

# APRESENTAÇÃO INSTITUTO DE ENGENHARIA

## COLETÂNEA DE PROJETOS ESPECIAIS

*Prof. Dr. Carlos Eduardo Moreira Maffei*

*Professor Titular do Departamento de Engenharia de Estruturas e Geotécnica da Escola Politécnica da USP*

*São Paulo, 14 de Junho de 2011.*

# ESCRITÓRIO TÉCNICO FRANCO ROCHA

## “OS DEZ MANDAMENTOS”

- não combata esforços sem necessidade
- não conceba uma estrutura que não saiba calcular

Brasil

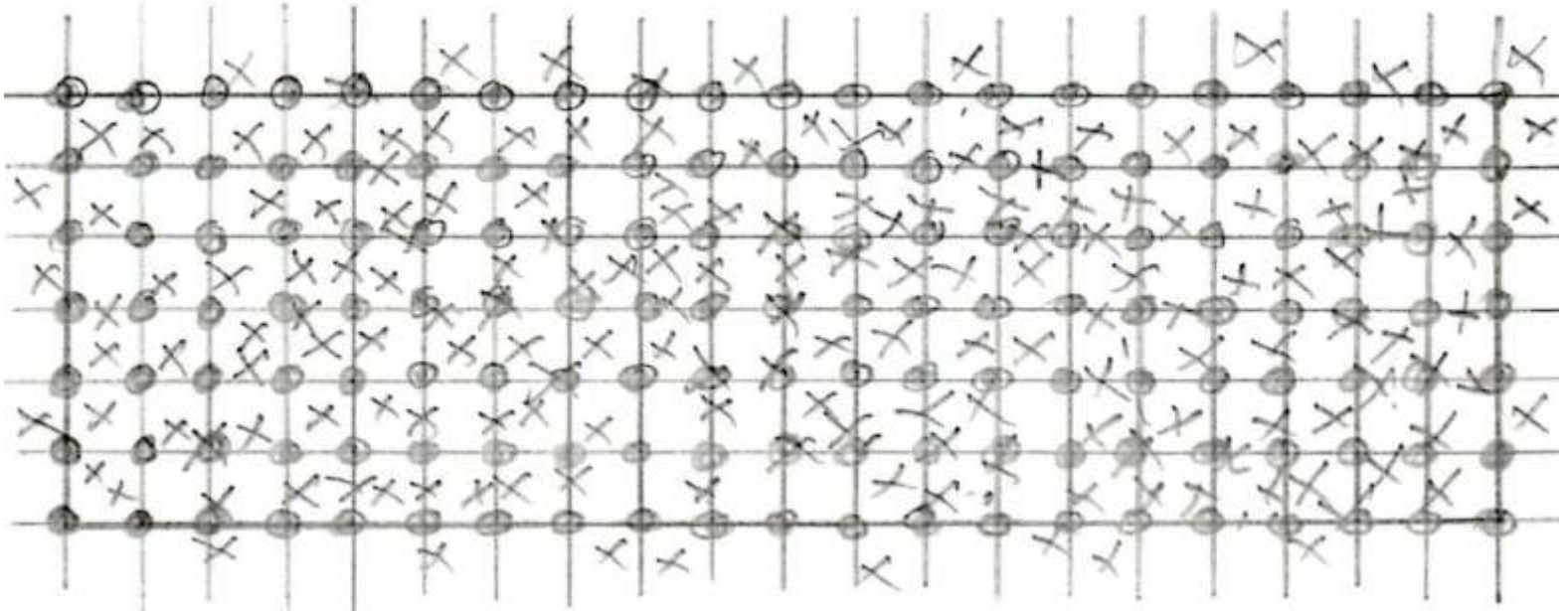


## ESCADA DO EDIFÍCIO COPAN (1964)

# PROMON

Dr. PAULO FRANCO ROCHA

- TRECHO 3 – METRO SP

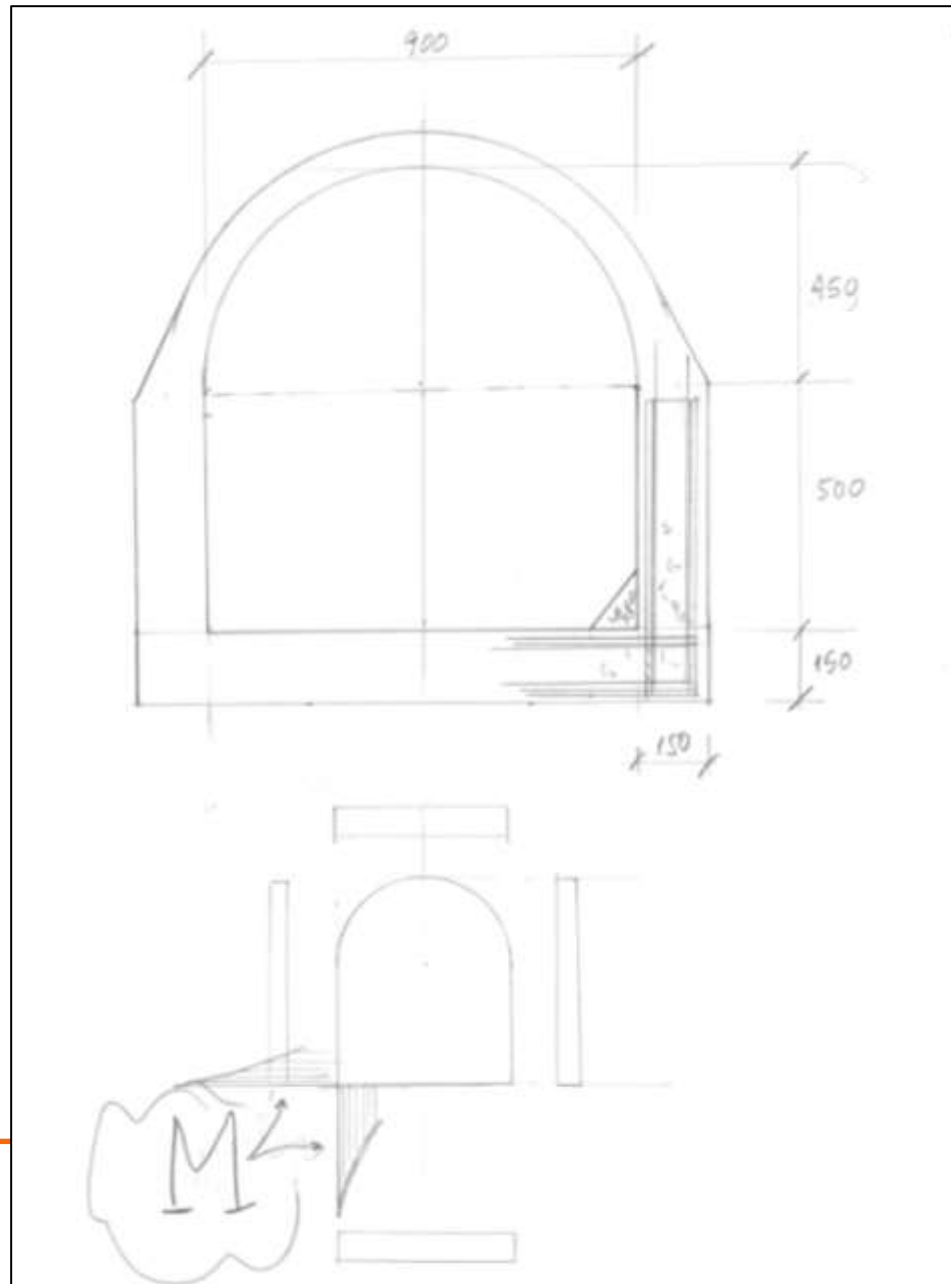


# PROMON

Prof. Dr. DÉCIO LEAL DE ZAGOTTIS

- THE ART OF TUNNELLING (K. SZÉCHY)

# TÚNEL SOB O JARAGUÁ



**INTERAÇÃO MACIÇO-ESTRUTURA**  
**MÉTODO  $\alpha$  (PATENTE)**

Prof. Dr<sup>a</sup>. EVELYNA BLOEM SOUTO

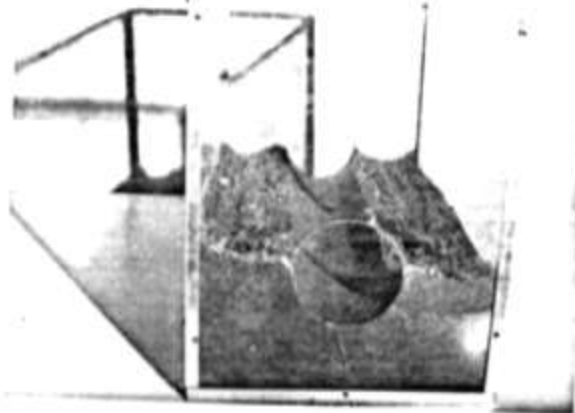


FOTO Nº 1 - BERÇO PRONTO PARA RECEBER O TUBO.

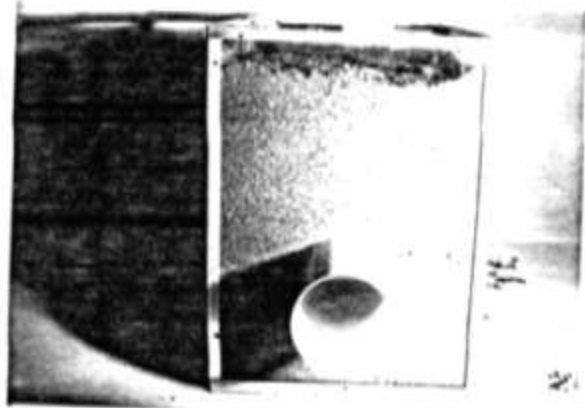


FOTO Nº 2 - TUBO COLOCADO COM ESCORAMENTO INTERNO E REATERRO COLOCADO.



FOTOS 14 E 15 - MOSTRAM A FOLHA DE POLIESTER QUE SIMULA O REVESTIMENTO.





FOTO Nº 3 - VISTA DO ESCORAMENTO INTERNO

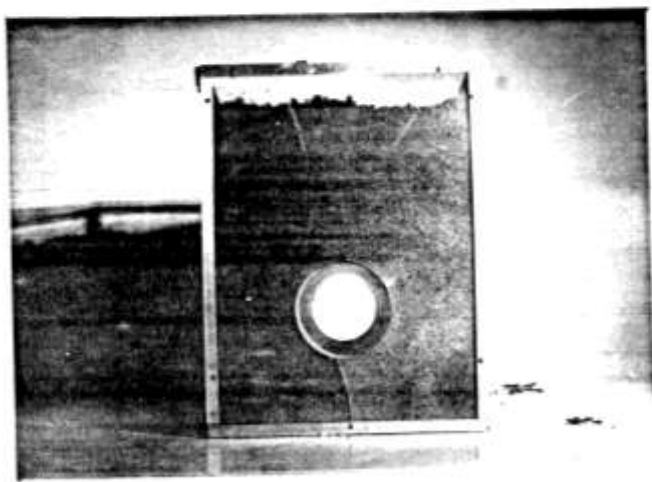
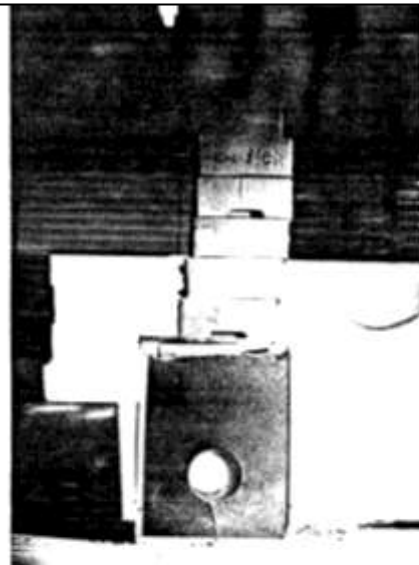


FOTO Nº 4 - ESTÁGIO DE CONSTRUÇÃO DA GALERIA  
APÓS A REMOÇÃO DO ESCORAMENTO INTERNO



FOTOS 7 E 8 - APLICAÇÃO DE  
SOBRECARGAS



FOTOS 7 E 8

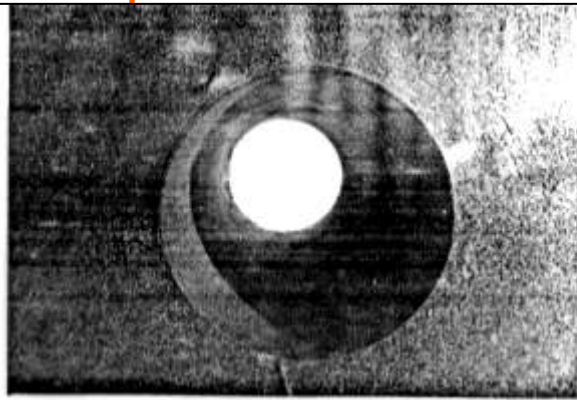


FOTO 9 - VISTA DO REVESTIMENTO DE POLIESTER

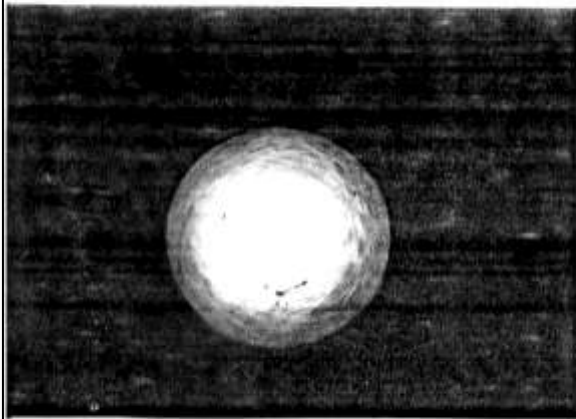
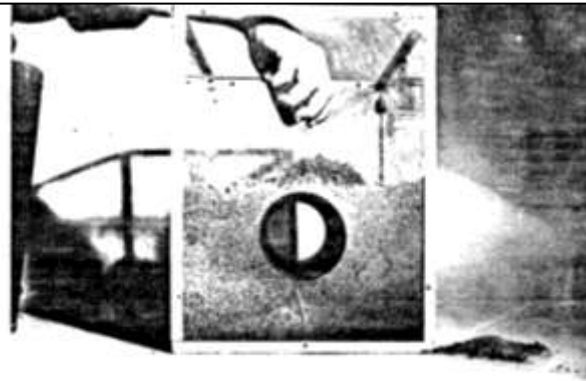
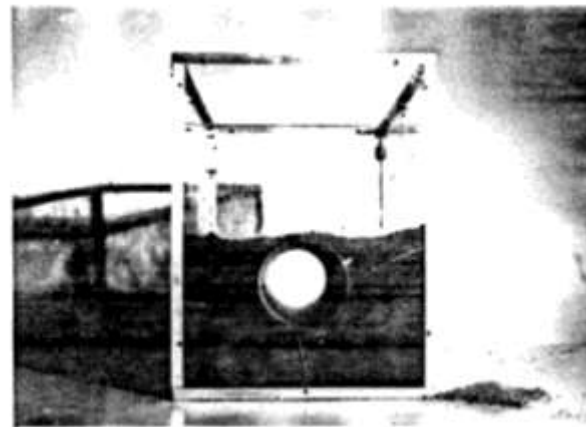


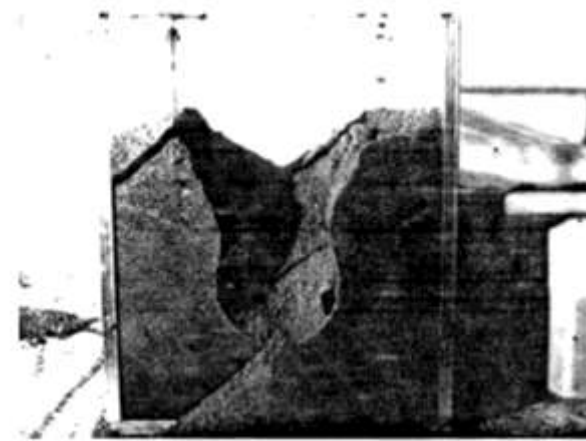
FOTO 10 - VISTA DO REVESTIMENTO SEM DEFORMAÇÕES SIGNIFICATIVAS



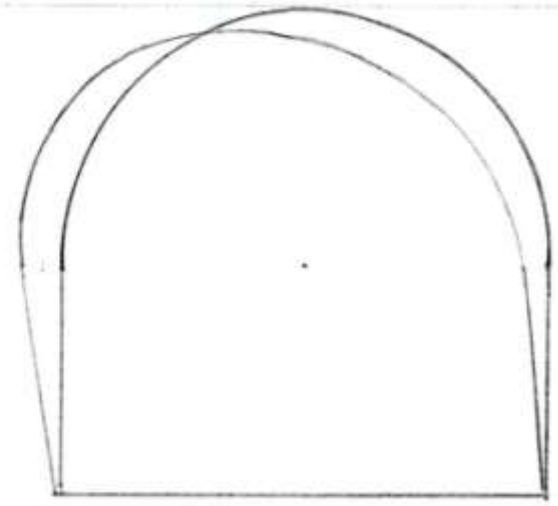
FOTOS 11, 12, 13  
TESTES COM REDUÇÃO  
DO ESCORAMENTO IN-  
TERNO QUANDO O RE-  
ATERRO ALCANÇA O  
TOPO DA GALERIA.



APLICAÇÃO MANUAL DO  
REATERRO



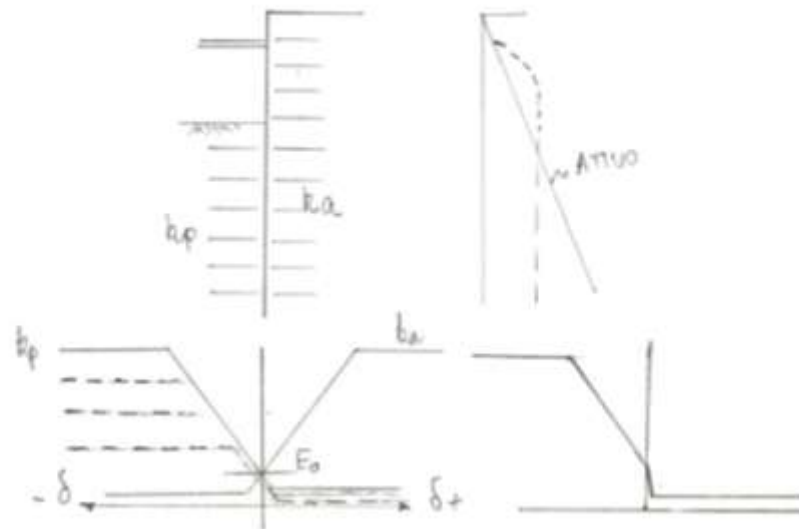
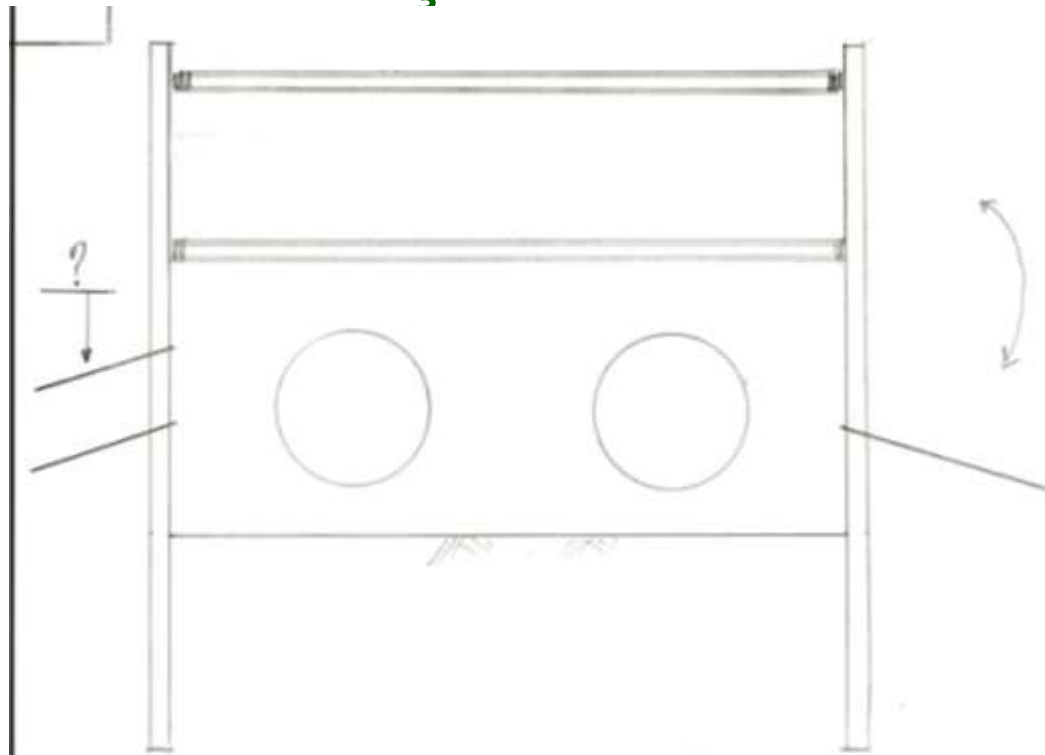
COLAPSO COM REATER-  
RO A 10 CM ACIMA  
DO TOPO DO TUBO.



