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To Analyze Different Excavation Pattern in NATM Construction

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***Abstract:** Underground construction is preferable due to lack of space availability on surface in urban areas, so the underground construction is increasing throughout the world for various reasons. Tunneling in urban area is a unique challenge, these challenge can be addressed with suitable tunnel design. New Austrian Tunneling Method (NATM) has become the method of choice for tunneling in urban areas to construct underground structure such as metro station, rail crossovers, multi-track metro lines. The aim of this report is to analyze different excavation pattern such as heading, benching and invert in NATM construction in varying geological conditions by using RS2 software for determining stresses across the tunnel surrounding and to give a best suitable excavation pattern for construction of tunnel.*
***Keywords:** Heading, Benching, Urban tunnels, Excavation Pattern, Underground Construction*.

I. INTRODUCTION

It is a method of modern tunnel design and construction employing cultured monitoring to optimize various wall reinforcement techniques based on the type of rock faced as tunnelling progresses. The name NATM was proposed to differentiate it from earlier methods, with its financial advantage of employing inherent geological strength available in the surrounding rock mass to stabilize the tunnel wherever possible rather than reinforcing the total tunnel. The effect of displacements in urban areas where broad scale of structures and facilities have been established on the ground surface is basically of profound importance. Since tunnels in urban areas are related to low depth, soft ground, and presence of structures and facilities on the bottom surface, optimum selection of excavation pattern along side well-designed sequences of excavation-if SEM has been chosen- has the potential to regulate ground surface settlement. Although few technical and economic issues meddles in excavation pattern selection, no comprehensive approach, ready to appropriately select an excavation method, has yet been introduced worldwide. All the forces used in the design will be obtained Analysis of primary support systems will be carried out using RocScience software tool (RS2).

A model is prepared in number of stages to assess the support requirement and ground movements due to the construction of crossover connecting station box and platform tunnel.

II. GEOLOGICAL PROPERTIES

A. Geological Parameters Of Soil

Table 1. Parameters of soil

PARAMETERS	UNITS	VALUES
Unit Weight	MN/m3	0.01286
Poisson's Ratio	-	0.35
Young's Modulus	Mpa	10000
Peak Tensile Strength	Mpa	0
Peak Friction Angle	Degree	12
Peak Cohesion	Mpa	1

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B. Geological Parameters Of Rock

Table 2. Parameters of rock

PARAMETERS	UNITS	SANDSTONE	BASALT
		VALUES	**VALUES**
Unit Weight	MN/m3	0.024	0.028
Poisson's Ratio	-	0.15	0.2
Young's Modulus	Mpa	6399	89000
Peak Tensile Strength	Mpa	0	0
Peak Friction Angle	Degree	40.9	35
Peak Cohesion	Mpa	4	10

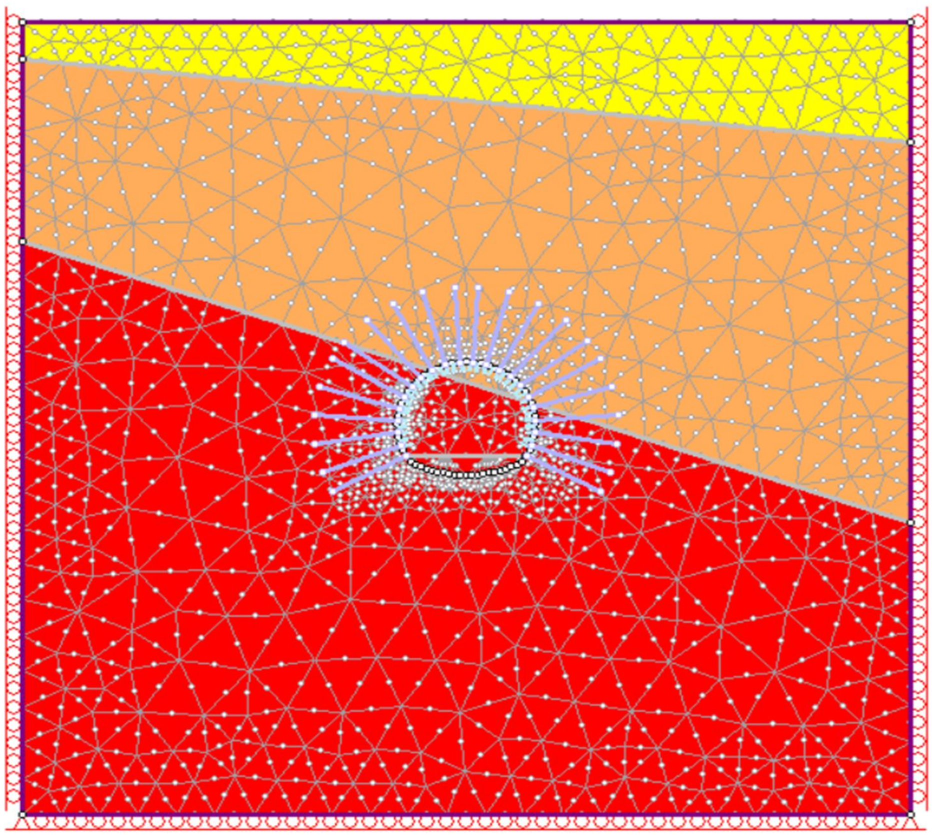

Figure 1. 2D Model of soil and rock strata

III. TUNNEL DIMENSIONS

A. Curved Horseshoe Properties

Table 3. Tunnel Dimension

PARAMETERS	UNITS	VALUES
Crown Radius	m	5
Overall Height to Invert Corners	m	8
Sidewall Radius	m	10
Invert Width	m	8
Invert Dish	m	1

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IV. TUNNEL LINERS

Details of liner used in the analysis is listed down in tables below. Shotcrete are going to be used together of the well-liked support elements in Tunnel.

