 at R=  40.0
Minimum FS for center = 1.711 at R=  25.0

Circle center at X=  98.0, Y=  40.0
FS= 1.696 at R=  25.0
FS= 1.794 at R=  28.0
FS= 2.020 at R=  31.0
FS= 2.276 at R=  34.0
FS= 2.481 at R=  37.0
FS= 2.735 at R=  40.0
Minimum FS for center = 1.696 at R=  25.0

Circle center at X= 100.0, Y=  40.0
FS= 1.680 at R=  25.0
FS= 1.836 at R=  28.0
FS= 2.109 at R=  31.0
FS= 2.364 at R=  34.0
FS= 2.671 at R=  37.0
FS= 2.801 at R=  40.0
Minimum FS for center = 1.680 at R=  25.0
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```
Circle center at X=  80.0, Y=  42.0
FS= 1.783 at R=  25.0
FS= 2.181 at R=  28.0
FS= 2.441 at R=  31.0
FS= 2.680 at R=  34.0
FS= 2.950 at R=  37.0
FS= 3.275 at R=  40.0
Minimum FS for center = 1.783 at R=  25.0

Circle center at X=  82.0, Y=  42.0
FS= 1.693 at R=  25.0
FS= 2.018 at R=  28.0
FS= 2.258 at R=  31.0
FS= 2.458 at R=  34.0
FS= 2.733 at R=  37.0
FS= 3.038 at R=  40.0
Minimum FS for center = 1.693 at R=  25.0

Circle center at X=  84.0, Y=  42.0
FS= 1.618 at R=  25.0
FS= 1.903 at R=  28.0
FS= 2.105 at R=  31.0
FS= 2.311 at R=  34.0
FS= 2.536 at R=  37.0
FS= 2.850 at R=  40.0
Minimum FS for center = 1.618 at R=  25.0

Circle center at X=  86.0, Y=  42.0
FS= 1.592 at R=  25.0
FS= 1.813 at R=  28.0
FS= 1.978 at R=  31.0
FS= 2.193 at R=  34.0
FS= 2.387 at R=  37.0
FS= 2.691 at R=  40.0
Minimum FS for center = 1.592 at R=  25.0

Circle center at X=  88.0, Y=  42.0
FS= 1.598 at R=  25.0
FS= 1.749 at R=  28.0
FS= 1.895 at R=  31.0
FS= 2.074 at R=  34.0
FS= 2.304 at R=  37.0
FS= 2.579 at R=  40.0
Minimum FS for center = 1.598 at R=  25.0

Circle center at X=  90.0, Y=  42.0
FS= 1.610 at R=  25.0
FS= 1.707 at R=  28.0
FS= 1.817 at R=  31.0
FS= 2.000 at R=  34.0
FS= 2.251 at R=  37.0
FS= 2.499 at R=  40.0
Minimum FS for center = 1.610 at R=  25.0
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```
Circle center at X=  92.0, Y=  42.0
FS= 1.632 at R=  25.0
FS= 1.694 at R=  28.0
FS= 1.781 at R=  31.0
FS= 1.958 at R=  34.0
FS= 2.199 at R=  37.0
FS= 2.486 at R=  40.0
Minimum FS for center = 1.632 at R=  25.0

Circle center at X=  94.0, Y=  42.0
FS= 1.666 at R=  25.0
FS= 1.679 at R=  28.0
FS= 1.777 at R=  31.0
FS= 1.946 at R=  34.0
FS= 2.196 at R=  37.0
FS= 2.466 at R=  40.0
Minimum FS for center = 1.666 at R=  25.0

Circle center at X=  96.0, Y=  42.0
FS= 1.712 at R=  25.0
FS= 1.670 at R=  28.0
FS= 1.794 at R=  31.0
FS= 1.985 at R=  34.0
FS= 2.202 at R=  37.0
FS= 2.470 at R=  40.0
Minimum FS for center = 1.670 at R=  28.0

Circle center at X=  98.0, Y=  42.0
FS= 1.740 at R=  25.0
FS= 1.664 at R=  28.0
FS= 1.823 at R=  31.0
FS= 2.064 at R=  34.0
FS= 2.276 at R=  37.0
FS= 2.506 at R=  40.0
Minimum FS for center = 1.664 at R=  28.0

Circle center at X= 100.0, Y=  42.0
FS= 1.762 at R=  25.0
FS= 1.667 at R=  28.0
FS= 1.874 at R=  31.0
FS= 2.137 at R=  34.0
FS= 2.374 at R=  37.0
FS= 2.577 at R=  40.0
Minimum FS for center = 1.667 at R=  28.0

Circle center at X=  80.0, Y=  44.0
FS= 1.665 at R=  25.0
FS= 2.063 at R=  28.0
FS= 2.266 at R=  31.0
FS= 2.506 at R=  34.0
FS= 2.795 at R=  37.0
FS= 3.058 at R=  40.0
Minimum FS for center = 1.665 at R=  25.0
```

```
Circle center at X=  82.0, Y=  44.0
FS= 1.583 at R=  25.0
FS= 1.922 at R=  28.0
FS= 2.100 at R=  31.0
FS= 2.330 at R=  34.0
FS= 2.558 at R=  37.0
FS= 2.821 at R=  40.0
Minimum FS for center = 1.583 at R=  25.0

Circle center at X=  84.0, Y=  44.0
FS= 1.533 at R=  25.0
FS= 1.827 at R=  28.0
FS= 1.954 at R=  31.0
FS= 2.169 at R=  34.0
FS= 2.366 at R=  37.0
FS= 2.654 at R=  40.0
Minimum FS for center = 1.533 at R=  25.0

Circle center at X=  86.0, Y=  44.0
FS= 1.525 at R=  25.0
FS= 1.746 at R=  28.0
FS= 1.844 at R=  31.0
FS= 2.039 at R=  34.0
FS= 2.239 at R=  37.0
FS= 2.498 at R=  40.0
Minimum FS for center = 1.525 at R=  25.0

Circle center at X=  88.0, Y=  44.0
FS= 1.555 at R=  25.0
FS= 1.707 at R=  28.0
FS= 1.757 at R=  31.0
FS= 1.926 at R=  34.0
FS= 2.148 at R=  37.0
FS= 2.386 at R=  40.0
Minimum FS for center = 1.555 at R=  25.0

Circle center at X=  90.0, Y=  44.0
FS= 1.599 at R=  25.0
FS= 1.699 at R=  28.0
FS= 1.692 at R=  31.0
FS= 1.849 at R=  34.0
FS= 2.064 at R=  37.0
FS= 2.321 at R=  40.0
Minimum FS for center = 1.599 at R=  25.0

Circle center at X=  92.0, Y=  44.0
FS= 1.666 at R=  25.0
FS= 1.701 at R=  28.0
FS= 1.662 at R=  31.0
FS= 1.795 at R=  34.0
FS= 2.016 at R=  37.0
FS= 2.290 at R=  40.0
Minimum FS for center = 1.662 at R=  31.0
```

```
Circle center at X=  94.0, Y=  44.0
FS= 1.762 at R=  25.0
FS= 1.689 at R=  28.0
FS= 1.653 at R=  31.0
FS= 1.777 at R=  34.0
FS= 1.999 at R=  37.0
FS= 2.261 at R=  40.0
Minimum FS for center = 1.653 at R=  31.0

Circle center at X=  96.0, Y=  44.0
FS= 1.898 at R=  25.0
FS= 1.689 at R=  28.0
FS= 1.645 at R=  31.0
FS= 1.805 at R=  34.0
FS= 2.010 at R=  37.0
FS= 2.263 at R=  40.0
Minimum FS for center = 1.645 at R=  31.0

Circle center at X=  98.0, Y=  44.0
FS= 2.062 at R=  25.0
FS= 1.697 at R=  28.0
FS= 1.655 at R=  31.0
FS= 1.847 at R=  34.0
FS= 2.056 at R=  37.0
FS= 2.295 at R=  40.0
Minimum FS for center = 1.655 at R=  31.0

Circle center at X= 100.0, Y=  44.0
FS= 2.158 at R=  25.0
FS= 1.705 at R=  28.0
FS= 1.687 at R=  31.0
FS= 1.908 at R=  34.0
FS= 2.161 at R=  37.0
FS= 2.368 at R=  40.0
Minimum FS for center = 1.687 at R=  31.0

Circle center at X=  80.0, Y=  46.0
FS= 1.567 at R=  25.0
FS= 1.733 at R=  28.0
FS= 2.104 at R=  31.0
FS= 2.381 at R=  34.0
FS= 2.616 at R=  37.0
FS= 2.892 at R=  40.0
Minimum FS for center = 1.567 at R=  25.0

Circle center at X=  82.0, Y=  46.0
FS= 1.494 at R=  25.0
FS= 1.627 at R=  28.0
FS= 1.950 at R=  31.0
FS= 2.185 at R=  34.0
FS= 2.394 at R=  37.0
FS= 2.669 at R=  40.0
Minimum FS for center = 1.494 at R=  25.0
```

Circle center at X= 84.0, Y= 46.0
FS= 1.476 at R= 25.0
FS= 1.555 at R= 28.0
FS= 1.821 at R= 31.0
FS= 2.027 at R= 34.0
FS= 2.245 at R= 37.0
FS= 2.473 at R= 40.0
Minimum FS for center = 1.476 at R= 25.0

Circle center at X= 86.0, Y= 46.0
FS= 1.509 at R= 25.0
FS= 1.507 at R= 28.0
FS= 1.728 at R= 31.0
FS= 1.896 at R= 34.0
FS= 2.106 at R= 37.0
FS= 2.320 at R= 40.0
Minimum FS for center = 1.507 at R= 28.0

Circle center at X= 88.0, Y= 46.0
FS= 1.581 at R= 25.0
FS= 1.498 at R= 28.0
FS= 1.654 at R= 31.0
FS= 1.795 at R= 34.0
FS= 1.994 at R= 37.0
FS= 2.220 at R= 40.0
Minimum FS for center = 1.498 at R= 28.0

Circle center at X= 90.0, Y= 46.0
FS= 1.700 at R= 25.0
FS= 1.523 at R= 28.0
FS= 1.604 at R= 31.0
FS= 1.723 at R= 34.0
FS= 1.904 at R= 37.0
FS= 2.158 at R= 40.0
Minimum FS for center = 1.523 at R= 28.0

Circle center at X= 92.0, Y= 46.0
FS= 1.897 at R= 25.0
FS= 1.562 at R= 28.0
FS= 1.575 at R= 31.0
FS= 1.663 at R= 34.0
FS= 1.849 at R= 37.0
FS= 2.101 at R= 40.0
Minimum FS for center = 1.562 at R= 28.0

Circle center at X= 94.0, Y= 46.0
FS= 2.240 at R= 25.0
FS= 1.616 at R= 28.0
FS= 1.573 at R= 31.0
FS= 1.639 at R= 34.0
FS= 1.824 at R= 37.0
FS= 2.070 at R= 40.0
Minimum FS for center = 1.573 at R= 31.0

```
Circle center at X=  96.0, Y=  46.0
FS= 2.810 at R=  25.0
FS= 1.694 at R=  28.0
FS= 1.576 at R=  31.0
FS= 1.651 at R=  34.0
FS= 1.826 at R=  37.0
FS= 2.073 at R=  40.0
Minimum FS for center = 1.576 at R=  31.0

Circle center at X=  98.0, Y=  46.0
FS= 3.396 at R=  25.0
FS= 1.796 at R=  28.0
FS= 1.580 at R=  31.0
FS= 1.674 at R=  34.0
FS= 1.866 at R=  37.0
FS= 2.097 at R=  40.0
Minimum FS for center = 1.580 at R=  31.0

Circle center at X= 100.0, Y=  46.0
FS=18.288 at R=  25.0
FS= 1.917 at R=  28.0
FS= 1.588 at R=  31.0
FS= 1.716 at R=  34.0
FS= 1.940 at R=  37.0
FS= 2.157 at R=  40.0
Minimum FS for center = 1.588 at R=  31.0

Circle center at X=  80.0, Y=  48.0
FS= 1.483 at R=  25.0
FS= 1.631 at R=  28.0
FS= 1.818 at R=  31.0
FS= 2.221 at R=  34.0
FS= 2.471 at R=  37.0
FS= 2.729 at R=  40.0
Minimum FS for center = 1.483 at R=  25.0

Circle center at X=  82.0, Y=  48.0
FS= 1.447 at R=  25.0
FS= 1.543 at R=  28.0
FS= 1.691 at R=  31.0
FS= 2.039 at R=  34.0
FS= 2.286 at R=  37.0
FS= 2.508 at R=  40.0
Minimum FS for center = 1.447 at R=  25.0

