REPUBLIK INDONESIA
KEMENTERIAN HUKUM DAN HAK ASASI MANUSIA

# SURAT PENCATATAN
# CIPTAAN

Dalam rangka pelindungan ciptaan di bidang ilmu pengetahuan, seni dan sastra berdasarkan Undang-Undang Nomor 28 Tahun 2014 tentang Hak Cipta, dengan ini menerangkan:

| | | |
|---|---|---|
| Nomor dan tanggal permohonan | : | EC00202155601, 18 Oktober 2021 |
| **Pencipta** | | |
| Nama | : | **Dr. techn. Indra Noer Hamdhan ST., MT.** |
| Alamat | : | Jl. Sariasih No. 63, RT/RW: 012/009 Sarijadi Sukasari , Bandung , JAWA BARAT, 40151 |
| Kewarganegaraan | : | Indonesia |
| **Pemegang Hak Cipta** | | |
| Nama | : | **LPPM Itenas** |
| Alamat | : | Jl. PHH. Mustafa No. 23 , Bandung, JAWA BARAT, 40124 |
| Kewarganegaraan | : | Indonesia |
| Jenis Ciptaan | : | **Poster** |
| Judul Ciptaan | : | **2D Vs. 3D Numerical Modelling Of NATM Tunnel Using Finite Element Method** |
| Tanggal dan tempat diumumkan untuk pertama kali di wilayah Indonesia atau di luar wilayah Indonesia | : | 18 Oktober 2021, di Bandung |
| Jangka waktu pelindungan | : | Berlaku selama 50 (lima puluh) tahun sejak Ciptaan tersebut pertama kali dilakukan Pengumuman. |
| Nomor pencatatan | : | 000295778 |

adalah benar berdasarkan keterangan yang diberikan oleh Pemohon.
Surat Pencatatan Hak Cipta atau produk Hak terkait ini sesuai dengan Pasal 72 Undang-Undang Nomor 28 Tahun 2014 tentang Hak Cipta.

a.n Menteri Hukum dan Hak Asasi Manusia
Direktur Jenderal Kekayaan Intelektual
u.b.
Direktur Hak Cipta dan Desain Industri

Dr. Syarifuddin, S.T., M.H.
NIP.197112182002121001

Disclaimer:
Dalam hal pemohon memberikan keterangan tidak sesuai dengan surat pernyataan, Menteri berwenang untuk mencabut surat pencatatan permohonan.

# Pengajuan Hak Kekayaan Intelektual (HKI)

# POSTER

## 2D vs. 3D Numerical Modelling of NATM Tunnel using Finite Element Method

**Oleh:**
**Indra Noer Hamdhan**

**BANDUNG – JAWA BARAT - INDONESIA**
**2021**

**2D vs. 3D Numerical Modelling of NATM Tunnel using Finite Element Method**

Indra Noer Hamdhan
08122334533

## Description

The examples of NATM Tunnel with three bench excavations at two different clay soil layers will be discussed. These examples will be analysed by the finite element method 2D model and will be compared with the finite element method 3D model. The analysis was performed by utilizing PLAXIS 2D and PLAXIS 3D. The main objective is to evaluate and to compare the deformation between 2D model and 3D model. The soil model used in the analysis is the Hardening Soil Model and used mesh medium with coarseness factor 1.0.

## Soil Parameters

Soil parameters for 2D and 3D numerical Modelling using Hardening Soil Model. Two different clay soils are stiff clay and very hard clay.

## Stage Constructions

Both models are simulated with one cycle stage construction using three bench excavation method. So that the stage constructions are modelled does not completely excavated: (1) excavation of top bench, (2) installation of shotcrete & top rock bolt, (3) excavation of middle bench, (4) installation of shotcrete & middle rock bolt, (5) excavation of bottom bench, (6) installation of shotcrete & bottom rock bolt, and (7) installation of lining reinforced concrete.

## 2D Numerical Modelling of NATM Tunnel

Geometry model with two different clay soil layers has assumed without ground water level. Round length excavation is assumed 3 meter in every step excavation. In PLAXIS 2D for simulation every step excavation needs to input strength reduction factor (β-value) with range value for partial excavation is $0{,}2 < \beta < 0{,}5$ for a top heading and $0{,}4 < \beta < 0{,}8$ for a wall heading from Laabmayr and Swoboda (1986). The results from 2D model showed that the largest deformation is occurs in the crown of the tunnel. The total deformation that occurs in the final stage of -34.74 mm.