Table 4. Tunnel Liner

PARAMETERS	UNITS	VALUES
Shotcrete Grade	-	M35
Thickness	m	0.2
Young's Modulus	Mpa	29580
Poisson's Ratio	-	0.2
Compressive Strength	Mpa	35
Tensile Strength	Mpa	3.89

V. ROCK-BOLTS

A. Rock-Bolts With Following Properties Are Proposed

Table 5. Properties of Rock-Bolt

PARAMETERS	UNITS	VALUES
Steel Grade	-	Fe500
Bolt Diameter	mm	25
Bolt Modulus	Mpa	210000
Tensile Capacity	MN	545
Residual Tensile Capacity	MN	0
Out of plane spacing	m	1

VI. EXCAVATION SEQUENCE (MODELLING STAGE)

A. Case One

1) A Full Face excavation is carried out for the construction of tunnel.
2) By using NATM technique and pattern, we will drill holes and carry out blasting for the entire tunnel face at a time.
3) First the heading part is excavated and after completion benching is constructed.
4) Shotcrete and rock-bolt is used as a primary support at tunnel excavation face.

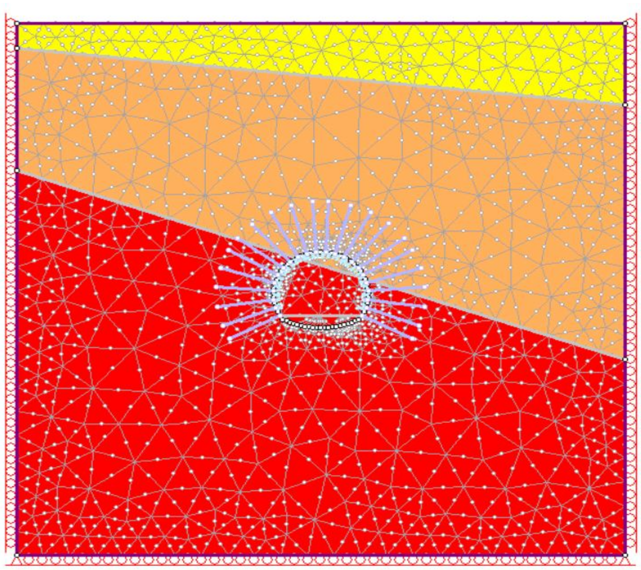

Figure 2. Initial Stage

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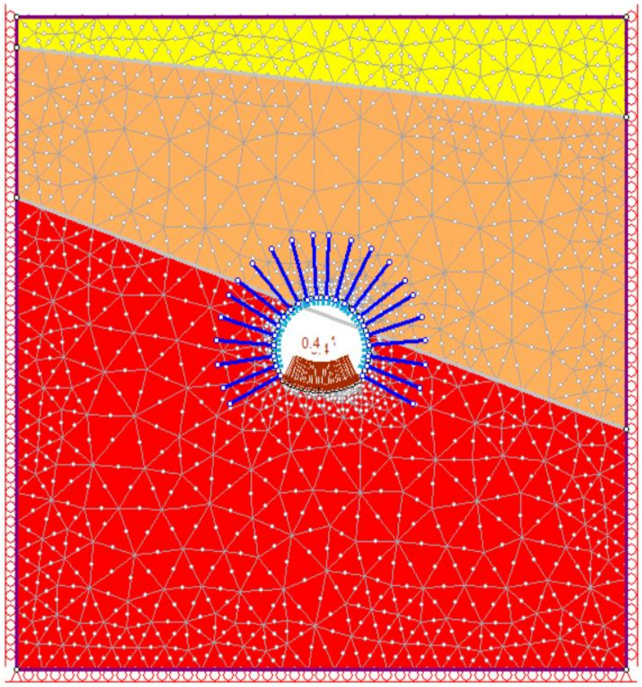

Figure 3. Final Stage

B. Case Two

1) The excavation is done in 3 faces.
2) First the heading is excavated by drilling hole pattern and blasting.
3) Second step is to excavated benching by same procedure.
4) At the end after completing heading and benching the invert is to be construct.
5) Primary support is provided after every excavation.