Circle center at X=  84.0, Y=  48.0
FS= 1.473 at R=  25.0
FS= 1.481 at R=  28.0
FS= 1.596 at R=  31.0
FS= 1.897 at R=  34.0
FS= 2.112 at R=  37.0
FS= 2.315 at R=  40.0
Minimum FS for center = 1.473 at R=  25.0
```

Circle center at X= 86.0, Y= 48.0
FS= 1.591 at R= 25.0
FS= 1.461 at R= 28.0
FS= 1.531 at R= 31.0
FS= 1.777 at R= 34.0
FS= 1.972 at R= 37.0
FS= 2.183 at R= 40.0
Minimum FS for center = 1.461 at R= 28.0

Circle center at X= 88.0, Y= 48.0
FS= 1.807 at R= 25.0
FS= 1.485 at R= 28.0
FS= 1.485 at R= 31.0
FS= 1.680 at R= 34.0
FS= 1.858 at R= 37.0
FS= 2.077 at R= 40.0
Minimum FS for center = 1.485 at R= 31.0

Circle center at X= 90.0, Y= 48.0
FS= 2.273 at R= 25.0
FS= 1.548 at R= 28.0
FS= 1.474 at R= 31.0
FS= 1.611 at R= 34.0
FS= 1.766 at R= 37.0
FS= 1.990 at R= 40.0
Minimum FS for center = 1.474 at R= 31.0

Circle center at X= 92.0, Y= 48.0
FS= 3.746 at R= 25.0
FS= 1.645 at R= 28.0
FS= 1.494 at R= 31.0
FS= 1.564 at R= 34.0
FS= 1.707 at R= 37.0
FS= 1.928 at R= 40.0
Minimum FS for center = 1.494 at R= 31.0

Circle center at X= 94.0, Y= 48.0
FS= 7.050 at R= 25.0
FS= 1.795 at R= 28.0
FS= 1.527 at R= 31.0
FS= 1.544 at R= 34.0
FS= 1.668 at R= 37.0
FS= 1.892 at R= 40.0
Minimum FS for center = 1.527 at R= 31.0

Circle center at X= 96.0, Y= 48.0
Circle did not intersect the slope at R= 25.0
FS= 2.033 at R= 28.0
FS= 1.567 at R= 31.0
FS= 1.544 at R= 34.0
FS= 1.665 at R= 37.0
FS= 1.890 at R= 40.0
Minimum FS for center = 1.544 at R= 34.0

Circle center at X= 98.0, Y= 48.0
Circle did not intersect the slope at R= 25.0
FS= 2.387 at R= 28.0
FS= 1.613 at R= 31.0
FS= 1.552 at R= 34.0
FS= 1.697 at R= 37.0
FS= 1.905 at R= 40.0
Minimum FS for center = 1.552 at R= 34.0

Circle center at X= 100.0, Y= 48.0
Circle did not intersect the slope at R= 25.0
FS= 2.687 at R= 28.0
FS= 1.675 at R= 31.0
FS= 1.573 at R= 34.0
FS= 1.751 at R= 37.0
FS= 1.970 at R= 40.0
Minimum FS for center = 1.573 at R= 34.0

Circle center at X= 80.0, Y= 50.0
FS= 1.429 at R= 25.0
FS= 1.548 at R= 28.0
FS= 1.717 at R= 31.0
FS= 2.131 at R= 34.0
FS= 2.349 at R= 37.0
FS= 2.568 at R= 40.0
Minimum FS for center = 1.429 at R= 25.0

Circle center at X= 82.0, Y= 50.0
FS= 1.432 at R= 25.0
FS= 1.474 at R= 28.0
FS= 1.602 at R= 31.0
FS= 1.966 at R= 34.0
FS= 2.147 at R= 37.0
FS= 2.363 at R= 40.0
Minimum FS for center = 1.432 at R= 25.0

Circle center at X= 84.0, Y= 50.0
FS= 1.579 at R= 25.0
FS= 1.443 at R= 28.0
FS= 1.521 at R= 31.0
FS= 1.832 at R= 34.0
FS= 1.983 at R= 37.0
FS= 2.211 at R= 40.0
Minimum FS for center = 1.443 at R= 28.0

Circle center at X= 86.0, Y= 50.0
FS= 1.954 at R= 25.0
FS= 1.462 at R= 28.0
FS= 1.466 at R= 31.0
FS= 1.727 at R= 34.0
FS= 1.947 at R= 37.0
FS= 2.059 at R= 40.0
Minimum FS for center = 1.462 at R= 28.0

Circle center at X= 88.0, Y= 50.0
FS= 3.493 at R= 25.0
FS= 1.561 at R= 28.0
FS= 1.446 at R= 31.0
FS= 1.650 at R= 34.0
FS= 1.737 at R= 37.0
FS= 1.935 at R= 40.0
Minimum FS for center = 1.446 at R= 31.0

Circle center at X= 90.0, Y= 50.0
Circle did not intersect the slope at R= 25.0
FS= 1.731 at R= 28.0
FS= 1.462 at R= 31.0
FS= 1.594 at R= 34.0
FS= 1.654 at R= 37.0
FS= 1.841 at R= 40.0
Minimum FS for center = 1.462 at R= 31.0

Circle center at X= 92.0, Y= 50.0
Circle did not intersect the slope at R= 25.0
FS= 2.055 at R= 28.0
FS= 1.519 at R= 31.0
FS= 1.564 at R= 34.0
FS= 1.592 at R= 37.0
FS= 1.771 at R= 40.0
Minimum FS for center = 1.519 at R= 31.0

Circle center at X= 94.0, Y= 50.0
Circle did not intersect the slope at R= 25.0
FS= 2.798 at R= 28.0
FS= 1.598 at R= 31.0
FS= 1.554 at R= 34.0
FS= 1.549 at R= 37.0
FS= 1.730 at R= 40.0
Minimum FS for center = 1.549 at R= 37.0

Circle center at X= 96.0, Y= 50.0
Circle did not intersect the slope at R= 25.0
FS= 4.470 at R= 28.0
FS= 1.716 at R= 31.0
FS= 1.562 at R= 34.0
FS= 1.537 at R= 37.0
FS= 1.718 at R= 40.0
Minimum FS for center = 1.537 at R= 37.0

Circle center at X= 98.0, Y= 50.0
Circle did not intersect the slope at R= 25.0
FS=14.134 at R= 28.0
FS= 1.890 at R= 31.0
FS= 1.580 at R= 34.0
FS= 1.556 at R= 37.0
FS= 1.733 at R= 40.0
Minimum FS for center = 1.556 at R= 37.0

Geonorte

Circle center at X= 100.0, Y= 50.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 28.0
FS= 2.129 at R= 31.0
FS= 1.604 at R= 34.0
FS= 1.591 at R= 37.0
FS= 1.786 at R= 40.0
Minimum FS for center = 1.591 at R= 37.0

Minimum FS found during grid pattern = 1.43
Found at X= 80.0, Y= 50.0, R= 25.0

SB-SLOPE

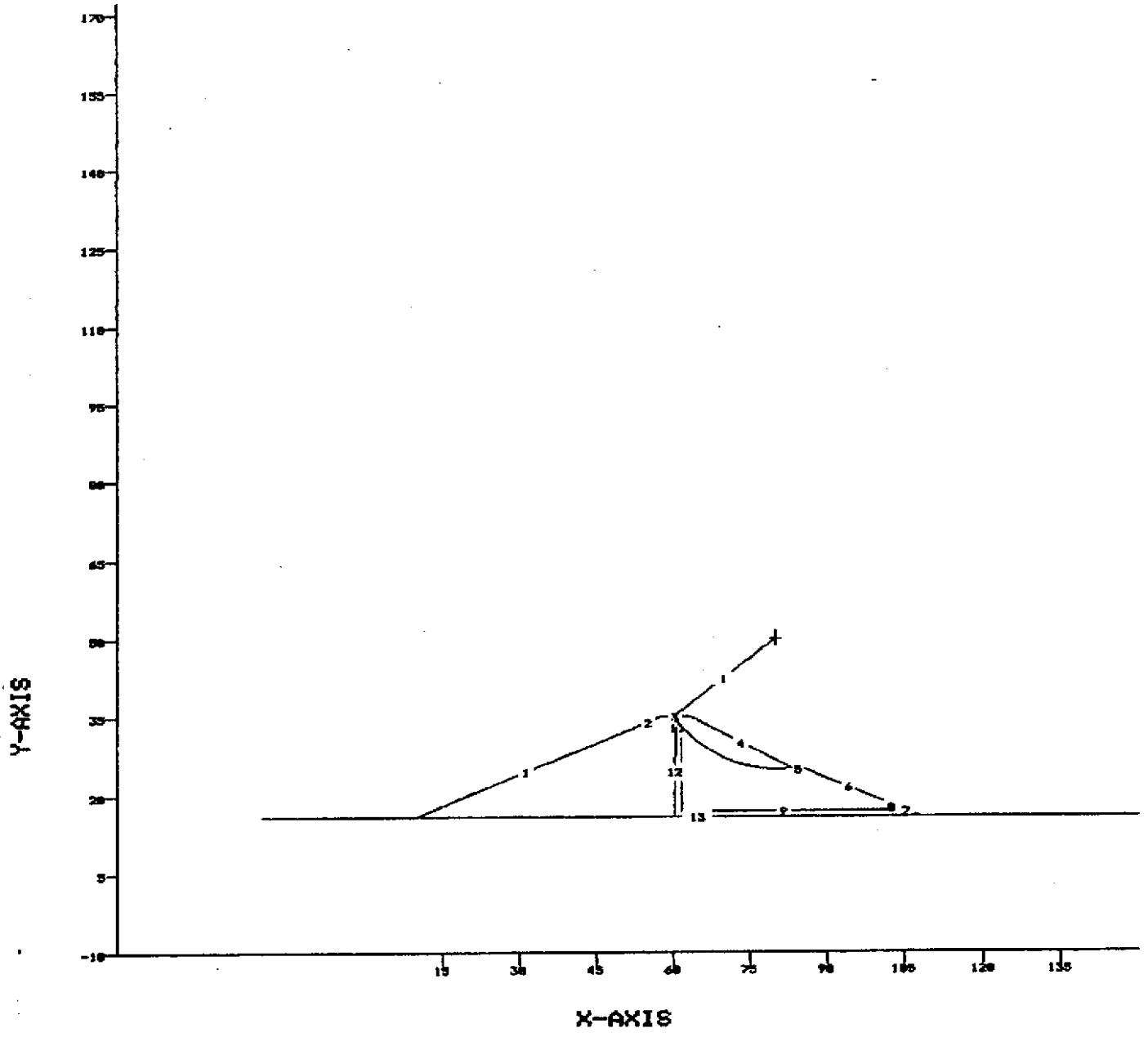
Simplified Bishop Slope Stability Analysis

PROJECT: MARCO

LOCATION: Marco - CE

FILE: FSL.SDT COMPLETE SLOPE CROSS SECTION

CIRCLE	X	Y	RADIUS	FS
1	80.0	50.0	25.0	1.43



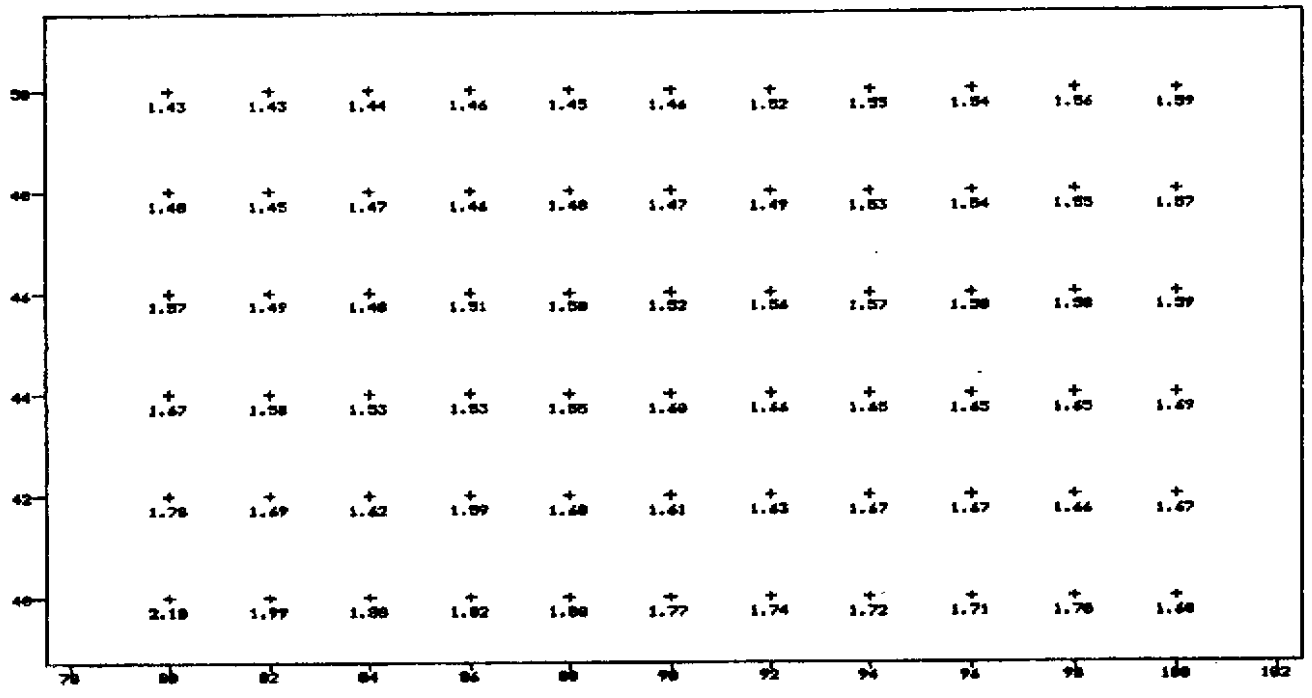
SB-SLOPE

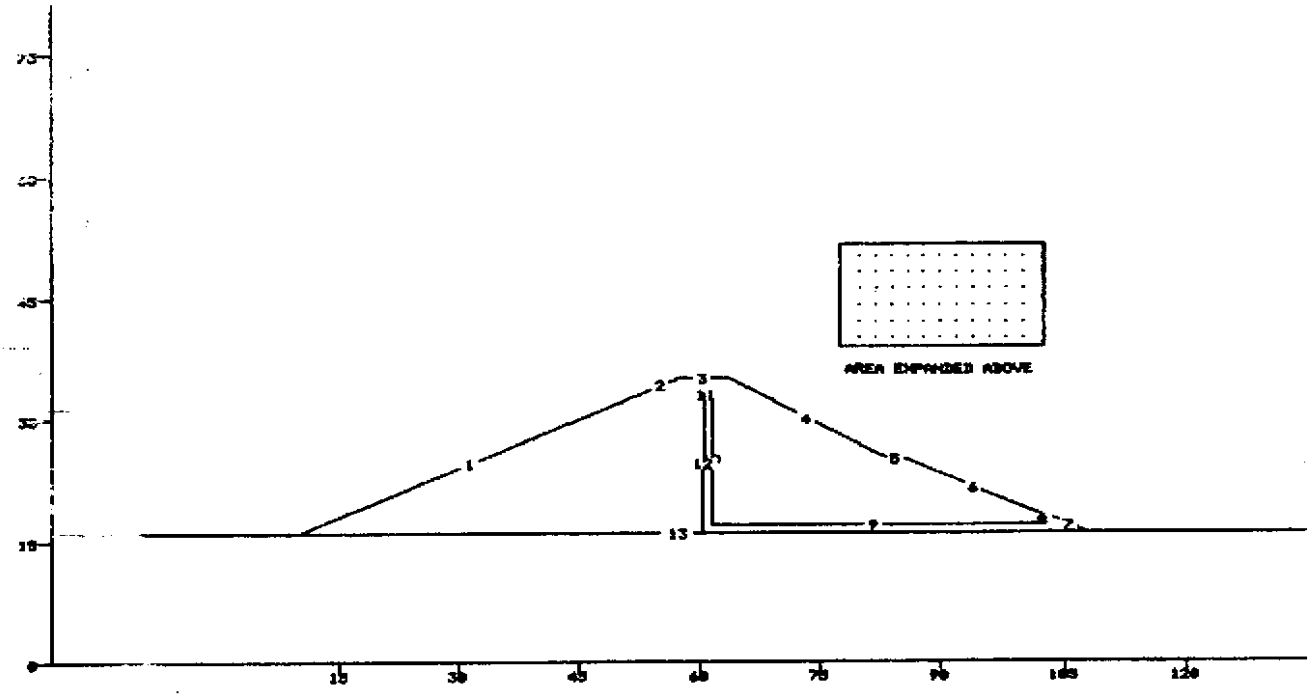
Simplified Bishop Slope Stability Analysis

PROJECT: MARCO

LOCATION: Marco - CE

FILE: MARCO1





Y-AXIS

X-AXIS

Geonorte

Reservatório Cheio

000103

MARCO2 - Reservatorio Cheio
GRID SEARCH ANALYSIS
Approximately 16 slices selected

Xmin=	75.0	Xmax=	85.0	Increment=	2.0
Ymin=	44.0	Ymax=	54.0	Increment=	2.0
Rmin=	20.0	Rmax=	35.0	Increment=	3.0

Circle center at X= 75.0, Y= 44.0
FS= 1.985 at R= 20.0
FS= 2.264 at R= 23.0
FS= 2.436 at R= 26.0
FS= 2.668 at R= 29.0
FS= 2.739 at R= 32.0
FS= 2.797 at R= 35.0
Minimum FS for center = 1.985 at R= 20.0

Circle center at X= 77.0, Y= 44.0
FS= 1.817 at R= 20.0
FS= 2.079 at R= 23.0
FS= 2.325 at R= 26.0
FS= 2.510 at R= 29.0
FS= 2.587 at R= 32.0
FS= 2.612 at R= 35.0
Minimum FS for center = 1.817 at R= 20.0

Circle center at X= 79.0, Y= 44.0
FS= 1.762 at R= 20.0
FS= 1.957 at R= 23.0
FS= 2.181 at R= 26.0
FS= 2.395 at R= 29.0
FS= 2.454 at R= 32.0
FS= 2.472 at R= 35.0
Minimum FS for center = 1.762 at R= 20.0

Circle center at X= 81.0, Y= 44.0
FS= 1.780 at R= 20.0
FS= 1.864 at R= 23.0
FS= 2.051 at R= 26.0
FS= 2.292 at R= 29.0
FS= 2.336 at R= 32.0
FS= 2.337 at R= 35.0
Minimum FS for center = 1.780 at R= 20.0

Circle center at X= 83.0, Y= 44.0
FS= 1.890 at R= 20.0
FS= 1.837 at R= 23.0
FS= 1.959 at R= 26.0
FS= 2.176 at R= 29.0
FS= 2.250 at R= 32.0
FS= 2.242 at R= 35.0
Minimum FS for center = 1.837 at R= 23.0

Circle center at X= 85.0, Y= 44.0
FS= 2.114 at R= 20.0
FS= 1.864 at R= 23.0
FS= 1.904 at R= 26.0
FS= 2.067 at R= 29.0
FS= 2.147 at R= 32.0
FS= 2.174 at R= 35.0
Minimum FS for center = 1.864 at R= 23.0

Circle center at X= 75.0, Y= 46.0
FS= 1.915 at R= 20.0
FS= 2.090 at R= 23.0
FS= 2.363 at R= 26.0
FS= 2.457 at R= 29.0
FS= 2.687 at R= 32.0
FS= 2.738 at R= 35.0
Minimum FS for center = 1.915 at R= 20.0

Circle center at X= 77.0, Y= 46.0
FS= 1.800 at R= 20.0
FS= 1.930 at R= 23.0
FS= 2.200 at R= 26.0
FS= 2.332 at R= 29.0
FS= 2.533 at R= 32.0
FS= 2.565 at R= 35.0
Minimum FS for center = 1.800 at R= 20.0

Circle center at X= 79.0, Y= 46.0
FS= 1.770 at R= 20.0
FS= 1.820 at R= 23.0
FS= 2.036 at R= 26.0
FS= 2.243 at R= 29.0
FS= 2.399 at R= 32.0
FS= 2.429 at R= 35.0
Minimum FS for center = 1.770 at R= 20.0

Circle center at X= 81.0, Y= 46.0
FS= 1.909 at R= 20.0
FS= 1.773 at R= 23.0
FS= 1.927 at R= 26.0
FS= 2.124 at R= 29.0
FS= 2.291 at R= 32.0
FS= 2.311 at R= 35.0
Minimum FS for center = 1.773 at R= 23.0

Circle center at X= 83.0, Y= 46.0
FS= 2.303 at R= 20.0
FS= 1.784 at R= 23.0
FS= 1.843 at R= 26.0
FS= 2.007 at R= 29.0
FS= 2.204 at R= 32.0
FS= 2.205 at R= 35.0
Minimum FS for center = 1.784 at R= 23.0