## 3D Numerical Modelling of NATM Tunnel

Geometry model with two different clay soil layers has assumed without ground water level. Round length excavation is assumed 3 meter in every step excavation. The results from 3D model showed that the largest deformation is occurs in soil at the crown of the tunnel. The total deformation that occurs in the final stage of -37.05 mm.

## Comparison Between 2D and 3D Model

The comparison of total vertical deformation in the soil around the tunnel between 2D and 3D numerical model showed no significant difference. The difference is only 5.7%. The difference of vertical deformation at the lining tunnel showed no significant too, the difference is maximum 7% at the crown of the tunnel. The difference of vertical deformation at ground surface between model 2D and 3D is maximum 10%, right above the tunnel.

## Summary

The approach of NATM tunnel using 3D model is widely used in numerical modelling, but 2D model can also be used by using the strength reduction factors (b-values). The comparison of deformation of both models are quite good. The assessment of strength reduction factors in 2D model is awkward, as they are not only dependent on the geometry of the tunnel cross-section, round length or the material behaviour, but they depend as well significantly on construction processes.

# 2D vs. 3D Numerical Modelling of NATM Tunnel using Finite Element Method

**Indra Noer Hamdhan,**
**Civil Engineering Department, Institut Teknologi Nasional, Bandung, Indonesia**

*The examples of NATM Tunnel with three bench excavations at two different clay soil layers will be discussed. These examples will be analysed by the finite element method 2D model and will be compared with the finite element method 3D model. The analysis was performed by utilizing PLAXIS 2D and PLAXIS 3D. The soil model used in the analysis is the Hardening Soil Model and used mesh medium with coarseness factor 1.0.*

## Soil Parameters and Stage Construction

Soil parameters for 2D and 3D numerical Modelling using Hardening Soil Model.

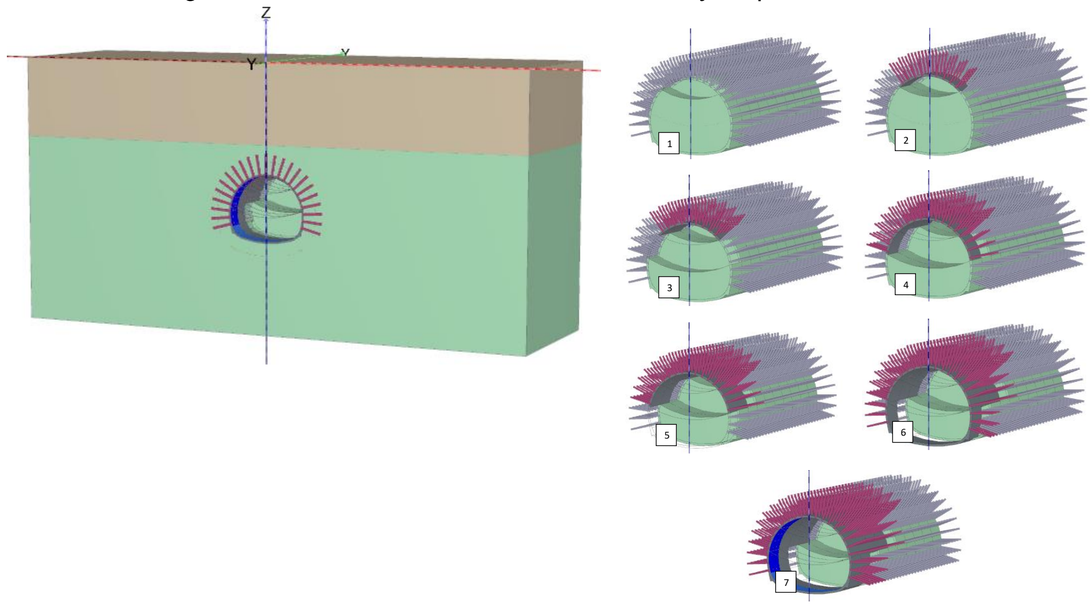
| Soil Parameter | Stiff Clay | Very Hard Clay | Unit |
|---|---|---|---|
| **Soil Model** | HS Model | HS Model | - |
| **Depth** | 0-15 | 15-50 | m |
| **Type** | Und. A | Und. A | - |
| $\gamma_{unsat}$ | 15 | 15 | (kN/m$^3$) |
| $\gamma_{sat}$ | 16 | 16 | (kN/m$^3$) |
| $E_{50}^{ref}$ | 65000 | 210000 | (kN/m$^2$) |
| $E_{oed}^{ref}$ | 52000 | 168000 | (kN/m$^2$) |
| $E_{ur}^{ref}$ | 195000 | 630000 | (kN/m$^2$) |
| **c'** | 15 | 25 | (kN/m$^2$) |
| **phi'** | 25 | 32 | ° |
| **Y** | 0 | 2 | ° |