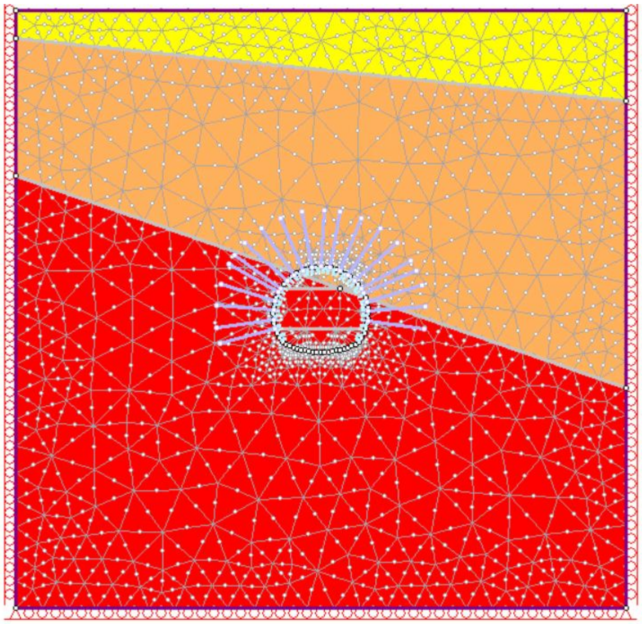

Figure 4. Initial Stage

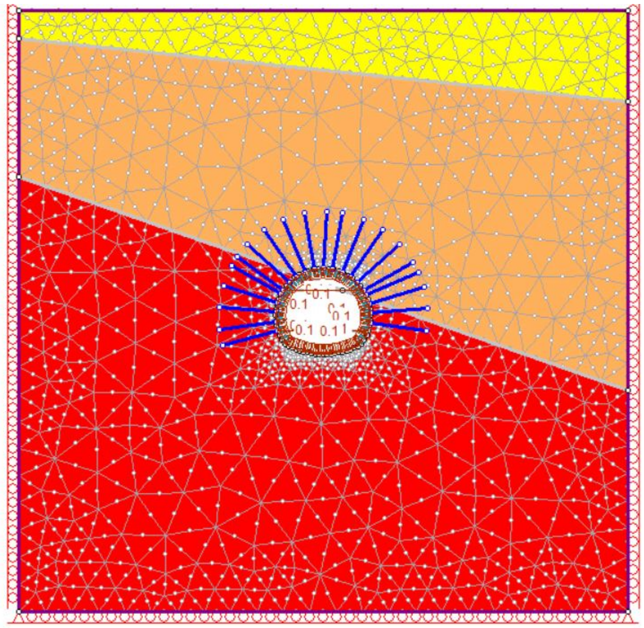

Figure 5. Final Stage

C. Case Three

1) The excavation sequence contains 3 heading and 1 benching.
2) Excavation will start within the top heading section 1.
3) Once the highest heading section 1 excavation completes, the excavation of top heading section 2 will start.
4) The top heading section 2 completes excavation, subsequent top heading section 3 will start.
5) Benching excavation will start once the highest heading 3 completes the excavation.

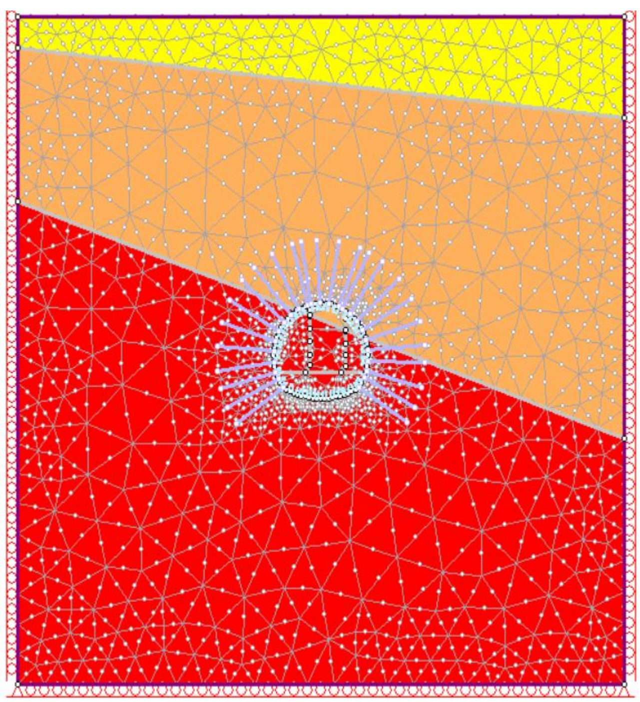

Figure 6. Initial Stage

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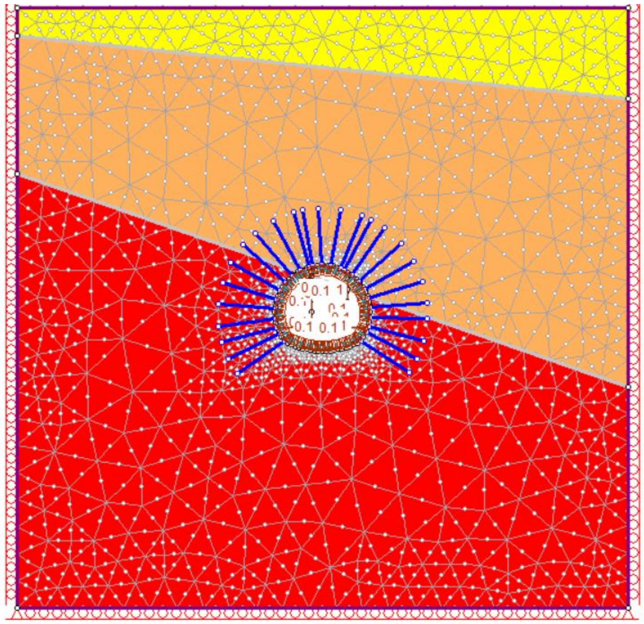

Figure 7. Final Stage

D. Case Four

1) The Central Diaphragm excavation sequences consist of 4 stages.
2) The left top heading 1 is to be excavated, after completing top heading 1 the right top heading 2 is excavated.
3) The completion of left top heading 1 and heading stage 2 once done the same procedure follows for right benching 3 and left benching stage 4.