```
Circle center at X=  85.0, Y=  46.0
FS= 4.160 at R=  20.0
FS= 1.882 at R=  23.0
FS= 1.819 at R=  26.0
FS= 1.926 at R=  29.0
FS= 2.092 at R=  32.0
FS= 2.129 at R=  35.0
Minimum FS for center = 1.819 at R=  26.0

Circle center at X=  75.0, Y=  48.0
FS= 1.961 at R=  20.0
FS= 1.998 at R=  23.0
FS= 2.256 at R=  26.0
FS= 2.391 at R=  29.0
FS= 2.536 at R=  32.0
FS= 2.691 at R=  35.0
Minimum FS for center = 1.961 at R=  20.0

Circle center at X=  77.0, Y=  48.0
FS= 1.944 at R=  20.0
FS= 1.834 at R=  23.0
FS= 2.052 at R=  26.0
FS= 2.269 at R=  29.0
FS= 2.385 at R=  32.0
FS= 2.544 at R=  35.0
Minimum FS for center = 1.834 at R=  23.0

Circle center at X=  79.0, Y=  48.0
FS= 2.303 at R=  20.0
FS= 1.739 at R=  23.0
FS= 1.910 at R=  26.0
FS= 2.144 at R=  29.0
FS= 2.270 at R=  32.0
FS= 2.404 at R=  35.0
Minimum FS for center = 1.739 at R=  23.0

Circle center at X=  81.0, Y=  48.0
FS= 4.160 at R=  20.0
FS= 1.708 at R=  23.0
FS= 1.815 at R=  26.0
FS= 1.999 at R=  29.0
FS= 2.183 at R=  32.0
FS= 2.282 at R=  35.0
Minimum FS for center = 1.708 at R=  23.0

Circle center at X=  83.0, Y=  48.0
Circle did not intersect the slope at R=  20.0
FS= 1.813 at R=  23.0
FS= 1.772 at R=  26.0
FS= 1.899 at R=  29.0
FS= 2.081 at R=  32.0
FS= 2.185 at R=  35.0
Minimum FS for center = 1.772 at R=  26.0
```

Geonorte

Circle center at X= 85.0, Y= 48.0
Circle did not intersect the slope at R= 20.0
FS= 2.089 at R= 23.0
FS= 1.777 at R= 26.0
FS= 1.827 at R= 29.0
FS= 1.963 at R= 32.0
FS= 2.103 at R= 35.0
Minimum FS for center = 1.777 at R= 26.0

Circle center at X= 75.0, Y= 50.0
FS= 2.406 at R= 20.0
FS= 1.980 at R= 23.0
FS= 2.115 at R= 26.0
FS= 2.344 at R= 29.0
FS= 2.426 at R= 32.0
FS= 2.640 at R= 35.0
Minimum FS for center = 1.980 at R= 23.0

Circle center at X= 77.0, Y= 50.0
FS= 4.160 at R= 20.0
FS= 1.869 at R= 23.0
FS= 1.916 at R= 26.0
FS= 2.194 at R= 29.0
FS= 2.294 at R= 32.0
FS= 2.483 at R= 35.0
Minimum FS for center = 1.869 at R= 23.0

Circle center at X= 79.0, Y= 50.0
Circle did not intersect the slope at R= 20.0
FS= 1.848 at R= 23.0
FS= 1.808 at R= 26.0
FS= 2.016 at R= 29.0
FS= 2.194 at R= 32.0
FS= 2.349 at R= 35.0
Minimum FS for center = 1.808 at R= 26.0

Circle center at X= 81.0, Y= 50.0
Circle did not intersect the slope at R= 20.0
FS= 2.089 at R= 23.0
FS= 1.745 at R= 26.0
FS= 1.889 at R= 29.0
FS= 2.093 at R= 32.0
FS= 2.239 at R= 35.0
Minimum FS for center = 1.745 at R= 26.0

Circle center at X= 83.0, Y= 50.0
Circle did not intersect the slope at R= 20.0
FS= 3.035 at R= 23.0
FS= 1.744 at R= 26.0
FS= 1.806 at R= 29.0
FS= 1.967 at R= 32.0
FS= 2.154 at R= 35.0
Minimum FS for center = 1.744 at R= 26.0

Circle center at X= 85.0, Y= 50.0
Circle did not intersect the slope at R= 20.0
Circle did not intersect the slope at R= 23.0
FS= 1.864 at R= 26.0
FS= 1.765 at R= 29.0
FS= 1.875 at R= 32.0
FS= 2.058 at R= 35.0
Minimum FS for center = 1.765 at R= 29.0

Circle center at X= 75.0, Y= 52.0
Circle did not intersect the slope at R= 20.0
FS= 2.134 at R= 23.0
FS= 2.061 at R= 26.0
FS= 2.276 at R= 29.0
FS= 2.384 at R= 32.0
FS= 2.461 at R= 35.0
Minimum FS for center = 2.061 at R= 26.0

Circle center at X= 77.0, Y= 52.0
Circle did not intersect the slope at R= 20.0
FS= 2.178 at R= 23.0
FS= 1.888 at R= 26.0
FS= 2.060 at R= 29.0
FS= 2.254 at R= 32.0
FS= 2.326 at R= 35.0
Minimum FS for center = 1.888 at R= 26.0

Circle center at X= 79.0, Y= 52.0
Circle did not intersect the slope at R= 20.0
FS= 3.035 at R= 23.0
FS= 1.791 at R= 26.0
FS= 1.904 at R= 29.0
FS= 2.138 at R= 32.0
FS= 2.217 at R= 35.0
Minimum FS for center = 1.791 at R= 26.0

Circle center at X= 81.0, Y= 52.0
Circle did not intersect the slope at R= 20.0
Circle did not intersect the slope at R= 23.0
FS= 1.773 at R= 26.0
FS= 1.803 at R= 29.0
FS= 1.984 at R= 32.0
FS= 2.130 at R= 35.0
Minimum FS for center = 1.773 at R= 26.0

Circle center at X= 83.0, Y= 52.0
Circle did not intersect the slope at R= 20.0
Circle did not intersect the slope at R= 23.0
FS= 1.934 at R= 26.0
FS= 1.746 at R= 29.0
FS= 1.870 at R= 32.0
FS= 2.050 at R= 35.0
Minimum FS for center = 1.746 at R= 29.0

```
Circle center at X=  85.0, Y=  52.0
Circle did not intersect the slope at R=  20.0
Circle did not intersect the slope at R=  23.0
FS= 2.515 at R=  26.0
FS= 1.746 at R=  29.0
FS= 1.795 at R=  32.0
FS= 1.939 at R=  35.0
Minimum FS for center = 1.746 at R=  29.0

Circle center at X=  75.0, Y=  54.0
Circle did not intersect the slope at R=  20.0
FS= 3.267 at R=  23.0
FS= 2.094 at R=  26.0
FS= 2.179 at R=  29.0
FS= 2.362 at R=  32.0
FS= 2.423 at R=  35.0
Minimum FS for center = 2.094 at R=  26.0

Circle center at X=  77.0, Y=  54.0
Circle did not intersect the slope at R=  20.0
Circle did not intersect the slope at R=  23.0
FS= 2.000 at R=  26.0
FS= 1.962 at R=  29.0
FS= 2.208 at R=  32.0
FS= 2.288 at R=  35.0
Minimum FS for center = 1.962 at R=  29.0

Circle center at X=  79.0, Y=  54.0
Circle did not intersect the slope at R=  20.0
Circle did not intersect the slope at R=  23.0
FS= 2.020 at R=  26.0
FS= 1.816 at R=  29.0
FS= 2.023 at R=  32.0
FS= 2.182 at R=  35.0
Minimum FS for center = 1.816 at R=  29.0

Circle center at X=  81.0, Y=  54.0
Circle did not intersect the slope at R=  20.0
Circle did not intersect the slope at R=  23.0
FS= 2.489 at R=  26.0
FS= 1.729 at R=  29.0
FS= 1.885 at R=  32.0
FS= 2.087 at R=  35.0
Minimum FS for center = 1.729 at R=  29.0

Circle center at X=  83.0, Y=  54.0
Circle did not intersect the slope at R=  20.0
Circle did not intersect the slope at R=  23.0
FS= 6.934 at R=  26.0
FS= 1.712 at R=  29.0
FS= 1.794 at R=  32.0
FS= 1.955 at R=  35.0
Minimum FS for center = 1.712 at R=  29.0
```

Geonorte

```
Circle center at X=  85.0, Y=  54.0
Circle did not intersect the slope at R=  20.0
Circle did not intersect the slope at R=  23.0
Circle did not intersect the slope at R=  26.0
FS= 1.822 at R=  29.0
FS= 1.741 at R=  32.0
FS= 1.852 at R=  35.0
Minimum FS for center = 1.741 at R=  32.0

