Reviewing on blow-out in tunnelling and analyzing for a case in Hochiminh Metro Line 1

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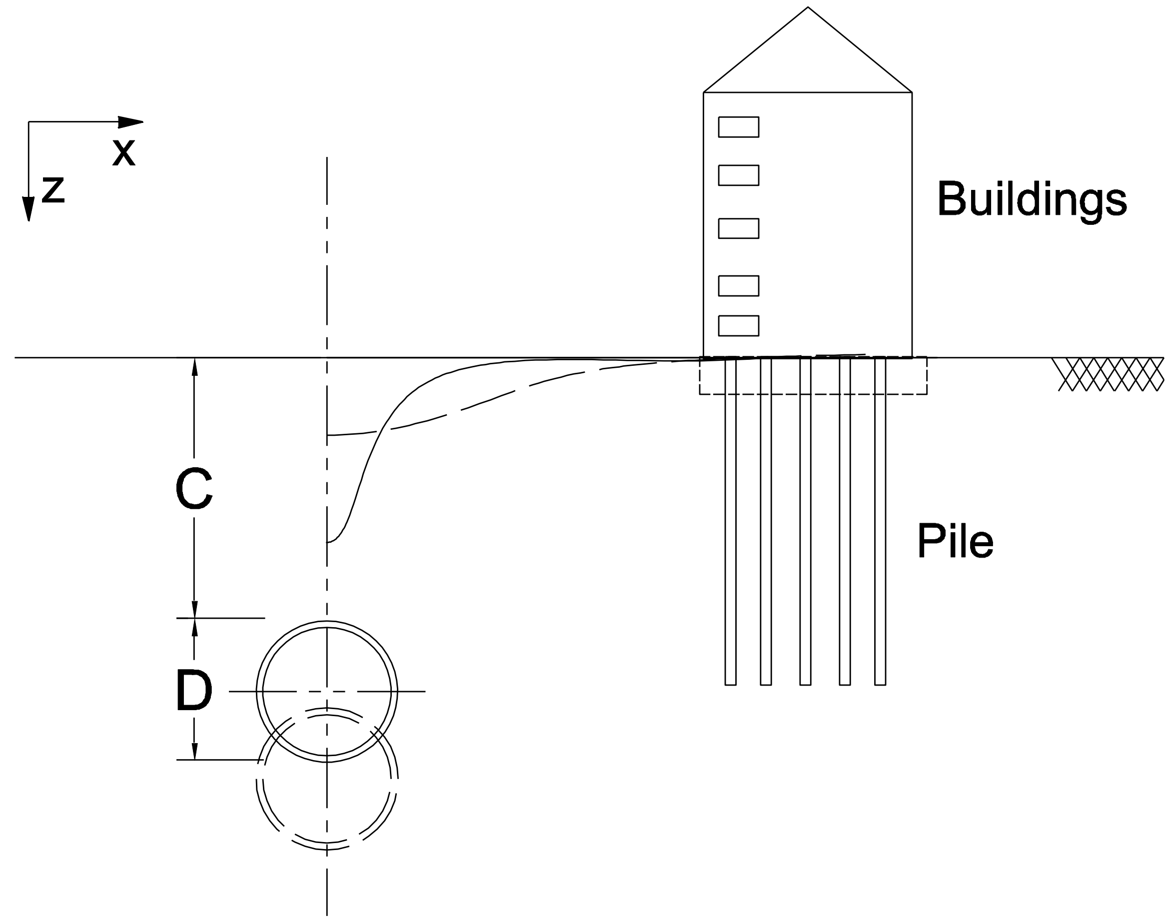
Nội dung

1. Introduction
2. Blow-out in tunnelling
3. Blow-out analysis models
4. Validations with experiments
5. Validations with case studies
6. Blow-out in HCM MRT Line 1
7. Conclusion

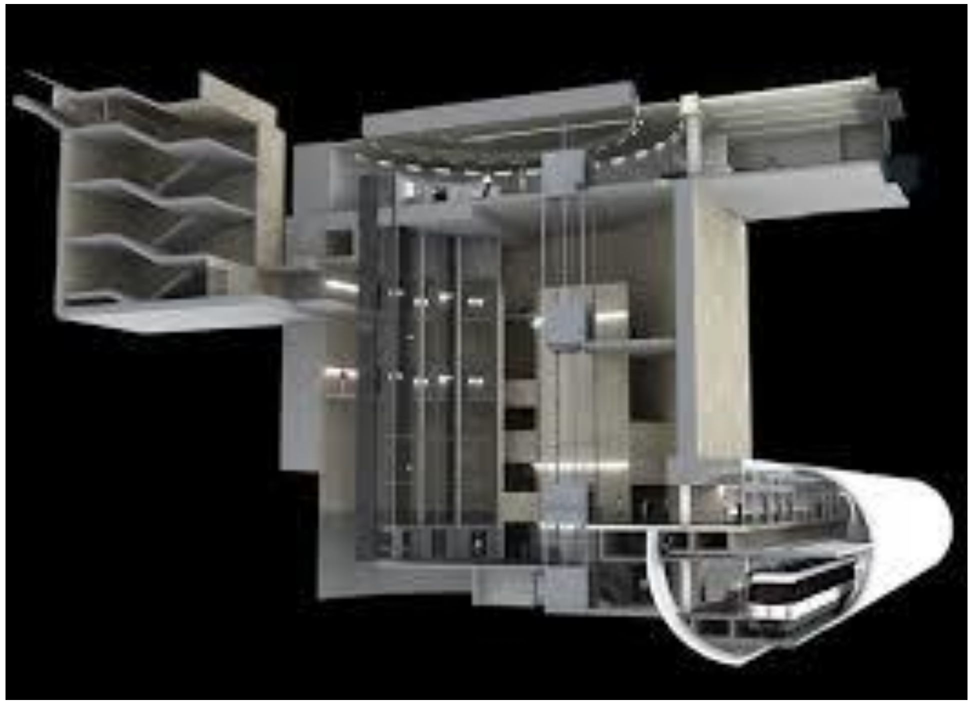
Introduction

- ❑ Deep, moderate and shallow tunnels



Deep tunnels

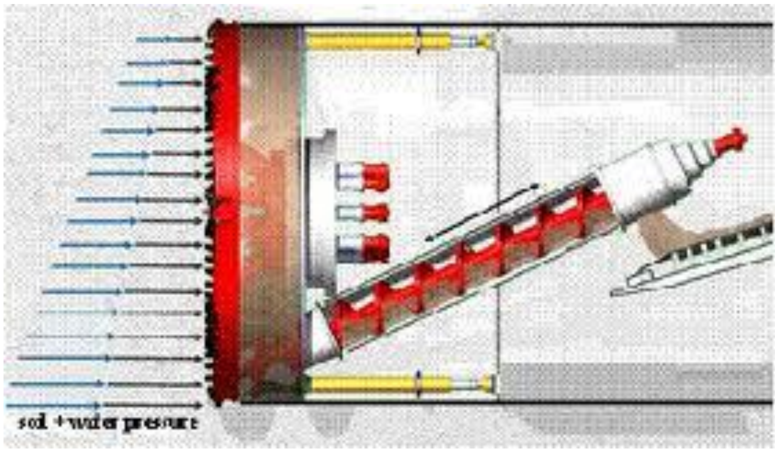
- High cost of construction
- High cost of operation



Shallow tunnels

- Reduction of construction cost;
- Low operational cost;
- Shorter travelling time;
- Minimal impact on foundation and existing buildings