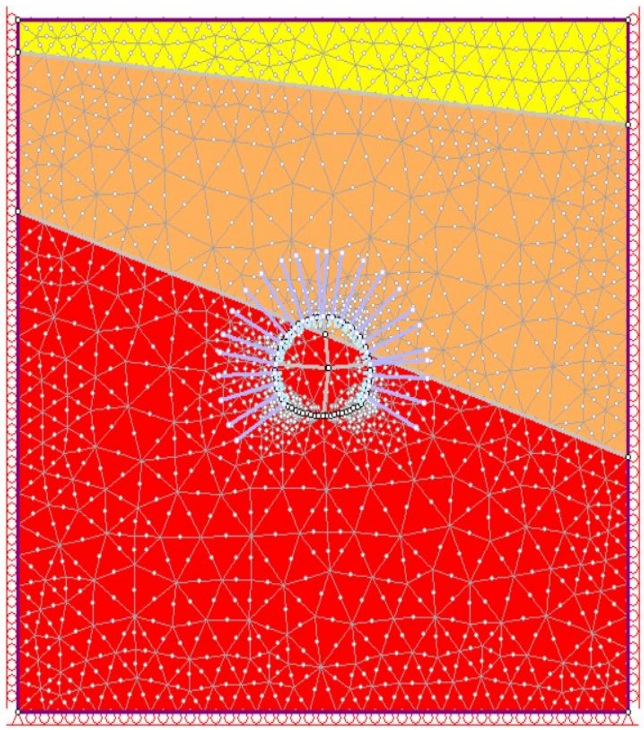

Figure 8. Initial Stage

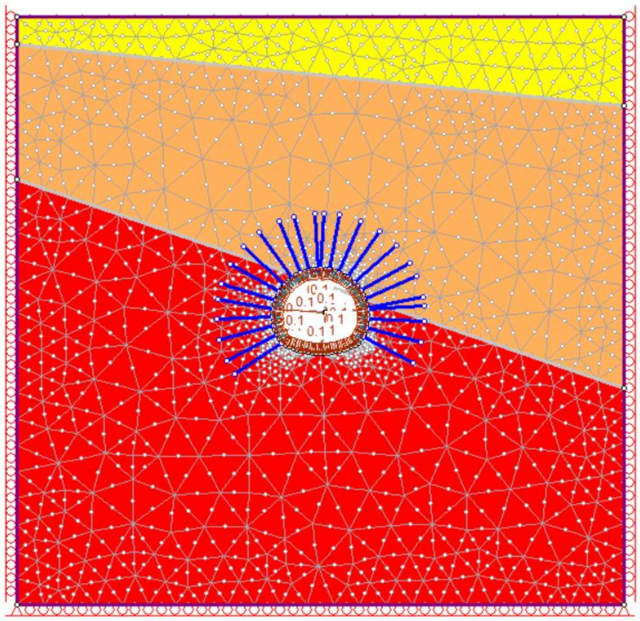

Figure 9. Final Stage

E. Case Five

1) The Side-drift excavation sequences consist of 5 stages.
2) In the first stage both 1 and 2 stage of excavation will be completed before proceeding to the next stage.
3) In the second part the crown area of the tunnel will be excavated.
4) The third part of the excavation will be done in centre area of tunnel.
5) The invert part of tunnel will constructed at the end.