Minimum FS found during grid pattern = 1.71
Found at X=  81.0, Y=  48.0, R=  23.0
```

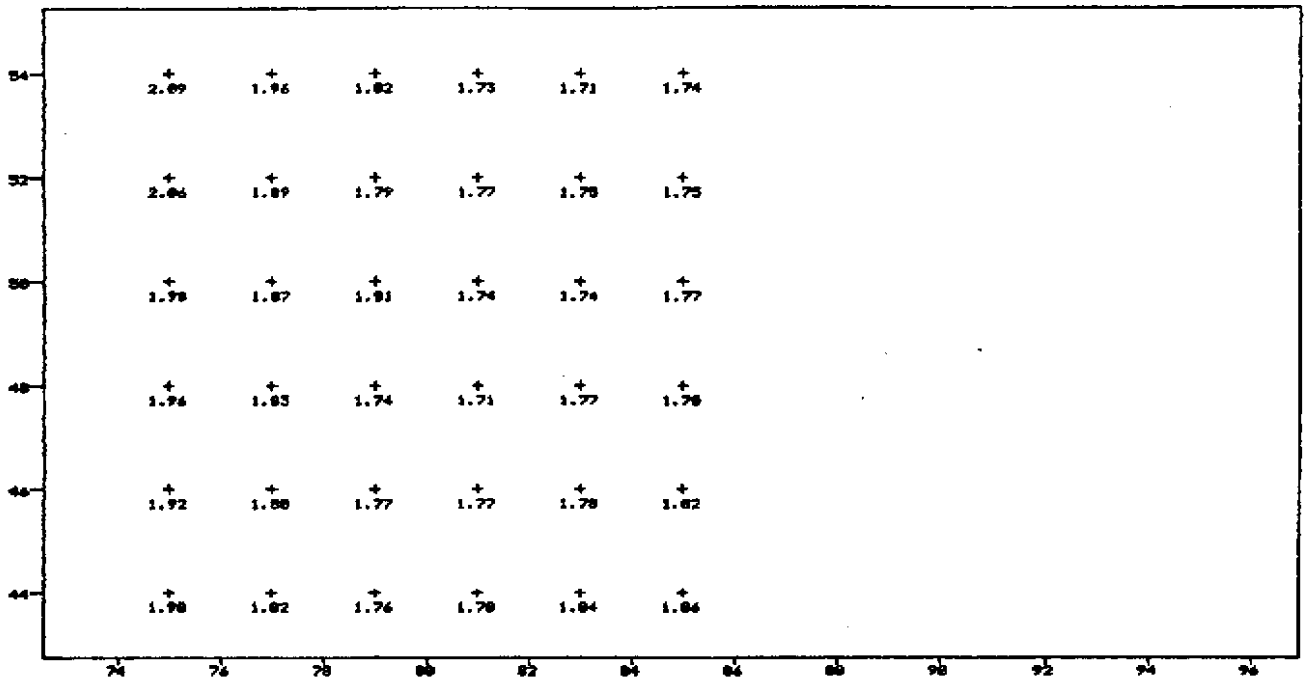
SB-SLOPE

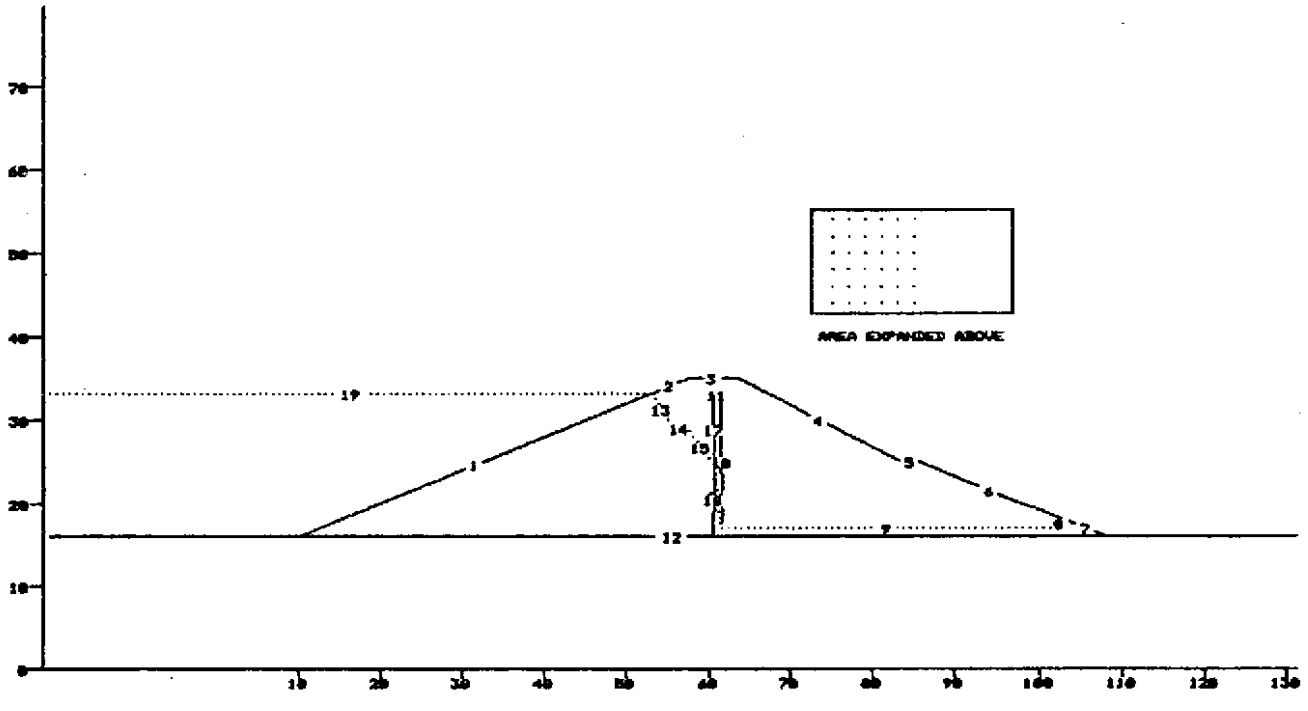
Simplified Bishop Slope Stability Analysis

PROJECT: MARCO

LOCATION: Marco - CE

FILE: MARCO2





Y-AXIS

X-AXIS

SB-SLOPE

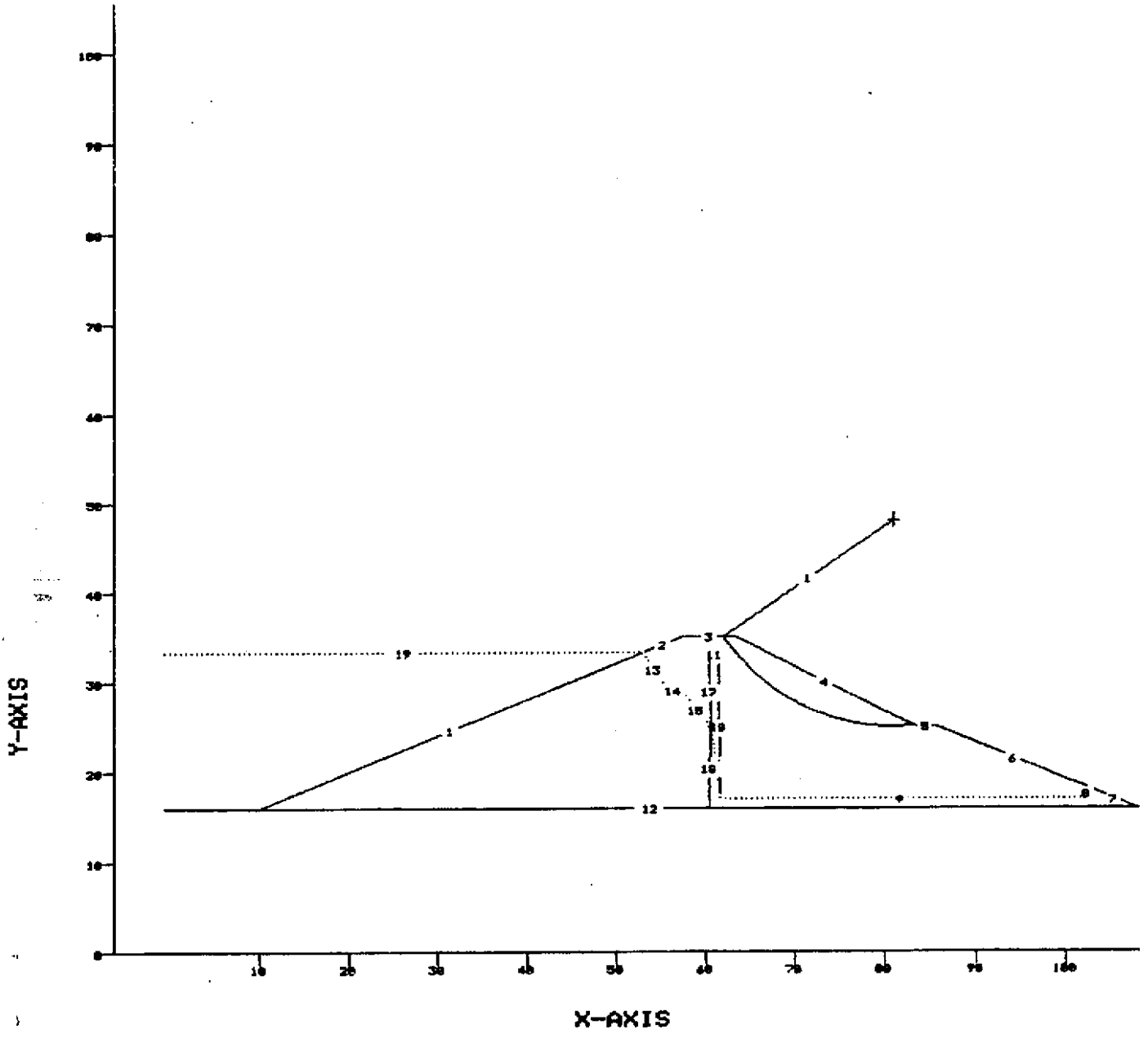
Simplified Bishop Slope Stability Analysis

PROJECT: MARCO

LOCATION: Marco - CE

FILE: FSL.5DT PARTIAL SLOPE CROSS SECTION

CIRCLE	X	Y	RADIUS	FS
1	81.0	48.0	23.0	1.71



Geonorte

Esvaziamento Ràpido

000113

Geonorte

MARCO3 - Esvaziamento Rapido
GRID SEARCH ANALYSIS
Approximately 16 slices selected

Xmin=	20.0	Xmax=	35.0	Increment=	3.0
Ymin=	40.0	Ymax=	60.0	Increment=	2.5
Rmin=	25.0	Rmax=	45.0	Increment=	2.5

Circle center at X= 20.0, Y= 40.0
FS= 1.666 at R= 25.0
FS= 1.647 at R= 27.5
FS= 1.759 at R= 30.0
FS= 1.911 at R= 32.5
FS= 2.000 at R= 35.0
FS= 2.161 at R= 37.5
FS= 2.329 at R= 40.0
FS= 2.518 at R= 42.5
FS= 2.765 at R= 45.0
Minimum FS for center = 1.647 at R= 27.5

Circle center at X= 23.0, Y= 40.0
FS= 1.575 at R= 25.0
FS= 1.578 at R= 27.5
FS= 1.666 at R= 30.0
FS= 1.764 at R= 32.5
FS= 1.919 at R= 35.0
FS= 2.093 at R= 37.5
FS= 2.287 at R= 40.0
FS= 2.537 at R= 42.5
FS= 2.865 at R= 45.0
Minimum FS for center = 1.575 at R= 25.0

Circle center at X= 26.0, Y= 40.0
FS= 1.509 at R= 25.0
FS= 1.559 at R= 27.5
FS= 1.615 at R= 30.0
FS= 1.746 at R= 32.5
FS= 1.909 at R= 35.0
FS= 2.100 at R= 37.5
FS= 2.353 at R= 40.0
FS= 2.680 at R= 42.5
FS= 2.997 at R= 45.0
Minimum FS for center = 1.509 at R= 25.0

Circle center at X= 29.0, Y= 40.0
FS= 1.469 at R= 25.0
FS= 1.567 at R= 27.5
FS= 1.672 at R= 30.0
FS= 1.796 at R= 32.5
FS= 1.968 at R= 35.0
FS= 2.220 at R= 37.5
FS= 2.543 at R= 40.0
FS= 2.857 at R= 42.5
FS= 3.162 at R= 45.0
Minimum FS for center = 1.469 at R= 25.0

Circle center at X= 32.0, Y= 40.0
FS= 1.481 at R= 25.0
FS= 1.642 at R= 27.5
FS= 1.774 at R= 30.0
FS= 1.924 at R= 32.5
FS= 2.157 at R= 35.0
FS= 2.470 at R= 37.5
FS= 2.772 at R= 40.0
FS= 3.071 at R= 42.5
FS= 3.406 at R= 45.0
Minimum FS for center = 1.481 at R= 25.0

Circle center at X= 35.0, Y= 40.0
FS= 1.568 at R= 25.0
FS= 1.757 at R= 27.5
FS= 1.944 at R= 30.0
FS= 2.194 at R= 32.5
FS= 2.493 at R= 35.0
FS= 2.776 at R= 37.5
FS= 3.060 at R= 40.0
FS= 3.384 at R= 42.5
FS= 3.735 at R= 45.0
Minimum FS for center = 1.568 at R= 25.0

Circle center at X= 20.0, Y= 42.5
FS= 1.762 at R= 25.0
FS= 1.569 at R= 27.5
FS= 1.565 at R= 30.0
FS= 1.676 at R= 32.5
FS= 1.797 at R= 35.0
FS= 1.940 at R= 37.5
FS= 2.101 at R= 40.0
FS= 2.278 at R= 42.5
FS= 2.504 at R= 45.0
Minimum FS for center = 1.565 at R= 30.0

Circle center at X= 23.0, Y= 42.5
FS= 1.512 at R= 25.0
FS= 1.490 at R= 27.5
FS= 1.499 at R= 30.0
FS= 1.575 at R= 32.5
FS= 1.715 at R= 35.0
FS= 1.878 at R= 37.5
FS= 2.056 at R= 40.0
FS= 2.283 at R= 42.5
FS= 2.577 at R= 45.0
Minimum FS for center = 1.490 at R= 27.5

Circle center at X= 26.0, Y= 42.5
FS= 1.371 at R= 25.0
FS= 1.434 at R= 27.5
FS= 1.480 at R= 30.0
FS= 1.576 at R= 32.5
FS= 1.716 at R= 35.0
FS= 1.884 at R= 37.5
FS= 2.108 at R= 40.0
FS= 2.401 at R= 42.5
FS= 2.732 at R= 45.0
Minimum FS for center = 1.371 at R= 25.0

```
Circle center at X=  29.0, Y=  42.5
FS= 1.290 at R=  25.0
FS= 1.407 at R=  27.5
FS= 1.531 at R=  30.0
FS= 1.641 at R=  32.5
FS= 1.780 at R=  35.0
FS= 1.983 at R=  37.5
FS= 2.273 at R=  40.0
FS= 2.598 at R=  42.5
FS= 2.903 at R=  45.0
Minimum FS for center = 1.290 at R=  25.0

Circle center at X=  32.0, Y=  42.5
FS= 1.265 at R=  25.0
FS= 1.457 at R=  27.5
FS= 1.619 at R=  30.0
FS= 1.762 at R=  32.5
FS= 1.942 at R=  35.0
FS= 2.209 at R=  37.5
FS= 2.520 at R=  40.0
FS= 2.821 at R=  42.5
FS= 3.134 at R=  45.0
Minimum FS for center = 1.265 at R=  25.0