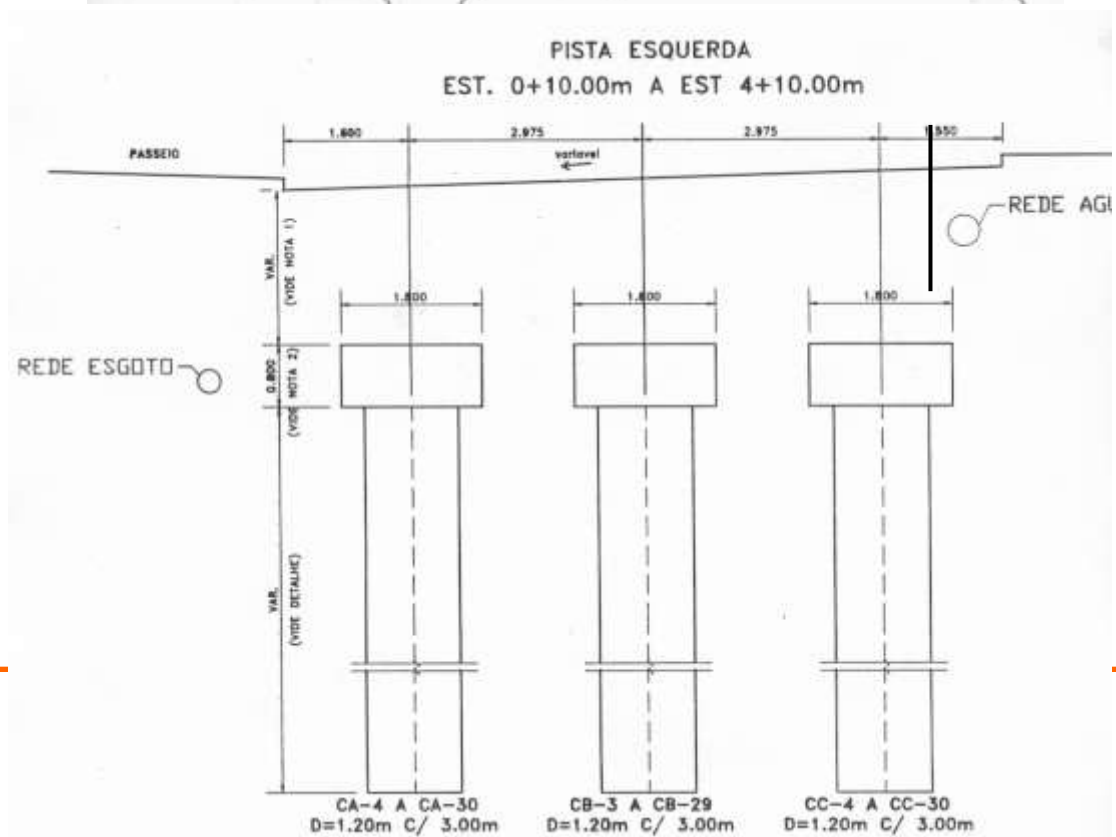
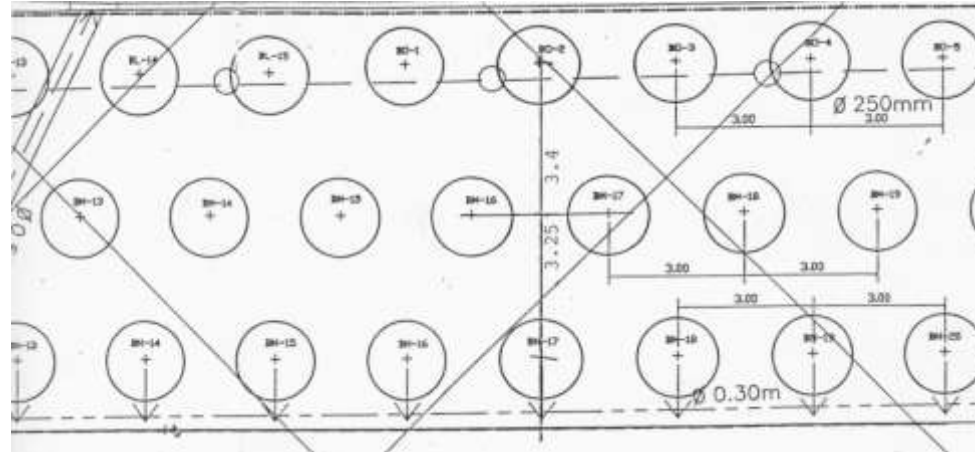
# MAFFEI ENGENHARIA (1982)

- ESTAÇÃO REPÚBLICA
- JAGUARÉ
- PRAÇA XV
- GARAGEM CLÍNICAS
- VIADUTO VÁRZEA PAULISTA
- AUMENTO DE CALADO DE PORTOS
- TÚNEIS:
  - SALVADOR
  - REBOUÇAS
  - CABULA
  - CAMG
- REAPRUMO NUNCIO MALZONI
  - BLOCO A
  - BLOCO B

# ESTAÇÃO REPÚBLICA

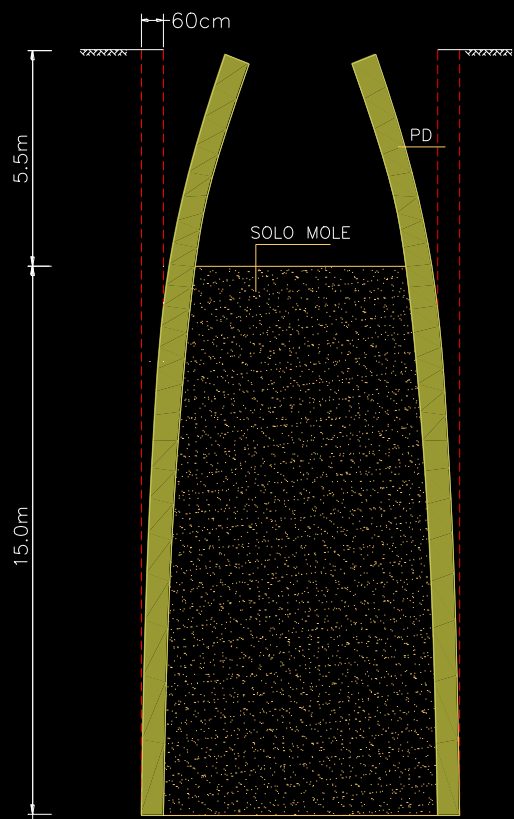


# JAGUARÉ

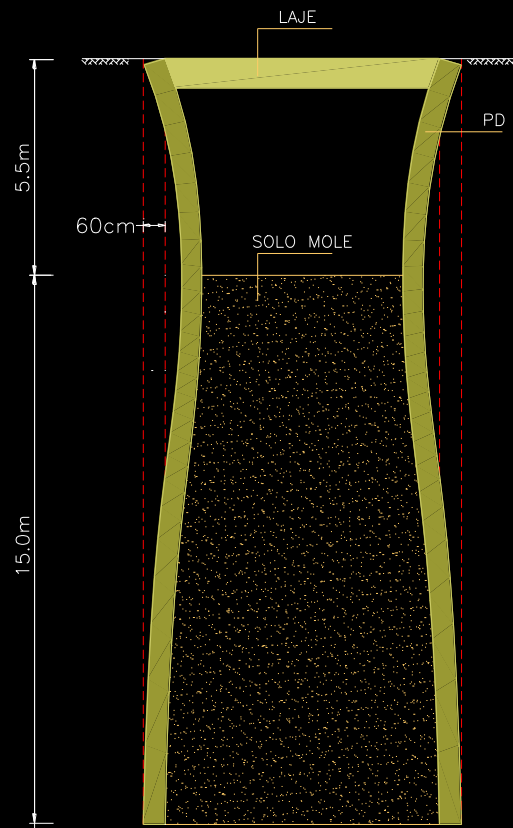


**PASSAGEM SUBTERRÂNEA – PRAÇA XV  
UMA UTILIZAÇÃO PIONEIRA DE JET-  
GROUTING**

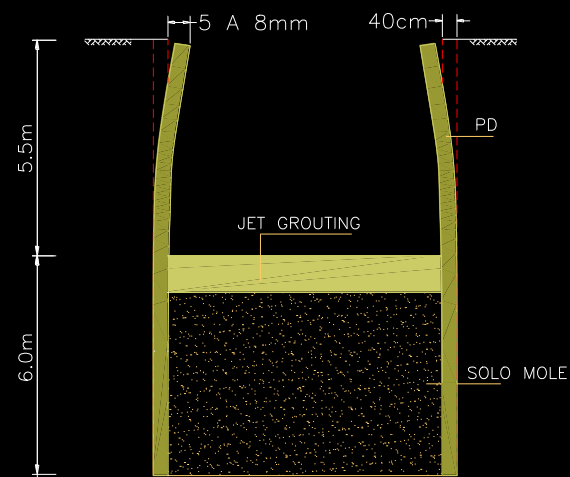
A) Balanço



B) Estronca de topo

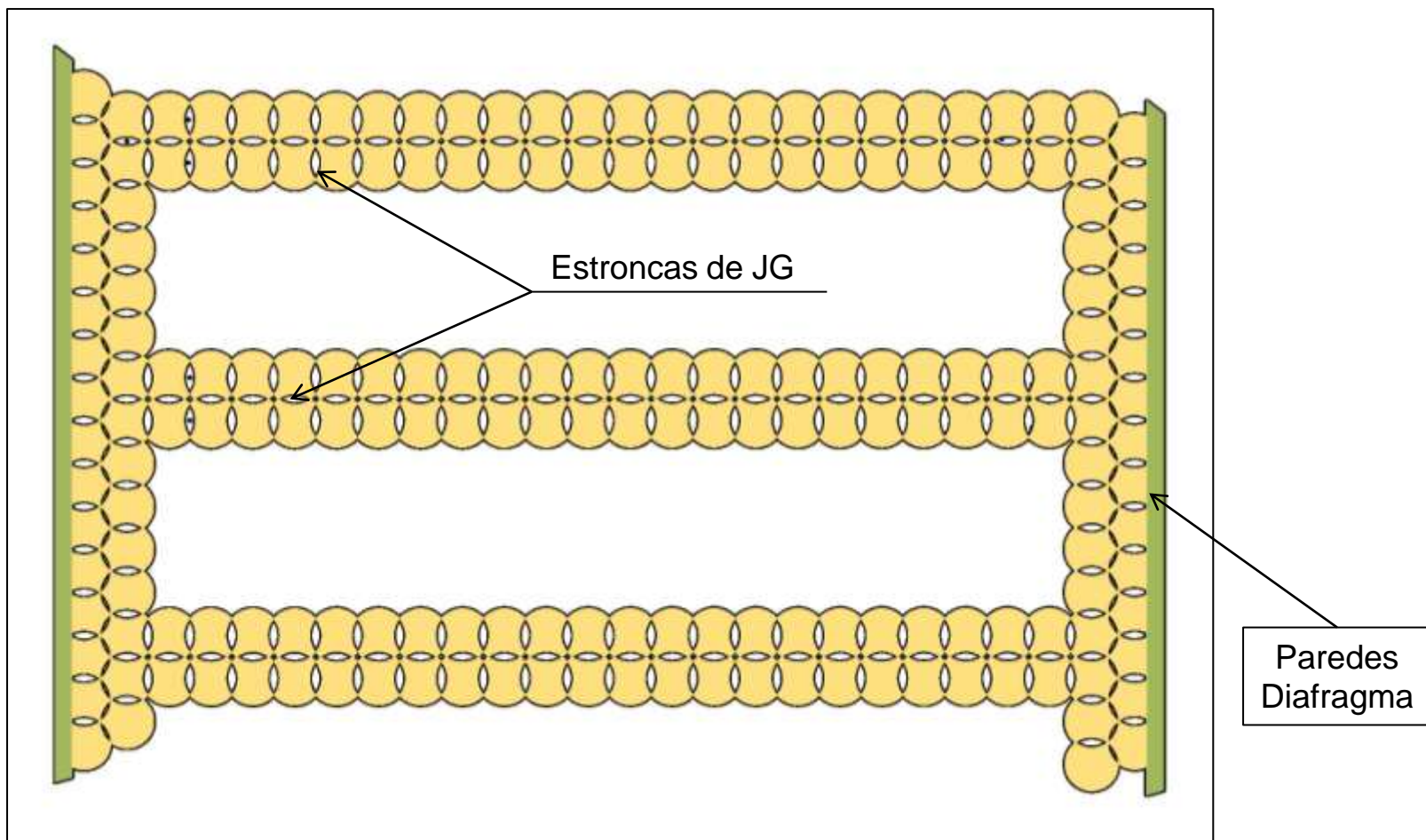


C) Estronca no nível do piso



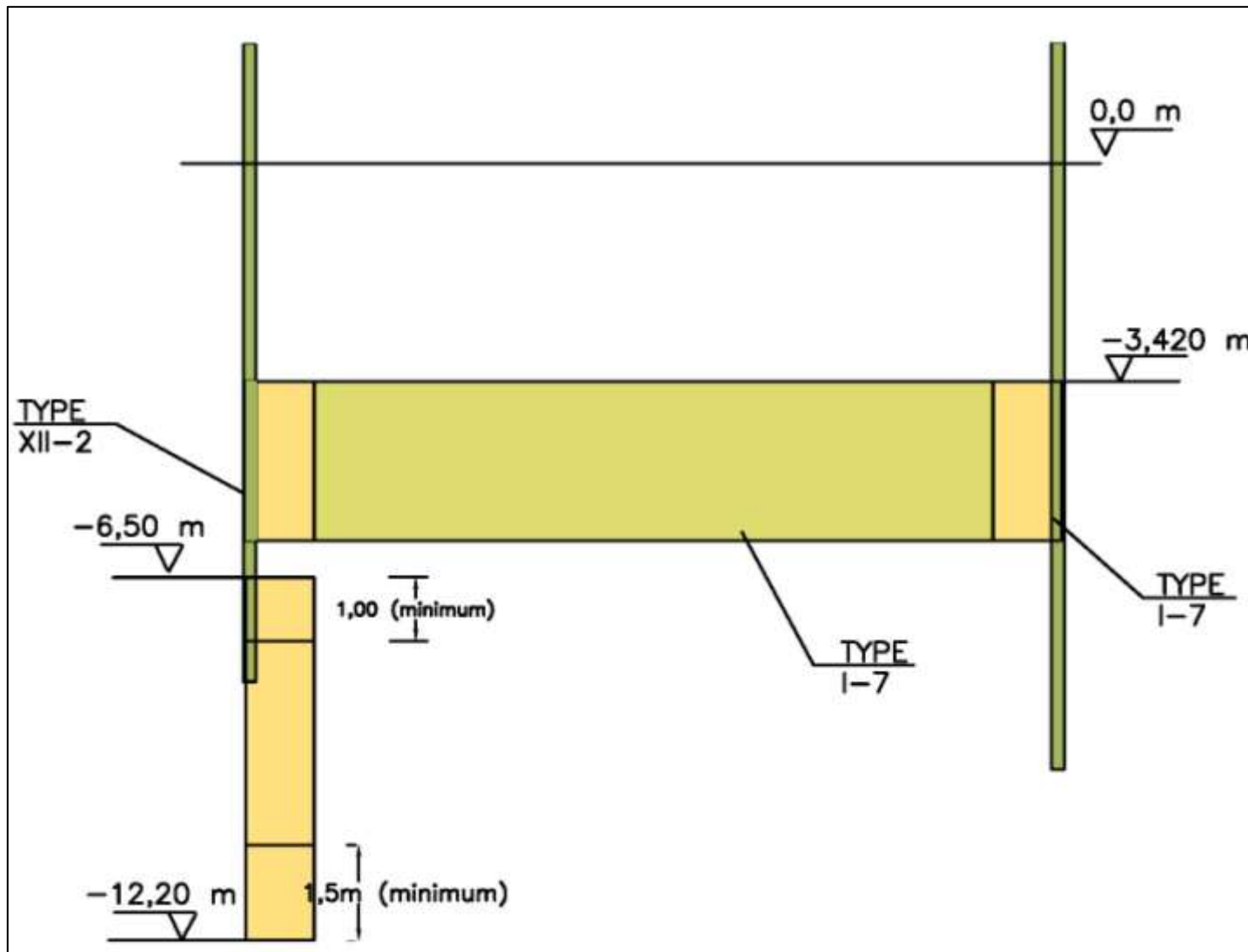
➤ *Comparação entre os deslocamentos das paredes diafragmas para diferentes situações de apoio*



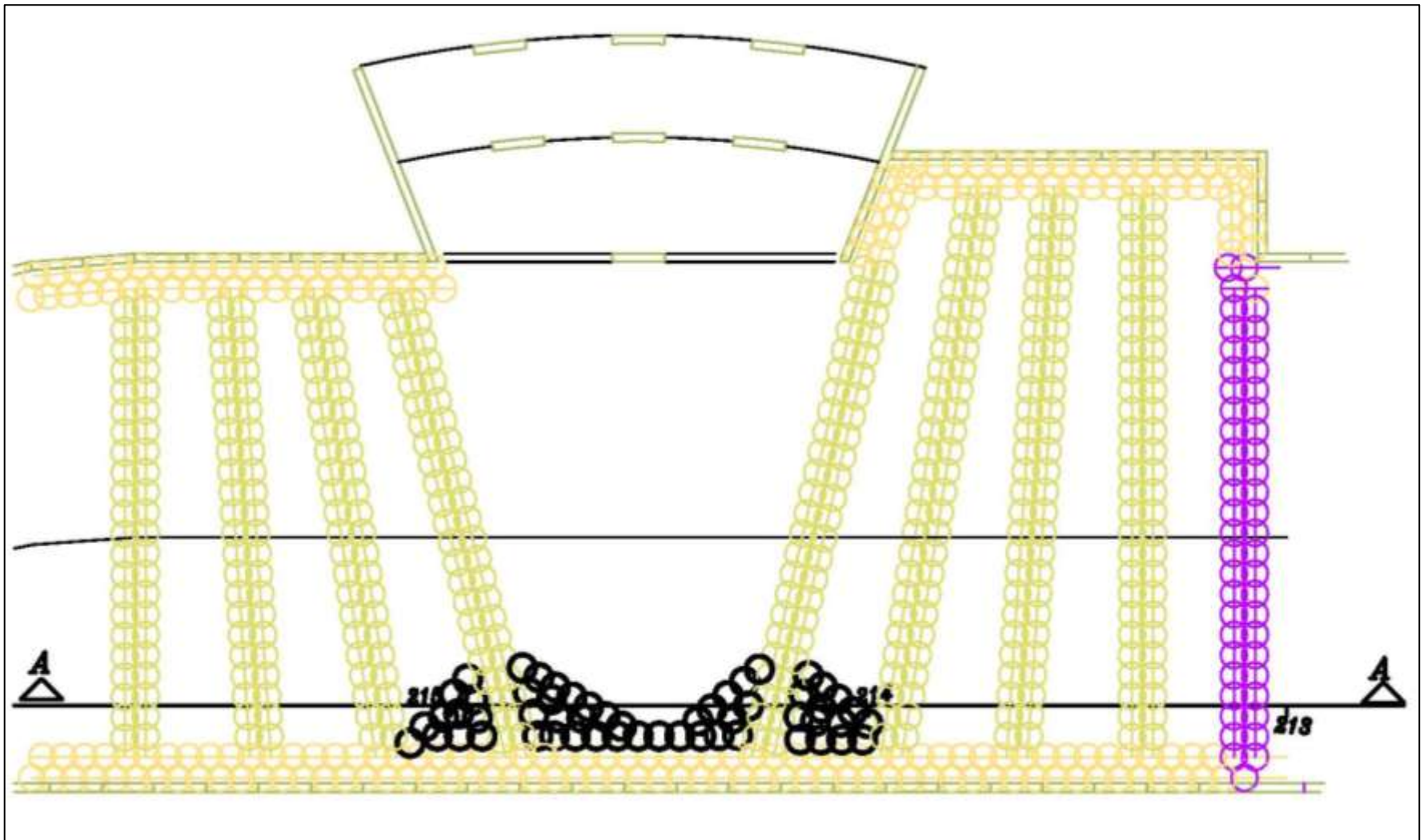


➤ *Vista esquemática em planta das colunas de JG utilizadas para o estroncamento inferior das paredes diafragma*

- Redução do comprimento da ficha
- Redução da espessura da parede diafragma



➤ Detalhe esquemático das colunas de JG utilizadas para garantir a estanqueidade da escavação

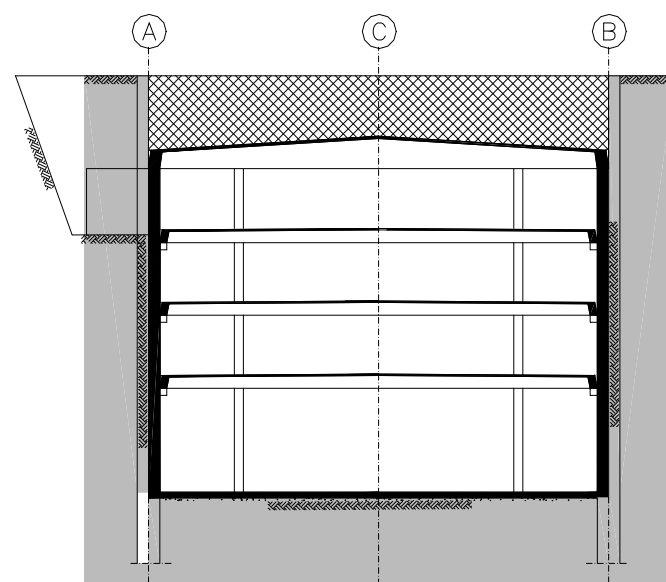
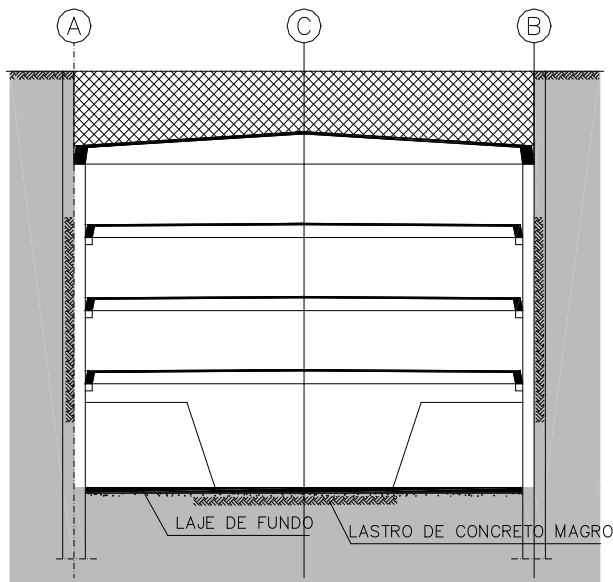
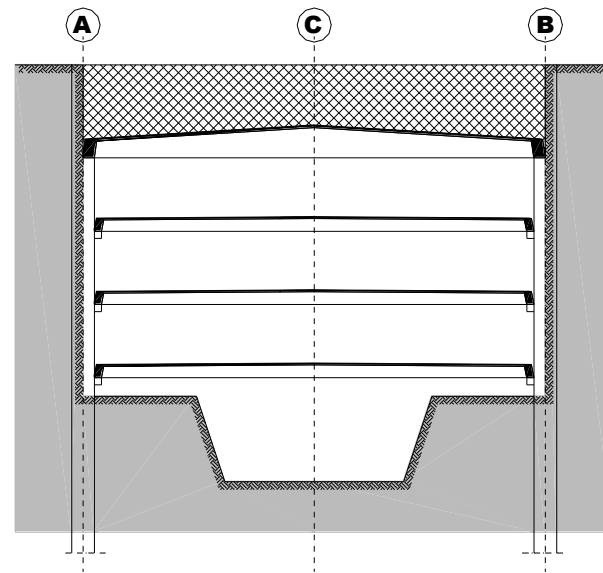
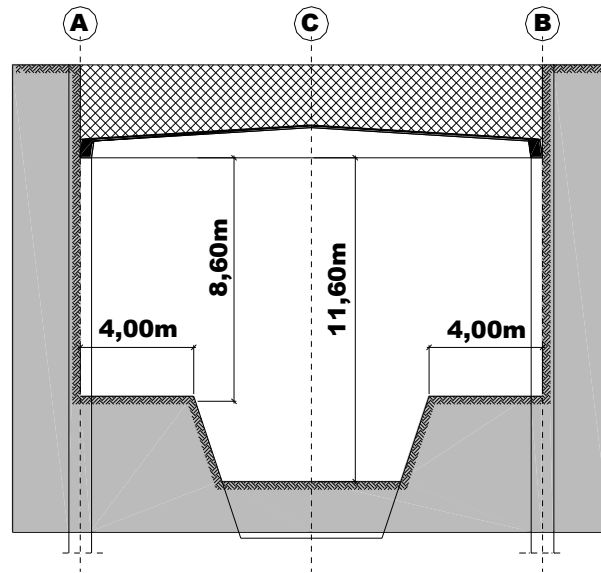


➤ *Distribuição e arranjo das estroncas de JG na passagem subterrânea da Praça XV*