Both models are simulated with one cycle stage construction using three bench excavation method. So that the stage constructions are modelled does not completely excavated.

| Stage | Construction |
|---|---|
| 1 | Excavation of top bench |
| 2 | Installation of shotcrete & top rock bolt |
| 3 | Excavation of middle bench |
| 4 | Installation of shotcrete & middle rock bolt |
| 5 | Excavation of bottom bench |
| 6 | Installation of shotcrete & bottom rock bolt |
| 7 | Installation of lining of reinforced concrete |

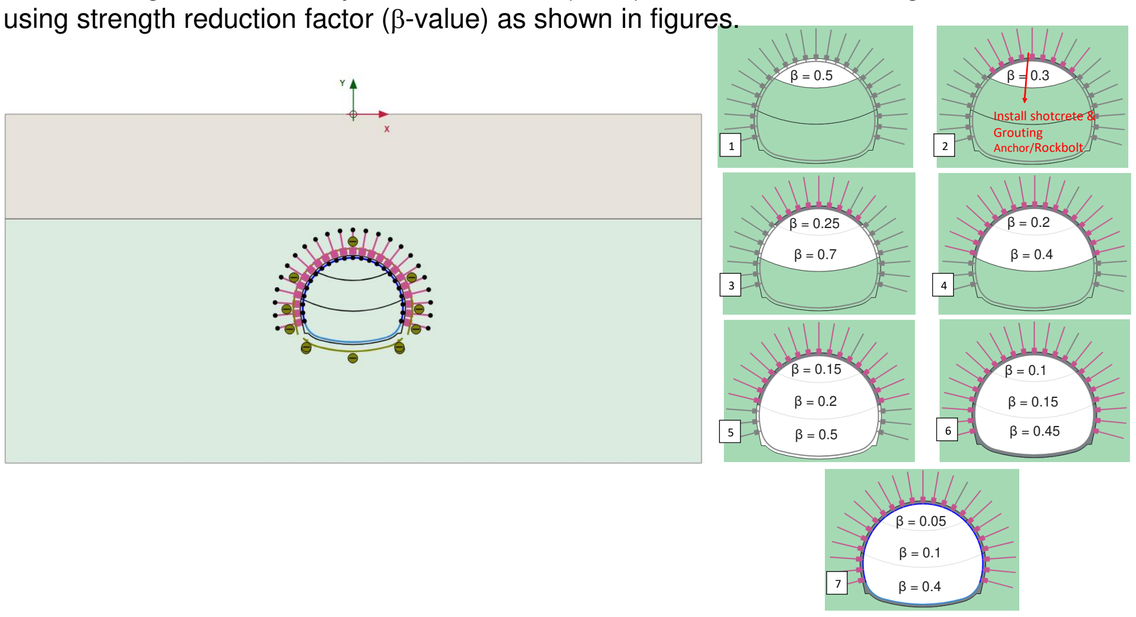
## 3D Numerical Modelling of NATM Tunnel

Geometry model with two different clay soil layer has assumed without ground water level. Round length excavation is assumed 3 meter in every step excavation.




## 2D Numerical Modelling of NATM Tunnel

Geometry model with two different clay soil layers has assumed without ground water level. Round length excavation is assumed 3 meter in every step excavation. In PLAXIS 2D for simulation every step excavation needs to input strength reduction factor (β-value) with range value for partial excavation is 0,2 < β < 0,5 for a top heading and 0,4 < β < 0,8 for a wall heading from Laabmayr and Swoboda (1986). In this 2D modelling of NATM tunnel using strength reduction factor (β-value) as shown in figures.