Circle center at X=  35.0, Y=  42.5
FS= 1.329 at R=  25.0
FS= 1.555 at R=  27.5
FS= 1.757 at R=  30.0
FS= 1.972 at R=  32.5
FS= 2.243 at R=  35.0
FS= 2.540 at R=  37.5
FS= 2.823 at R=  40.0
FS= 3.122 at R=  42.5
FS= 3.463 at R=  45.0
Minimum FS for center = 1.329 at R=  25.0

Circle center at X=  20.0, Y=  45.0
FS= 2.446 at R=  25.0
FS= 1.649 at R=  27.5
FS= 1.486 at R=  30.0
FS= 1.496 at R=  32.5
FS= 1.596 at R=  35.0
FS= 1.726 at R=  37.5
FS= 1.889 at R=  40.0
FS= 2.064 at R=  42.5
FS= 2.262 at R=  45.0
Minimum FS for center = 1.486 at R=  30.0

Circle center at X=  23.0, Y=  45.0
FS= 1.694 at R=  25.0
FS= 1.436 at R=  27.5
FS= 1.418 at R=  30.0
FS= 1.432 at R=  32.5
FS= 1.531 at R=  35.0
FS= 1.684 at R=  37.5
FS= 1.853 at R=  40.0
FS= 2.053 at R=  42.5
FS= 2.315 at R=  45.0
Minimum FS for center = 1.418 at R=  30.0
```

Circle center at X= 26.0, Y= 45.0
FS= 1.398 at R= 25.0
FS= 1.312 at R= 27.5
FS= 1.369 at R= 30.0
FS= 1.442 at R= 32.5
FS= 1.551 at R= 35.0
FS= 1.699 at R= 37.5
FS= 1.889 at R= 40.0
FS= 2.148 at R= 42.5
FS= 2.466 at R= 45.0
Minimum FS for center = 1.312 at R= 27.5

Circle center at X= 29.0, Y= 45.0
FS= 1.255 at R= 25.0
FS= 1.241 at R= 27.5
FS= 1.382 at R= 30.0
FS= 1.511 at R= 32.5
FS= 1.622 at R= 35.0
FS= 1.786 at R= 37.5
FS= 2.031 at R= 40.0
FS= 2.340 at R= 42.5
FS= 2.655 at R= 45.0
Minimum FS for center = 1.241 at R= 27.5

Circle center at X= 32.0, Y= 45.0
FS= 1.187 at R= 25.0
FS= 1.256 at R= 27.5
FS= 1.450 at R= 30.0
FS= 1.610 at R= 32.5
FS= 1.769 at R= 35.0
FS= 1.985 at R= 37.5
FS= 2.276 at R= 40.0
FS= 2.583 at R= 42.5
FS= 2.886 at R= 45.0
Minimum FS for center = 1.187 at R= 25.0

Circle center at X= 35.0, Y= 45.0
FS= 1.227 at R= 25.0
FS= 1.335 at R= 27.5
FS= 1.560 at R= 30.0
FS= 1.776 at R= 32.5
FS= 2.020 at R= 35.0
FS= 2.306 at R= 37.5
FS= 2.580 at R= 40.0
FS= 2.887 at R= 42.5
FS= 3.200 at R= 45.0
Minimum FS for center = 1.227 at R= 25.0

Circle center at X= 20.0, Y= 47.5
Circle did not intersect the slope at R= 25.0
FS= 2.184 at R= 27.5
FS= 1.558 at R= 30.0
FS= 1.419 at R= 32.5
FS= 1.439 at R= 35.0
FS= 1.541 at R= 37.5
FS= 1.693 at R= 40.0
FS= 1.864 at R= 42.5
FS= 2.048 at R= 45.0
Minimum FS for center = 1.419 at R= 32.5

```
Circle center at X=  23.0, Y=  47.5
FS= 4.128 at R=  25.0
FS= 1.588 at R=  27.5
FS= 1.371 at R=  30.0
FS= 1.359 at R=  32.5
FS= 1.388 at R=  35.0
FS= 1.513 at R=  37.5
FS= 1.670 at R=  40.0
FS= 1.851 at R=  42.5
FS= 2.077 at R=  45.0
Minimum FS for center = 1.359 at R=  32.5

Circle center at X=  26.0, Y=  47.5
FS= 1.844 at R=  25.0
FS= 1.339 at R=  27.5
FS= 1.262 at R=  30.0
FS= 1.332 at R=  32.5
FS= 1.422 at R=  35.0
FS= 1.542 at R=  37.5
FS= 1.704 at R=  40.0
FS= 1.920 at R=  42.5
FS= 2.204 at R=  45.0
Minimum FS for center = 1.262 at R=  30.0

Circle center at X=  29.0, Y=  47.5
FS= 1.391 at R=  25.0
FS= 1.213 at R=  27.5
FS= 1.219 at R=  30.0
FS= 1.373 at R=  32.5
FS= 1.501 at R=  35.0
FS= 1.629 at R=  37.5
FS= 1.820 at R=  40.0
FS= 2.090 at R=  42.5
FS= 2.408 at R=  45.0
Minimum FS for center = 1.213 at R=  27.5

Circle center at X=  32.0, Y=  47.5
FS= 1.217 at R=  25.0
FS= 1.178 at R=  27.5
FS= 1.261 at R=  30.0
FS= 1.449 at R=  32.5
FS= 1.623 at R=  35.0
FS= 1.804 at R=  37.5
FS= 2.043 at R=  40.0
FS= 2.352 at R=  42.5
FS= 2.648 at R=  45.0
Minimum FS for center = 1.178 at R=  27.5

Circle center at X=  35.0, Y=  47.5
FS= 1.185 at R=  25.0
FS= 1.245 at R=  27.5
FS= 1.346 at R=  30.0
FS= 1.584 at R=  32.5
FS= 1.821 at R=  35.0
FS= 2.081 at R=  37.5
FS= 2.369 at R=  40.0
FS= 2.651 at R=  42.5
FS= 2.966 at R=  45.0
Minimum FS for center = 1.185 at R=  25.0
```

Geonorte

Circle center at X= 20.0, Y= 50.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
FS= 1.984 at R= 30.0
FS= 1.479 at R= 32.5
FS= 1.360 at R= 35.0
FS= 1.388 at R= 37.5
FS= 1.512 at R= 40.0
FS= 1.675 at R= 42.5
FS= 1.848 at R= 45.0
Minimum FS for center = 1.360 at R= 35.0

Circle center at X= 23.0, Y= 50.0
Circle did not intersect the slope at R= 25.0
FS= 3.245 at R= 27.5
FS= 1.502 at R= 30.0
FS= 1.318 at R= 32.5
FS= 1.310 at R= 35.0
FS= 1.367 at R= 37.5
FS= 1.502 at R= 40.0
FS= 1.665 at R= 42.5
FS= 1.863 at R= 45.0
Minimum FS for center = 1.310 at R= 35.0

Circle center at X= 26.0, Y= 50.0
Circle did not intersect the slope at R= 25.0
FS= 1.712 at R= 27.5
FS= 1.288 at R= 30.0
FS= 1.223 at R= 32.5
FS= 1.317 at R= 35.0
FS= 1.414 at R= 37.5
FS= 1.542 at R= 40.0
FS= 1.724 at R= 42.5
FS= 1.969 at R= 45.0
Minimum FS for center = 1.223 at R= 32.5

Circle center at X= 29.0, Y= 50.0
FS= 4.285 at R= 25.0
FS= 1.337 at R= 27.5
FS= 1.180 at R= 30.0
FS= 1.215 at R= 32.5
FS= 1.374 at R= 35.0
FS= 1.506 at R= 37.5
FS= 1.650 at R= 40.0
FS= 1.869 at R= 42.5
FS= 2.158 at R= 45.0
Minimum FS for center = 1.180 at R= 30.0

Circle center at X= 32.0, Y= 50.0
FS= 1.779 at R= 25.0
FS= 1.187 at R= 27.5
FS= 1.185 at R= 30.0
FS= 1.274 at R= 32.5
FS= 1.465 at R= 35.0
FS= 1.650 at R= 37.5
FS= 1.850 at R= 40.0
FS= 2.110 at R= 42.5
FS= 2.410 at R= 45.0
Minimum FS for center = 1.185 at R= 30.0

```
Circle center at X=  35.0, Y=  50.0
FS= 1.362 at R=  25.0
FS= 1.202 at R=  27.5
FS= 1.269 at R=  30.0
FS= 1.373 at R=  32.5
FS= 1.621 at R=  35.0
FS= 1.877 at R=  37.5
FS= 2.150 at R=  40.0
FS= 2.450 at R=  42.5
FS= 2.731 at R=  45.0
Minimum FS for center = 1.202 at R=  27.5

Circle center at X=  20.0, Y=  52.5
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
Circle did not intersect the slope at R=  30.0
FS= 1.828 at R=  32.5
FS= 1.414 at R=  35.0
FS= 1.311 at R=  37.5
FS= 1.355 at R=  40.0
FS= 1.500 at R=  42.5
FS= 1.666 at R=  45.0
Minimum FS for center = 1.311 at R=  37.5

Circle center at X=  23.0, Y=  52.5
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
FS= 2.711 at R=  30.0
FS= 1.429 at R=  32.5
FS= 1.272 at R=  35.0
FS= 1.281 at R=  37.5
FS= 1.360 at R=  40.0
FS= 1.501 at R=  42.5
FS= 1.677 at R=  45.0
Minimum FS for center = 1.272 at R=  35.0

Circle center at X=  26.0, Y=  52.5
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
FS= 1.605 at R=  30.0
FS= 1.245 at R=  32.5
FS= 1.204 at R=  35.0
FS= 1.314 at R=  37.5
FS= 1.414 at R=  40.0
FS= 1.558 at R=  42.5
FS= 1.760 at R=  45.0
Minimum FS for center = 1.204 at R=  35.0