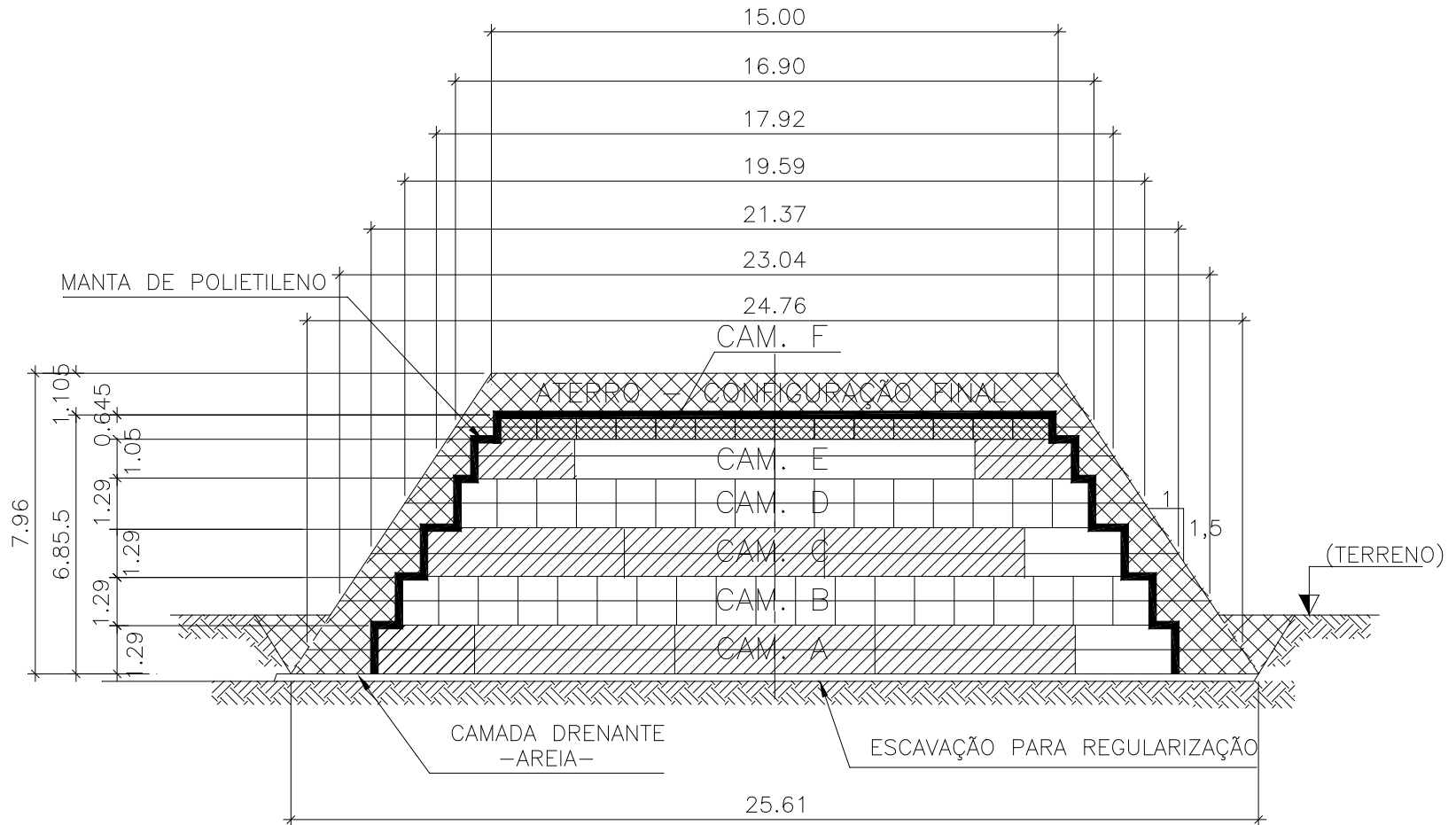


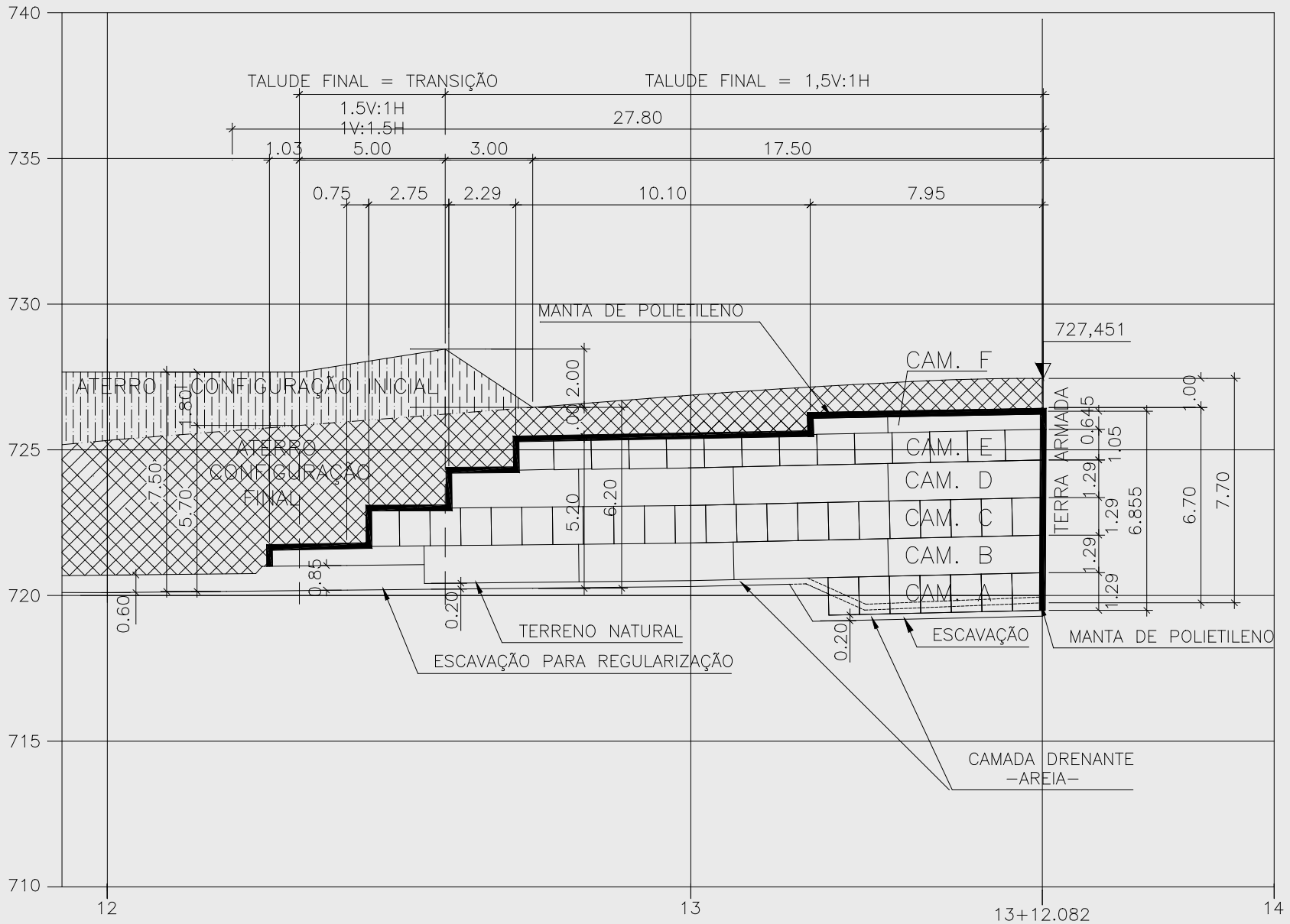


# GARAGEM CLÍNICAS



# VIADUTO VÁRZEA PAULISTA

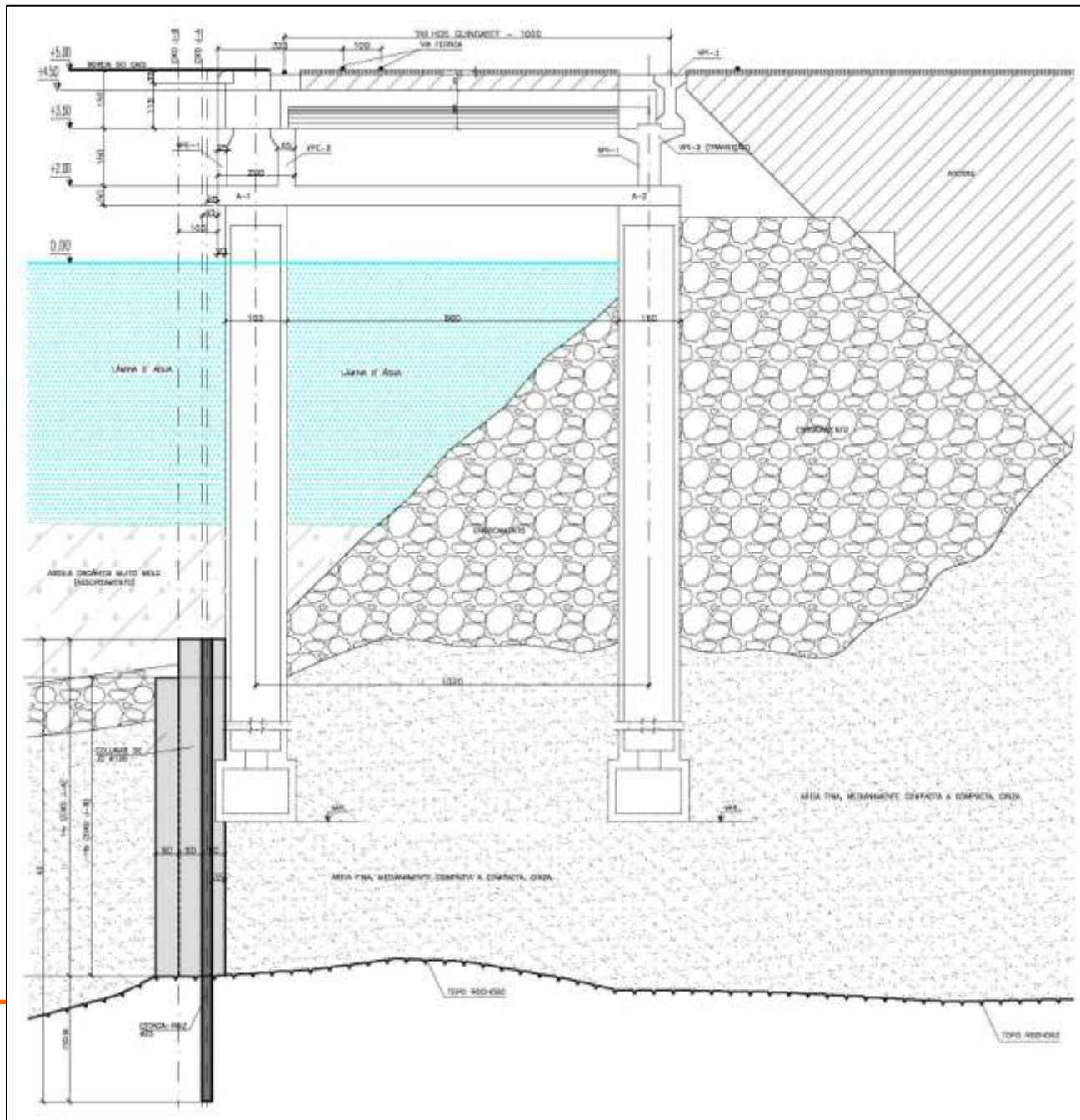


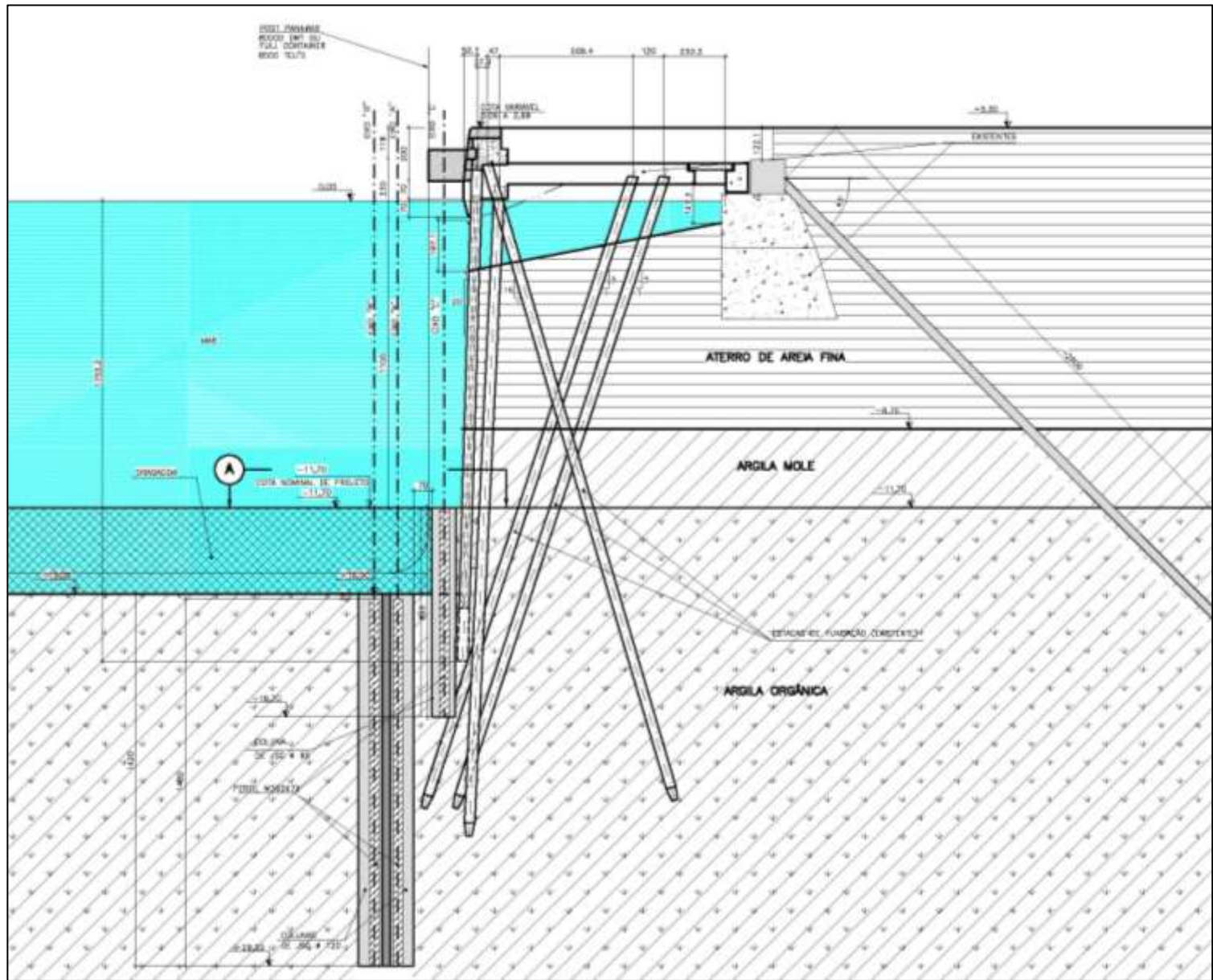






# **AUMENTO DO CALADO DE TERMINAIS PORTUÁRIOS**







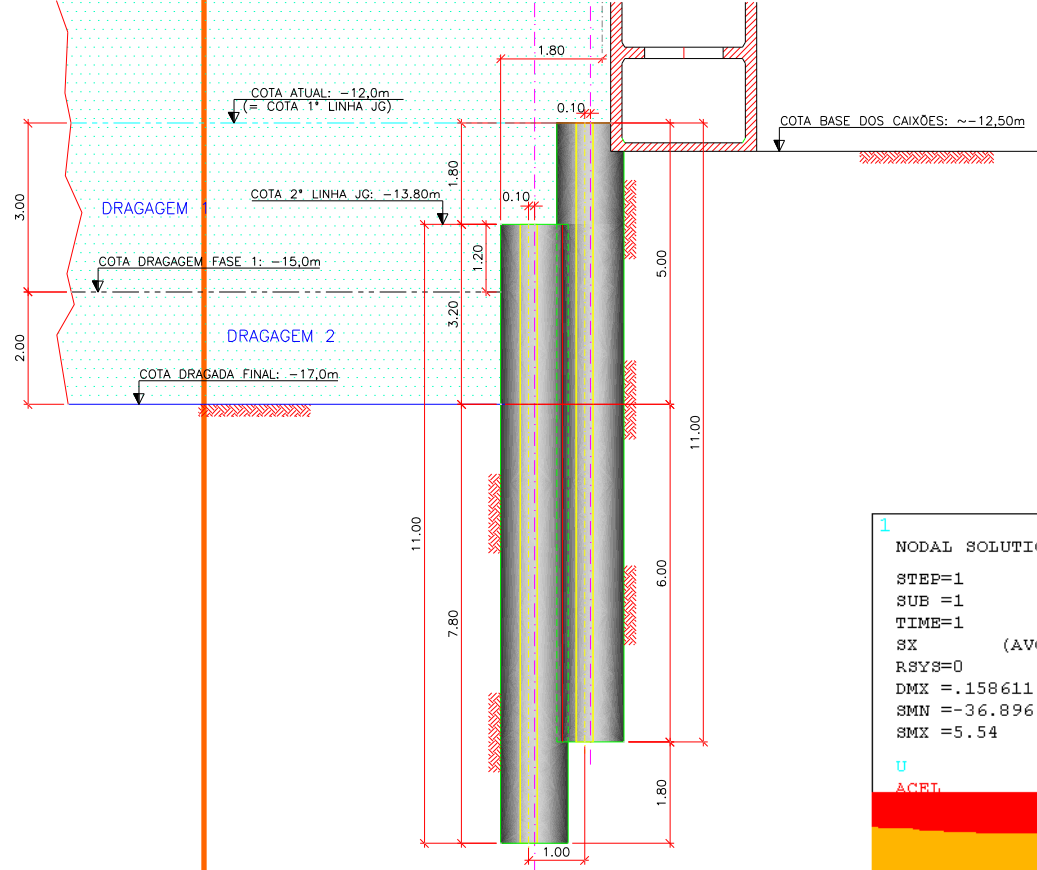




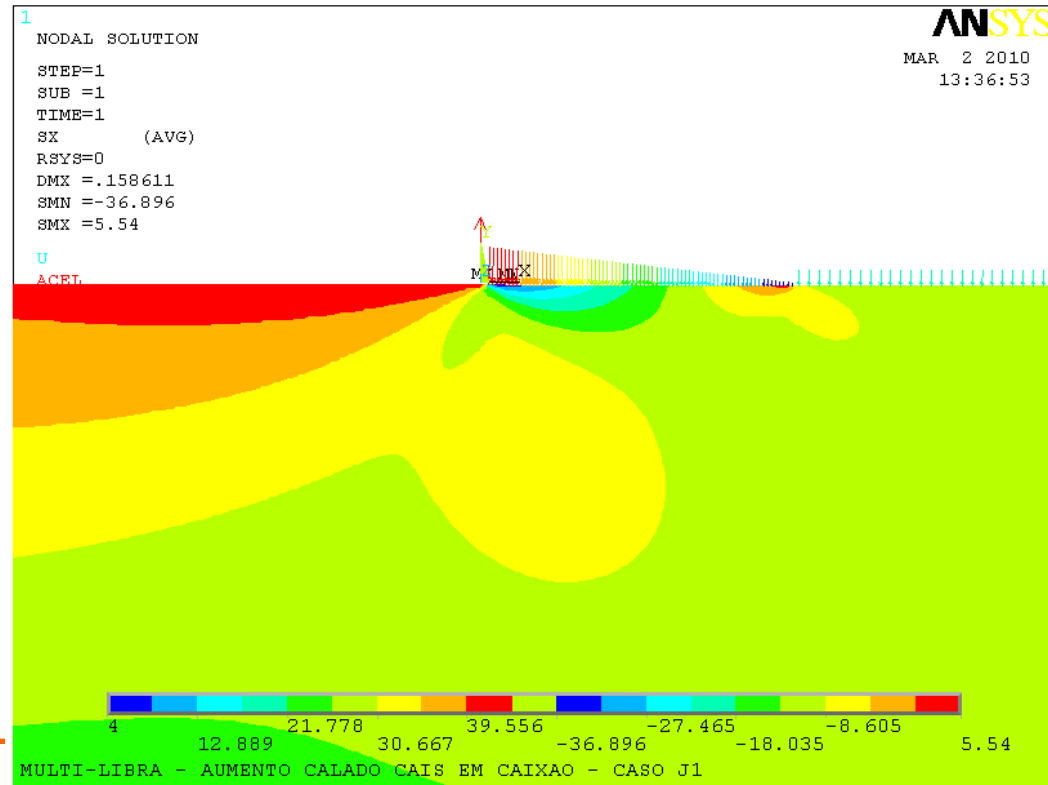
# AUMENTO DE CALADO CAIS CAIXÃO







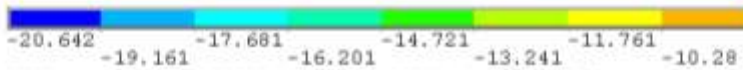
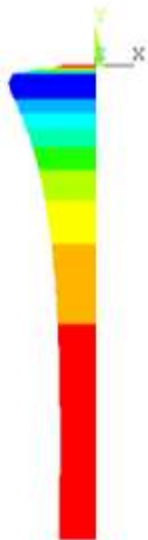
## GEOMETRIA DO REFORÇO



## MODELO CONTÍNUO PARA OBTENÇÃO DOS EMPUXOS

1  
PATH= J9  
VALUE= BX  
SCAL=20

ANSYS  
MAR 2 2010  
13:31:21



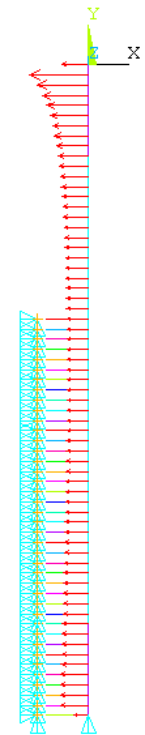
MULTI-LIBRA - AUMENTO CALADO CAIS EM CAIXAO - CASO I1

### EMPUXOS NA FACE ESCAVADA

1

E-L  
U  
ROT  
F

ANSYS  
MAR 2 2010  
13:48:50

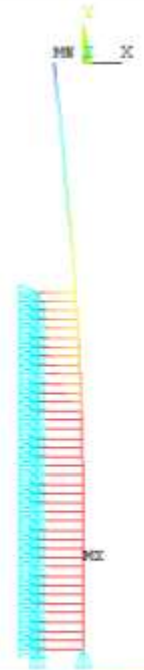


MULTIRIO - AUMENTO CALADO CAIS EM CAIXAO - CASO FINAL 4

### MODELO ANSYS BARRAS E MOLAS - DRAGAGEM

MODAL SOLUTION

STEP=1  
SUB =1  
TIME=1  
UX (AVG)  
RSTB=0  
DMX =.034351  
SMN =-.034351  
SMX =.323E-03

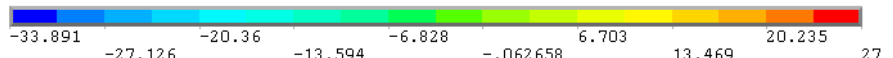
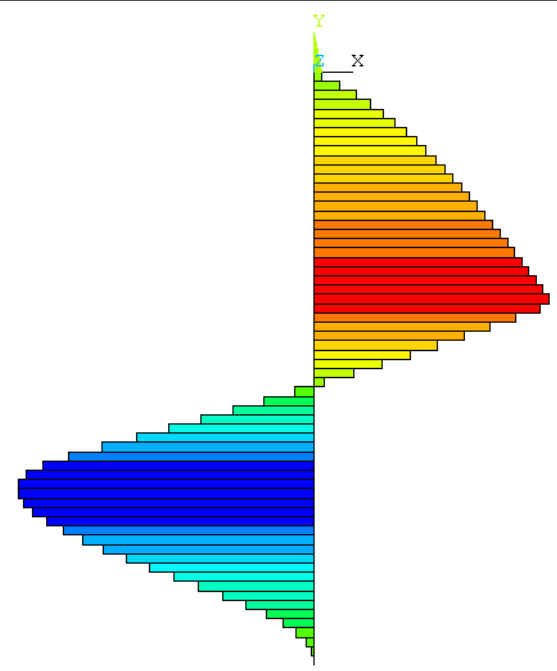