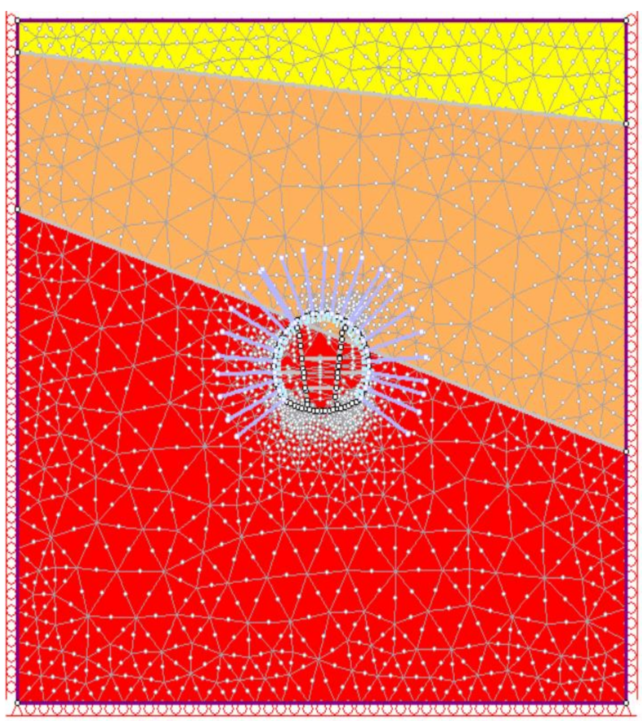

Figure 10. Initial Stage

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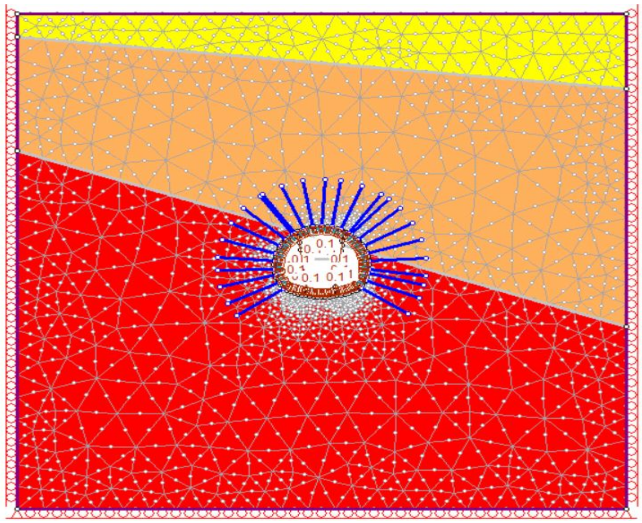
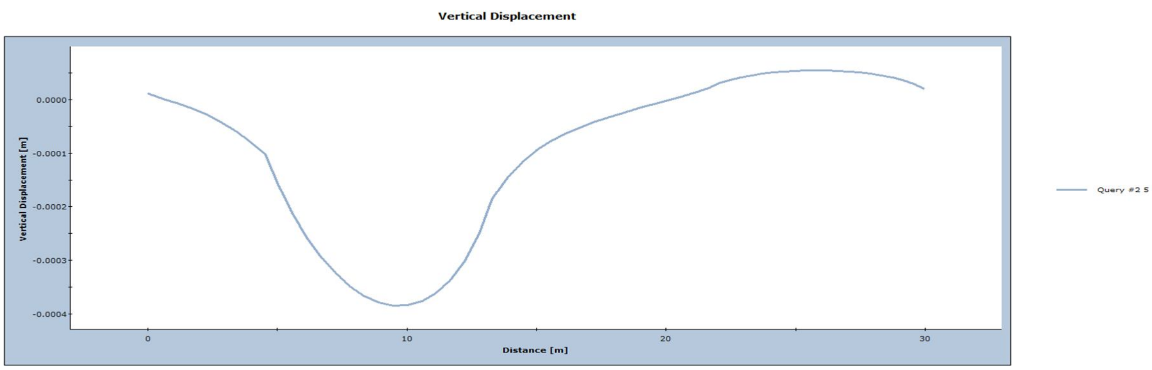


Figure 11. Final Stage

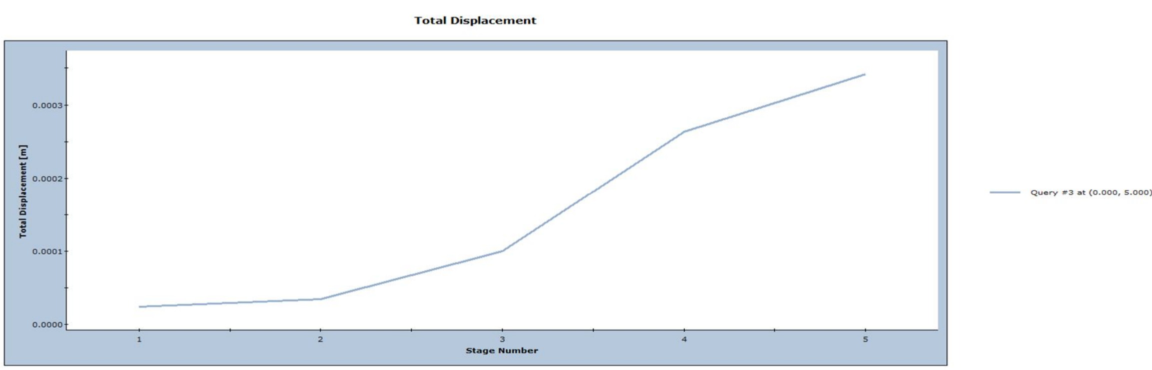
VII. RESULTS

A. Case One



Graph 1. Vertical Displacement

The graph shows the vertical displacement for distance from 0 to 30m. The horizontal axis represents the distance and the vertical axis represents vertical displacement. The graph presents both the increase and decline in displacement, as maximum vertical displacement was at 10m.



Graph 2. Total Displacement

The graph shows the number of total displacement for stages from 1 to 5. The horizontal axis presents the stage number and the vertical axis shows the total displacement. The graph indicates that number of displacement on each stages have fluctuated. There was a stable in total displacement from stage 1 - 2, but generally displacement have increased over the period.