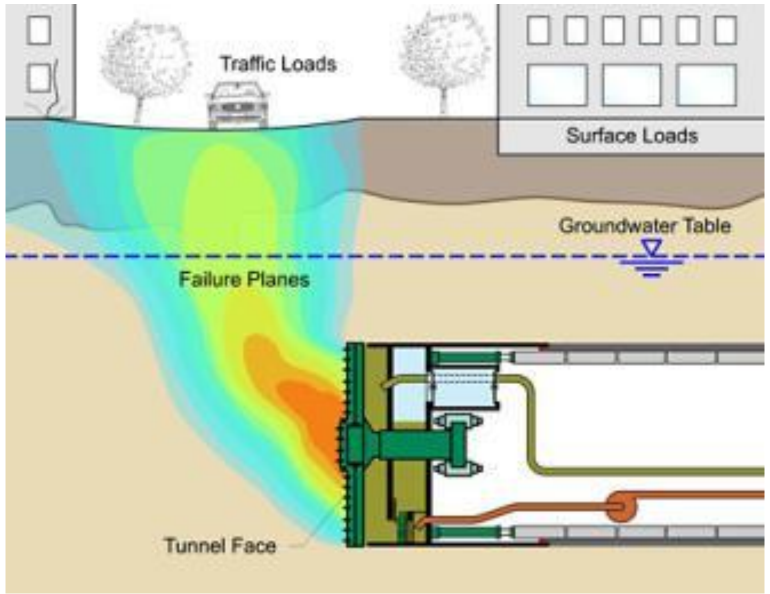
Stability in shallow tunnelling

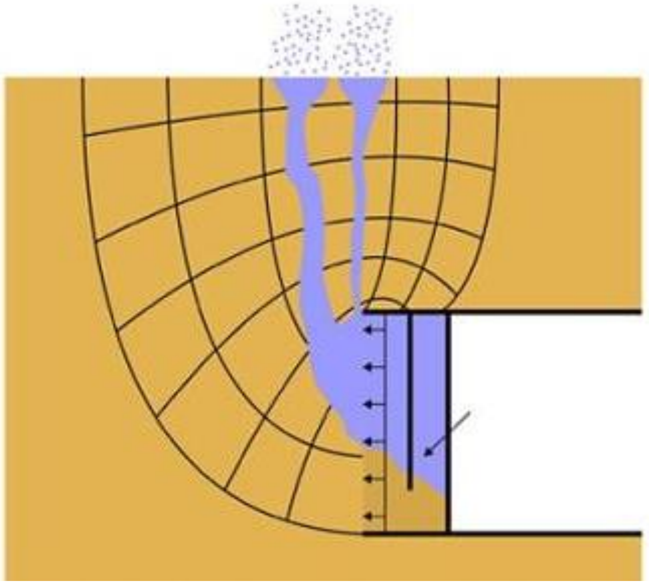


Support pressure estimate

Wedge model

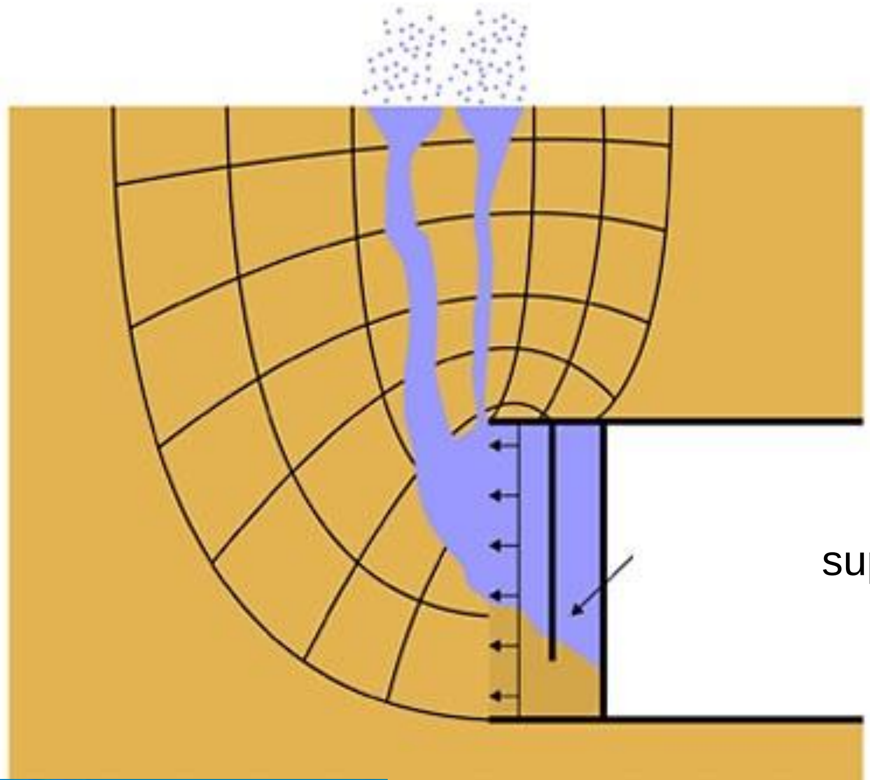
Blow-out

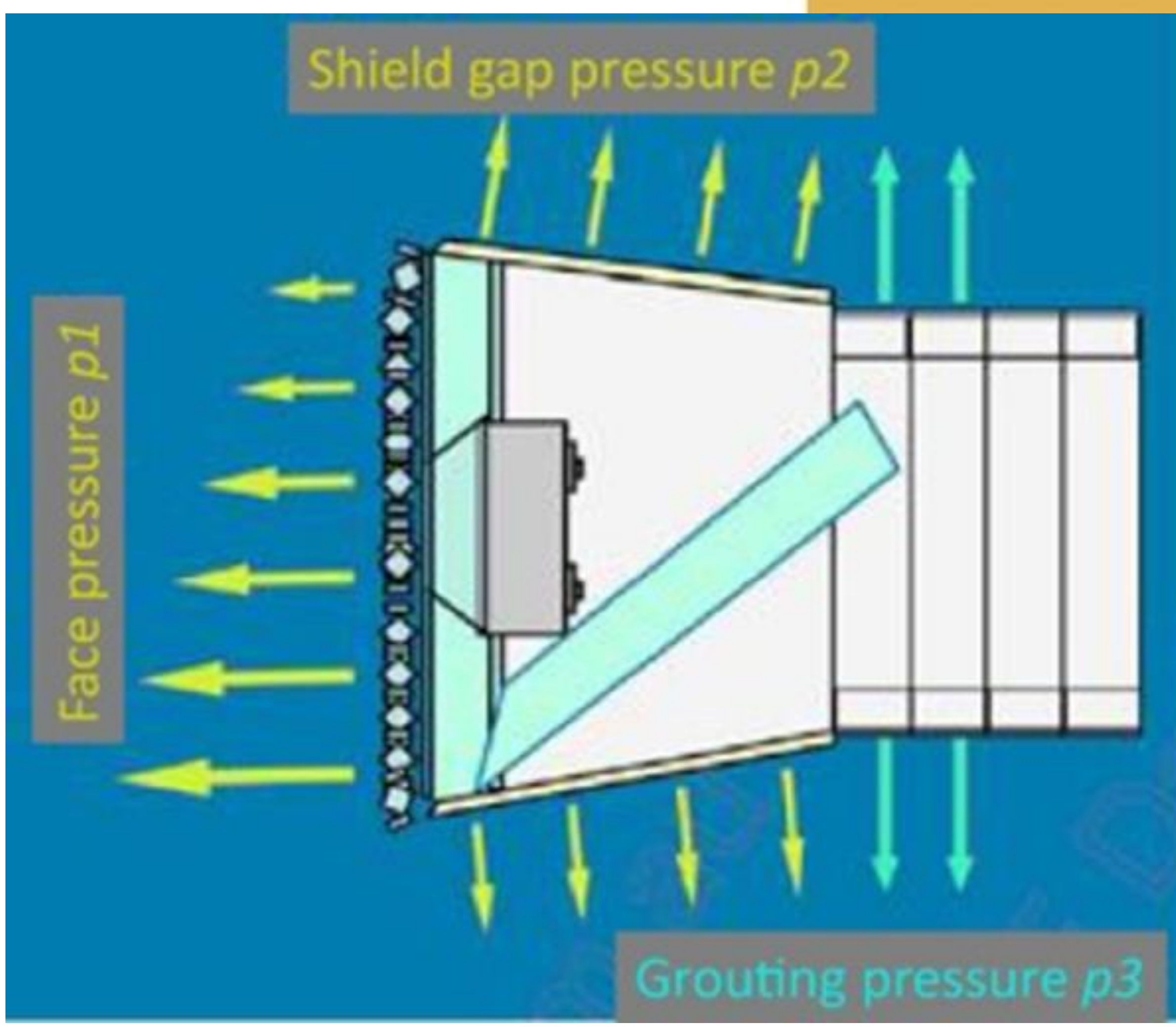


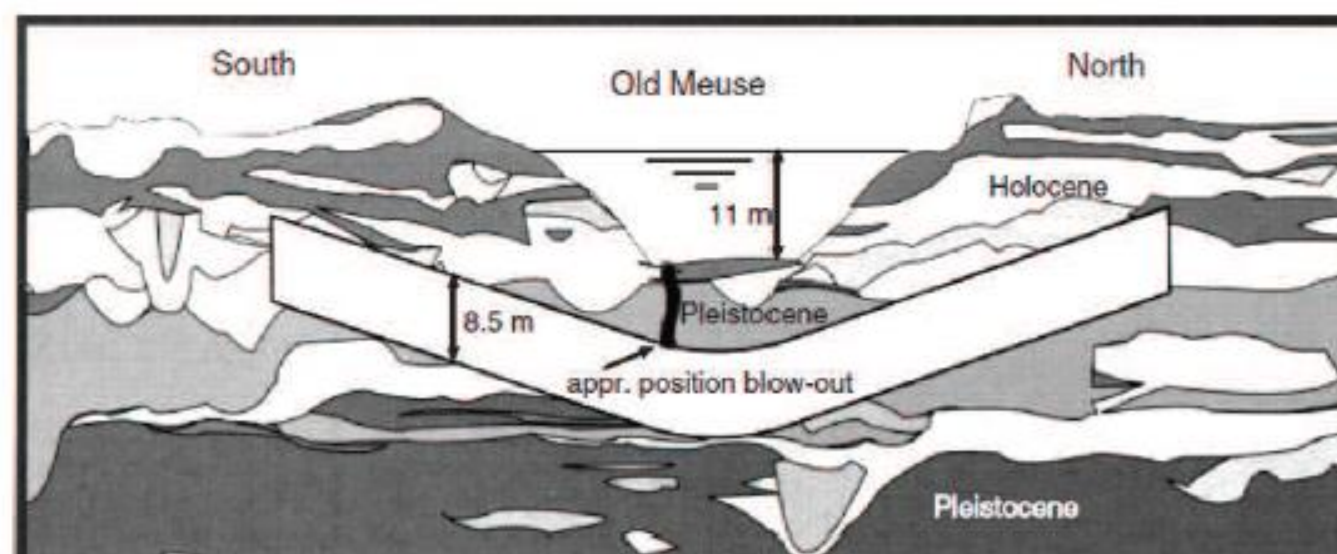


Blow-out

(Source: facesupport.org)