MULTIRIO - AUMENTO CALADO CAIS EM CAIXAO - CASO FINAL 4

**DESLOCAMENTOS DO REFOÇO APÓS DRAGAGEM**

1  
LINE STRESS

STEP=1  
SUB =1  
TIME=1  
VI VJ  
MIN =-33.891  
ELEM=121  
MAX =27  
ELEM=186

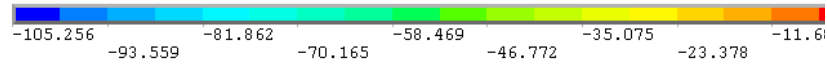
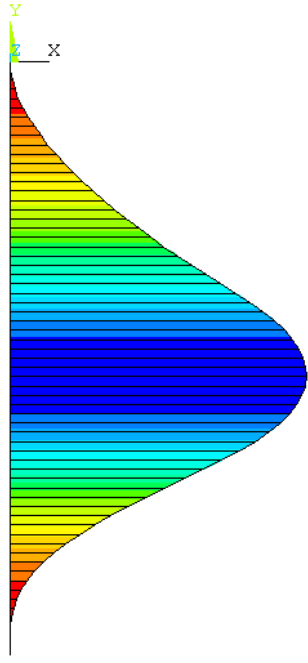


MULTIRIO - AUMENTO CALADO CAIS EM CAIXAO - CASO FINAL 4

**FORÇAS CORTANTES NO REFORÇO APÓS DRAGAGEM**

LINE STRESS  
STEP=1  
SUB =1  
TIME=1  
MI MJ  
MIN =-105.256  
ELEM=109  
MAX =.015675  
ELEM=201

ANSYS  
MAR 2 2010  
13:54:15



MULTIRIO - AUMENTO CALADO CAIS EM CAIXAO - CASO FINAL 4

### MOMENTOS FLETORES NO REFORÇO APÓS DRAGAGEM

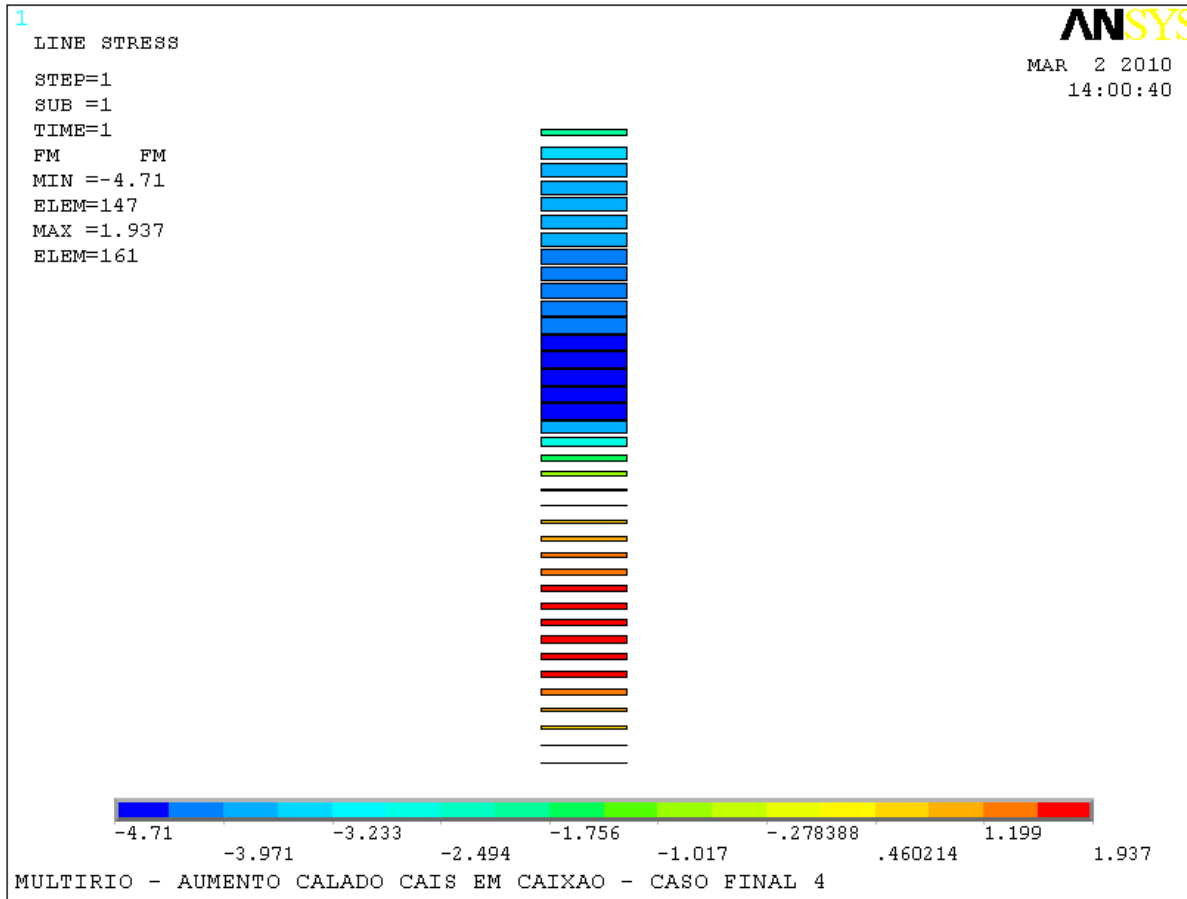
ANSYS  
MAR 2 2010  
13:59:28

LINE STRESS  
STEP=1  
SUB =1  
TIME=1  
SLIDE SLIDE  
MIN =-.00836  
ELEM=131  
MAX =0  
ELEM=148



MULTIRIO - AUMENTO CALADO CAIS EM CAIXAO - CASO FINAL 4

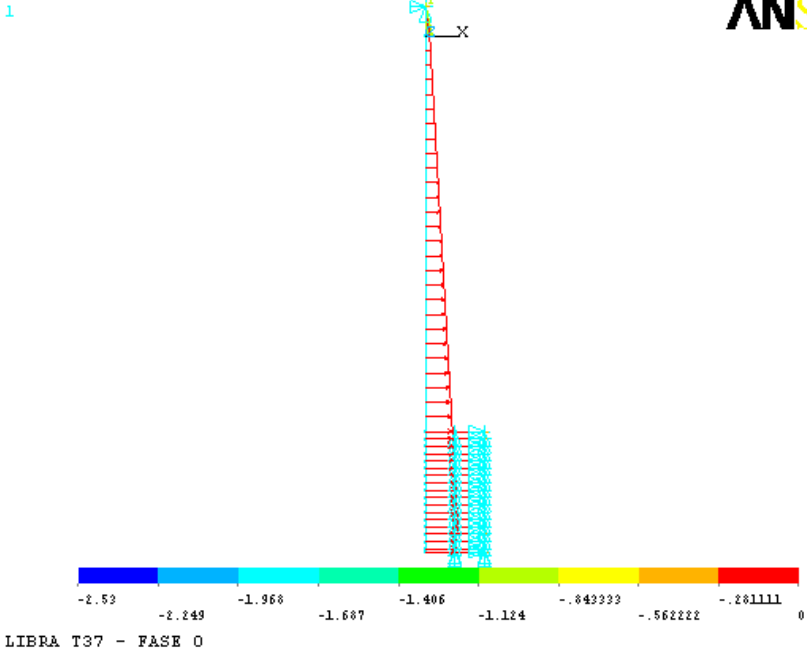
### MOLAS PLASTIFICADAS NO PASSIVO DO REFORÇO APÓS DRAGAGEM



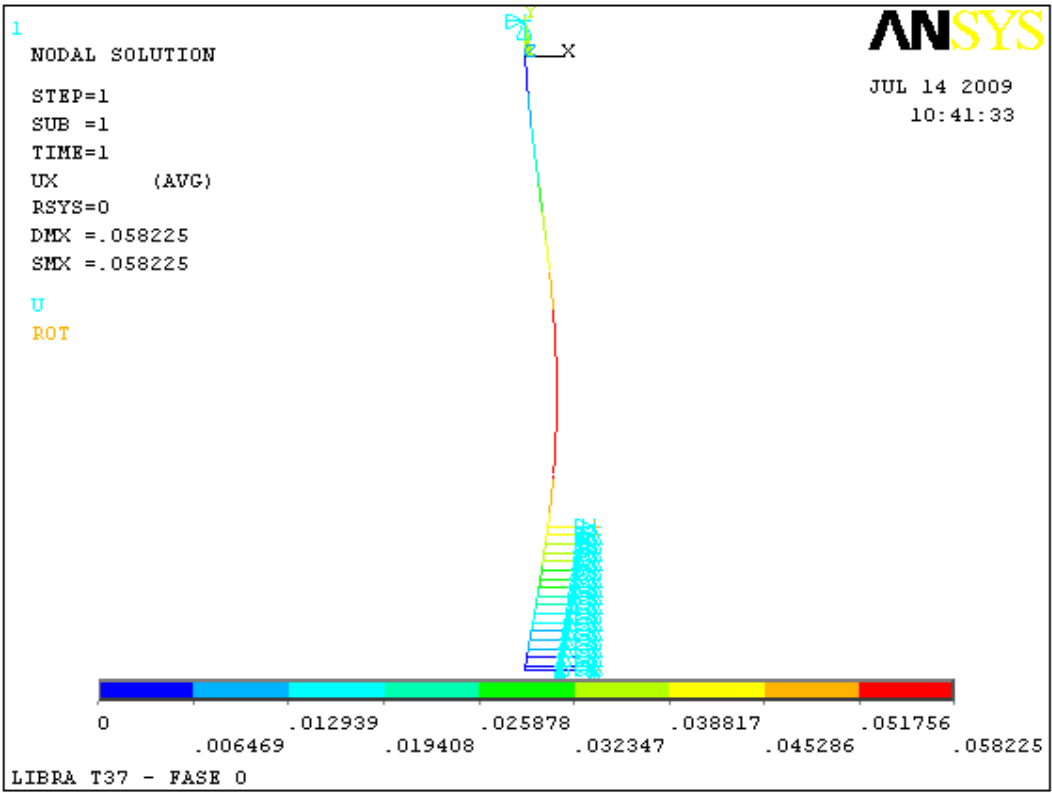
### FORÇAS DA MOLAS (SOLO) APÓS DRAGAGEM

# AUMENTO DE CALADO SANTOS





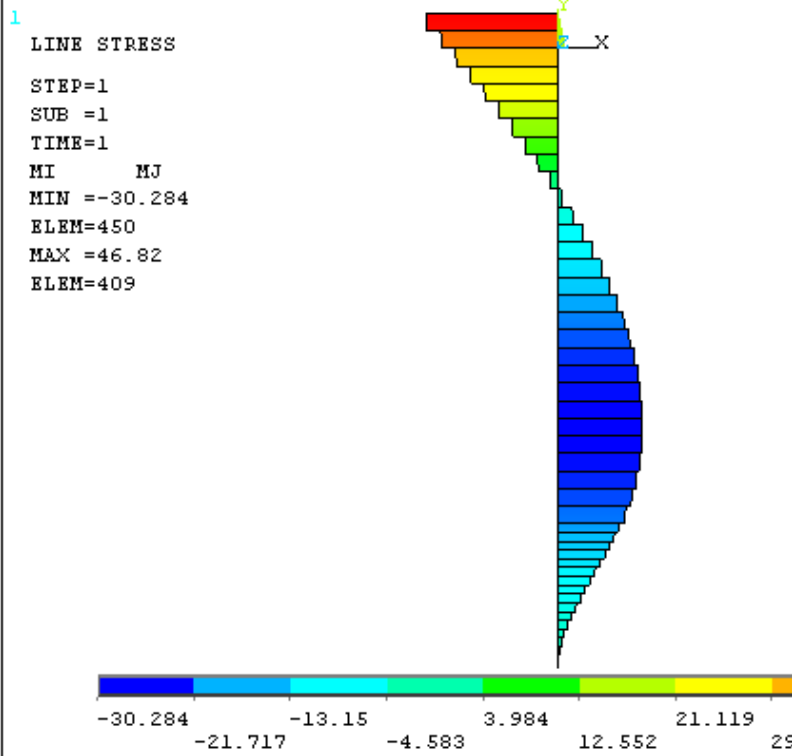
CARREGAMENTO INICIAL NAS ESTACAS PRANCHA



DESLOCAMENTOS INICIAIS DA ESTACA PRANCHA

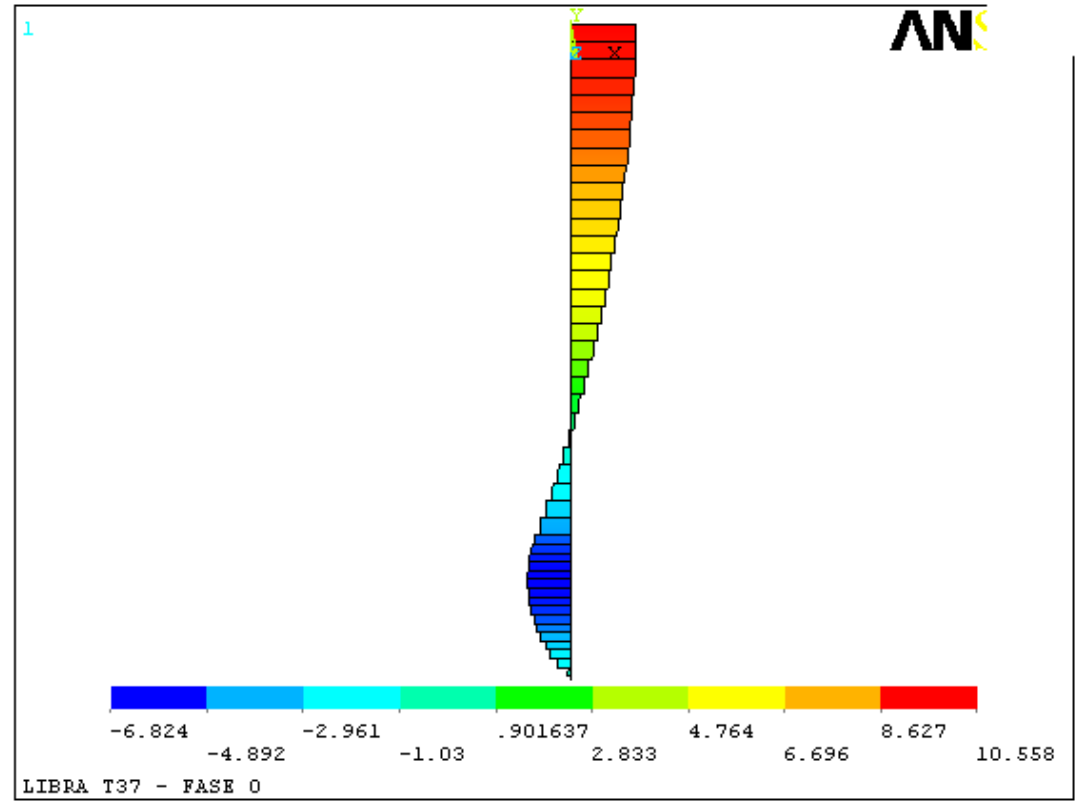


JUL 14 2009  
10:43:01



LIBRA T37 - FASE 0

**MOMENTOS FLETORES INICIAIS DA ESTACA PRANCHA**



**FORÇAS CORTANTES INICIAIS DA ESTACA PRANCHA**





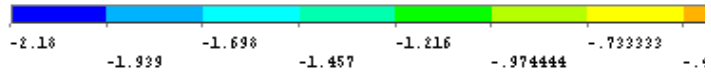
JUL 14 2009

10:44:01

1

ELEMENT SOLUTION

STEP=1  
 SUB =1  
 TIME=1  
 FM (NOAVG)  
 DMX =.058225  
 SMN =-2.18  
 SMX =-.01



LIBRA T37 - FASE 0

FORÇAS DAS MOLAS FASE INICIAL



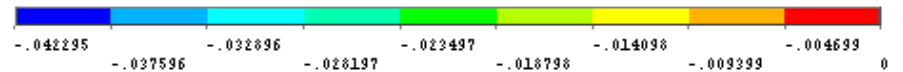
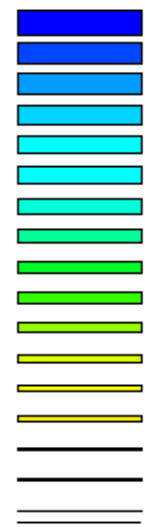
JUL 14 2009

10:55:22

1

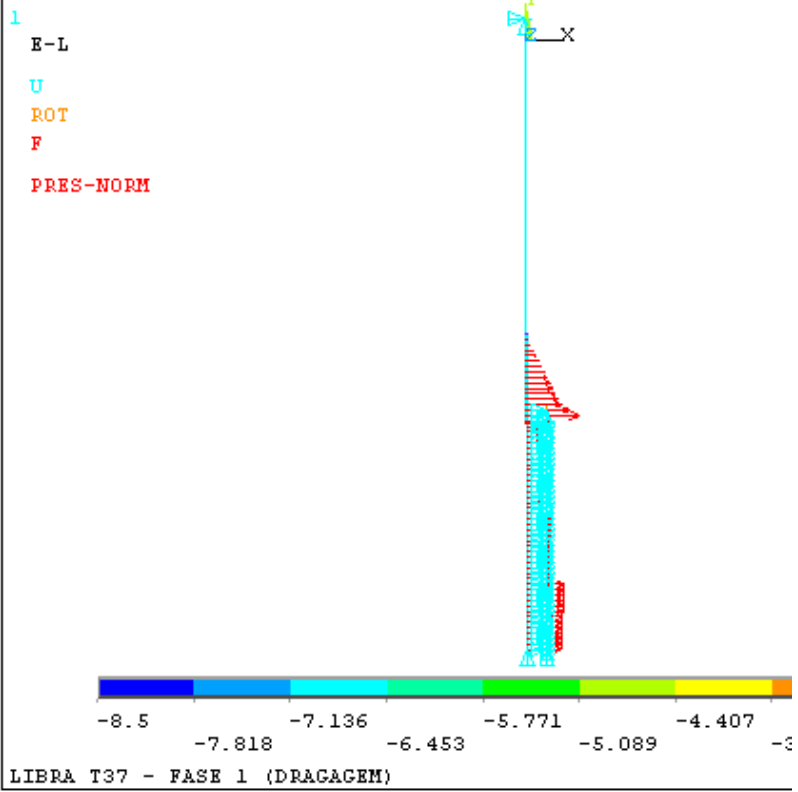
LINE STRESS

STEP=1  
 SUB =1  
 TIME=1  
 SLIDE SLIDE  
 MIN =-.042295  
 ELEM=374  
 MAX =0  
 ELEM=406



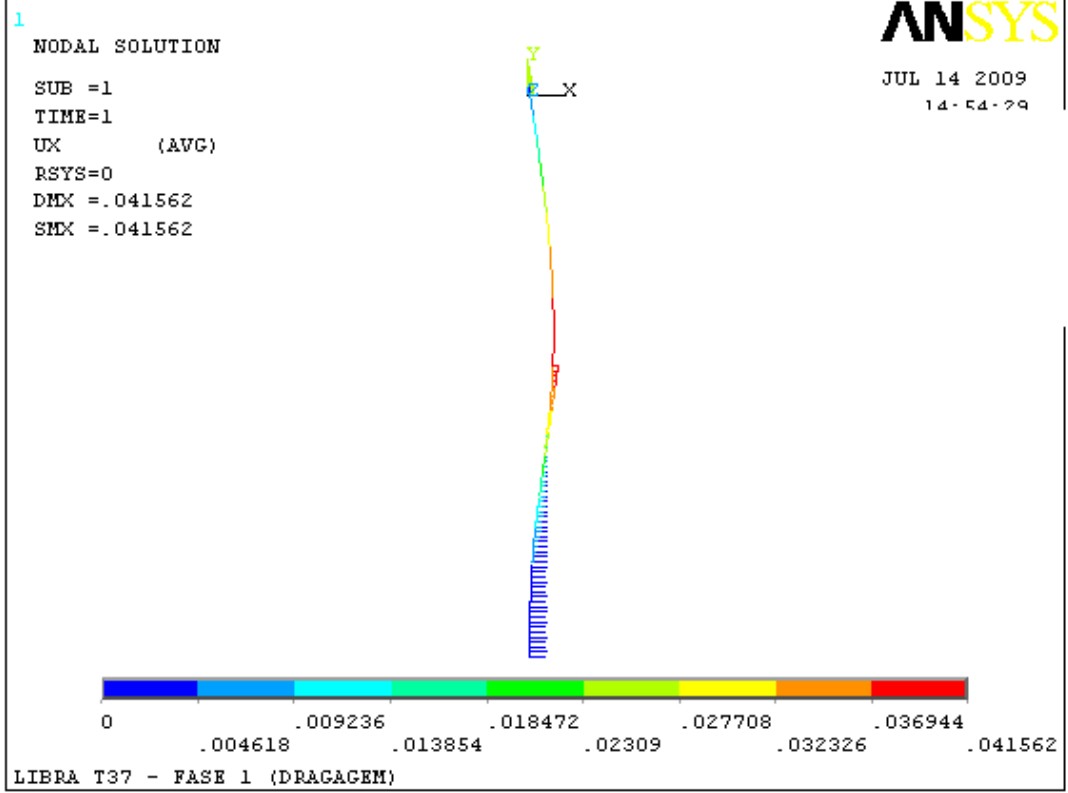
LIBRA T37 - FASE 0

MOLAS PLASTIFICADAS NA FASE INICIAL



**ANSYS**

JUL 14 2009  
14:53:14



**ANSYS**

JUL 14 2009  
14:54:29

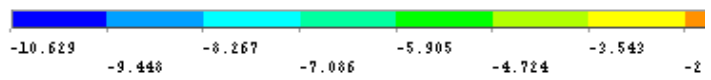
**CARREGAMENTOS NA FASE DRAGADA C/  
REFORÇO INSTALADO**

**DESLOCAMENTOS NA FASE DRAGADA C/ REFORÇO INSTALADO**

1

LINE STRESS

SUB =1  
TIME=1  
MI MJ  
MIN =-10.629  
ELEM=416  
MAX =.115E-06  
ELEM=409



LIBRA T37 - FASE 1 (DRAGAGEM)

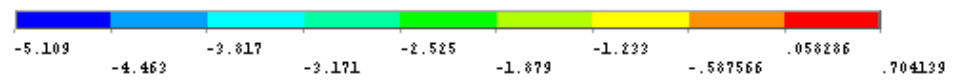
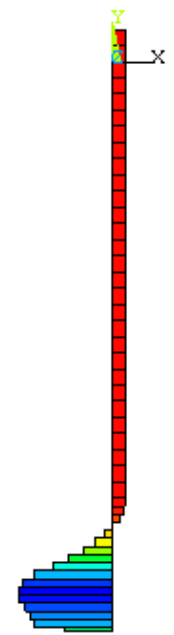


JUL 14 2009  
14:56:47

1

LINE STRESS

SUB =1  
TIME=1  
VI VJ  
MIN =-5.109  
ELEM=423  
MAX =.704139  
ELEM=409



LIBRA T37 - FASE 1 (DRAGAGEM)

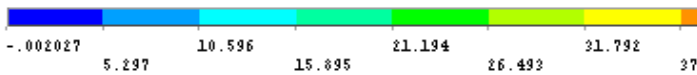
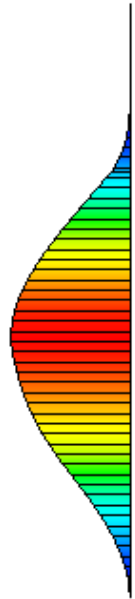