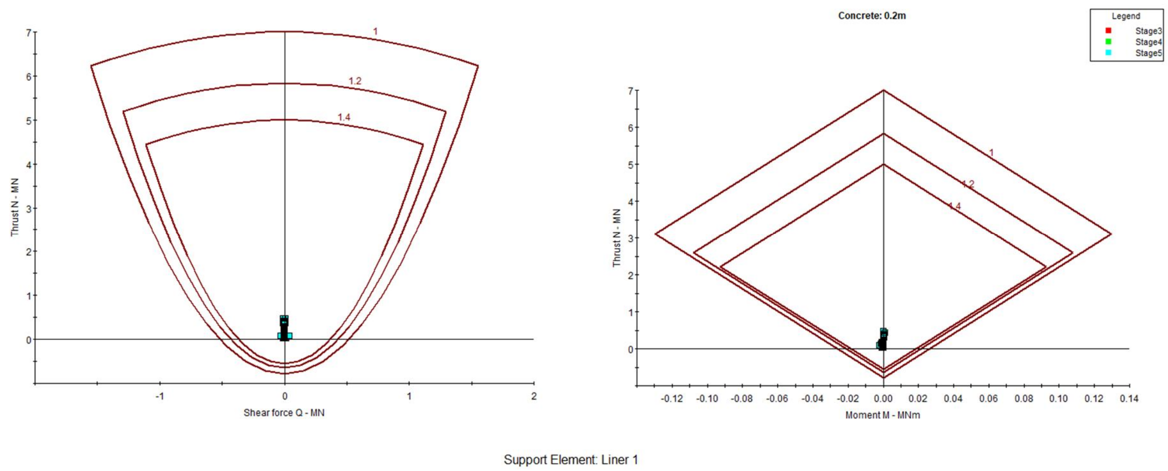
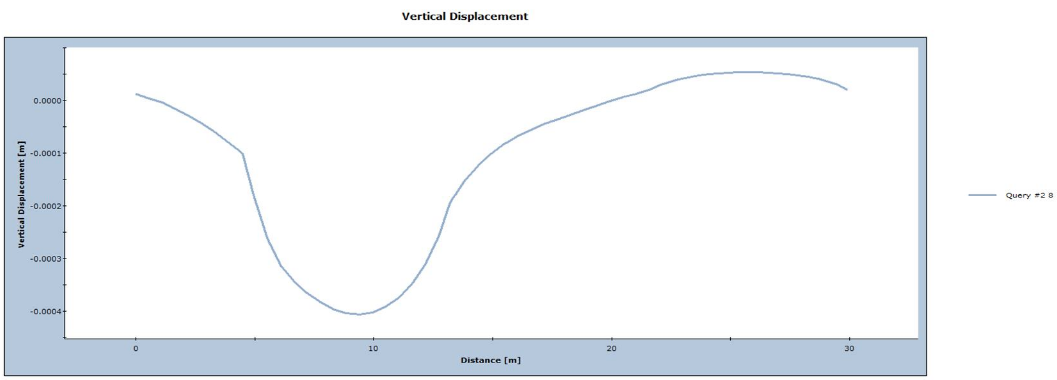


Figure 12. Support Element

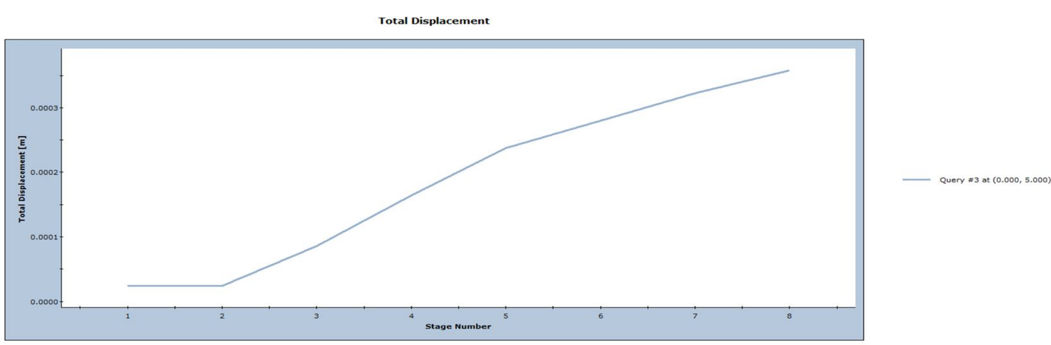
The maximum settlement at tunnel is about 0.35 mm with proposed support system. Thus, provided support is sufficient to safe guard the excavation as initial support.

B. Case Two



Graph 3. Vertical Displacement

The graph shows the vertical displacement for distance from 0 to 30m. The horizontal axis represents the distance and the vertical axis represents vertical displacement. The graph presents both the increase and decline in displacement, as maximum vertical displacement was at 9m.



Graph 4. Total Displacement

The graph shows the number of total displacement for stages from 1 to 8. The horizontal axis presents the stage number and the vertical axis shows the total displacement. The graph indicates that number of displacement on each stages have fluctuated. There was a stable in total displacement from stage 1 - 2, but generally displacement have increased from stage 2 - 8 over the period.