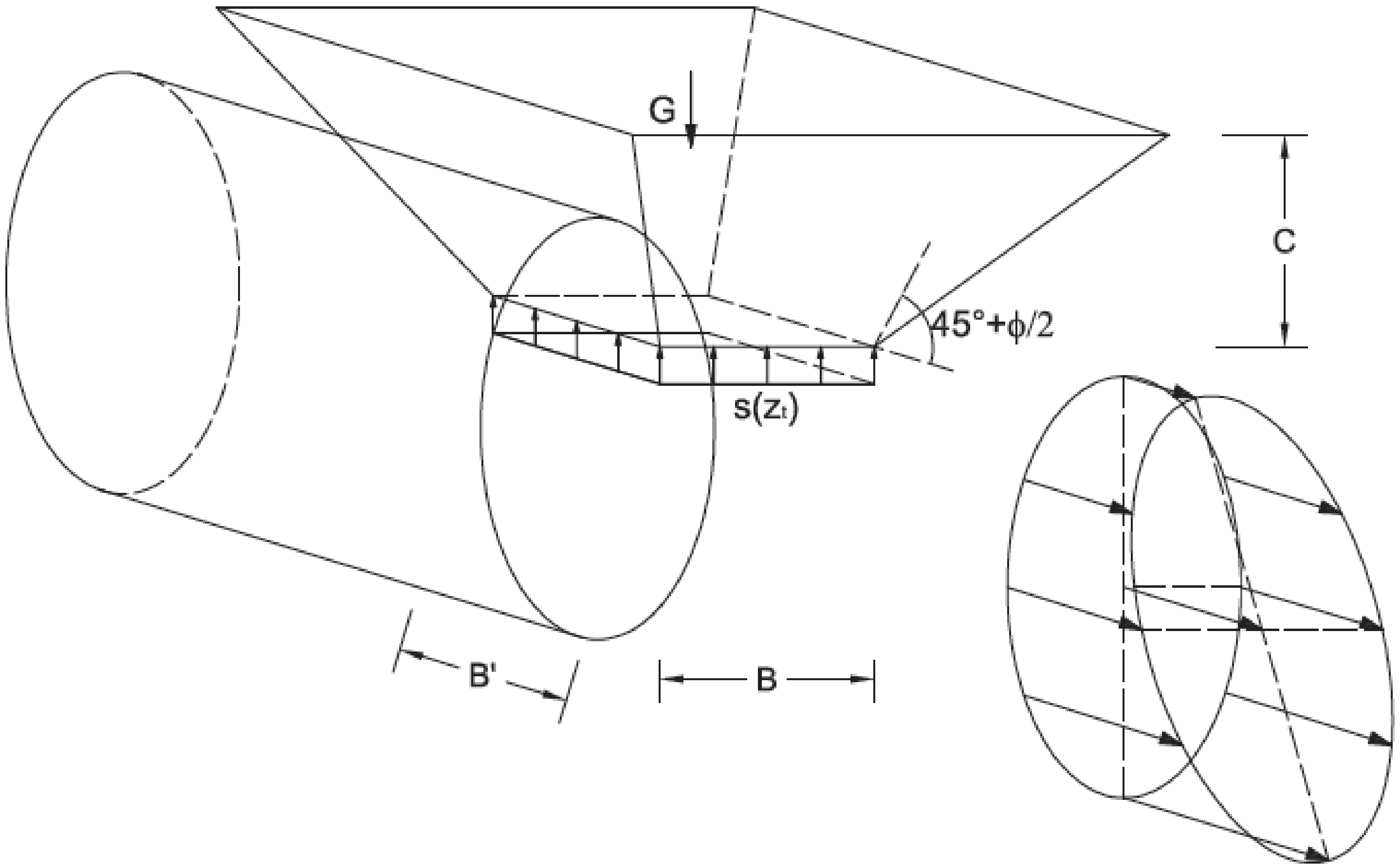






(a) Scheme of the Second Heinenoord Tunnel and the blow-out position

Blow-out models

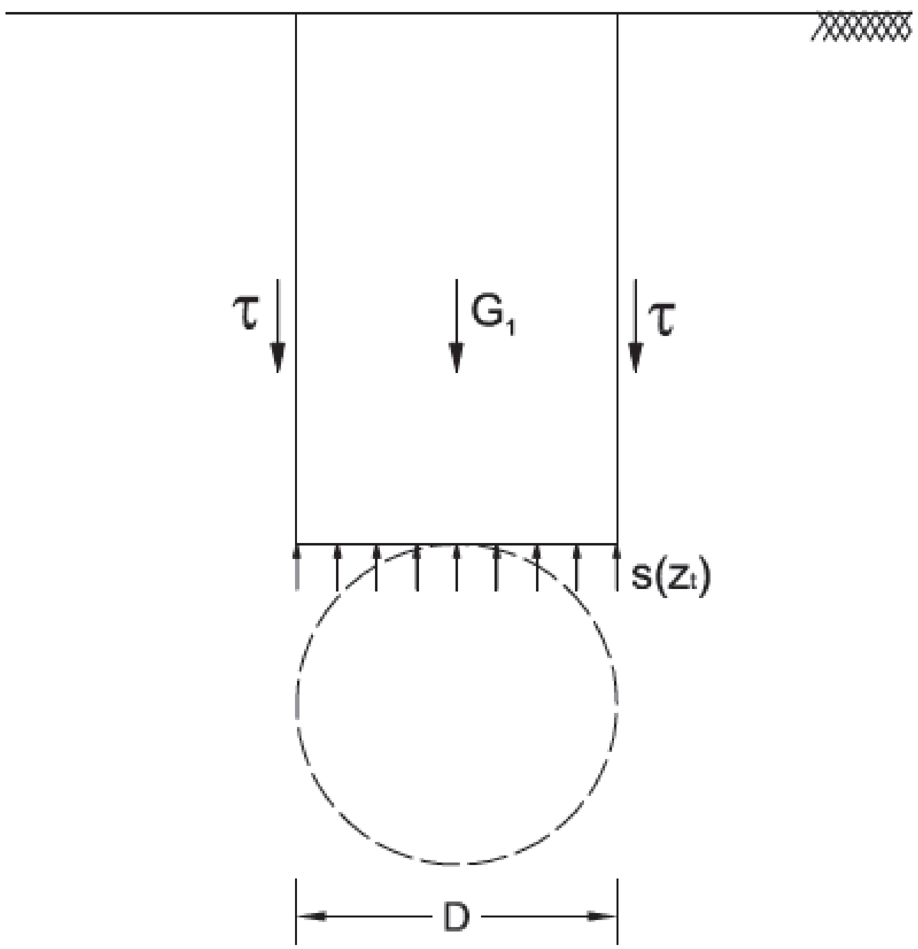


Calculation model of Balthaus for the safety against blow-out (Balthaus, 1991)

Safety indexes against the blow out :

$$\eta = \frac{G}{S} > \eta_1 = \frac{\gamma C\left(B' + C\cot\left(45^o + \varphi/2\right)\right)}{B' s\left(z_t\right)} > \eta_2 = \frac{\gamma C}{s\left(z_t\right)}$$

Blow-out models

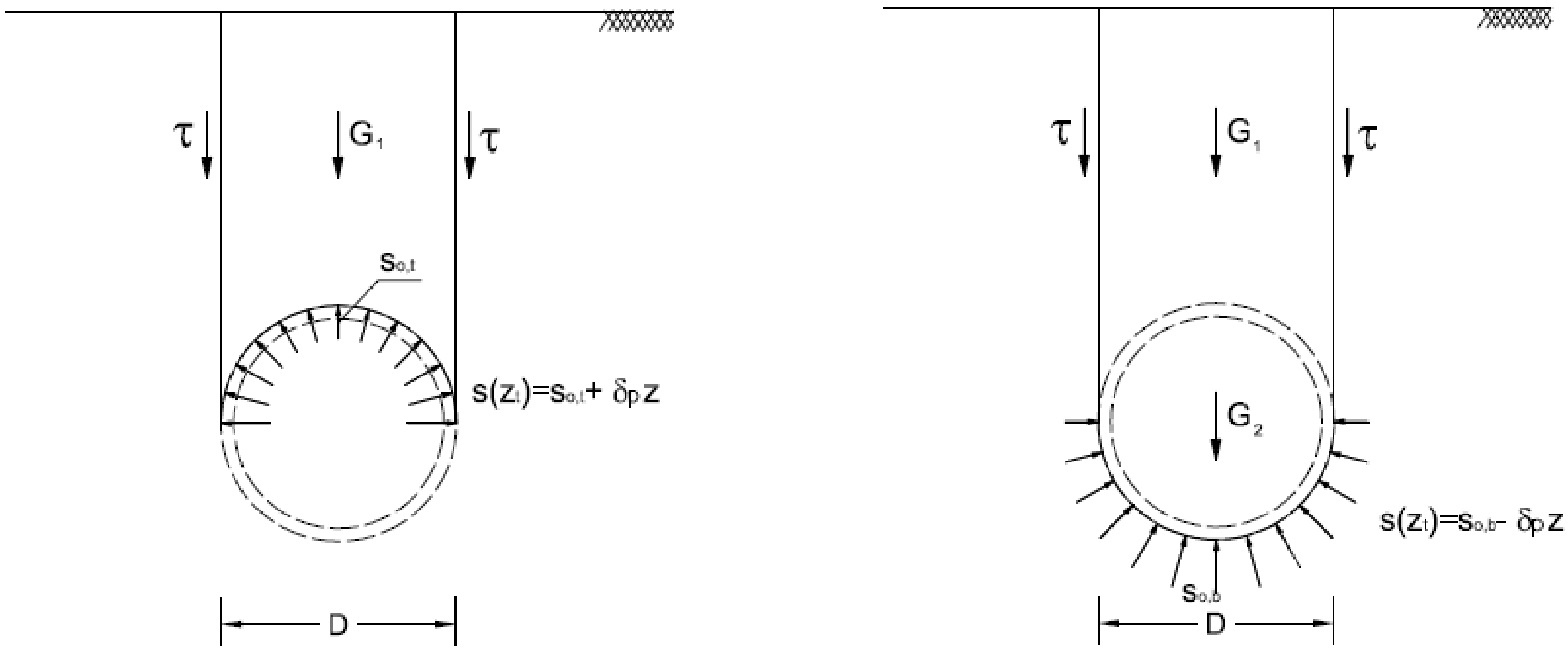


$$s_{max} = C\left(\gamma + \frac{2c + CK_y\gamma' \tan\varphi}{D}\right)$$

Blow-out model including friction at boundaries (Broere, 2001)

Blow-out models

Model model including the supporting pressure changes (VU et al., 2015)