JUL 14 2009  
14:56:59

MOMENTOS FLETORES ADICIONAIS NA ESTACA PRANCHA

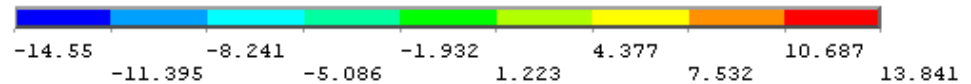
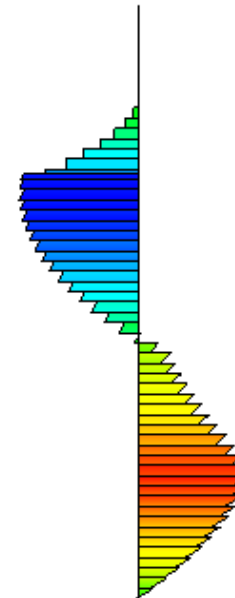
FORÇAS CORTANTES ADICIONAIS NA ESTACA PRANCHA

1  
LINE STRESS  
SUB =1  
TIME=1  
MI MJ  
MIN =-.002027  
ELEM=483  
MAX =47.69  
ELEM=507



LIBRA T37 - FASE 1 (DRAGAGEM)

1  
LINE STRESS  
SUB =1  
TIME=1  
VI VJ  
MIN =-14.55  
ELEM=493  
MAX =13.841  
ELEM=521

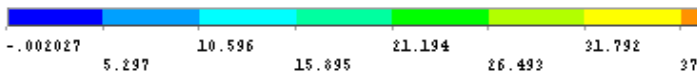
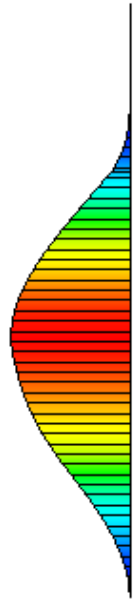


LIBRA T37 - FASE 1 (DRAGAGEM)

**MOMENTOS FLETORES NOS REFORÇOS EM JG+PERFIS**

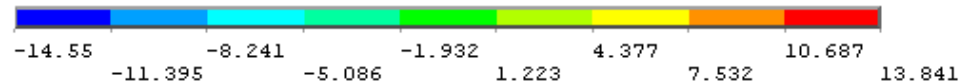
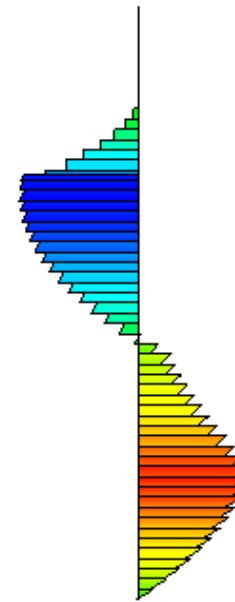
**FORÇAS CORTANTES NOS REFORÇOS EM JG+PERFIS**

1  
LINE STRESS  
SUB =1  
TIME=1  
MI MJ  
MIN =-.002027  
ELEM=483  
MAX =47.69  
ELEM=507



LIBRA T37 - FASE 1 (DRAGAGEM)

1  
LINE STRESS  
SUB =1  
TIME=1  
VI VJ  
MIN =-14.55  
ELEM=493  
MAX =13.841  
ELEM=521



LIBRA T37 - FASE 1 (DRAGAGEM)

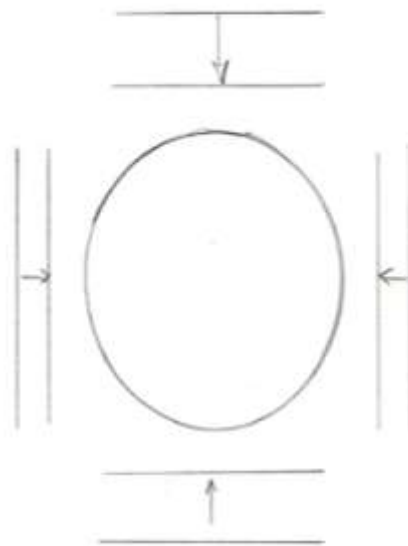
**MOMENTOS FLETORES NOS REFORÇOS EM JG+PERFIS**

**FORÇAS CORTANTES NOS REFORÇOS EM JG+PERFIS**

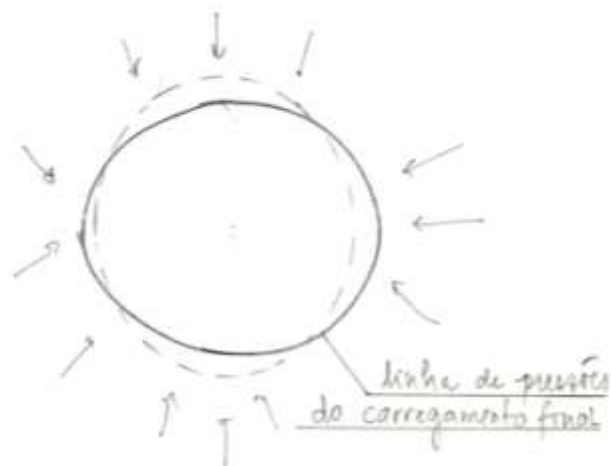
TÚNEIS

# NÃO-LINEARIDADE GEOMÉTRICA

REVESTIMENTOS FLEXÍVEIS  $\frac{E_1 t_1}{E_2 t_2}$ ; articulações

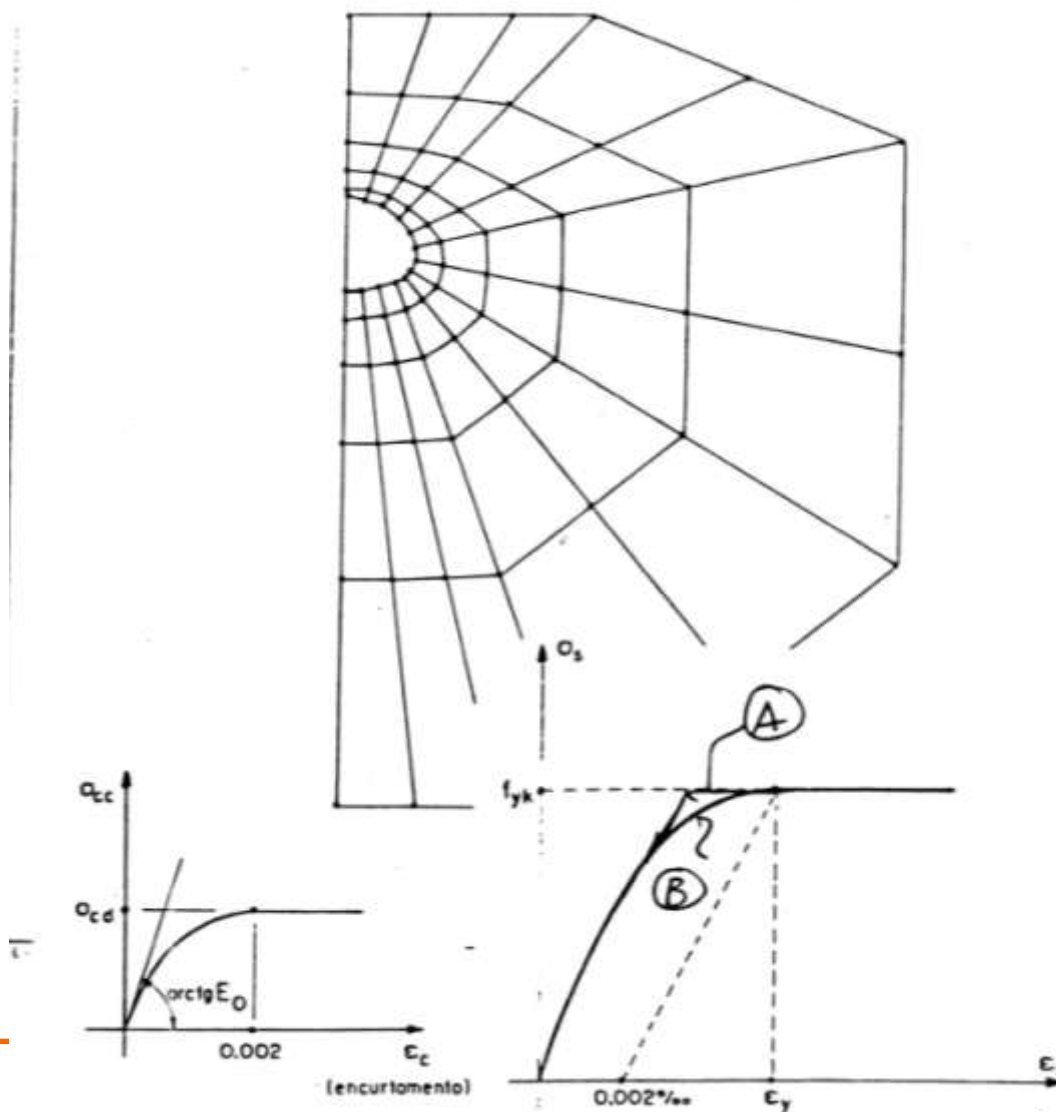


MÍNIMA ENERGIA



# NÃO-LINEARIDADE FÍSICA

## RÓTULAS PLÁSTICAS ?





## NÃO-LINEARIDADE FÍSICA

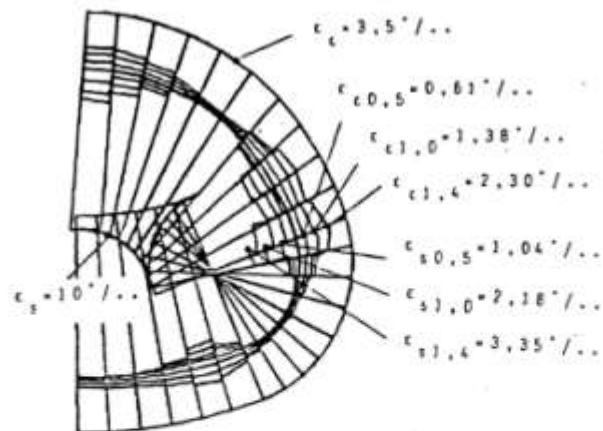


Figura 4.1.3 - Revestimento de Concreto Simples. Diagramas de Deformações Específicas no Concreto e na Fibra Correspondente à Posição da Armadura de Tração.

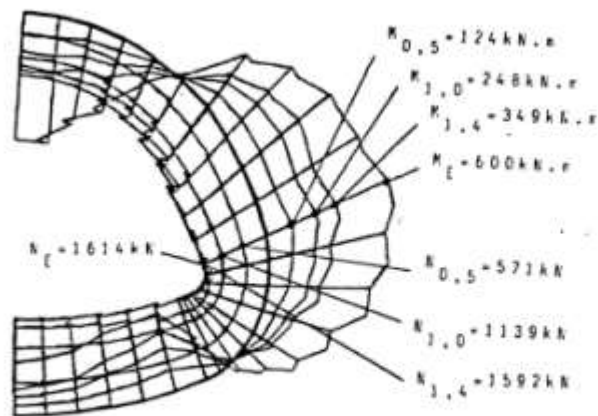
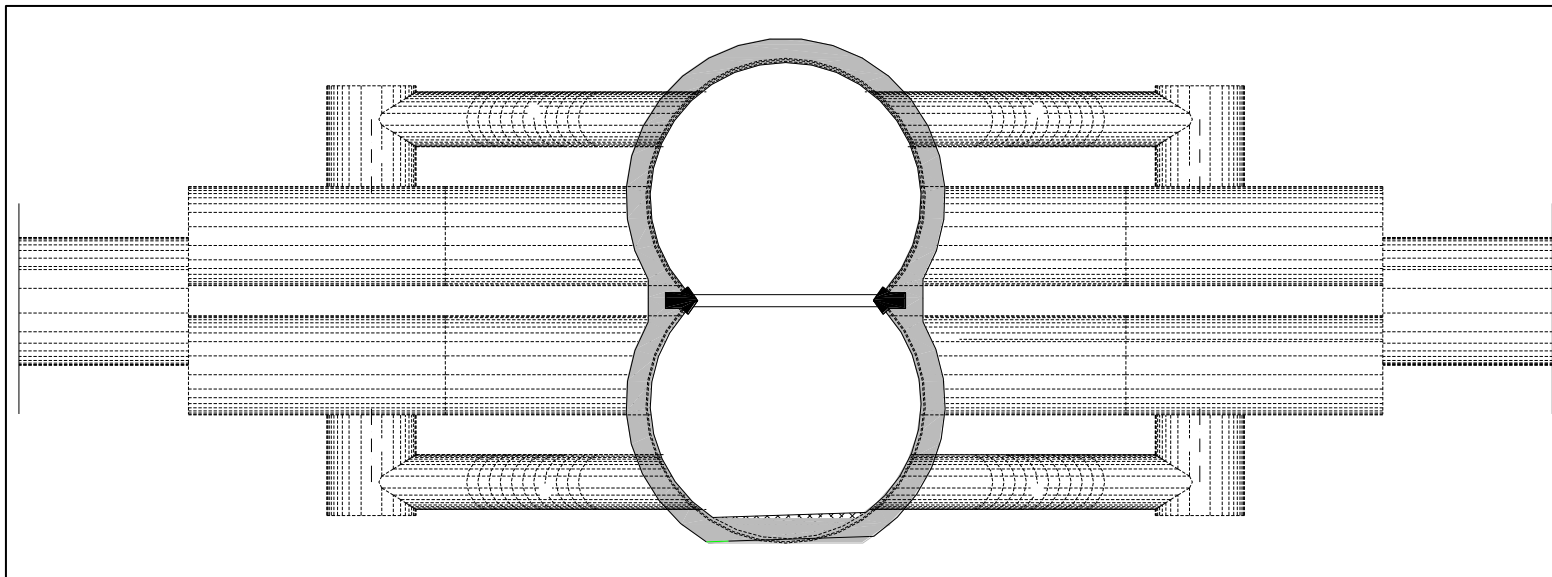
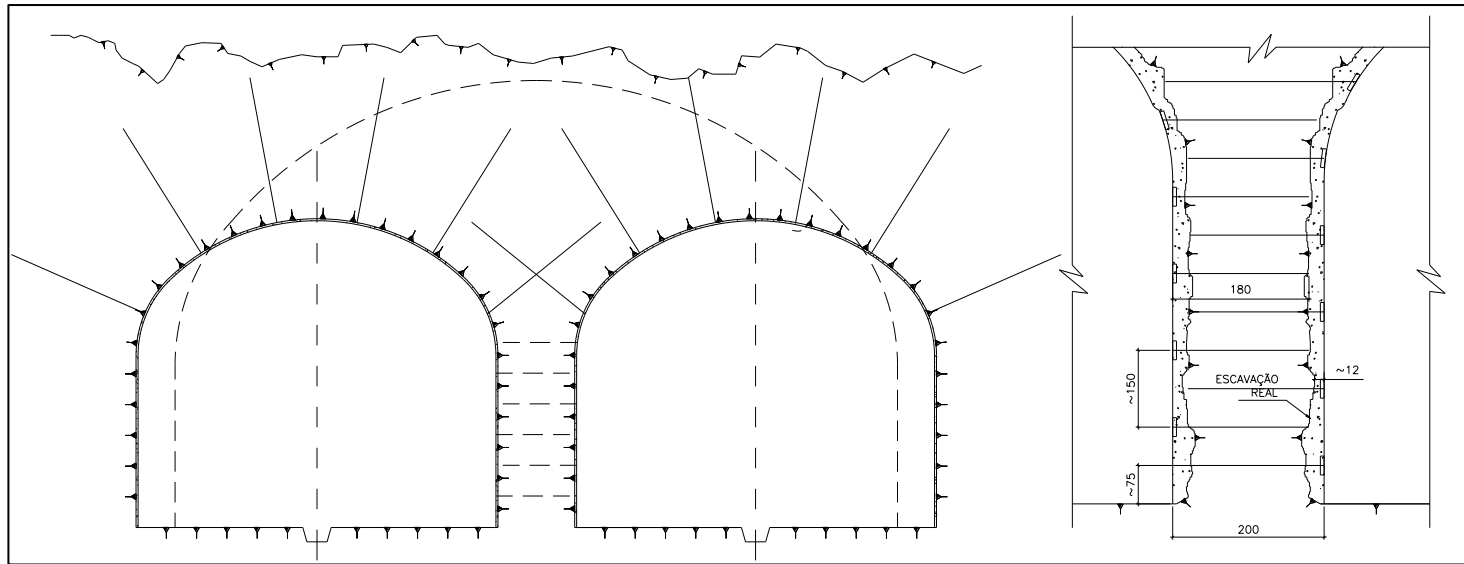


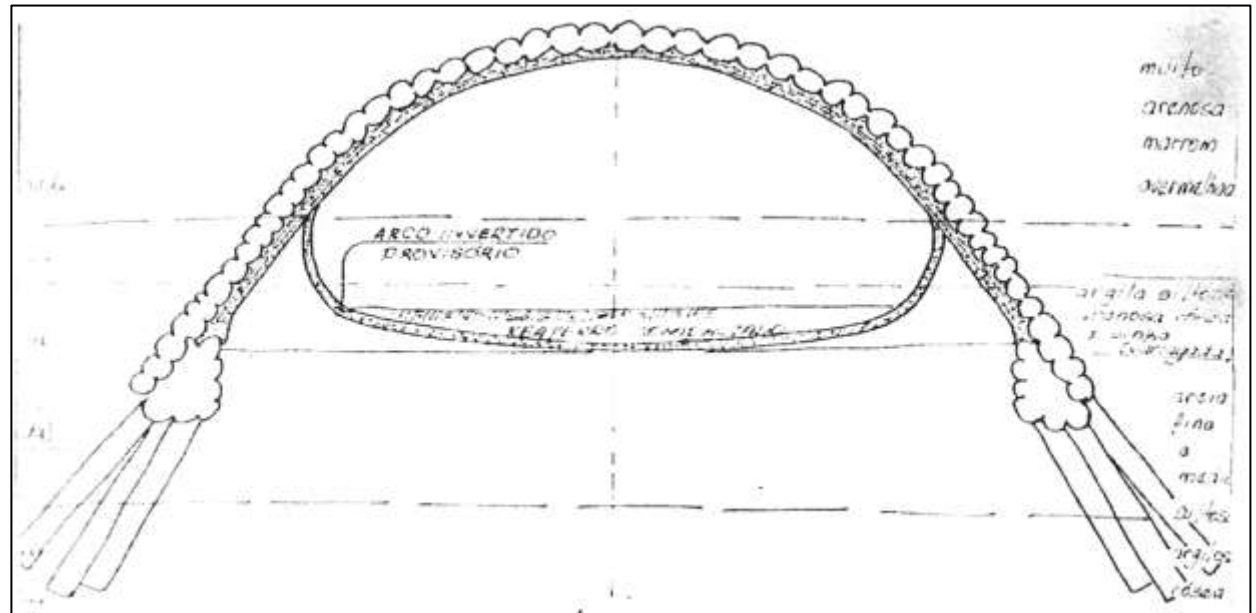
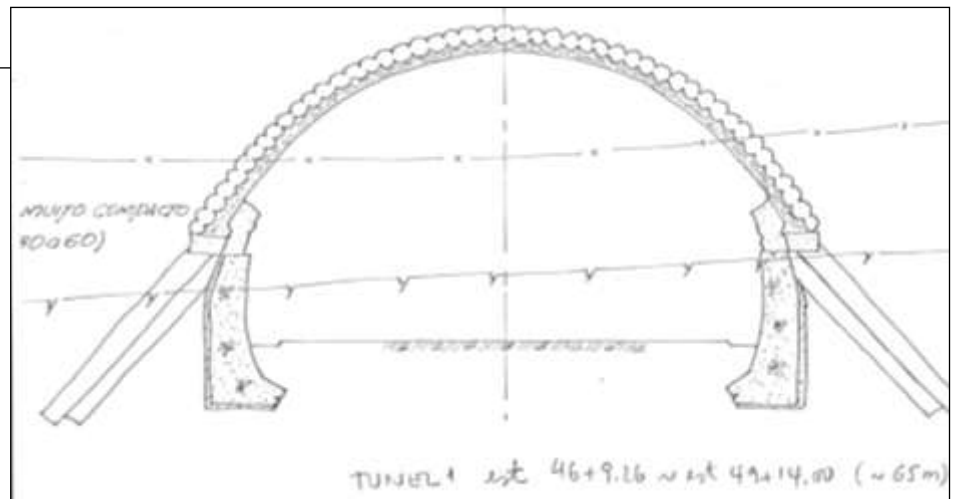
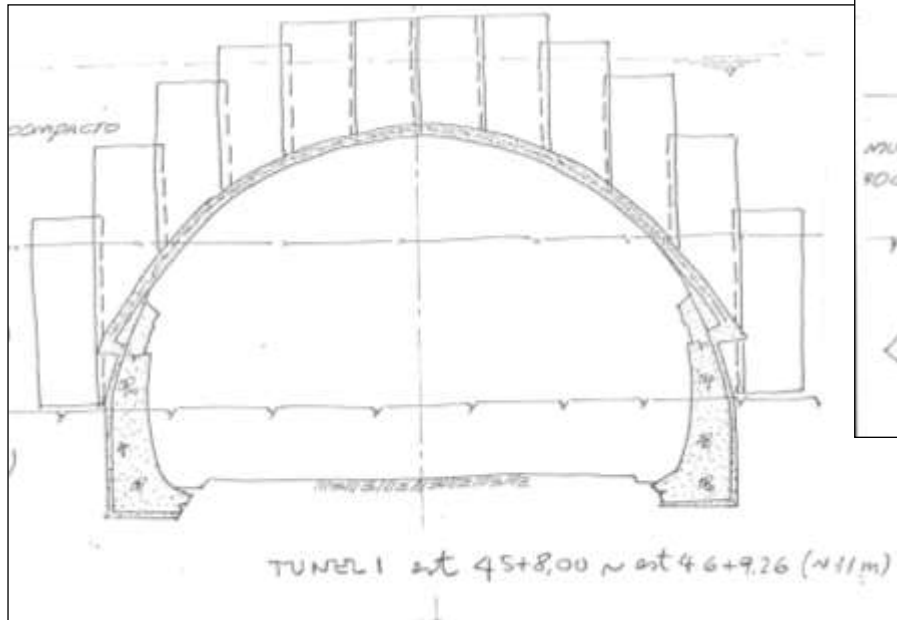
Figura 4.2.3 - Revestimento de Concreto Armado. Diagramas de Momento Fletor e Força Cortante.