Circle center at X=  29.0, Y=  52.5
Circle did not intersect the slope at R=  25.0
FS= 3.305 at R=  27.5
FS= 1.290 at R=  30.0
FS= 1.170 at R=  32.5
FS= 1.224 at R=  35.0
FS= 1.380 at R=  37.5
FS= 1.523 at R=  40.0
FS= 1.687 at R=  42.5
FS= 1.927 at R=  45.0
Minimum FS for center = 1.170 at R=  32.5
```

Circle center at X= 32.0, Y= 52.5
Circle did not intersect the slope at R= 25.0
FS= 1.663 at R= 27.5
FS= 1.182 at R= 30.0
FS= 1.202 at R= 32.5
FS= 1.288 at R= 35.0
FS= 1.491 at R= 37.5
FS= 1.689 at R= 40.0
FS= 1.906 at R= 42.5
FS= 2.184 at R= 45.0
Minimum FS for center = 1.182 at R= 30.0

Circle center at X= 35.0, Y= 52.5
FS= 5.138 at R= 25.0
FS= 1.345 at R= 27.5
FS= 1.229 at R= 30.0
FS= 1.293 at R= 32.5
FS= 1.408 at R= 35.0
FS= 1.666 at R= 37.5
FS= 1.940 at R= 40.0
FS= 2.224 at R= 42.5
FS= 2.527 at R= 45.0
Minimum FS for center = 1.229 at R= 30.0

Circle center at X= 20.0, Y= 55.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
FS=%537.715683754 at R= 32.5
FS= 1.702 at R= 35.0
FS= 1.358 at R= 37.5
FS= 1.268 at R= 40.0
FS= 1.342 at R= 42.5
FS= 1.494 at R= 45.0
Minimum FS for center = 1.268 at R= 40.0

Circle center at X= 23.0, Y= 55.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
FS= 2.357 at R= 32.5
FS= 1.369 at R= 35.0
FS= 1.232 at R= 37.5
FS= 1.268 at R= 40.0
FS= 1.361 at R= 42.5
FS= 1.509 at R= 45.0
Minimum FS for center = 1.232 at R= 37.5

Circle center at X= 26.0, Y= 55.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
FS= 1.518 at R= 32.5
FS= 1.208 at R= 35.0
FS= 1.200 at R= 37.5
FS= 1.319 at R= 40.0
FS= 1.424 at R= 42.5
FS= 1.584 at R= 45.0
Minimum FS for center = 1.200 at R= 37.5

Circle center at X= 29.0, Y= 55.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
FS= 2.739 at R= 30.0
FS= 1.249 at R= 32.5
FS= 1.173 at R= 35.0
FS= 1.239 at R= 37.5
FS= 1.396 at R= 40.0
FS= 1.550 at R= 42.5
FS= 1.735 at R= 45.0
Minimum FS for center = 1.173 at R= 35.0

Circle center at X= 32.0, Y= 55.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
FS= 1.568 at R= 30.0
FS= 1.193 at R= 32.5
FS= 1.229 at R= 35.0
FS= 1.313 at R= 37.5
FS= 1.527 at R= 40.0
FS= 1.739 at R= 42.5
FS= 1.968 at R= 45.0
Minimum FS for center = 1.193 at R= 32.5

Circle center at X= 35.0, Y= 55.0
Circle did not intersect the slope at R= 25.0
FS= 3.735 at R= 27.5
FS= 1.354 at R= 30.0
FS= 1.267 at R= 32.5
FS= 1.324 at R= 35.0
FS= 1.452 at R= 37.5
FS= 1.723 at R= 40.0
FS= 2.008 at R= 42.5
FS= 2.308 at R= 45.0
Minimum FS for center = 1.267 at R= 32.5

Circle center at X= 20.0, Y= 57.5
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
FS=10.435 at R= 35.0
FS= 1.601 at R= 37.5
FS= 1.309 at R= 40.0
FS= 1.241 at R= 42.5
FS= 1.337 at R= 45.0
Minimum FS for center = 1.241 at R= 42.5

Circle center at X= 23.0, Y= 57.5
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
FS= 2.104 at R= 35.0
FS= 1.317 at R= 37.5
FS= 1.209 at R= 40.0
FS= 1.266 at R= 42.5
FS= 1.366 at R= 45.0
Minimum FS for center = 1.209 at R= 40.0

Circle center at X= 26.0, Y= 57.5
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
FS= 1.446 at R= 35.0
FS= 1.188 at R= 37.5
FS= 1.205 at R= 40.0
FS= 1.327 at R= 42.5
FS= 1.444 at R= 45.0
Minimum FS for center = 1.188 at R= 37.5

Circle center at X= 29.0, Y= 57.5
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
FS= 2.369 at R= 32.5
FS= 1.225 at R= 35.0
FS= 1.186 at R= 37.5
FS= 1.257 at R= 40.0
FS= 1.421 at R= 42.5
FS= 1.585 at R= 45.0
Minimum FS for center = 1.186 at R= 37.5

Circle center at X= 32.0, Y= 57.5
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
FS= 1.494 at R= 32.5
FS= 1.211 at R= 35.0
FS= 1.258 at R= 37.5
FS= 1.346 at R= 40.0
FS= 1.569 at R= 42.5
FS= 1.795 at R= 45.0
Minimum FS for center = 1.211 at R= 35.0

Circle center at X= 35.0, Y= 57.5
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
FS= 2.996 at R= 30.0
FS= 1.368 at R= 32.5
FS= 1.310 at R= 35.0
FS= 1.366 at R= 37.5
FS= 1.500 at R= 40.0
FS= 1.785 at R= 42.5
FS= 2.084 at R= 45.0
Minimum FS for center = 1.310 at R= 35.0

Circle center at X= 20.0, Y= 60.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
Circle did not intersect the slope at R= 35.0
FS= 5.633 at R= 37.5
FS= 1.515 at R= 40.0
FS= 1.266 at R= 42.5
FS= 1.229 at R= 45.0
Minimum FS for center = 1.229 at R= 45.0

Circle center at X= 23.0, Y= 60.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
Circle did not intersect the slope at R= 35.0
FS= 1.915 at R= 37.5
FS= 1.272 at R= 40.0
FS= 1.201 at R= 42.5
FS= 1.273 at R= 45.0
Minimum FS for center = 1.201 at R= 42.5

Circle center at X= 26.0, Y= 60.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
FS=20.560 at R= 35.0
FS= 1.384 at R= 37.5
FS= 1.184 at R= 40.0
FS= 1.219 at R= 42.5
FS= 1.340 at R= 45.0
Minimum FS for center = 1.184 at R= 40.0

Circle center at X= 29.0, Y= 60.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
FS= 2.109 at R= 35.0
FS= 1.221 at R= 37.5
FS= 1.207 at R= 40.0
FS= 1.274 at R= 42.5
FS= 1.453 at R= 45.0
Minimum FS for center = 1.207 at R= 40.0

Circle center at X= 32.0, Y= 60.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
FS= 1.461 at R= 35.0
FS= 1.240 at R= 37.5
FS= 1.278 at R= 40.0
FS= 1.385 at R= 42.5
FS= 1.615 at R= 45.0
Minimum FS for center = 1.240 at R= 37.5

Circle center at X= 35.0, Y= 60.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
FS= 2.552 at R= 32.5
FS= 1.398 at R= 35.0
FS= 1.345 at R= 37.5
FS= 1.412 at R= 40.0
FS= 1.552 at R= 42.5
FS= 1.851 at R= 45.0
Minimum FS for center = 1.345 at R= 37.5

Minimum FS found during grid pattern = 1.17
Found at X= 29.0 Y= 52.5 R= 32.5

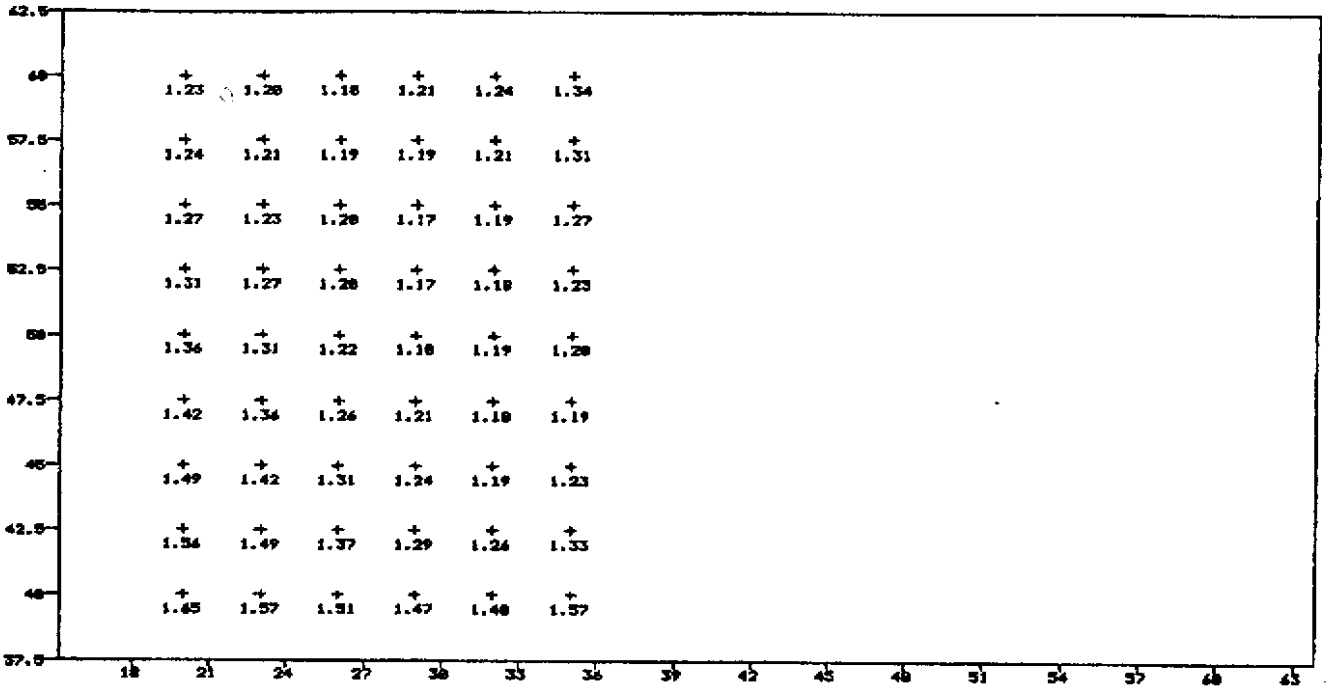
SB-SLOPE

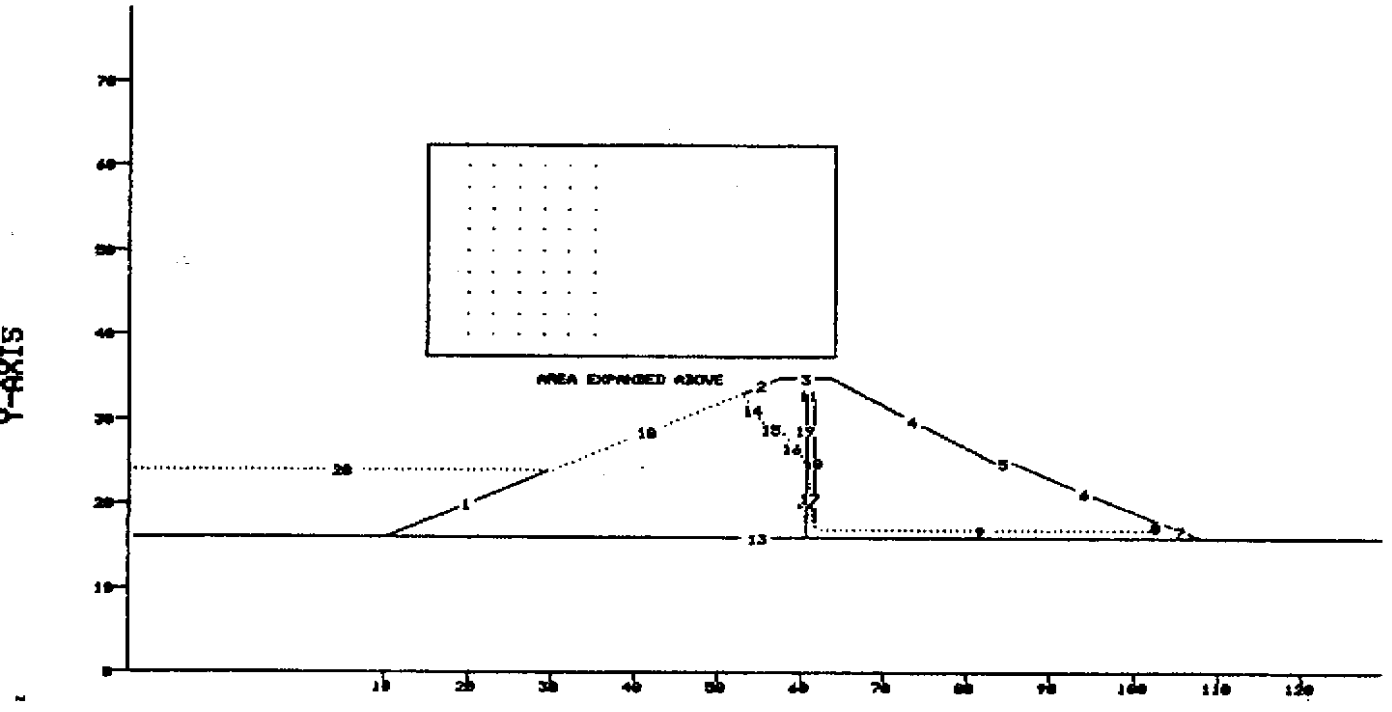
Simplified Bishop Slope Stability Analysis

PROJECT: MARCO

LOCATION: Marco - CE

FILE: MARCO3





X-AXIS

SB-SLOPE

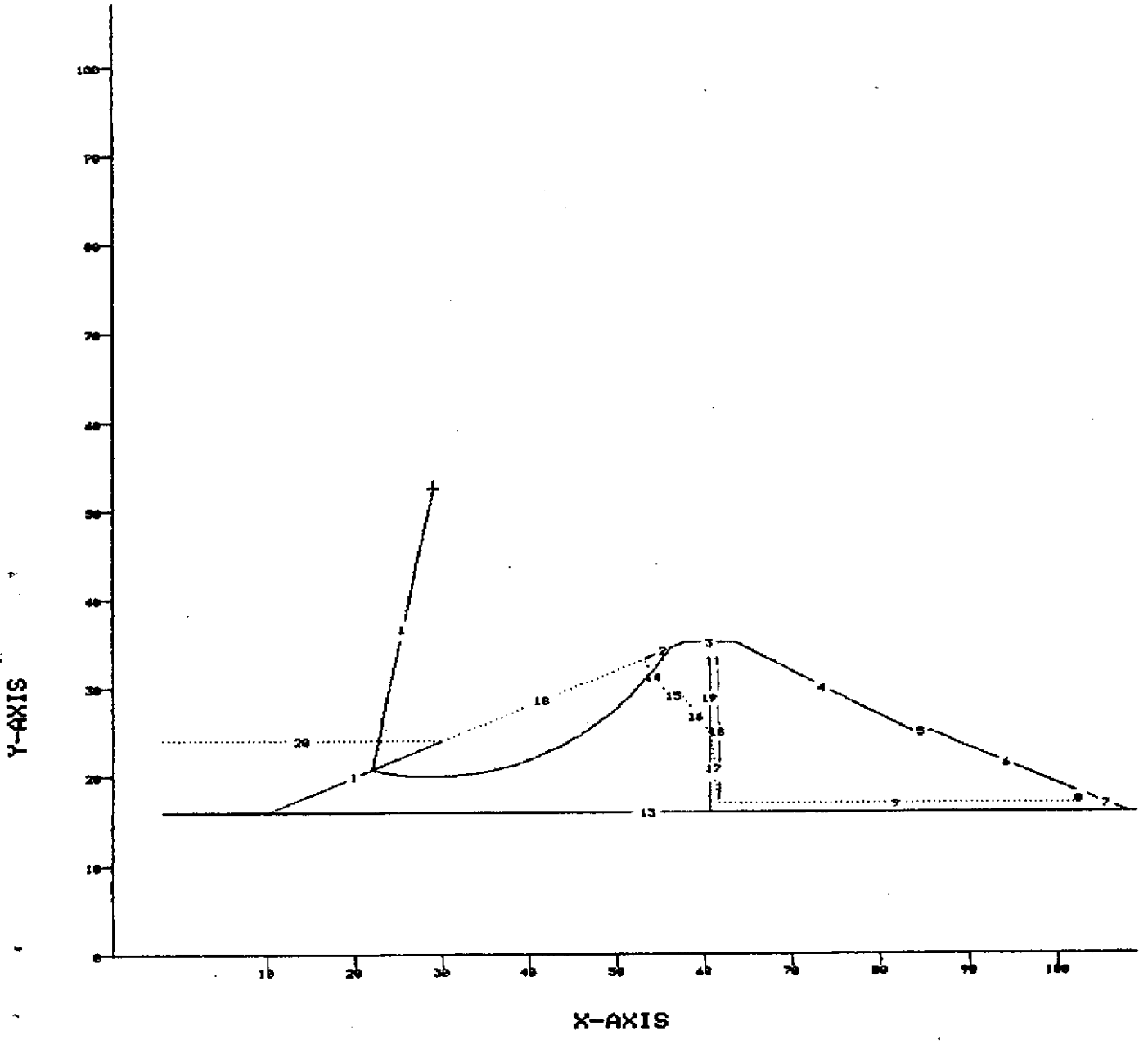
Simplified Bishop Slope Stability Analysis

PROJECT: MARCO

LOCATION: Marco - CE

FILE: FSL.5DT PARTIAL SLOPE CROSS SECTION

CIRCLE	X	Y	RADIUS	FS
1	29.0	52.5	32.5	1.17



Geonorte

Abalo Sismico

000127

Geonorte

MARCO4 - Abalo Sismico
GRID SEARCH ANALYSIS
Approximately 16 slices selected

Xmin=	20.0	Xmax=	35.0	Increment=	3.0
Ymin=	40.0	Ymax=	60.0	Increment=	2.5
Rmin=	25.0	Rmax=	45.0	Increment=	2.5

Circle center at X= 20.0, Y= 40.0
FS= 1.106 at R= 25.0
FS= 1.074 at R= 27.5
FS= 1.192 at R= 30.0
FS= 1.348 at R= 32.5
FS= 1.455 at R= 35.0
FS= 1.600 at R= 37.5
FS= 1.740 at R= 40.0
FS= 1.880 at R= 42.5
FS= 2.044 at R= 45.0
Minimum FS for center = 1.074 at R= 27.5

Circle center at X= 23.0, Y= 40.0
FS= 1.174 at R= 25.0
FS= 1.165 at R= 27.5
FS= 1.246 at R= 30.0
FS= 1.347 at R= 32.5
FS= 1.483 at R= 35.0
FS= 1.624 at R= 37.5
FS= 1.772 at R= 40.0
FS= 1.940 at R= 42.5
FS= 2.145 at R= 45.0
Minimum FS for center = 1.165 at R= 27.5

Circle center at X= 26.0, Y= 40.0
FS= 1.237 at R= 25.0
FS= 1.254 at R= 27.5
FS= 1.304 at R= 30.0
FS= 1.412 at R= 32.5
FS= 1.540 at R= 35.0
FS= 1.687 at R= 37.5
FS= 1.859 at R= 40.0
FS= 2.071 at R= 42.5
FS= 2.291 at R= 45.0
Minimum FS for center = 1.237 at R= 25.0

Circle center at X= 29.0, Y= 40.0
FS= 1.300 at R= 25.0
FS= 1.341 at R= 27.5
FS= 1.421 at R= 30.0
FS= 1.509 at R= 32.5
FS= 1.641 at R= 35.0
FS= 1.809 at R= 37.5
FS= 2.025 at R= 40.0
FS= 2.251 at R= 42.5
FS= 2.454 at R= 45.0
Minimum FS for center = 1.300 at R= 25.0