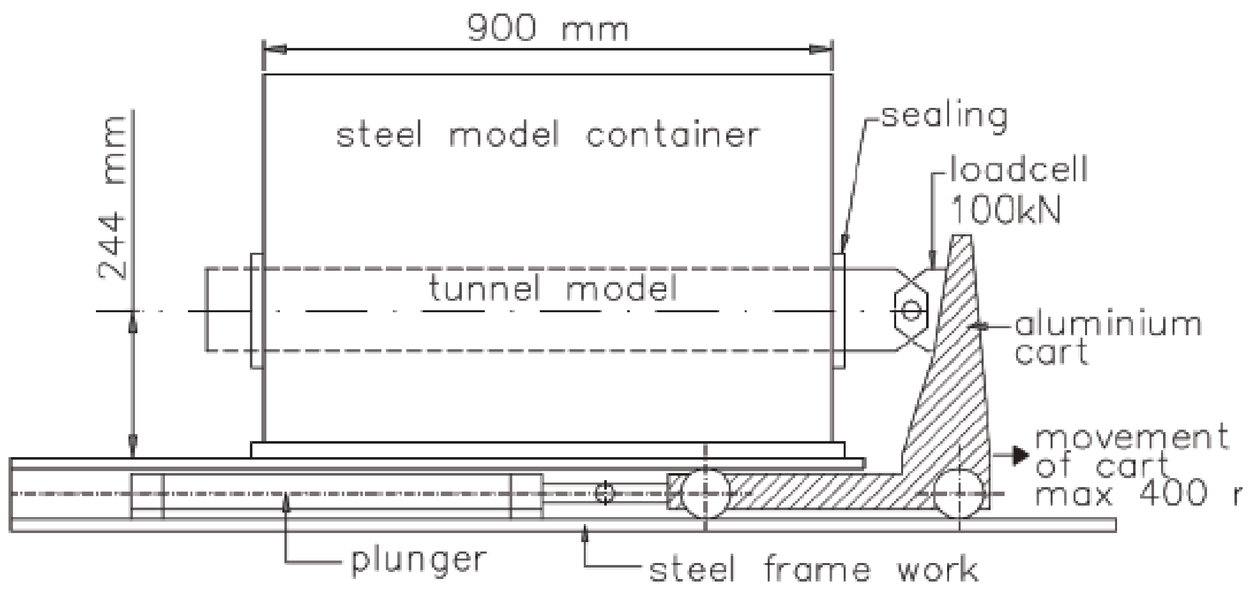
(a) upper part (b) lower part

Linear support pressure with vertical support pressure gradient δp

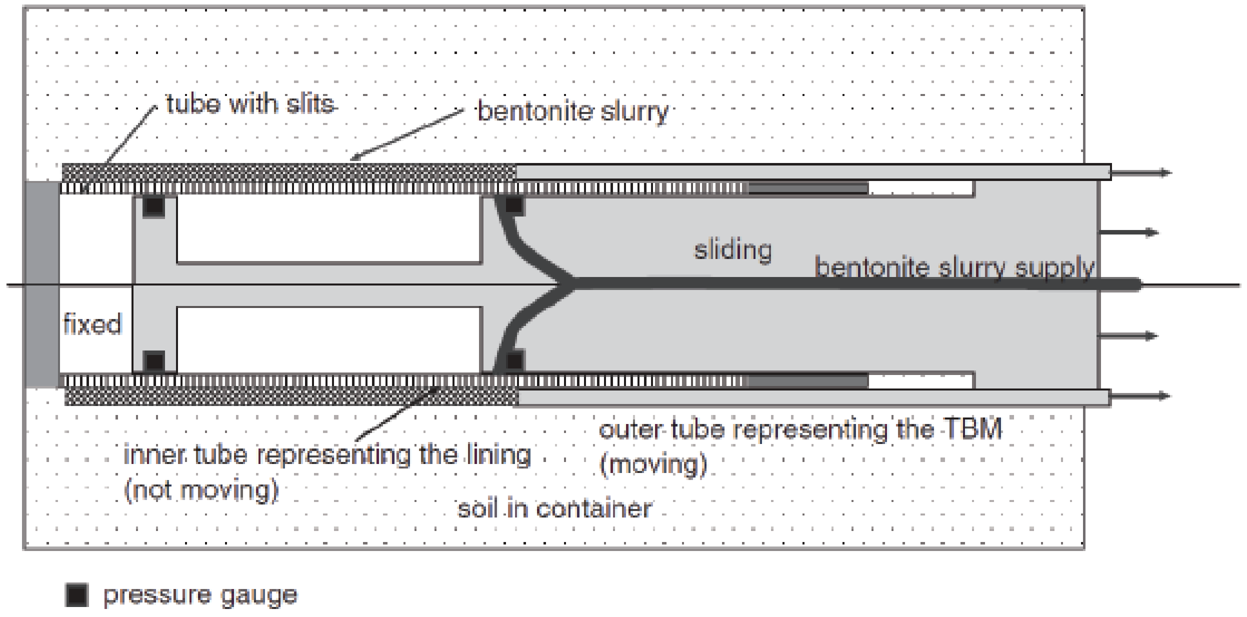
$$s_{t,max} = \left(\frac{C}{D} + \frac{1}{2}\right)^2 2DK_y\gamma' tan\varphi + \left(\frac{C}{D} + \frac{1}{2}\right)(\gamma D + 2c) - \frac{\pi}{8}\gamma D$$

$$s_{b,max} = \left(\frac{C}{D} + \frac{1}{2}\right)^2 2DK_y\gamma' tan\varphi + \left(\frac{C}{D} + \frac{1}{2}\right)(\gamma D + 2c) + \gamma_T \pi d - \frac{\pi}{8}\gamma D$$

Validation with experiments



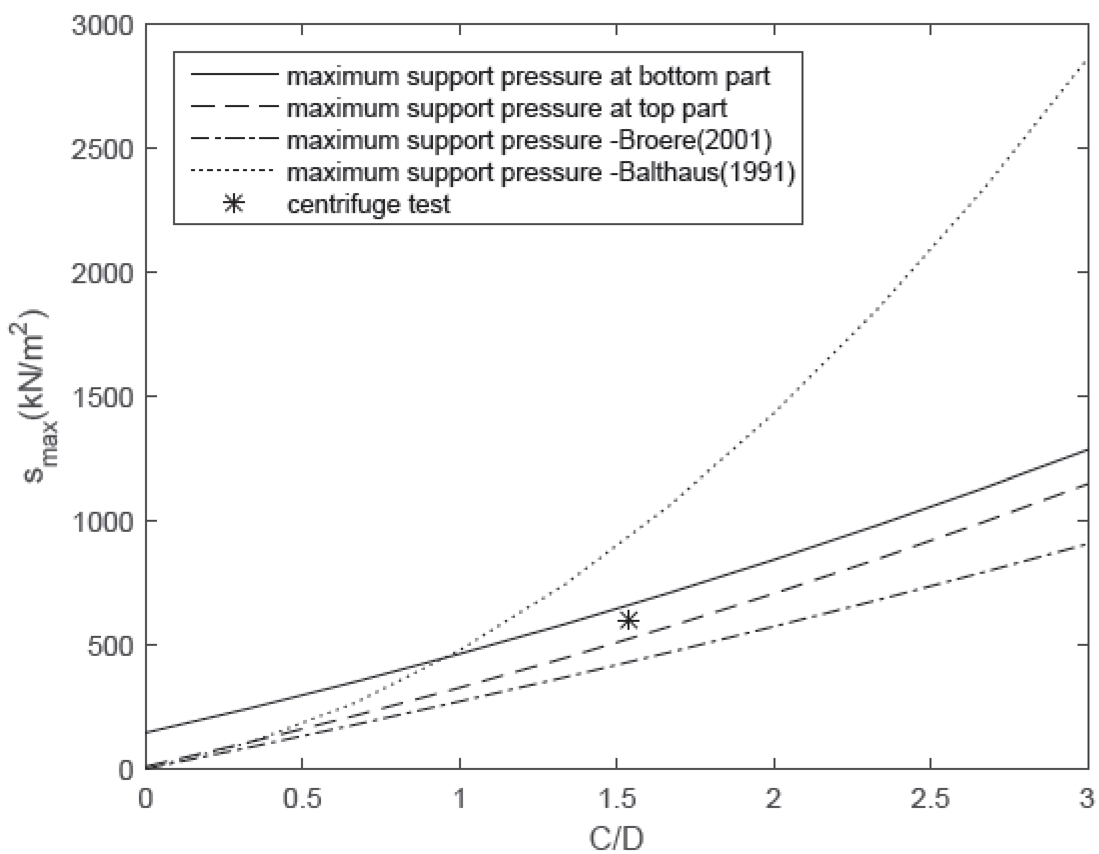
(a) Side view



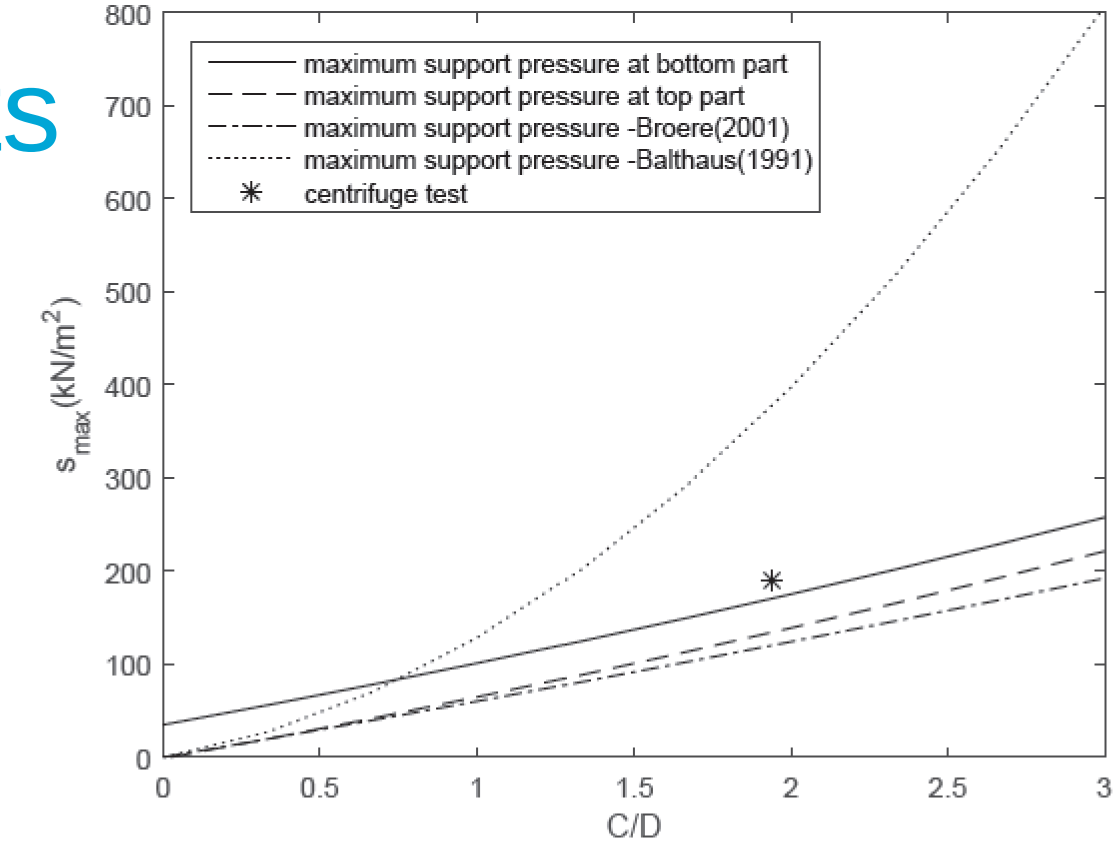
(b) Sketch of the module made to simulate the grouting process