# METRÔ DE SALVADOR (2002)

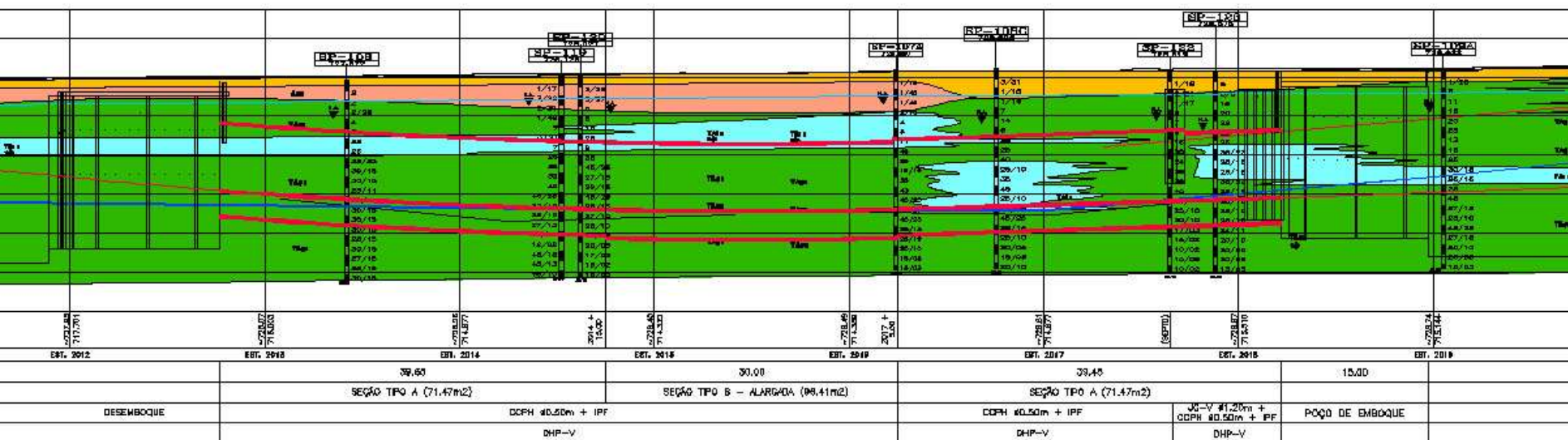
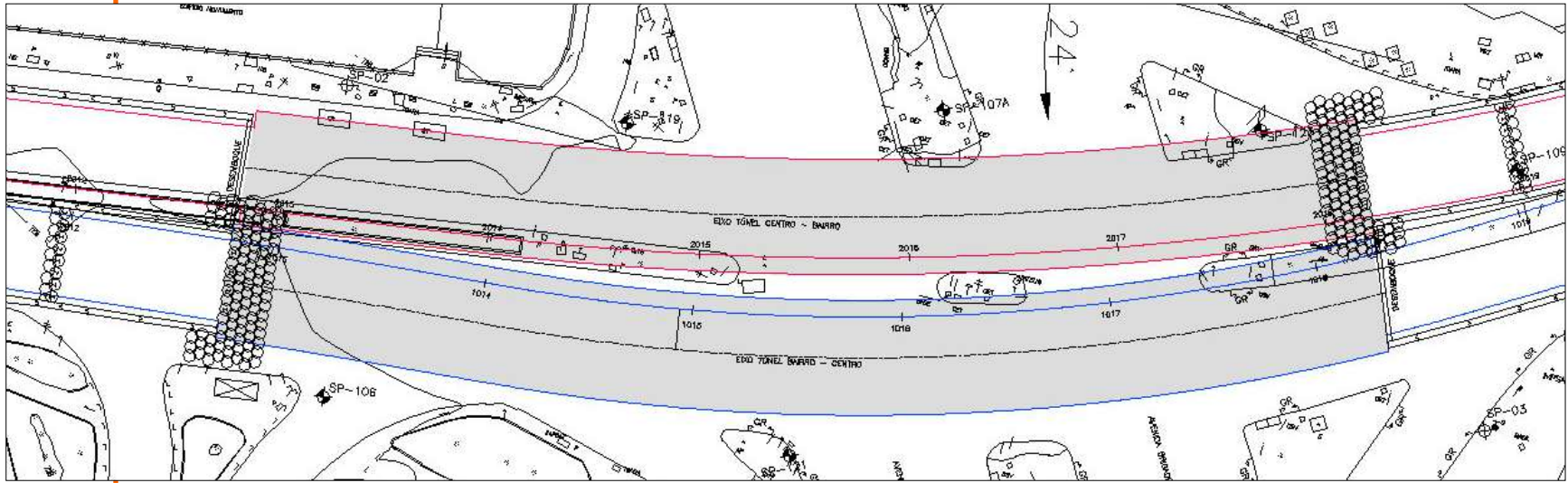


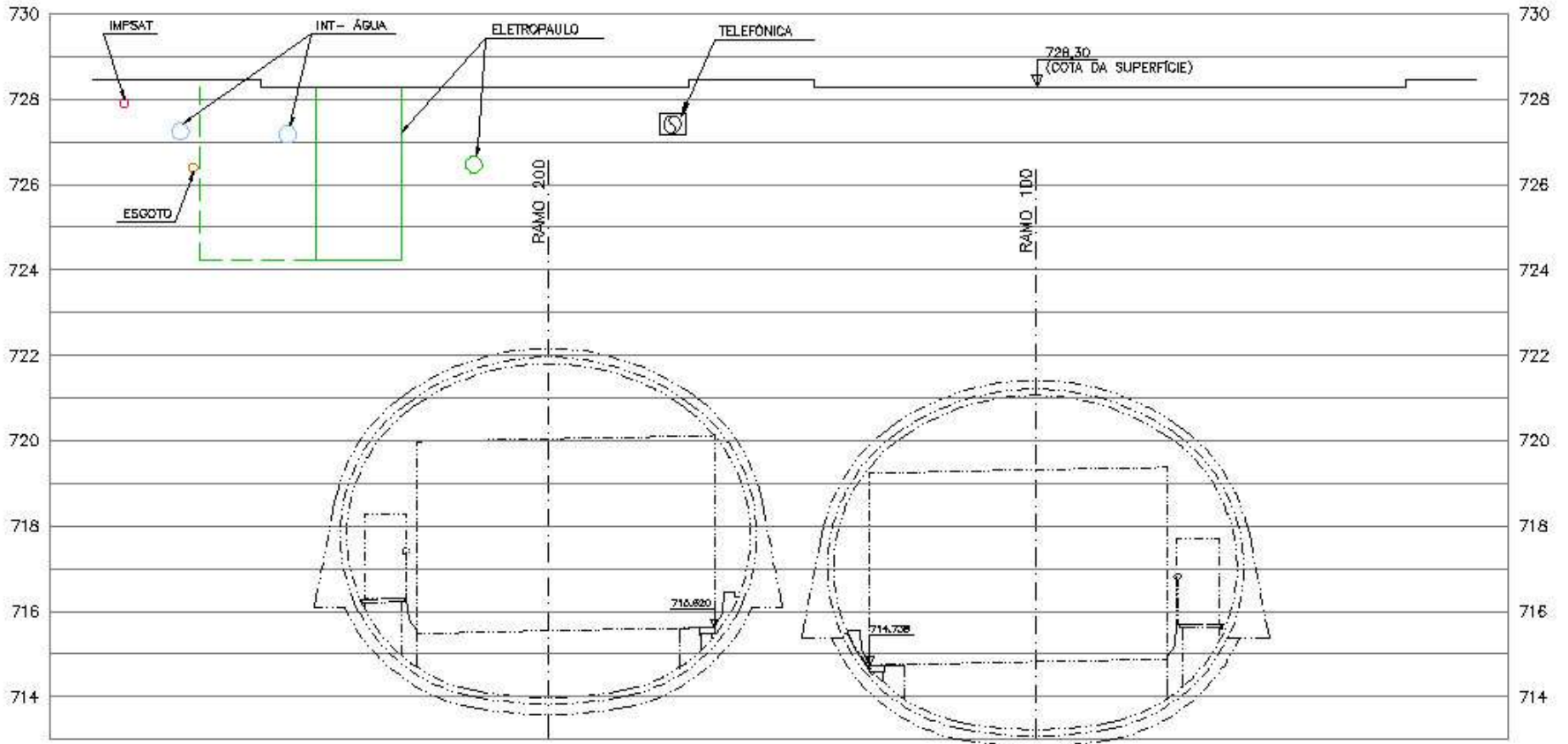
# TÚNEL DE CAMPINAS (1987)





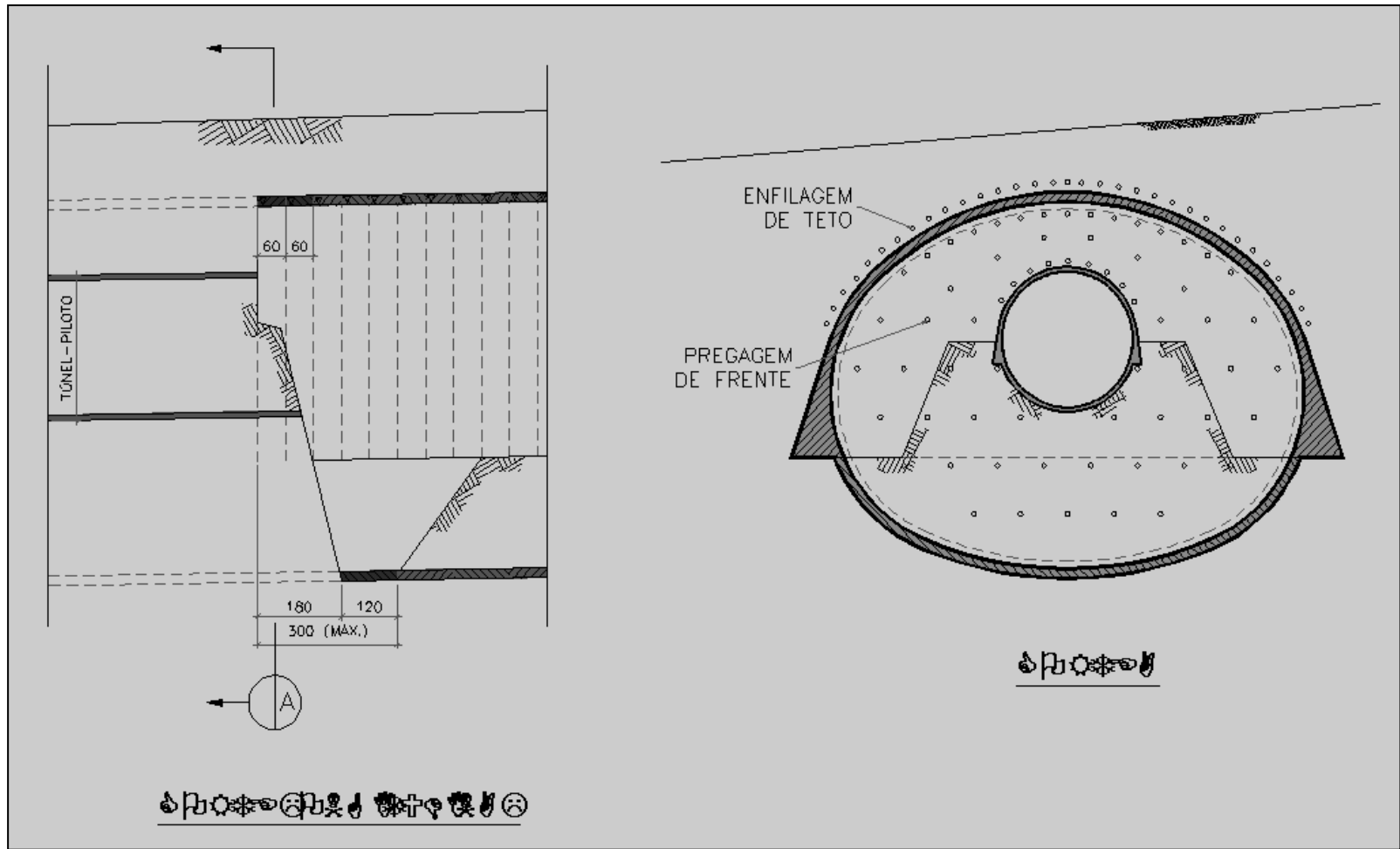
# TÚNEL REBOUÇAS – FARIA LIMA (2004)





CORTE TRANSVERSAL — ESTACA 1013+3.60 / 2013+3.727  
 ESCALA 1:100

# PASSAGEM DO CABULA







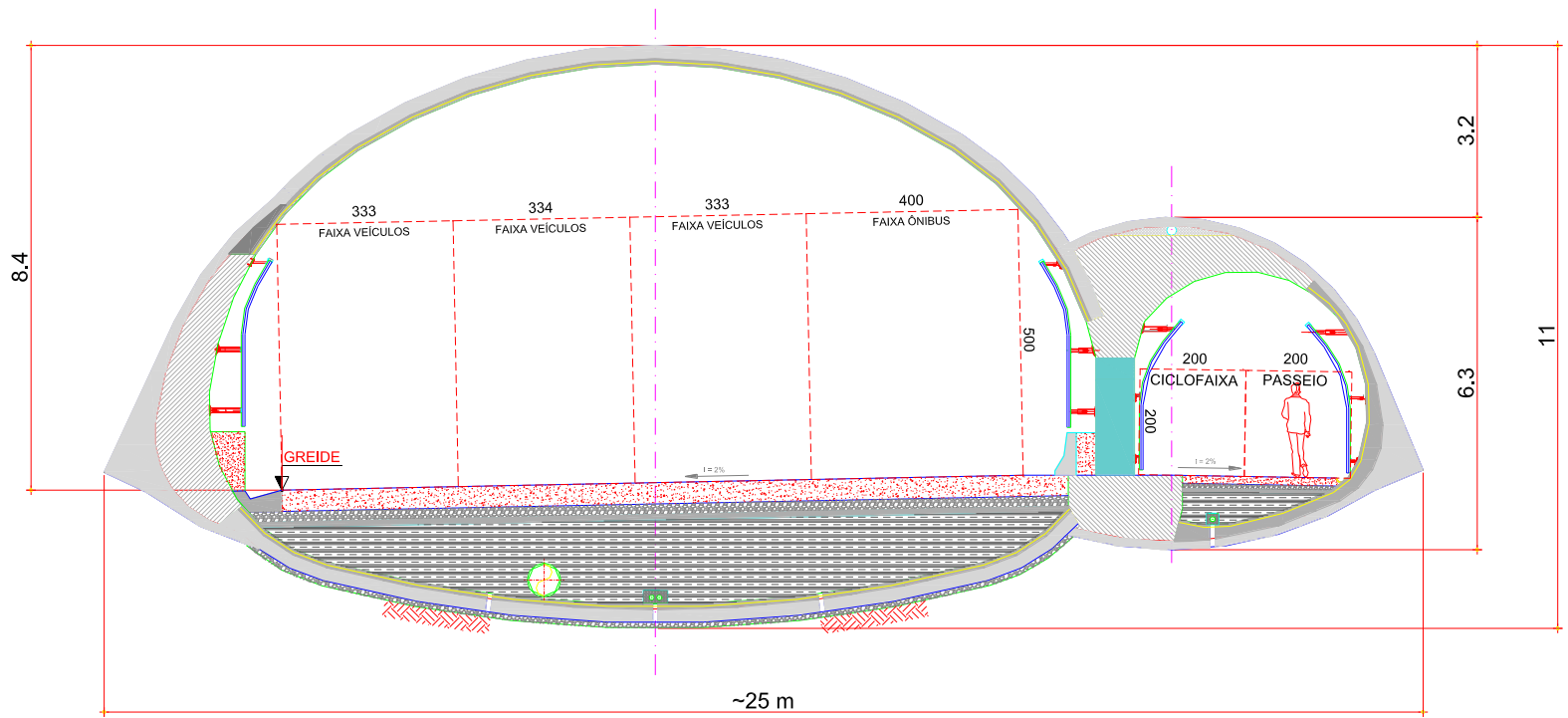


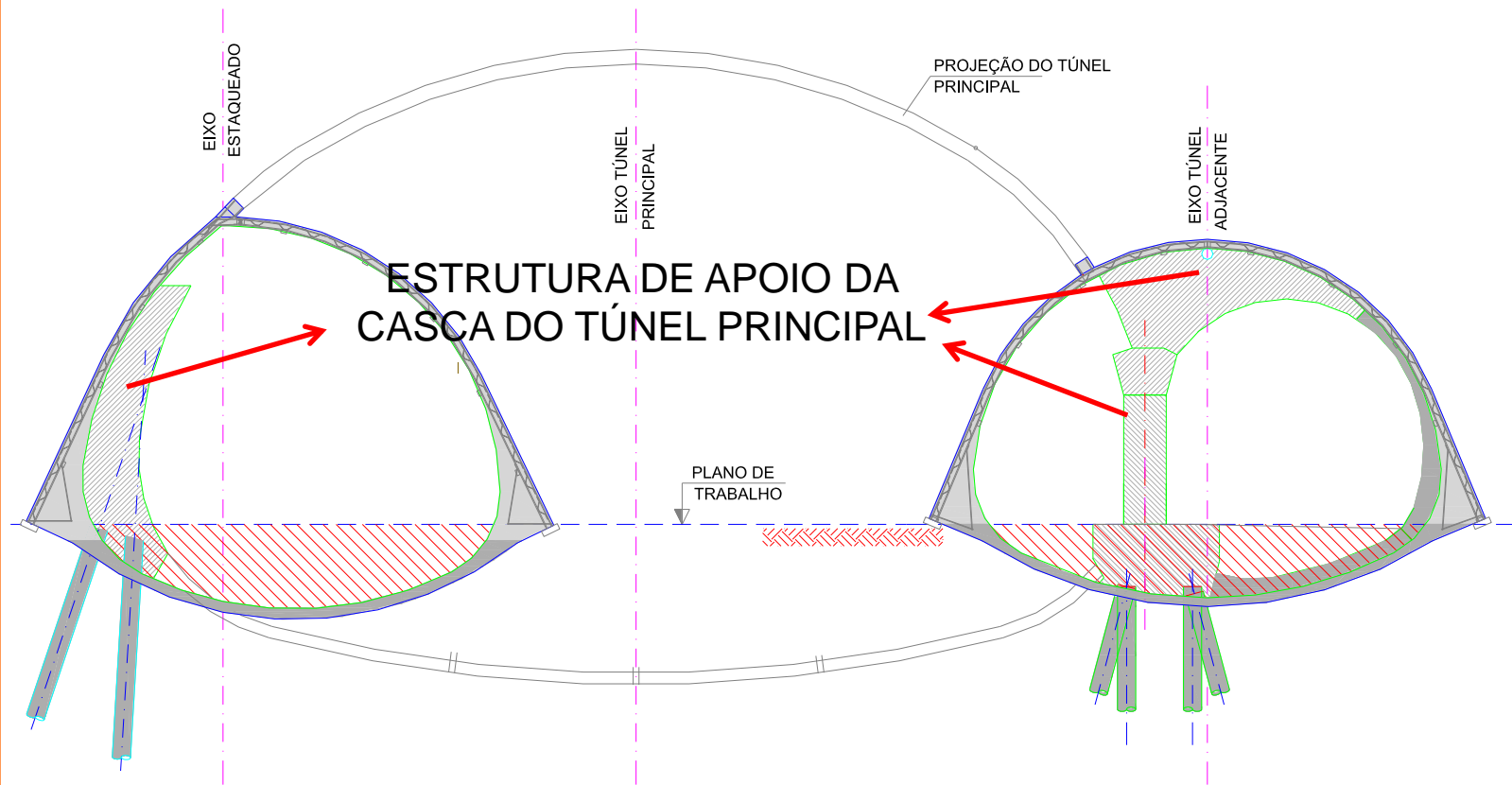


**TÚNEL ESTRADA DA RAINHA (2005)**

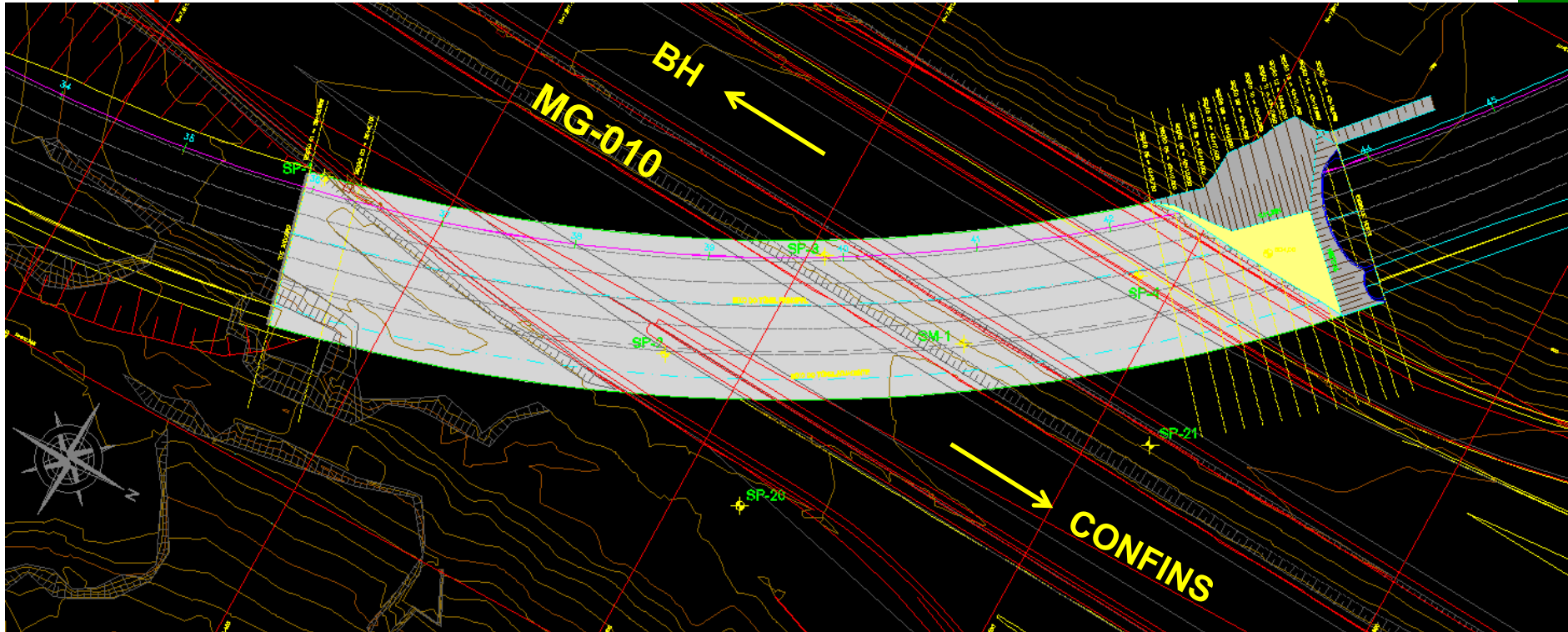
**TÚNEL DE ACESSO AO  
NOVO CENTRO ADMINISTRATIVO DE  
MINAS GERAIS**







# SITUAÇÃO EM PLANTA



# PERFIL

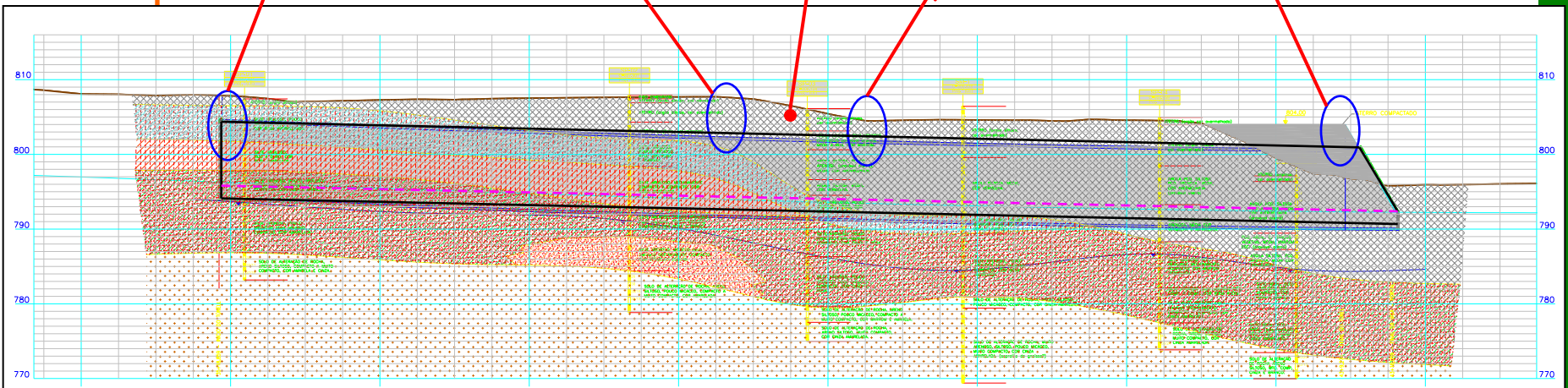
3.2 m

5.3 m

TUB. GÁS

2.6 m (!)