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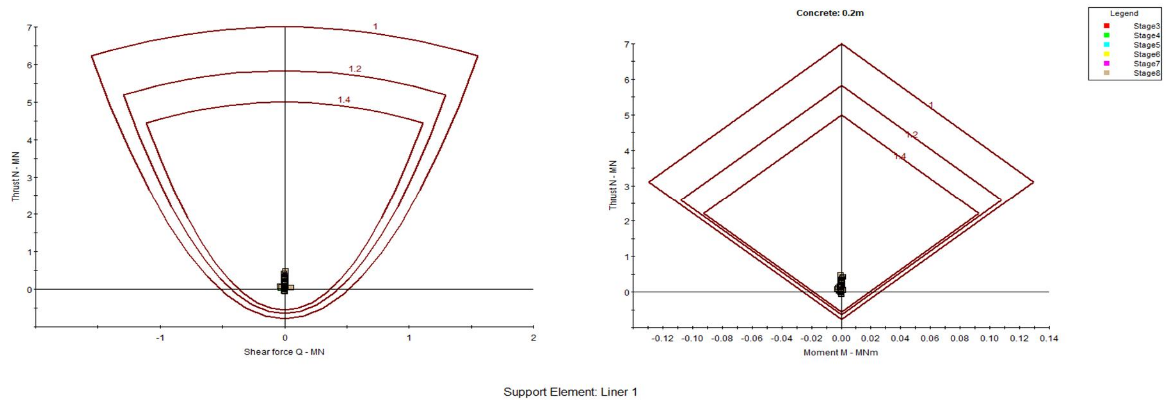
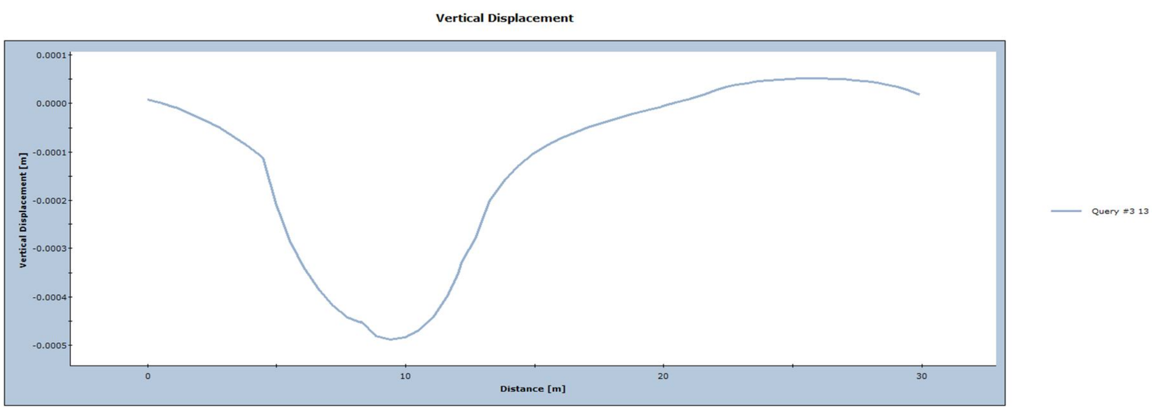


Figure 13. Support Element

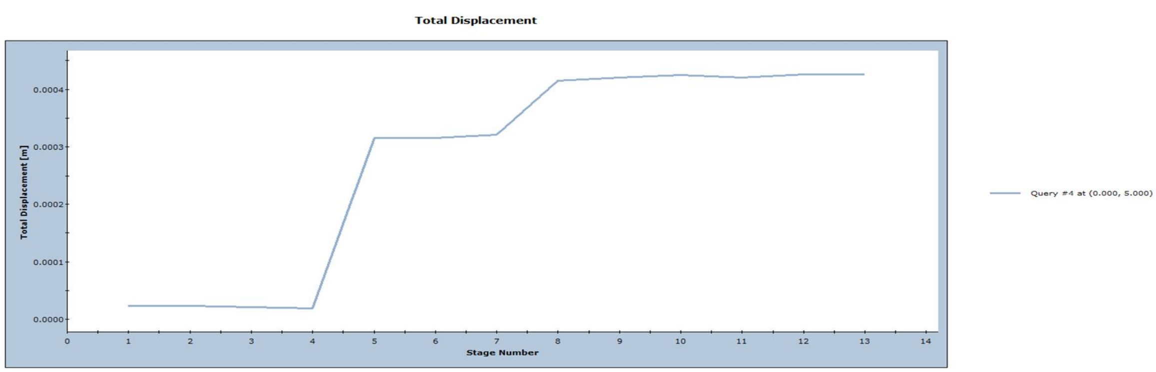
The maximum settlement at tunnel is about 0.37 mm with proposed support system. Thus, provided support is sufficient to safe guard the excavation as initial support.

C. Case Three



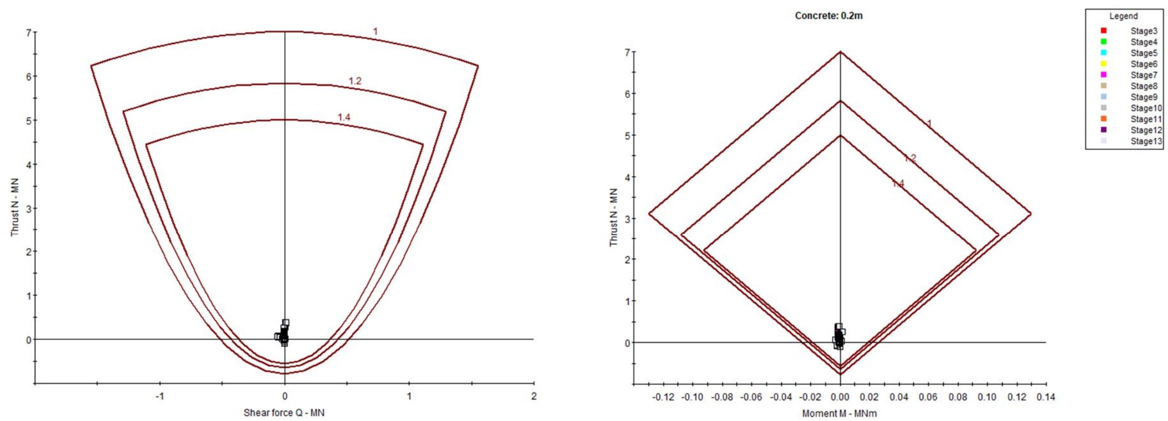
Graph 5. Vertical Displacement

The graph shows the vertical displacement for distance from 0 to 30m. The horizontal axis represents the distance and the vertical axis represents vertical displacement. The graph presents both the increase and decline in displacement, as vertical displacement fluctuated between 0 – 10 distance and maximum vertical displacement was at 10m.