Sketch of centrifuge tests in Bezuijen and Brassinga (2006)

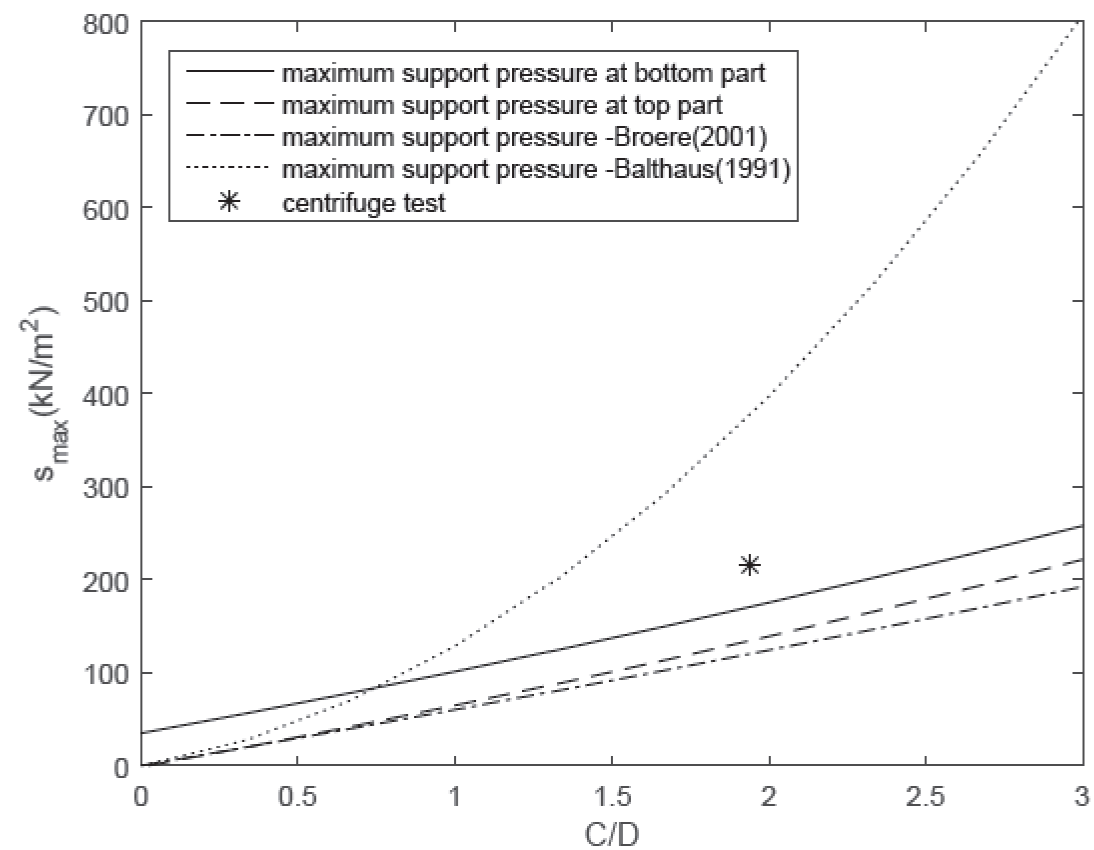
Validation with experiments



(a) with the 1^{st} centrifuge test

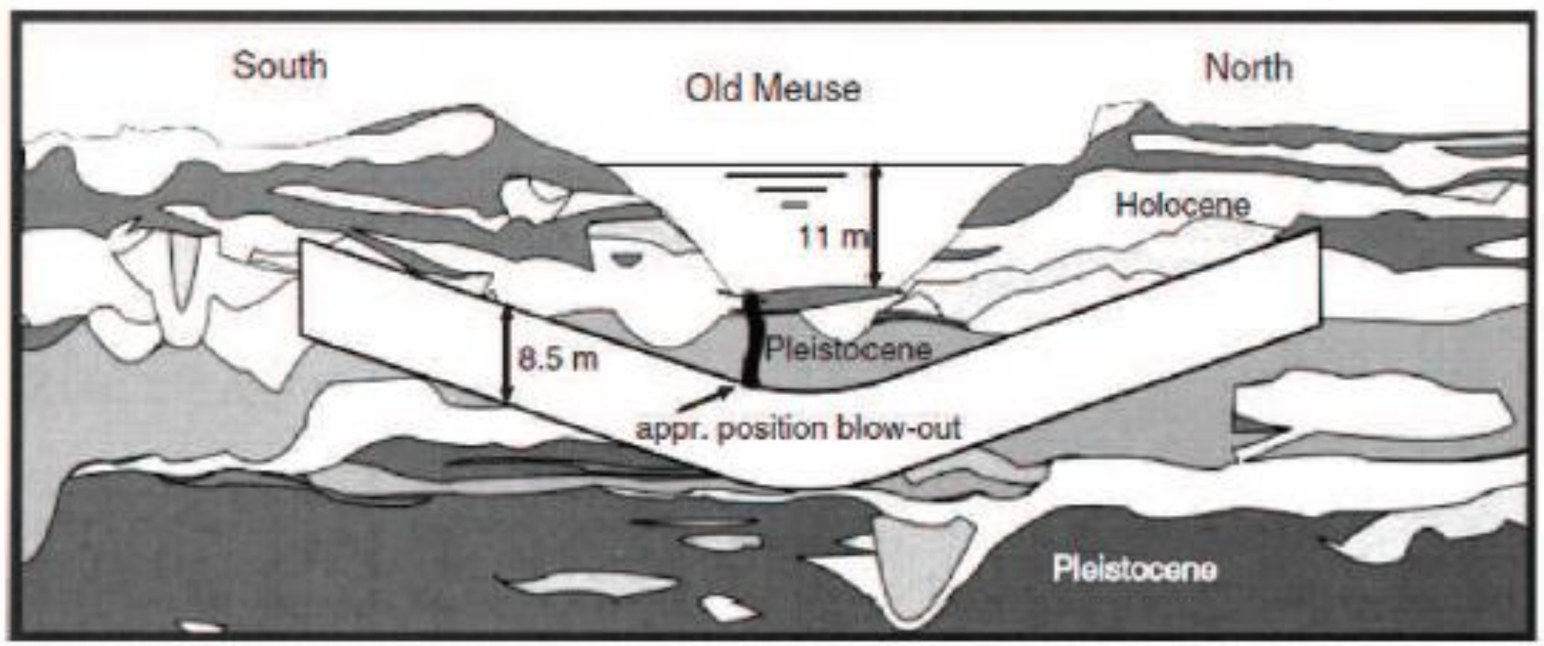


(b) with the 2^{nd} centrifuge test



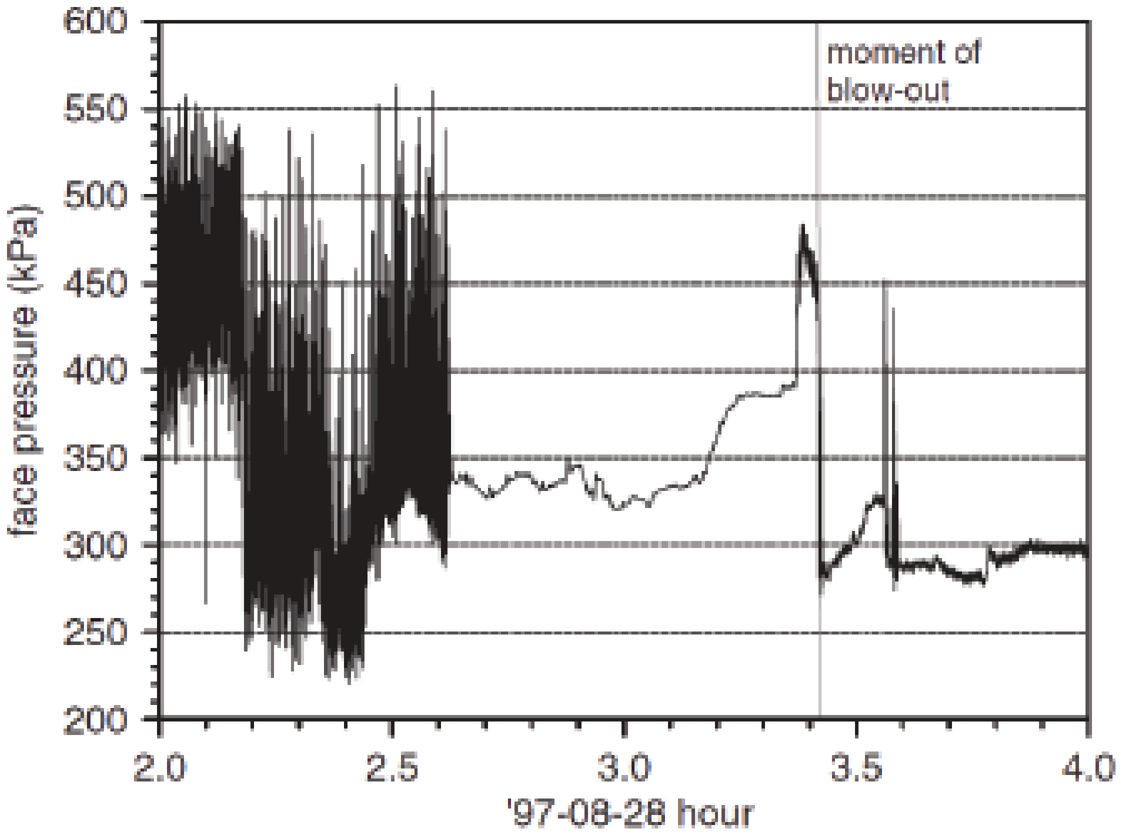
(c) with the 3^{rd} centrifuge test

Validation with case studies

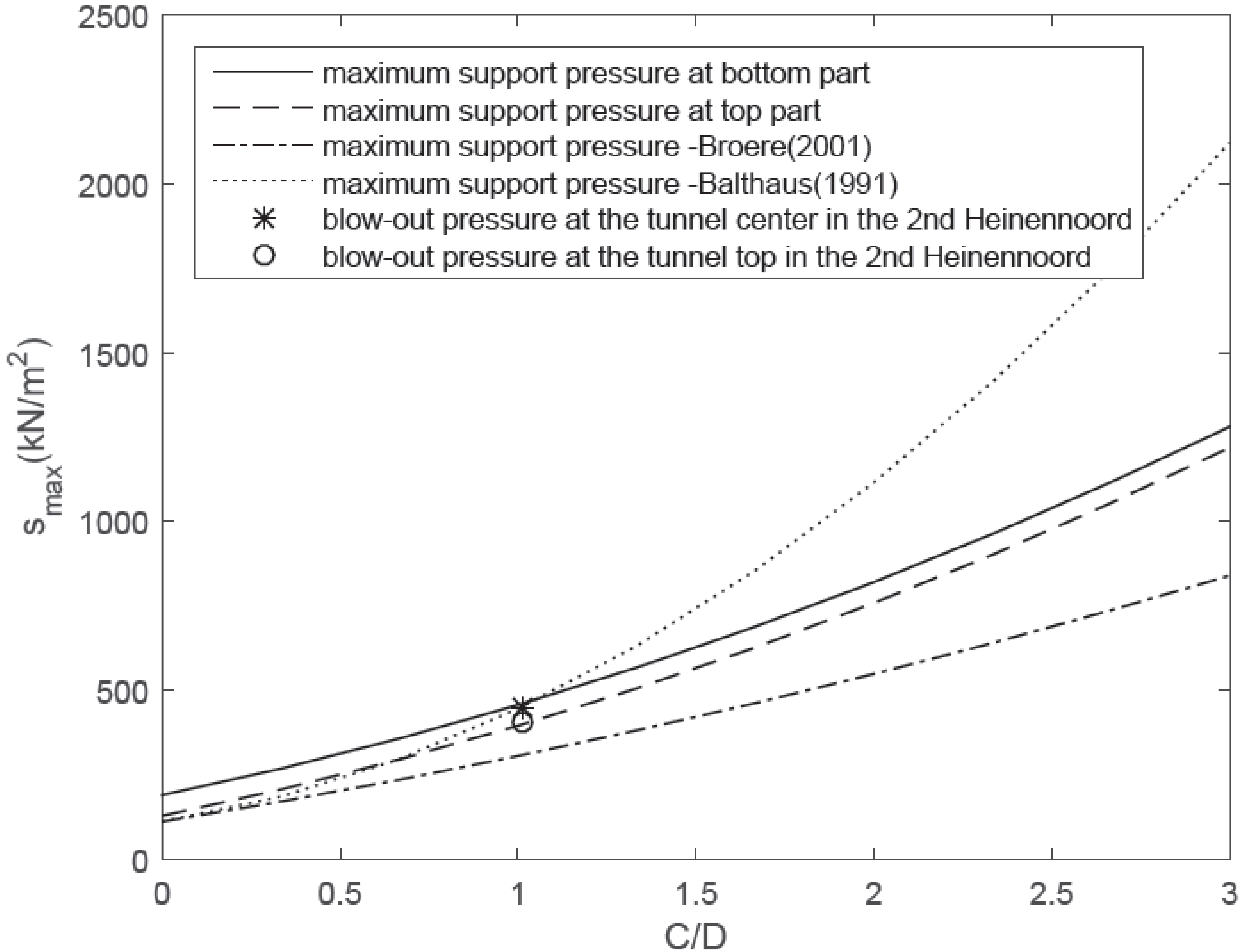