3.5 m



**OBS:** N-SPT's NA BASE DA SAPATA DA ORDEM DE 7 A 18 GOLPES

# MÉTODO EXECUTIVO

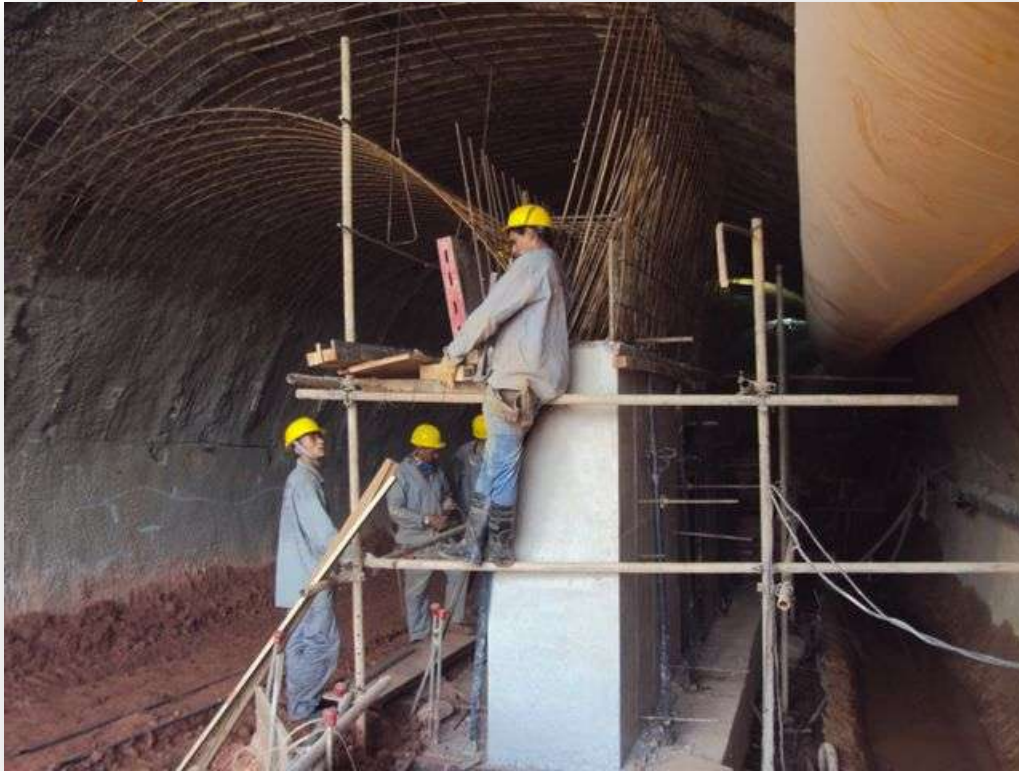




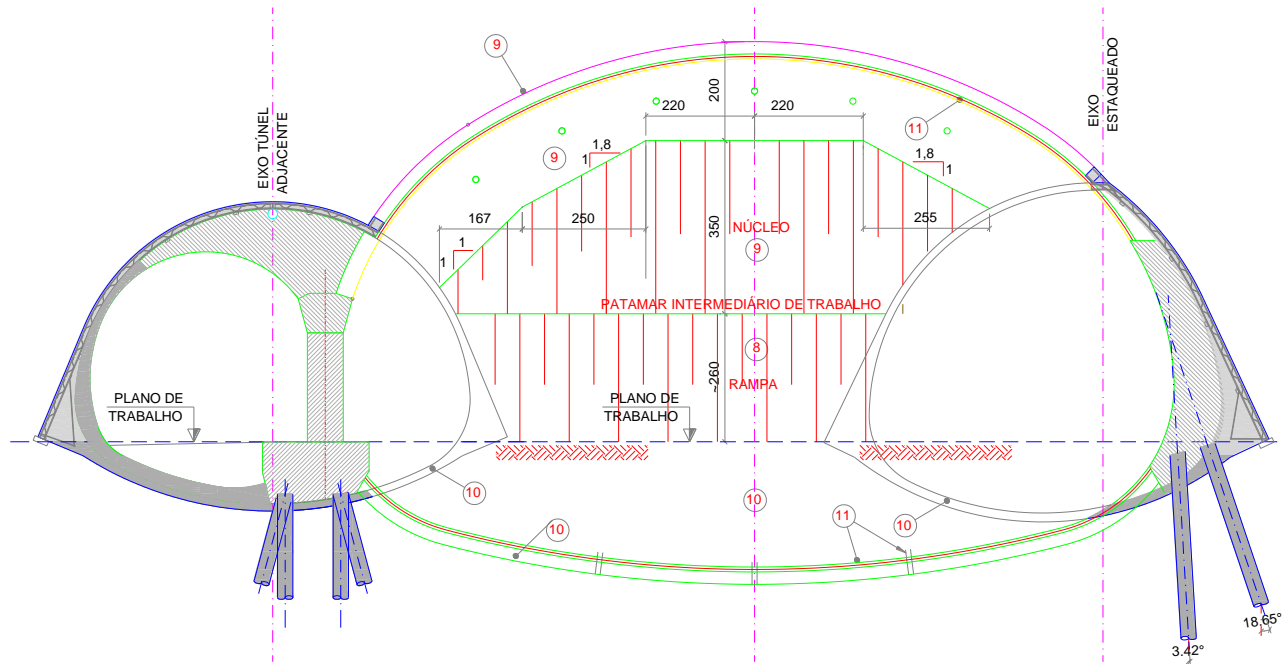
# MÉTODO EXECUTIVO



# MÉTODO EXECUTIVO



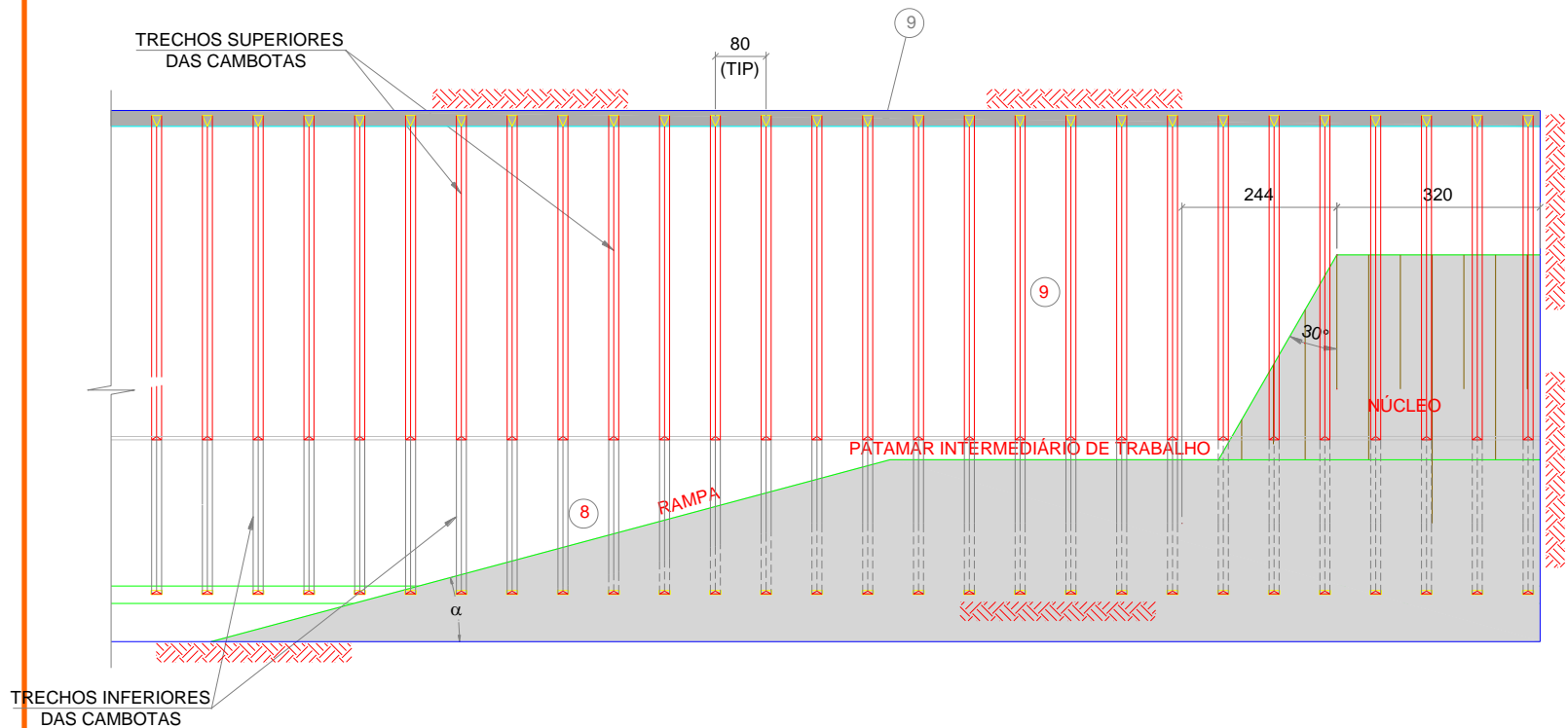
# MÉTODO EXECUTIVO



## FASE 4 - EXECUÇÃO DO TÚNEL PRINCIPAL

- ⑧ EXECUÇÃO DA RAMPA PARA O ACESSO PARA A PLATAFORMA INTERMEDIÁRIA DE TRABALHO E EXECUÇÃO DAS PREGAGENS DA FACE E TRATAMENTO DA CALOTA DO TÚNEL PRINCIPAL.
- ⑨ ESCAVAÇÃO E EXECUÇÃO DO REVESTIMENTO PRIMÁRIO (CONCRETO PROJETADO + SEGMENTO SUPERIOR DA CABBOTA) DA CALOTA DO TÚNEL PRINCIPAL, CONFORMANDO UM NÚCLEO CENTRAL.  
ESCAVAÇÃO E EXECUÇÃO DO REVESTIMENTO PRIMÁRIO (CONCRETO PROJETADO) DO REBAIXO DO TÚNEL PRINCIPAL, DEMOLINDO AS PORÇÕES RESTANTES DO REVESTIMENTO DOS TÚNEIS QUE INTERFEREM COM A SEÇÃO DO TÚNEL (CONCRETO PROJETADO); PODE-SE EXECUTAR ESTA ETAPA EM QUALQUER MOMENTO, DADO QUE A FUNDAÇÃO DA CALOTA JÁ ESTARÁ GARANTIDA ATRAVÉS DAS ESTACAS RAIZ.
- ⑩

# MÉTODO EXECUTIVO



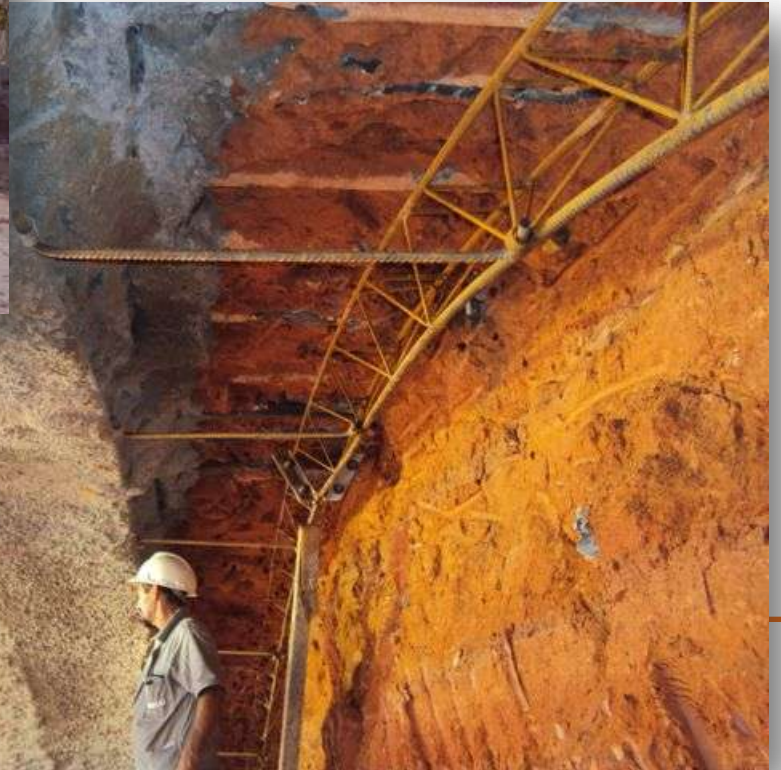
## ESCAVAÇÃO DA CALOTA - CORTE LONGITUDINAL

- 11 EXECUÇÃO DO REVESTIMENTO SECUNDÁRIO (CONCRETO PROJETADO + TELA TIPO Q159) EM TODO O PERÍMETRO DO TÚNEL; DEIXAR LIVRES OS TUBOS DE PVC DE Ø4" PARA ALÍVIO DE PRESSÕES HIDROSTÁTICAS JUNTO AO ARCO INVERTIDO.
- 12 PREENCHIMENTO DO ARCO INVERTIDO DO TÚNEL COM MATERIAL DRENANTE, DE MODO A POSSIBILITAR O ENCAMINHAMENTO DAS ÁGUAS DE INFILTRAÇÃO ATRAVÉS DO SISTEMA DE DRENAGEM DE FUNDO; EXECUÇÃO DO PAVIMENTO E DEMAIS SISTEMAS E ELEMENTOS INTERNOS E ACABAMENTO FINAL.

# MÉTODO EXECUTIVO



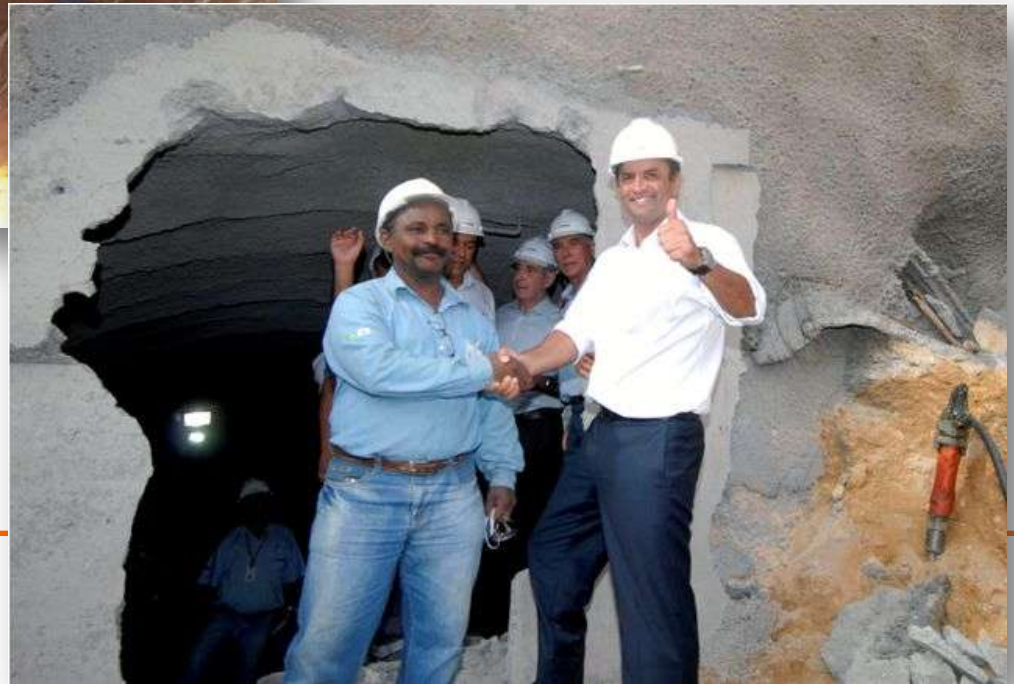
# MÉTODO EXECUTIVO



# MÉTODO EXECUTIVO



# MÉTODO EXECUTIVO

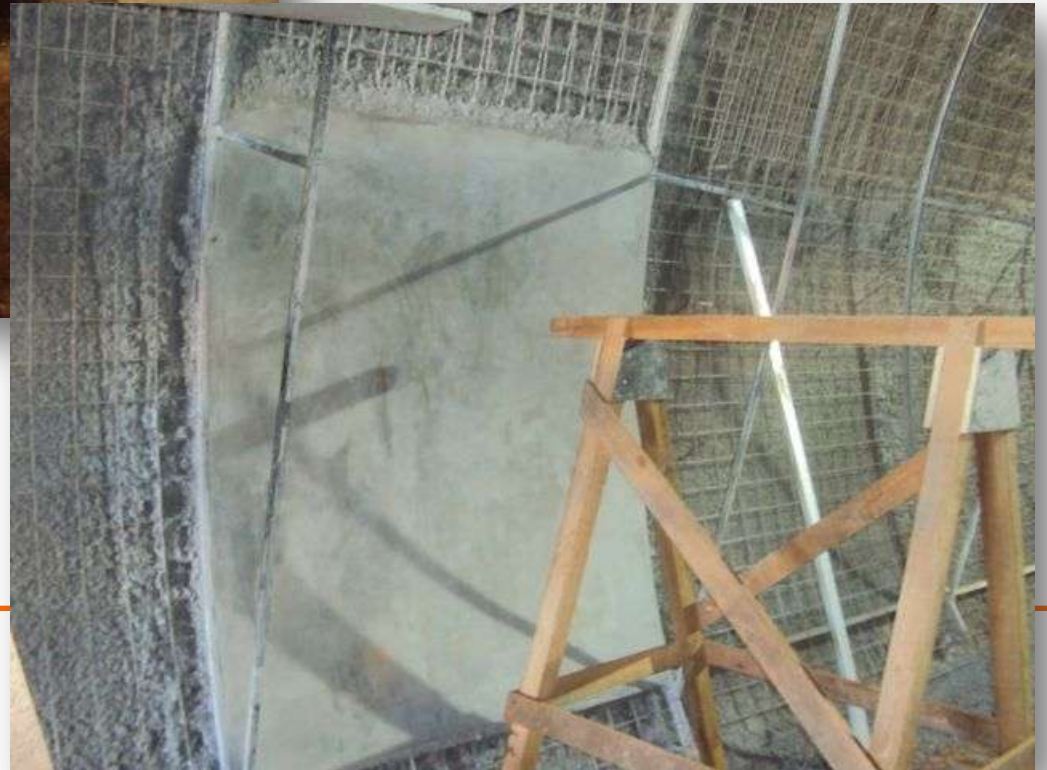




# MÉTODO EXECUTIVO



# MÉTODO EXECUTIVO



# MÉTODO EXECUTIVO



# MÉTODO EXECUTIVO



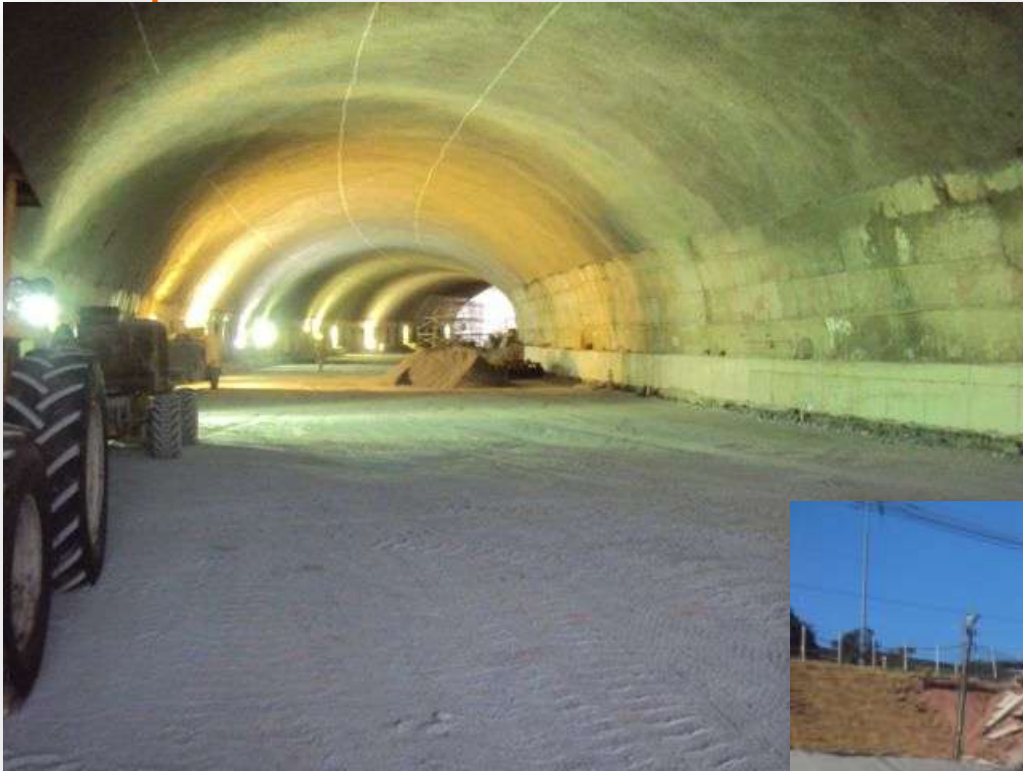
# MÉTODO EXECUTIVO



# MÉTODO EXECUTIVO



# MÉTODO EXECUTIVO



# MÉTODO EXECUTIVO





# MÉTODO EXECUTIVO



# TÚNEL PRONTO



# TÚNEL PRONTO



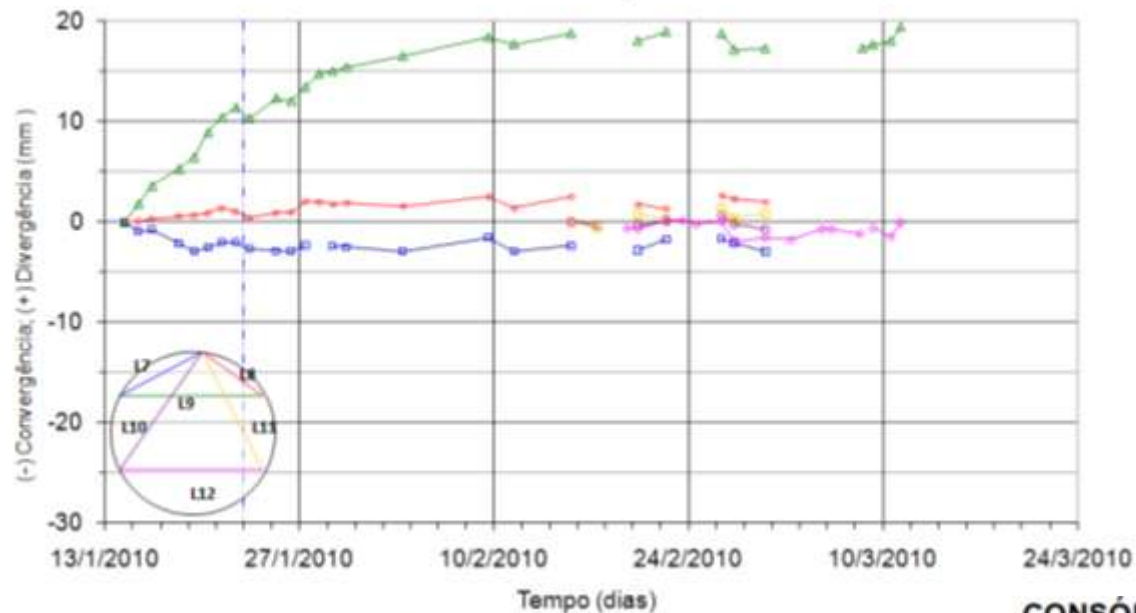
# TÚNEL PRONTO



# CONSÓRCIO MENDES JÚNIOR - SANTA BÁRBARA

TÚNEL - CAMG

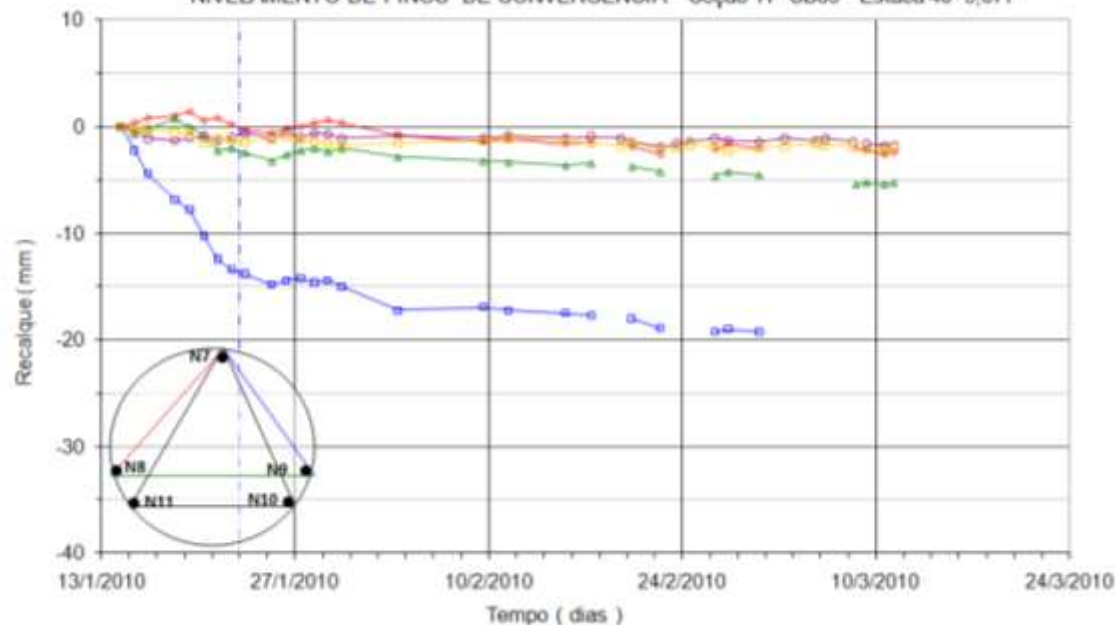
MEDIDAS DE CONVERGÊNCIA - Seção TP-CB89 - Estaca 40+9,577