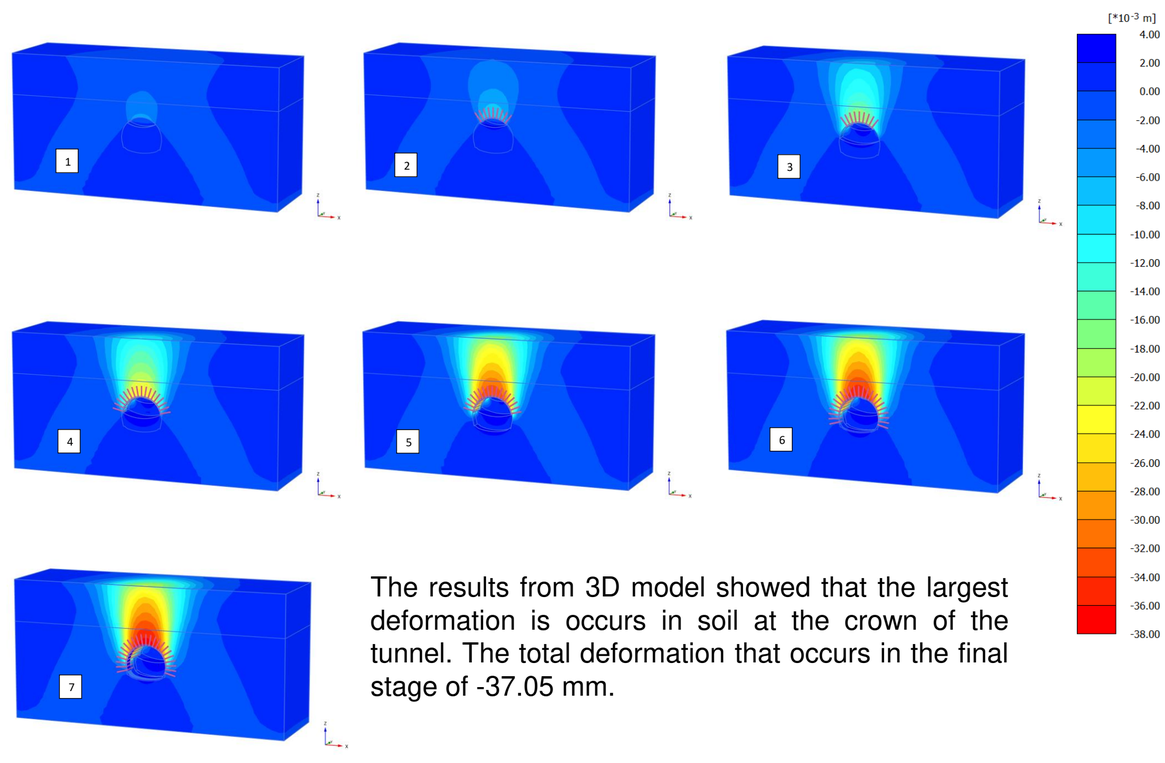



The total deformation in every excavation stage in 2D model are shown in figures below:




The results from 2D model showed that the largest deformation is occurs in the crown of the tunnel. The total deformation that occurs in the final stage of -34.74 mm.

The total deformation in every excavation stage in 3D model are shown in figures below:




The results from 3D model showed that the largest deformation is occurs in soil at the crown of the tunnel. The total deformation that occurs in the final stage of -37.05 mm.

## Comparison Between 2D and 3D Model

The comparison of total vertical deformation in the soil around the tunnel between 2D and 3D numerical model showed no significant difference. The difference is only 5.7%.

The difference of vertical deformation at the lining tunnel showed no significant too, the difference is maximum 7% at the crown of the tunnel (position 0º or 360º).




| Stage | Total Vertical Deformation (mm) | | Δ (%) |
|---|---|---|---|
| | 2D Model | 3D Model | |
| 1 | -5.54 | -4.38 | 20.94 |
| 2 | -7.95 | -7.68 | 3.40 |
| 3 | -23.74 | -18.24 | 23.17 |
| 4 | -24.24 | -23.49 | 3.09 |
| 5 | -33.96 | -33.84 | 0.35 |
| 6 | -34.33 | -35.90 | -4.57 |
| 7 | -34.74 | -37.05 | -6.65 |
| Average | | | 5.68 |

The difference of vertical deformation at ground surface between model 2D and 3D is maximum 10%, right above the tunnel.




Vertical deformation at ground surface




Vertical deformation at lining tunnel

## Summary

The approach of NATM tunnel using 3D model is widely used in numerical modelling, but 2D model can also be used by using the strength reduction factors (β-values). The comparison of deformation of both models are quite good. The assessment of strength reduction factors in 2D model is awkward, as they are not only dependent on the geometry of the tunnel cross-section, round length or the material behaviour, but they depend as well significantly on construction processes.