(a) Scheme of the Second Heinenoord Tunnel and the blow-out position

Blow-out at the Second Heneinoord Tunnel (Bezuijen and Brassinga, 2006)



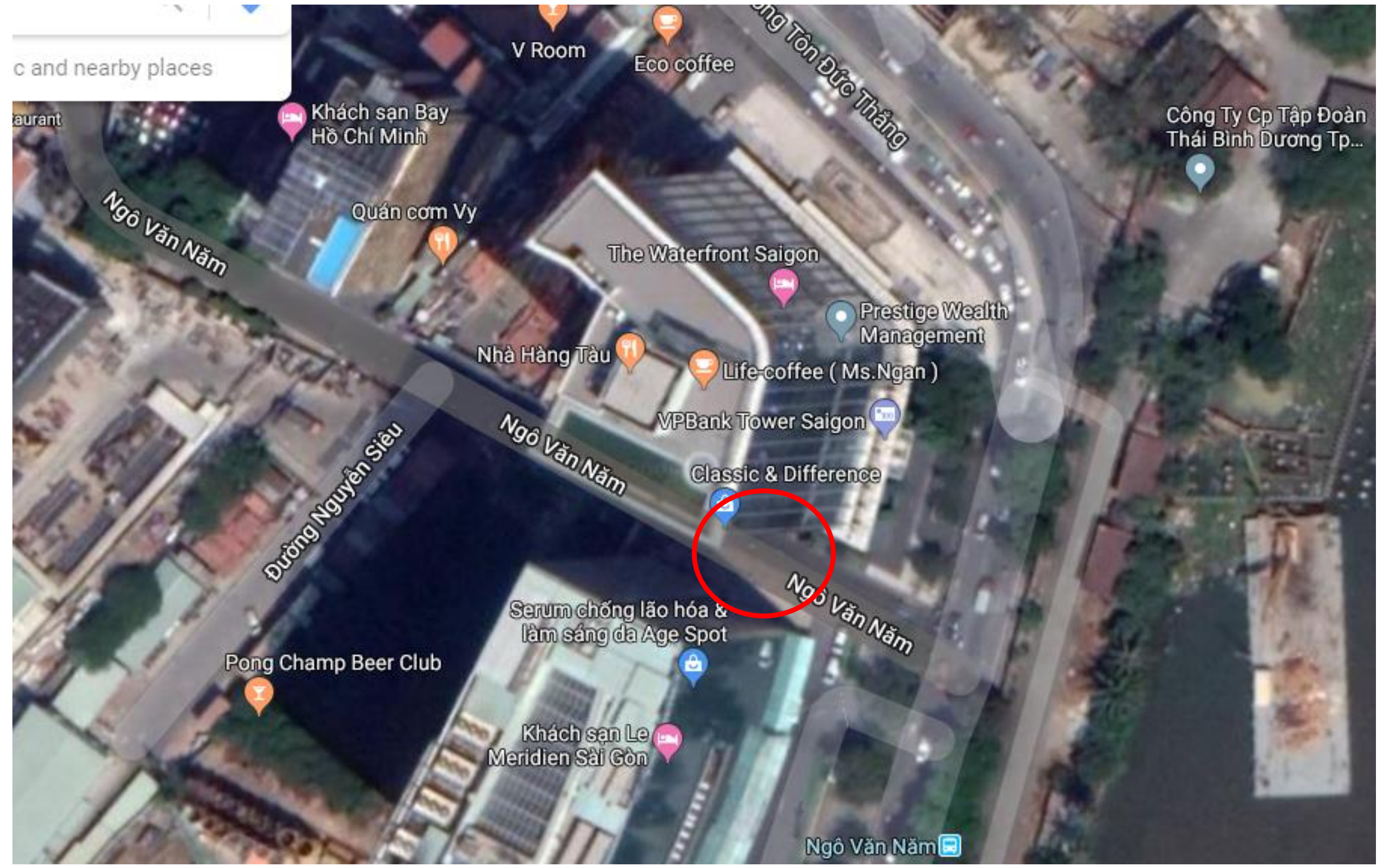
(b) Face support pressure measurement at the tunnel centre during blow-out

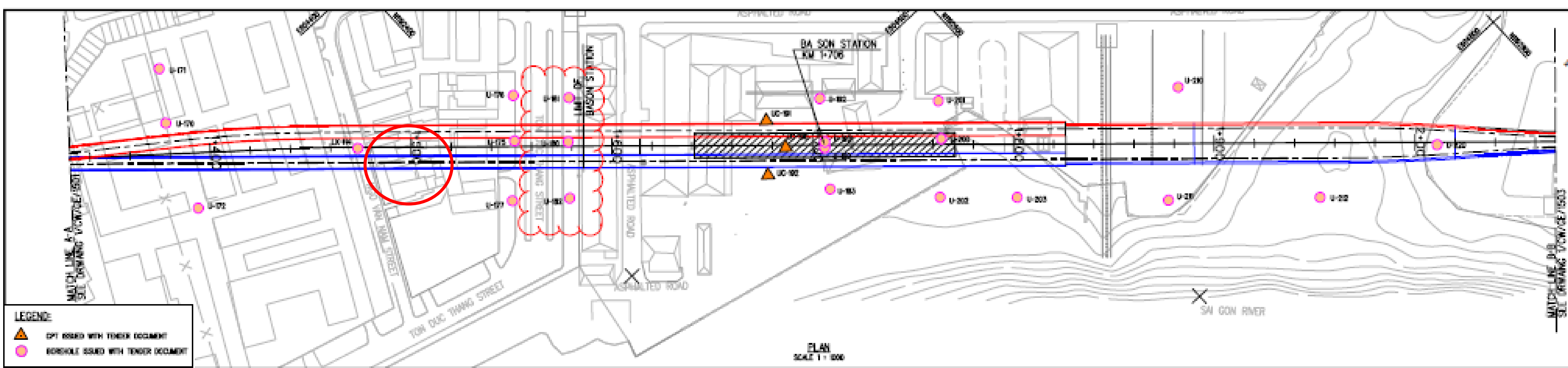


A comparison of maximum support pressures calculated from new blow-out models, Broere's model, Balthaus's model and in the Second Heinenoord Tunnel case