# CONSÓRCIO MENDES JÚNIOR - SANTA BÁRBARA

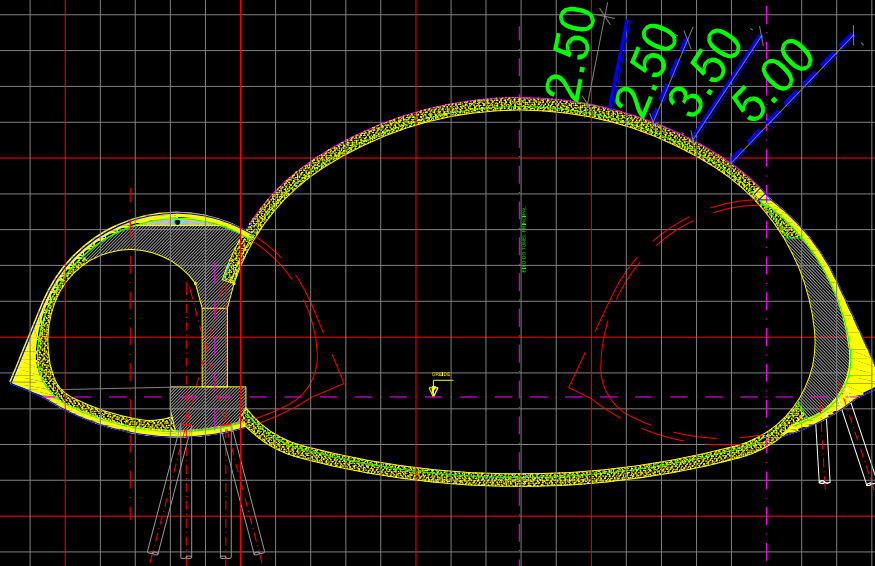
TÚNEL - CAMG

NIVELAMENTO DE PINOS DE CONVERGÊNCIA - Seção TP-CB89 - Estaca 40+9,577



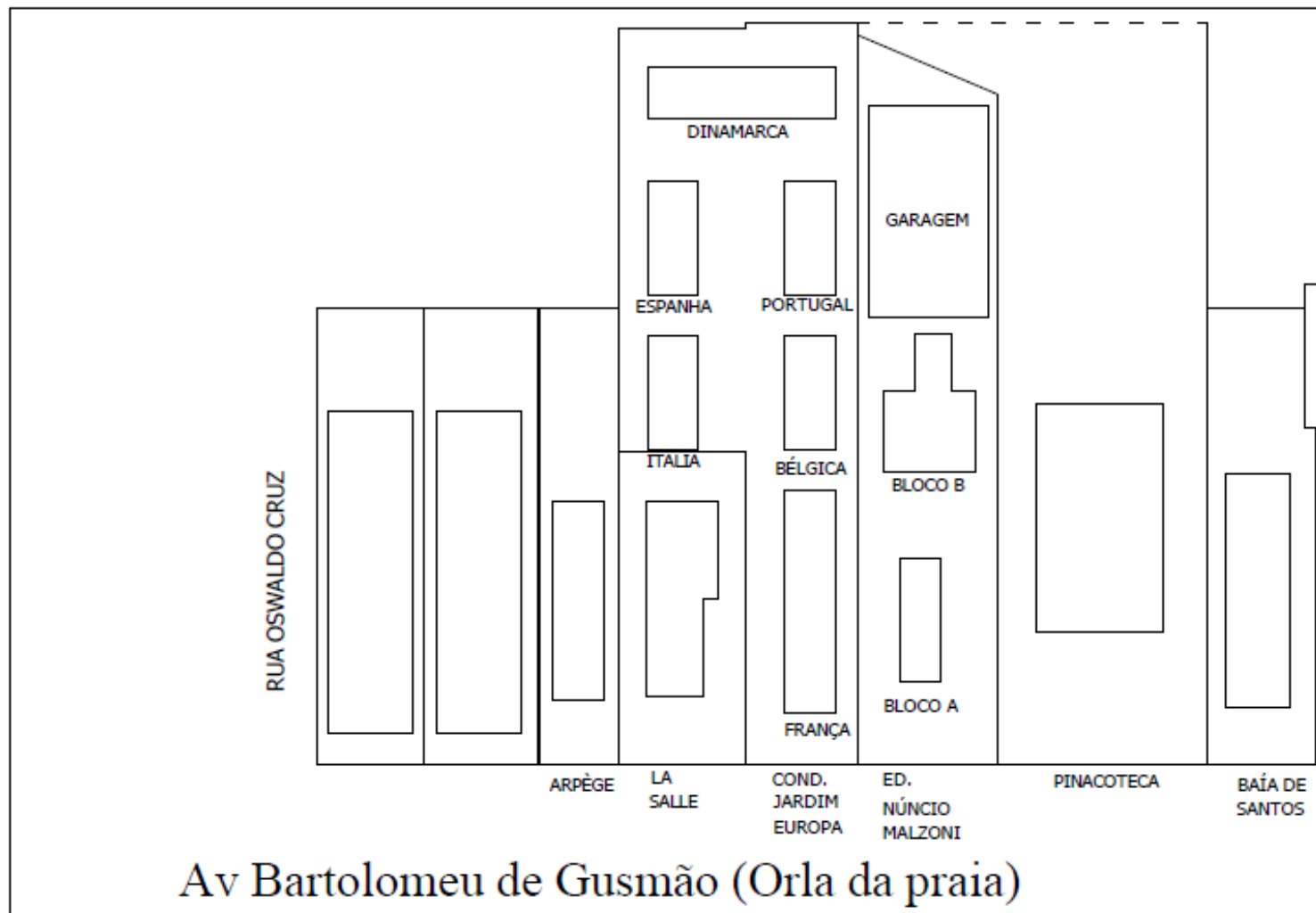
# INJEÇÕES

ESTACA 40+10,00



# REAPRUMO DE EDIFÍCIOS EM SANTOS

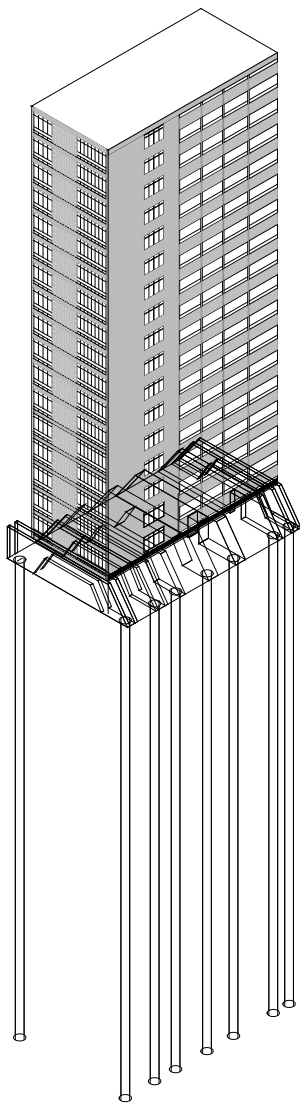




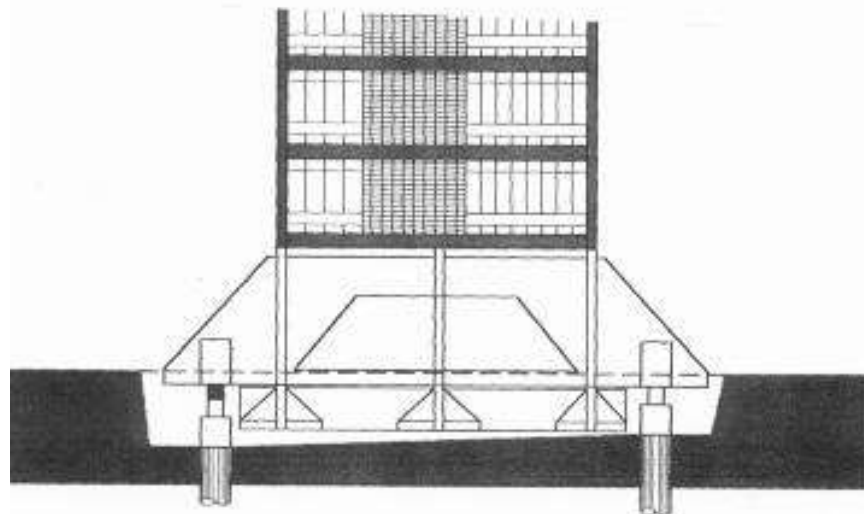
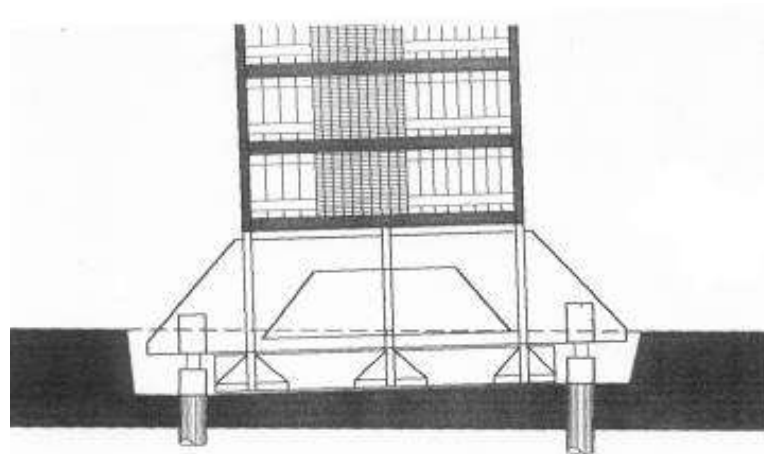
Av Bartolomeu de Gusmão (Orla da praia)

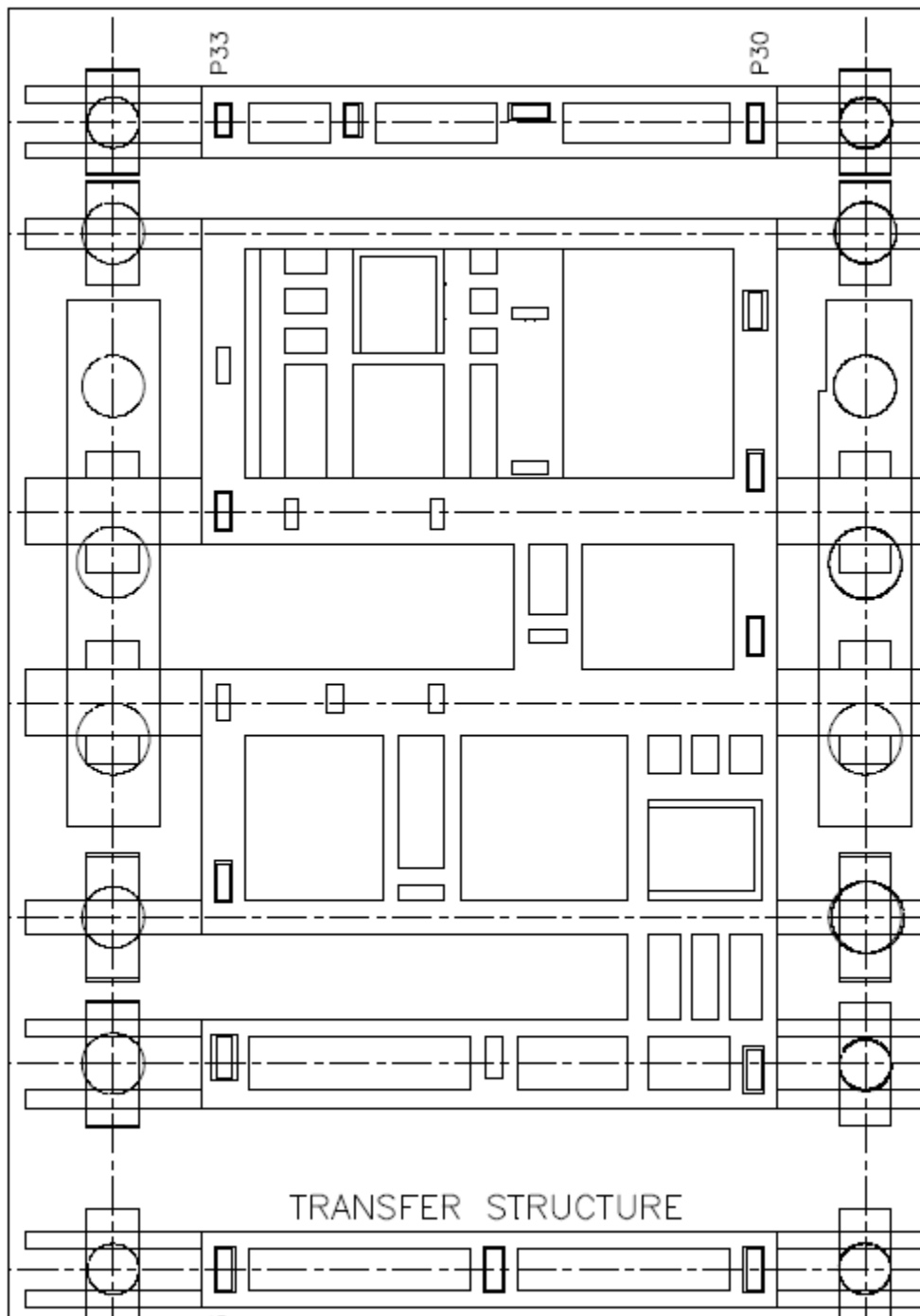


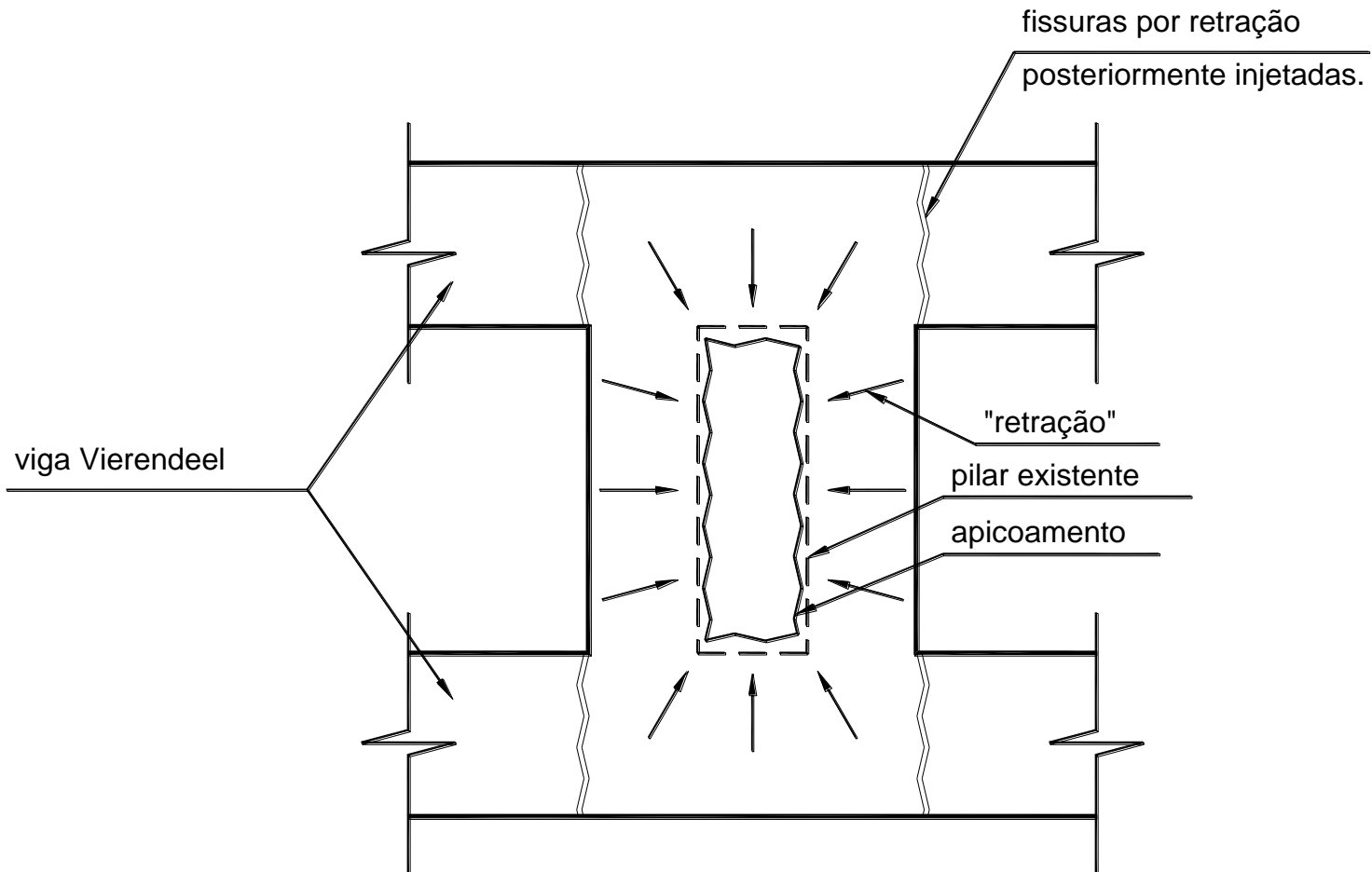
## Vista espacial do reforço:

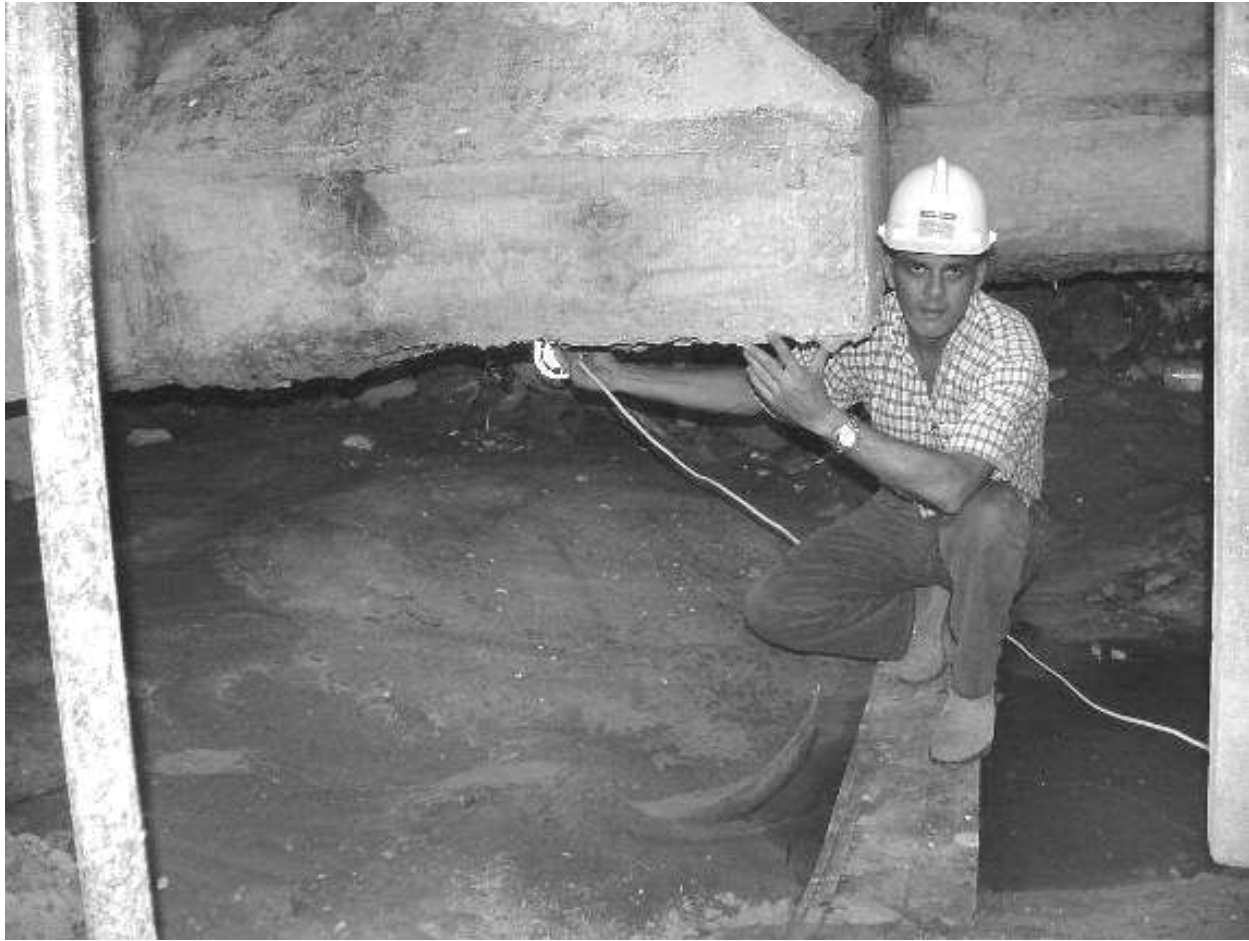


## Seção transversal antes e depois do reaprumo:









## Início do macaqueamento:



## Durante o macaqueamento:



# Edifício Núncio Malzoni – Bloco A



**ANTES**



**DEPOIS**

# HOTEL SUAREZ – NOVO HAMBURGO



# HOTEL SUAREZ – NOVO HAMBURGO





# HOTEL SUAREZ – NOVO HAMBURGO



# HOTEL SUAREZ – NOVO HAMBURGO