```
Circle center at X=  32.0, Y=  40.0
FS= 1.382 at R=  25.0
FS= 1.463 at R=  27.5
FS= 1.549 at R=  30.0
FS= 1.664 at R=  32.5
FS= 1.815 at R=  35.0
FS= 2.022 at R=  37.5
FS= 2.248 at R=  40.0
FS= 2.453 at R=  42.5
FS= 2.665 at R=  45.0
Minimum FS for center = 1.382 at R=  25.0

Circle center at X=  35.0, Y=  40.0
FS= 1.505 at R=  25.0
FS= 1.596 at R=  27.5
FS= 1.726 at R=  30.0
FS= 1.895 at R=  32.5
FS= 2.098 at R=  35.0
FS= 2.310 at R=  37.5
FS= 2.510 at R=  40.0
FS= 2.718 at R=  42.5
FS= 2.937 at R=  45.0
Minimum FS for center = 1.505 at R=  25.0

Circle center at X=  20.0, Y=  42.5
FS= 1.444 at R=  25.0
FS= 1.085 at R=  27.5
FS= 1.057 at R=  30.0
FS= 1.169 at R=  32.5
FS= 1.299 at R=  35.0
FS= 1.432 at R=  37.5
FS= 1.568 at R=  40.0
FS= 1.705 at R=  42.5
FS= 1.863 at R=  45.0
Minimum FS for center = 1.057 at R=  30.0

Circle center at X=  23.0, Y=  42.5
FS= 1.335 at R=  25.0
FS= 1.147 at R=  27.5
FS= 1.135 at R=  30.0
FS= 1.203 at R=  32.5
FS= 1.325 at R=  35.0
FS= 1.459 at R=  37.5
FS= 1.596 at R=  40.0
FS= 1.758 at R=  42.5
FS= 1.945 at R=  45.0
Minimum FS for center = 1.135 at R=  30.0

Circle center at X=  26.0, Y=  42.5
FS= 1.296 at R=  25.0
FS= 1.204 at R=  27.5
FS= 1.213 at R=  30.0
FS= 1.282 at R=  32.5
FS= 1.391 at R=  35.0
FS= 1.517 at R=  37.5
FS= 1.676 at R=  40.0
FS= 1.869 at R=  42.5
FS= 2.091 at R=  45.0
Minimum FS for center = 1.204 at R=  27.5
```

```
Circle center at X=  29.0, Y=  42.5
FS= 1.292 at R=  25.0
FS= 1.260 at R=  27.5
FS= 1.315 at R=  30.0
FS= 1.395 at R=  32.5
FS= 1.490 at R=  35.0
FS= 1.633 at R=  37.5
FS= 1.823 at R=  40.0
FS= 2.047 at R=  42.5
FS= 2.259 at R=  45.0
Minimum FS for center = 1.260 at R=  27.5

Circle center at X=  32.0, Y=  42.5
FS= 1.317 at R=  25.0
FS= 1.353 at R=  27.5
FS= 1.432 at R=  30.0
FS= 1.530 at R=  32.5
FS= 1.652 at R=  35.0
FS= 1.827 at R=  37.5
FS= 2.043 at R=  40.0
FS= 2.258 at R=  42.5
FS= 2.466 at R=  45.0
Minimum FS for center = 1.317 at R=  25.0

Circle center at X=  35.0, Y=  42.5
FS= 1.396 at R=  25.0
FS= 1.467 at R=  27.5
FS= 1.579 at R=  30.0
FS= 1.721 at R=  32.5
FS= 1.904 at R=  35.0
FS= 2.109 at R=  37.5
FS= 2.318 at R=  40.0
FS= 2.520 at R=  42.5
FS= 2.732 at R=  45.0
Minimum FS for center = 1.396 at R=  25.0

Circle center at X=  20.0, Y=  45.0
FS= 2.975 at R=  25.0
FS= 1.402 at R=  27.5
FS= 1.068 at R=  30.0
FS= 1.042 at R=  32.5
FS= 1.142 at R=  35.0
FS= 1.269 at R=  37.5
FS= 1.408 at R=  40.0
FS= 1.545 at R=  42.5
FS= 1.693 at R=  45.0
Minimum FS for center = 1.042 at R=  32.5

Circle center at X=  23.0, Y=  45.0
FS= 1.764 at R=  25.0
FS= 1.303 at R=  27.5
FS= 1.123 at R=  30.0
FS= 1.108 at R=  32.5
FS= 1.185 at R=  35.0
FS= 1.309 at R=  37.5
FS= 1.439 at R=  40.0
FS= 1.591 at R=  42.5
FS= 1.763 at R=  45.0
Minimum FS for center = 1.108 at R=  32.5
```

```
Circle center at X=  26.0, Y=  45.0
FS= 1.470 at R=  25.0
FS= 1.266 at R=  27.5
FS= 1.173 at R=  30.0
FS= 1.193 at R=  32.5
FS= 1.265 at R=  35.0
FS= 1.371 at R=  37.5
FS= 1.515 at R=  40.0
FS= 1.687 at R=  42.5
FS= 1.891 at R=  45.0
Minimum FS for center = 1.173 at R=  30.0

Circle center at X=  29.0, Y=  45.0
FS= 1.360 at R=  25.0
FS= 1.258 at R=  27.5
FS= 1.243 at R=  30.0
FS= 1.298 at R=  32.5
FS= 1.371 at R=  35.0
FS= 1.484 at R=  37.5
FS= 1.646 at R=  40.0
FS= 1.847 at R=  42.5
FS= 2.070 at R=  45.0
Minimum FS for center = 1.243 at R=  30.0

Circle center at X=  32.0, Y=  45.0
FS= 1.320 at R=  25.0
FS= 1.300 at R=  27.5
FS= 1.339 at R=  30.0
FS= 1.413 at R=  32.5
FS= 1.523 at R=  35.0
FS= 1.663 at R=  37.5
FS= 1.849 at R=  40.0
FS= 2.069 at R=  42.5
FS= 2.279 at R=  45.0
Minimum FS for center = 1.300 at R=  27.5

Circle center at X=  35.0, Y=  45.0
FS= 1.354 at R=  25.0
FS= 1.384 at R=  27.5
FS= 1.455 at R=  30.0
FS= 1.577 at R=  32.5
FS= 1.734 at R=  35.0
FS= 1.924 at R=  37.5
FS= 2.109 at R=  40.0
FS= 2.337 at R=  42.5
FS= 2.543 at R=  45.0
Minimum FS for center = 1.354 at R=  25.0

Circle center at X=  20.0, Y=  47.5
Circle did not intersect the slope at R=  25.0
FS= 2.565 at R=  27.5
FS= 1.365 at R=  30.0
FS= 1.055 at R=  32.5
FS= 1.030 at R=  35.0
FS= 1.126 at R=  37.5
FS= 1.258 at R=  40.0
FS= 1.396 at R=  42.5
FS= 1.535 at R=  45.0
Minimum FS for center = 1.030 at R=  35.0
```

Circle center at X= 23.0, Y= 47.5
Negative FS at R= 25.0
FS= 1.677 at R= 27.5
FS= 1.276 at R= 30.0
FS= 1.105 at R= 32.5
FS= 1.091 at R= 35.0
FS= 1.178 at R= 37.5
FS= 1.301 at R= 40.0
FS= 1.437 at R= 42.5
FS= 1.595 at R= 45.0
Minimum FS for center = 1.091 at R= 35.0

Circle center at X= 26.0, Y= 47.5
FS= 2.838 at R= 25.0
FS= 1.427 at R= 27.5
FS= 1.239 at R= 30.0
FS= 1.155 at R= 32.5
FS= 1.182 at R= 35.0
FS= 1.256 at R= 37.5
FS= 1.372 at R= 40.0
FS= 1.524 at R= 42.5
FS= 1.708 at R= 45.0
Minimum FS for center = 1.155 at R= 32.5

Circle center at X= 29.0, Y= 47.5
FS= 1.776 at R= 25.0
FS= 1.327 at R= 27.5
FS= 1.240 at R= 30.0
FS= 1.231 at R= 32.5
FS= 1.285 at R= 35.0
FS= 1.368 at R= 37.5
FS= 1.495 at R= 40.0
FS= 1.670 at R= 42.5
FS= 1.878 at R= 45.0
Minimum FS for center = 1.231 at R= 32.5

Circle center at X= 32.0, Y= 47.5
FS= 1.493 at R= 25.0
FS= 1.302 at R= 27.5
FS= 1.290 at R= 30.0
FS= 1.324 at R= 32.5
FS= 1.412 at R= 35.0
FS= 1.533 at R= 37.5
FS= 1.685 at R= 40.0
FS= 1.879 at R= 42.5
FS= 2.097 at R= 45.0
Minimum FS for center = 1.290 at R= 30.0

Circle center at X= 35.0, Y= 47.5
FS= 1.403 at R= 25.0
FS= 1.345 at R= 27.5
FS= 1.370 at R= 30.0
FS= 1.456 at R= 32.5
FS= 1.592 at R= 35.0
FS= 1.758 at R= 37.5
FS= 1.939 at R= 40.0
FS= 2.143 at R= 42.5
FS= 2.365 at R= 45.0
Minimum FS for center = 1.345 at R= 27.5

```
Circle center at X=  20.0, Y=  50.0
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
FS= 2.288 at R=  30.0
FS= 1.332 at R=  32.5
FS= 1.042 at R=  35.0
FS= 1.018 at R=  37.5
FS= 1.119 at R=  40.0
FS= 1.253 at R=  42.5
FS= 1.385 at R=  45.0
Minimum FS for center = 1.018 at R=  37.5

Circle center at X=  23.0, Y=  50.0
Circle did not intersect the slope at R=  25.0
FS=%124.69153185 at R=  27.5
FS= 1.605 at R=  30.0
FS= 1.251 at R=  32.5
FS= 1.087 at R=  35.0
FS= 1.086 at R=  37.5
FS= 1.176 at R=  40.0
FS= 1.296 at R=  42.5
FS= 1.442 at R=  45.0
Minimum FS for center = 1.086 at R=  37.5

Circle center at X=  26.0, Y=  50.0
Circle did not intersect the slope at R=  25.0
FS= 2.494 at R=  27.5
FS= 1.389 at R=  30.0
FS= 1.217 at R=  32.5
FS= 1.148 at R=  35.0
FS= 1.179 at R=  37.5
FS= 1.253 at R=  40.0
FS= 1.381 at R=  42.5
FS= 1.544 at R=  45.0
Minimum FS for center = 1.148 at R=  35.0

Circle center at X=  29.0, Y=  50.0
Negative FS at R=  25.0
FS= 1.692 at R=  27.5
FS= 1.300 at R=  30.0
FS= 1.231 at R=  32.5
FS= 1.230 at R=  35.0
FS= 1.284 at R=  37.5
FS= 1.376 at R=  40.0
FS= 1.516 at R=  42.5
FS= 1.700 at R=  45.0
Minimum FS for center = 1.230 at R=  35.0

Circle center at X=  32.0, Y=  50.0
FS= 2.728 at R=  25.0
FS= 1.450 at R=  27.5
FS= 1.290 at R=  30.0
FS= 1.290 at R=  32.5
FS= 1.327 at R=  35.0
FS= 1.424 at R=  37.5
FS= 1.554 at R=  40.0
FS= 1.713 at R=  42.5
FS= 1.904 at R=  45.0
Minimum FS for center = 1.290 at R=  30.0
```

```
Circle center at X=  35.0, Y=  50.0
FS= 1.787 at R=  25.0
FS= 1.385 at R=  27.5
FS= 1.349 at R=  30.0
FS= 1.377 at R=  32.5
FS= 1.475 at R=  35.0
FS= 1.617 at R=  37.5
FS= 1.789 at R=  40.0
FS= 1.975 at R=  42.5
FS= 2.182 at R=  45.0
Minimum FS for center = 1.349 at R=  30.0

Circle center at X=  20.0, Y=  52.5
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
Circle did not intersect the slope at R=  30.0
FS= 2.086 at R=  32.5
FS= 1.303 at R=  35.0
FS= 1.031 at R=  37.5
FS= 1.013 at R=  40.0
FS= 1.119 at R=  42.5
FS= 1.250 at R=  45.0
Minimum FS for center = 1.013 at R=  40.0

Circle center at X=  23.0, Y=  52.5
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
FS= 9.978 at R=  30.0
FS= 1.544 at R=  32.5
FS= 1.230 at R=  35.0
FS= 1.080 at R=  37.5
FS= 1.083 at R=  40.0
FS= 1.175 at R=  42.5
FS= 1.303 at R=  45.0
Minimum FS for center = 1.080 at R=  37.5

Circle center at X=  26.0, Y=  52.5
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
FS= 2.251 at R=  30.0
FS= 1.355 at R=  32.5
FS= 1.204 at R=  35.0
FS= 1.146 at R=  37.5
FS= 1.176 at R=  40.0
FS= 1.261 at R=  42.5
FS= 1.398 at R=  45.0
Minimum FS for center = 1.146 at R=  37.5

Circle center at X=  29.0, Y=  52.5
Circle did not intersect the slope at R=  25.0
FS=15.950 at R=  27.5
FS= 1.622 at R=  30.0
FS= 1.283 at R=  32.5
FS= 1.227 at R=  35.0
FS= 1.229 at R=  37.5
FS= 1.291 at R=  40.0
FS= 1.393 at R=  42.5
FS= 1.543 at R=  45.0
Minimum FS for center = 1.227 at R=  35.0
```