Blow-out in HCM MRT Line 1

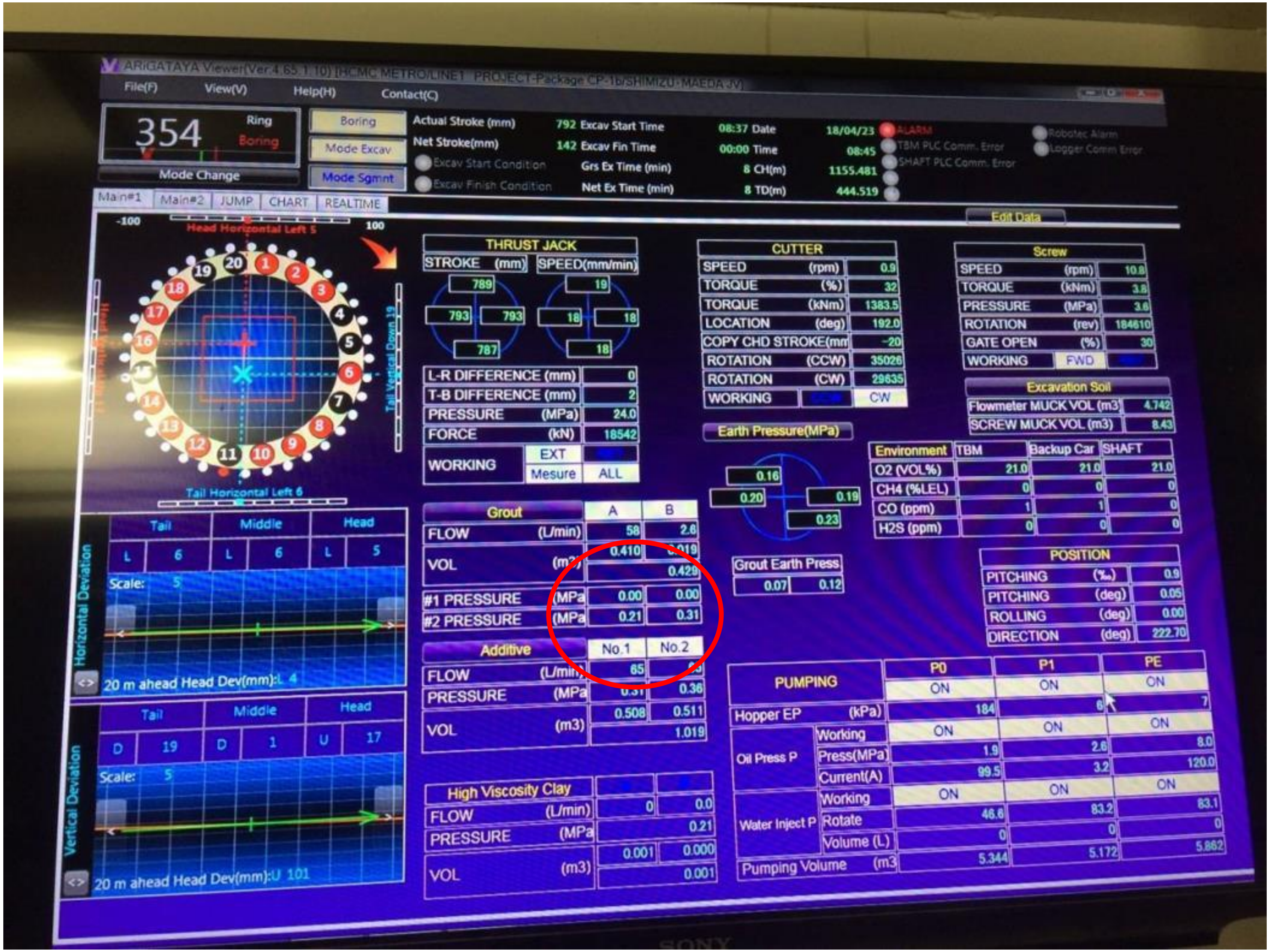
Blow-out in HCM MRT Line 1





Blow-out in HCM MRT Line 1

Blow-out in HCM MRT Line 1



File(F) View(V) Help(H) Contact(C)
354 Ring Boring
Mode Change
Boring
Mode Excav
Mode Sgmnt
Actual Stroke (mm) 792 Excav Start Time 08:37 Date 18/04/23
Net Stroke(mm) 142 Excav Fin Time 00:00 Time 08:45
Excav Start Condition Grs Ex Time (min) 8 CH(m) 1155.481
Excav Finish Condition Net Ex Time (min) 8 TD(m) 444.519
Main#1 Main#2 JUMP CHART REALTIME
Edit Data
Head Horizontal Left 5
Tail Horizontal Left 6
THRUST JACK
STROKE (mm)
SPEED(mm/min)
L-R DIFFERENCE (mm) 0
T-B DIFFERENCE (mm) 2
PRESSURE (MPa) 24.0
FORCE (kN) 18542
WORKING EXT Mesure ALL
CUTTER
SPEED (rpm) 0.9
TORQUE (%) 32
TORQUE (kNm) 1383.5
LOCATION (deg) 192.0
ROTATION (CCW) 35026
ROTATION (CW) 29635
WORKING CW
Earth Pressure(MPa)
Screw
SPEED (rpm) 10.8
TORQUE (kNm) 3.8
PRESSURE (MPa) 3.6
ROTATION (rev) 184610
GATE OPEN (%) 30
WORKING FWD
Excavation Soil
Flowmeter MUCK VOL (m3) 4.742
SCREW MUCK VOL (m3) 8.43
Environment TBM Backup Car SHAFT
O2 (VOL%) 21.0 21.0 21.0
CH4 (%LEL)
CO (ppm)
H2S (ppm)
Grout A B
FLOW (L/min) 58 2.6
VOL (m3) 0.410 0.019 0.429
#1 PRESSURE (MPa) 0.00 0.00
#2 PRESSURE (MPa) 0.21 0.31
Grout Earth Press 0.07 0.12
POSITION
PITCHING (‰) 0.9
PITCHING (deg) 0.05
ROLLING (deg) 0.00
DIRECTION (deg) 222.70
Additive No.1 No.2
FLOW (L/min) 65
PRESSURE (MPa) 0.36
VOL (m3) 0.508 0.511 1.019
Horizontal Deviation
Tail Middle Head
Scale: 5
20 m ahead Head Dev(mm):L 4
Vertical Deviation
Scale: 5
20 m ahead Head Dev(mm):U 101
PUMPING P0 P1 PE
Hopper EP (kPa) 184
Oil Press P Working Press(MPa) Current(A)
Water Inject P Working Rotate Volume (L)
Pumping Volume (m3) 5.344 5.172 5.862
High Viscosity Clay
FLOW (L/min)
PRESSURE (MPa)
VOL (m3) 0.001 0.000 0.001

Geo conditions

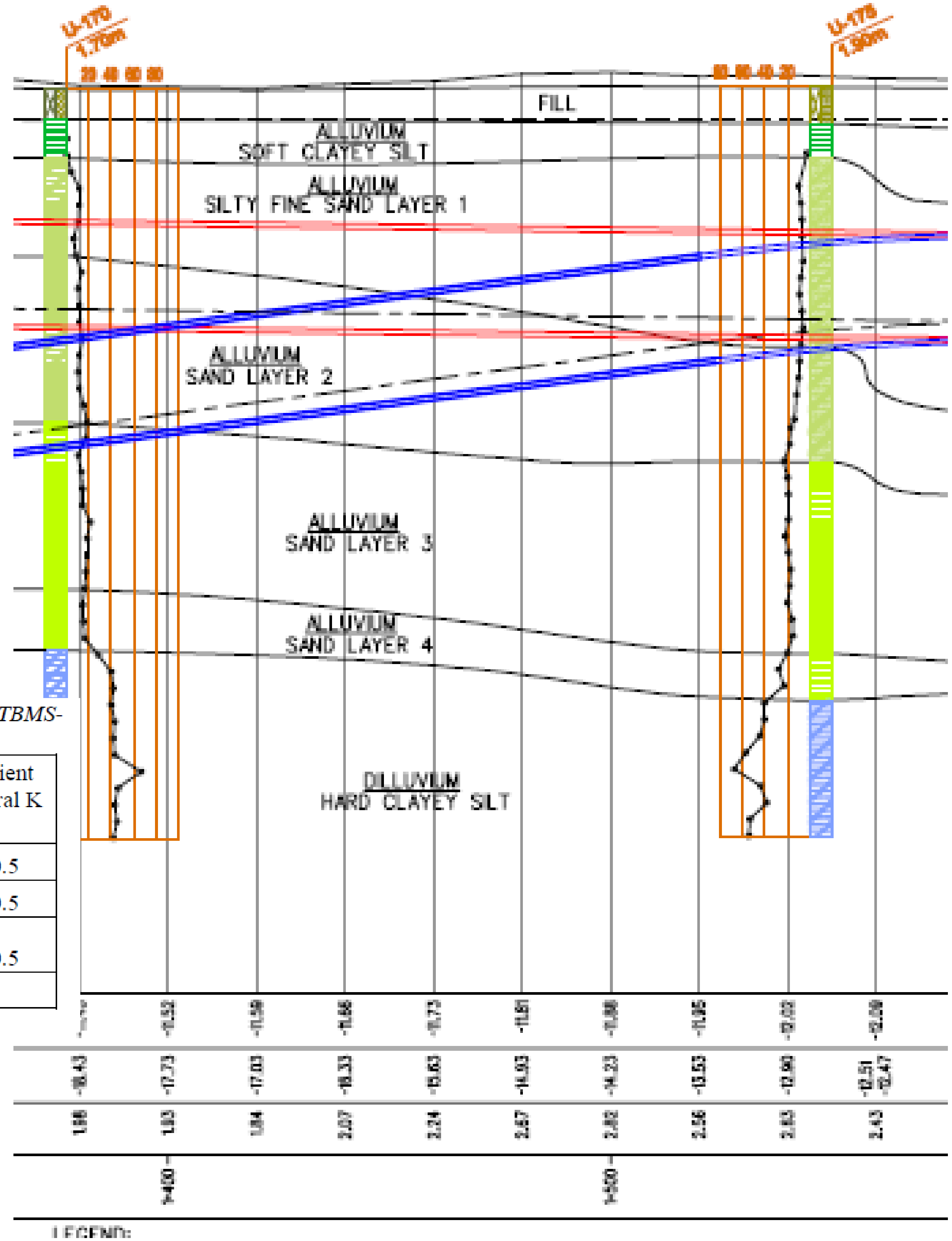


Table 1. Soil parameters applied in Hochiminh Metro Line 1 Project based on UMRTL1-CP1b-TBMS-CGE-RPT-00073-C report

Layer	Description	Level		Weight unit γ (kN/m³)	Cohe-sion c (kPa)	Friction angle φ (deg.)	Coefficient of Lateral K
		From	To				
1	Fill layer	2.58	0.23	19	10	25	0.6-0.5
2	Alluvium Clay Layer 2	0.23	-1.77	16.5	0	24	0.6-0.5
3	Alluvium Silty Fine Sand Layer 1	-1.77	-13.2	20.5	0	30	0.6-0.5
4	Alluvium Sand Layer 2	-13.2	-17.4	20.5	0	33	0.5

Layer	Description	Level		Weight unit g (kN/m³)	Cohe-sion c (kPa)	Friction angle j (deg.)	Coefficient of Lateral K
		From	To				
1	Fill layer	2.58	0.23	19	10	25	0.6-0.5
2	Alluvium Clay Layer 2	0.23	-1.77	16.5	0	24	0.6-0.5
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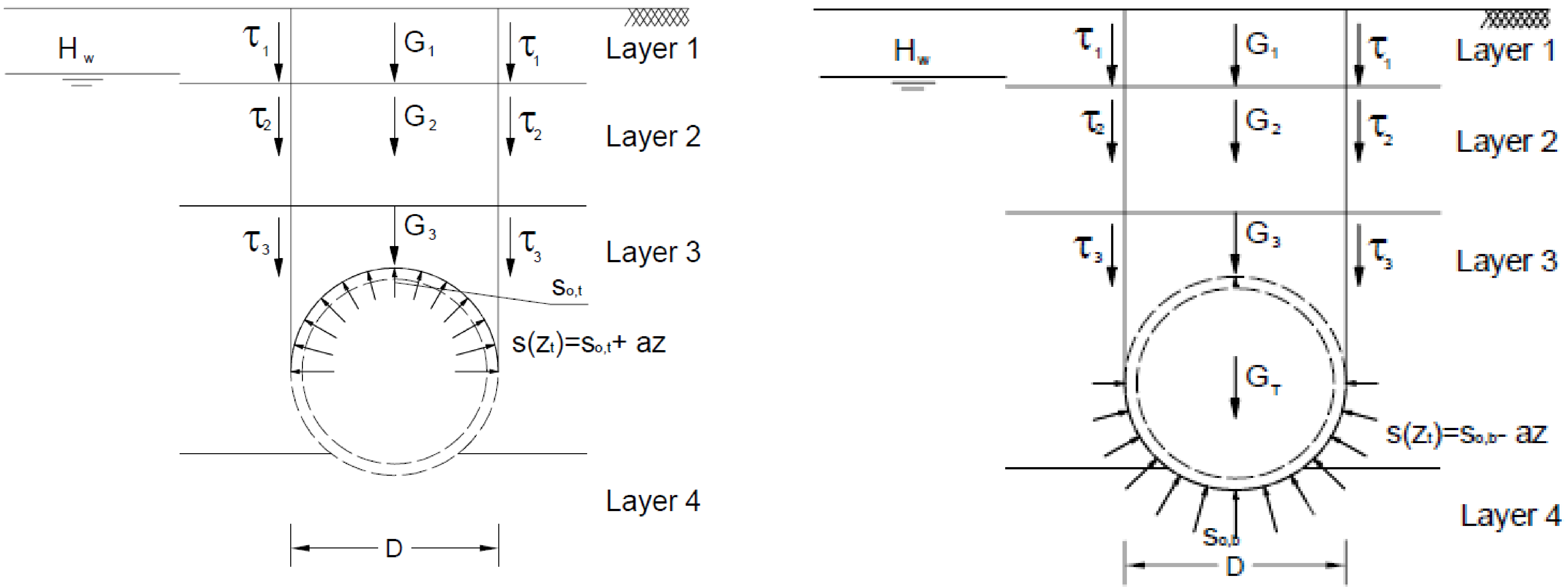
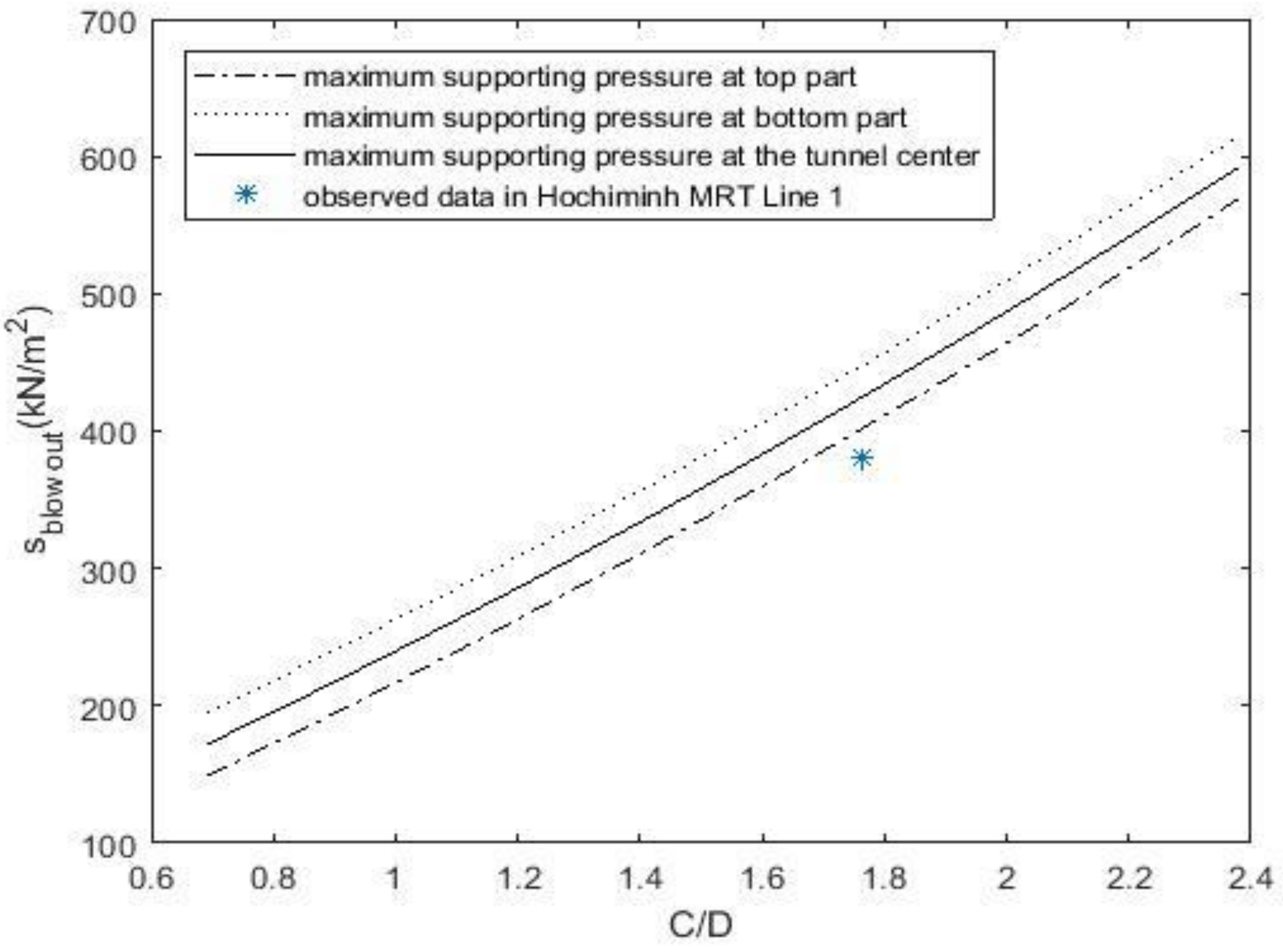
4	Alluvium Sand Layer 2	-13.2	-17.4	20.5	0	33	0.5

Calculation



Hình 6. Mô hình phân tích hiện tượng đẩy trồi tại Dự án Hochiminh Metro Line 1
(a) Phần trên (b) Phần dưới

Result:



maximum supporting pressure at top part
maximum supporting pressure at bottom part
maximum supporting pressure at the tunnel center
observed data in Hochiminh MRT Line 1
$S_{blow\,out}(kN/m^2)$
C/D
700
600
500
400
300
200
100
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4

Conclusions

- Blow-out condition is an essential stability calculation in tunnelling design, especially when shallow tunnelling in soft soils in order to prevent damage on the tunnelling process and existing buildings.

- Blow-out models have been reviewed and compared.

- Validation with the blow-out case study of Hochiminh Metro Line 1 shows a good agreement with the blow-out pressures derived from the linear support pressure blow-out models proposed by Vu et al. (2015).

- The solutions used in the real project of Hochiminh Metro Line 1 show that a careful preparation for risk in tunnelling is very important to have a success tunnelling project.

Thank you very much!