```
Circle center at X=  32.0, Y=  52.5
Circle did not intersect the slope at R=  25.0
FS= 2.433 at R=  27.5
FS= 1.422 at R=  30.0
FS= 1.287 at R=  32.5
FS= 1.290 at R=  35.0
FS= 1.339 at R=  37.5
FS= 1.444 at R=  40.0
FS= 1.581 at R=  42.5
FS= 1.747 at R=  45.0
Minimum FS for center = 1.287 at R=  32.5

Circle center at X=  35.0, Y=  52.5
FS=36.473 at R=  25.0
FS= 1.716 at R=  27.5
FS= 1.378 at R=  30.0
FS= 1.352 at R=  32.5
FS= 1.392 at R=  35.0
FS= 1.500 at R=  37.5
FS= 1.648 at R=  40.0
FS= 1.820 at R=  42.5
FS= 2.016 at R=  45.0
Minimum FS for center = 1.352 at R=  32.5

Circle center at X=  20.0, Y=  55.0
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
Circle did not intersect the slope at R=  30.0
Negative FS at R=  32.5
FS= 1.932 at R=  35.0
FS= 1.278 at R=  37.5
FS= 1.022 at R=  40.0
FS= 1.015 at R=  42.5
FS= 1.122 at R=  45.0
Minimum FS for center = 1.015 at R=  42.5

Circle center at X=  23.0, Y=  55.0
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
Circle did not intersect the slope at R=  30.0
FS= 5.562 at R=  32.5
FS= 1.492 at R=  35.0
FS= 1.210 at R=  37.5
FS= 1.077 at R=  40.0
FS= 1.088 at R=  42.5
FS= 1.180 at R=  45.0
Minimum FS for center = 1.077 at R=  40.0

Circle center at X=  26.0, Y=  55.0
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
Circle did not intersect the slope at R=  30.0
FS= 2.068 at R=  32.5
FS= 1.325 at R=  35.0
FS= 1.197 at R=  37.5
FS= 1.150 at R=  40.0
FS= 1.180 at R=  42.5
FS= 1.277 at R=  45.0
Minimum FS for center = 1.150 at R=  40.0
```

Circle center at X= 29.0, Y= 55.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
FS= 6.992 at R= 30.0
FS= 1.561 at R= 32.5
FS= 1.272 at R= 35.0
FS= 1.233 at R= 37.5
FS= 1.236 at R= 40.0
FS= 1.308 at R= 42.5
FS= 1.417 at R= 45.0
Minimum FS for center = 1.233 at R= 37.5

Circle center at X= 32.0, Y= 55.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
FS= 2.216 at R= 30.0
FS= 1.400 at R= 32.5
FS= 1.295 at R= 35.0
FS= 1.299 at R= 37.5
FS= 1.359 at R= 40.0
FS= 1.471 at R= 42.5
FS= 1.611 at R= 45.0
Minimum FS for center = 1.295 at R= 35.0

Circle center at X= 35.0, Y= 55.0
Circle did not intersect the slope at R= 25.0
FS= 9.217 at R= 27.5
FS= 1.659 at R= 30.0
FS= 1.385 at R= 32.5
FS= 1.364 at R= 35.0
FS= 1.418 at R= 37.5
FS= 1.531 at R= 40.0
FS= 1.684 at R= 42.5
FS= 1.862 at R= 45.0
Minimum FS for center = 1.364 at R= 35.0

Circle center at X= 20.0, Y= 57.5
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
Negative FS at R= 35.0
FS= 1.813 at R= 37.5
FS= 1.254 at R= 40.0
FS= 1.018 at R= 42.5
FS= 1.018 at R= 45.0
Minimum FS for center = 1.018 at R= 42.5

Circle center at X= 23.0, Y= 57.5
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
FS= 4.020 at R= 35.0
FS= 1.446 at R= 37.5
FS= 1.198 at R= 40.0
FS= 1.077 at R= 42.5
FS= 1.093 at R= 45.0
Minimum FS for center = 1.077 at R= 42.5

```
Circle center at X=  26.0, Y=  57.5
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
Circle did not intersect the slope at R=  30.0
Circle did not intersect the slope at R=  32.5
FS= 1.927 at R=  35.0
FS= 1.304 at R=  37.5
FS= 1.194 at R=  40.0
FS= 1.156 at R=  42.5
FS= 1.191 at R=  45.0
Minimum FS for center = 1.156 at R=  42.5

Circle center at X=  29.0, Y=  57.5
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
Circle did not intersect the slope at R=  30.0
FS= 4.691 at R=  32.5
FS= 1.514 at R=  35.0
FS= 1.265 at R=  37.5
FS= 1.241 at R=  40.0
FS= 1.250 at R=  42.5
FS= 1.329 at R=  45.0
Minimum FS for center = 1.241 at R=  40.0

Circle center at X=  32.0, Y=  57.5
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
Circle did not intersect the slope at R=  30.0
FS= 2.052 at R=  32.5
FS= 1.381 at R=  35.0
FS= 1.306 at R=  37.5
FS= 1.316 at R=  40.0
FS= 1.385 at R=  42.5
FS= 1.502 at R=  45.0
Minimum FS for center = 1.306 at R=  37.5

Circle center at X=  35.0, Y=  57.5
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
FS= 5.577 at R=  30.0
FS= 1.602 at R=  32.5
FS= 1.399 at R=  35.0
FS= 1.384 at R=  37.5
FS= 1.449 at R=  40.0
FS= 1.566 at R=  42.5
FS= 1.722 at R=  45.0
Minimum FS for center = 1.384 at R=  37.5

Circle center at X=  20.0, Y=  60.0
Circle did not intersect the slope at R=  25.0
Circle did not intersect the slope at R=  27.5
Circle did not intersect the slope at R=  30.0
Circle did not intersect the slope at R=  32.5
Circle did not intersect the slope at R=  35.0
Negative FS at R=  37.5
FS= 1.715 at R=  40.0
FS= 1.237 at R=  42.5
FS= 1.019 at R=  45.0
Minimum FS for center = 1.019 at R=  45.0
```

Circle center at X= 23.0, Y= 60.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
Circle did not intersect the slope at R= 35.0
FS= 3.229 at R= 37.5
FS= 1.406 at R= 40.0
FS= 1.190 at R= 42.5
FS= 1.085 at R= 45.0
Minimum FS for center = 1.085 at R= 45.0

Circle center at X= 26.0, Y= 60.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
Negative FS at R= 35.0
FS= 1.814 at R= 37.5
FS= 1.289 at R= 40.0
FS= 1.200 at R= 42.5
FS= 1.164 at R= 45.0
Minimum FS for center = 1.164 at R= 45.0

Circle center at X= 29.0, Y= 60.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
FS= 3.640 at R= 35.0
FS= 1.477 at R= 37.5
FS= 1.269 at R= 40.0
FS= 1.249 at R= 42.5
FS= 1.270 at R= 45.0
Minimum FS for center = 1.249 at R= 42.5

Circle center at X= 32.0, Y= 60.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
Circle did not intersect the slope at R= 32.5
FS= 1.928 at R= 35.0
FS= 1.379 at R= 37.5
FS= 1.313 at R= 40.0
FS= 1.340 at R= 42.5
FS= 1.414 at R= 45.0
Minimum FS for center = 1.313 at R= 40.0

Circle center at X= 35.0, Y= 60.0
Circle did not intersect the slope at R= 25.0
Circle did not intersect the slope at R= 27.5
Circle did not intersect the slope at R= 30.0
FS= 4.131 at R= 32.5
FS= 1.577 at R= 35.0
FS= 1.412 at R= 37.5
FS= 1.412 at R= 40.0
FS= 1.484 at R= 42.5
FS= 1.604 at R= 45.0
Minimum FS for center = 1.412 at R= 40.0

Minimum FS found during grid pattern = 1.01
Found at X= 20.0 Y= 52.5 R= 40.0

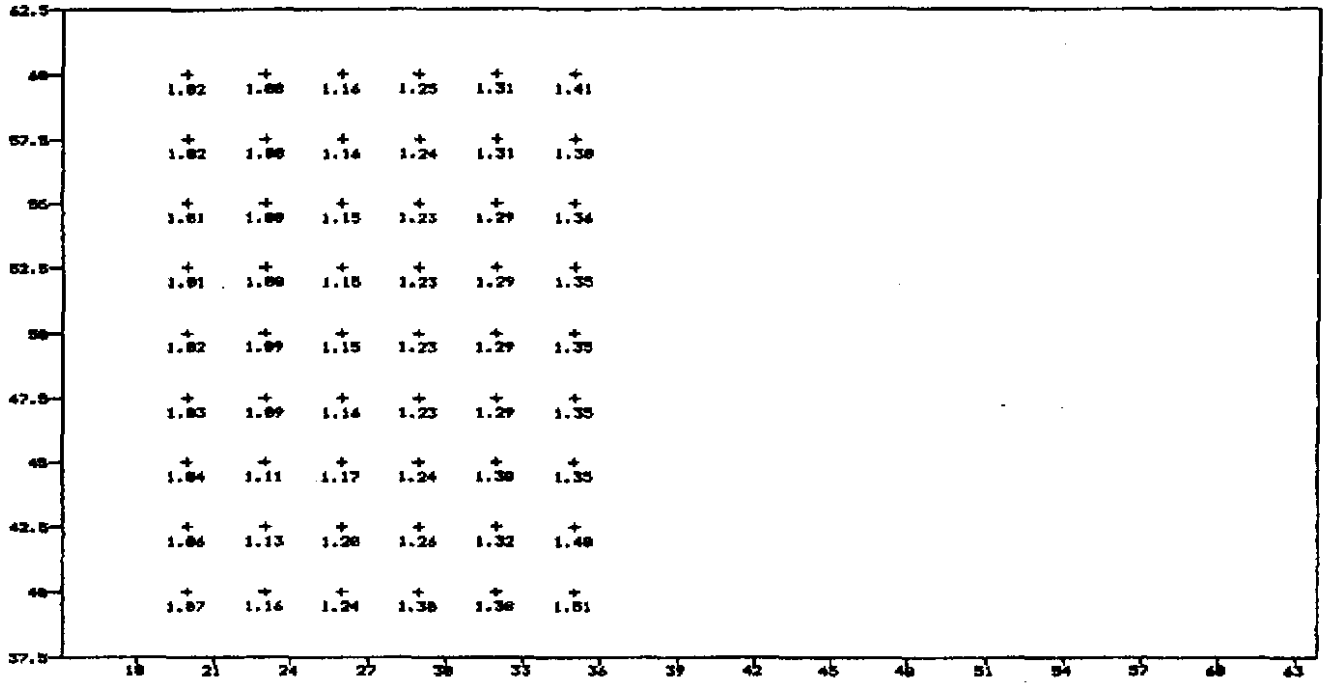
SB-SLOPE

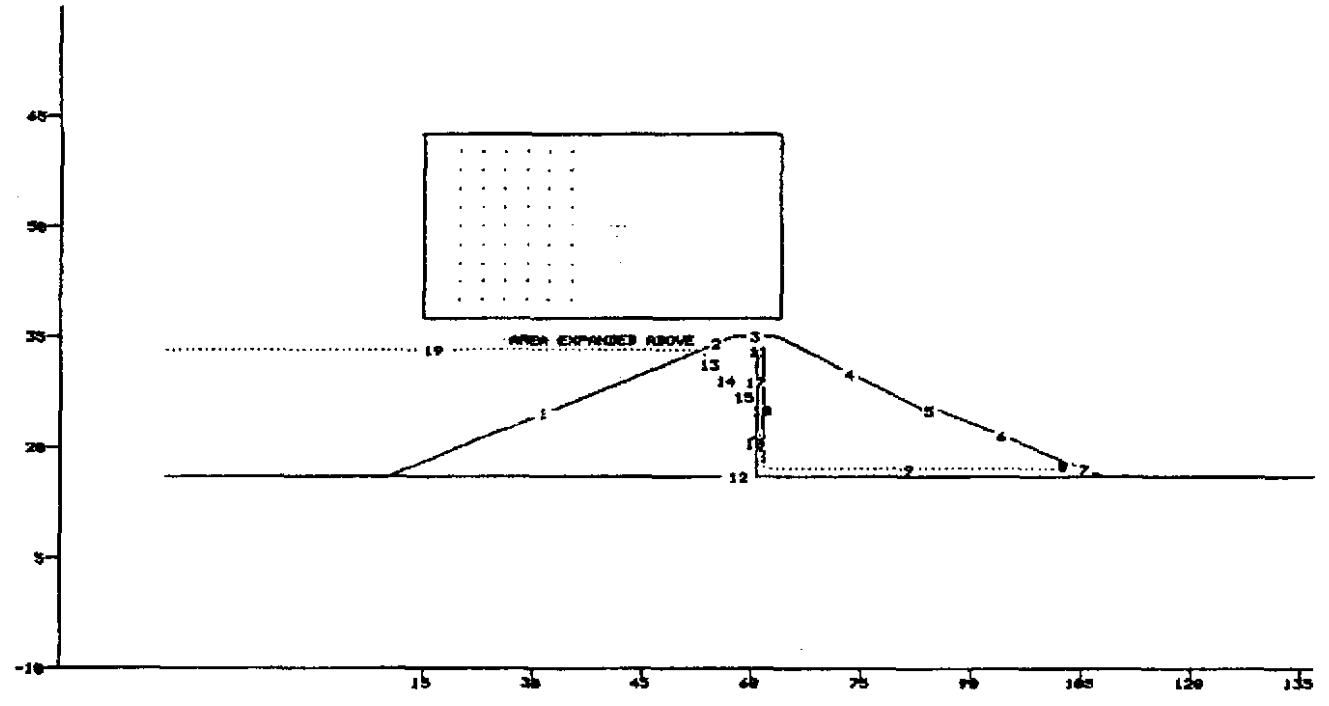
Simplified Bishop Slope Stability Analysis

PROJECT: MARCO

LOCATION: Marco - CE

FILE: MARCO4





Y-AXIS

X-AXIS

000139

SB-SLOPE

Simplified Bishop Slope Stability Analysis

PROJECT: MARCO

LOCATION: Marco - CE

FILE: FSL.5DT PARTIAL SLOPE CROSS SECTION

CIRCLE	X	Y	RADIUS	FS
1	20.0	52.5	40.0	1.01