Graph 6. Total Displacement

The graph shows the number of total displacement for stages from 1 to 14. The horizontal axis presents the stage number and the vertical axis shows the total displacement. The graph indicates that number of displacement on each stages have fluctuated. There was a stable in total displacement from stage 1 - 4, 5 – 7, and 8 - 13 but generally displacement have increased over the period.

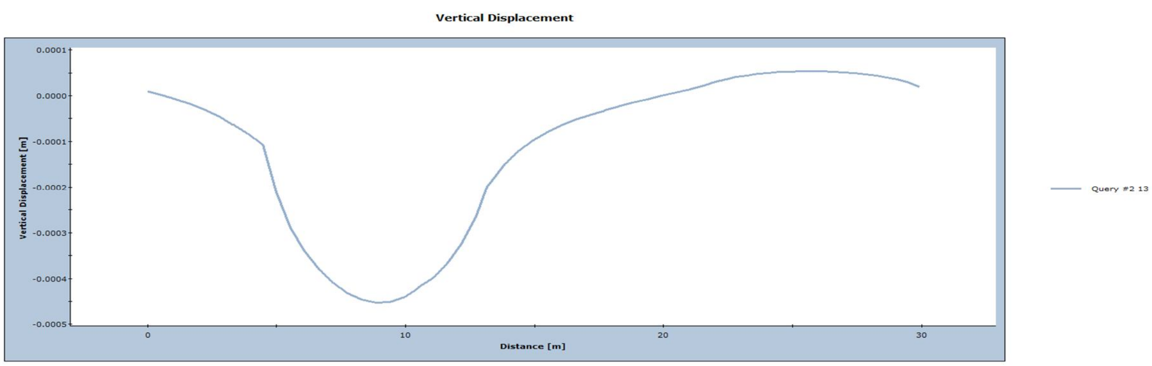


Support Element: Liner 1

Figure 14. Support Element

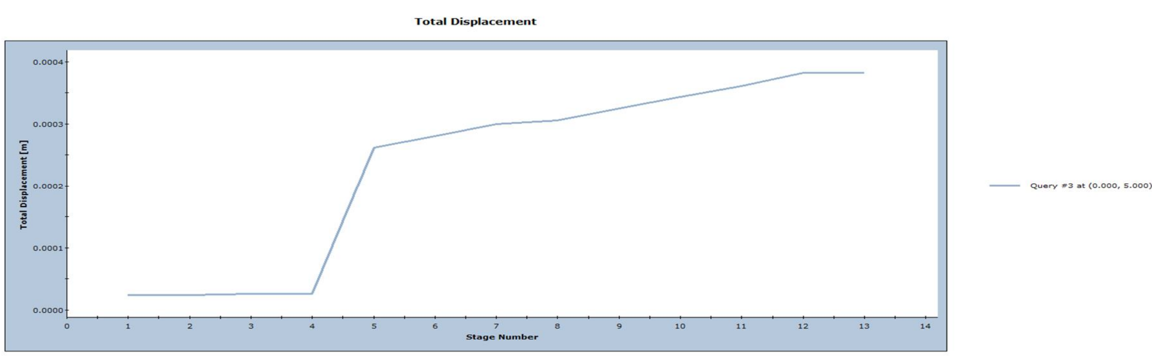
The maximum settlement at tunnel is about 0.42 mm with proposed support system. Thus, provided support is sufficient to safe guard the excavation as initial support.

D. Case Four



Graph 7. Vertical Displacement

The graph shows the vertical displacement for distance from 0 to 30m. The horizontal axis represents the distance and the vertical axis represents vertical displacement. The graph presents both the increase and decline in displacement, as maximum vertical displacement was at 10m.



Graph 8. Total Displacement

The graph shows the number of total displacement for stages from 1 to 14. The horizontal axis presents the stage number and the vertical axis shows the total displacement. The graph indicates that number of displacement on each stages have fluctuated. There was a stable in total displacement from stage 1 - 4, and 12 - 13 but generally displacement have increased over the period.

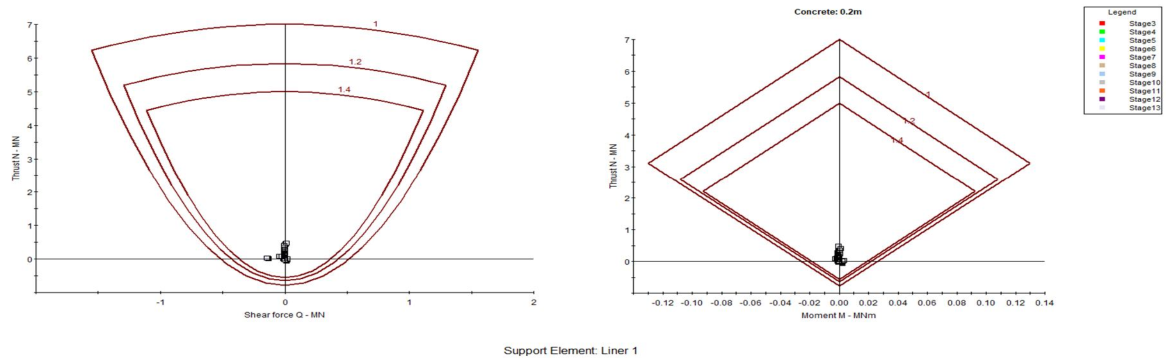
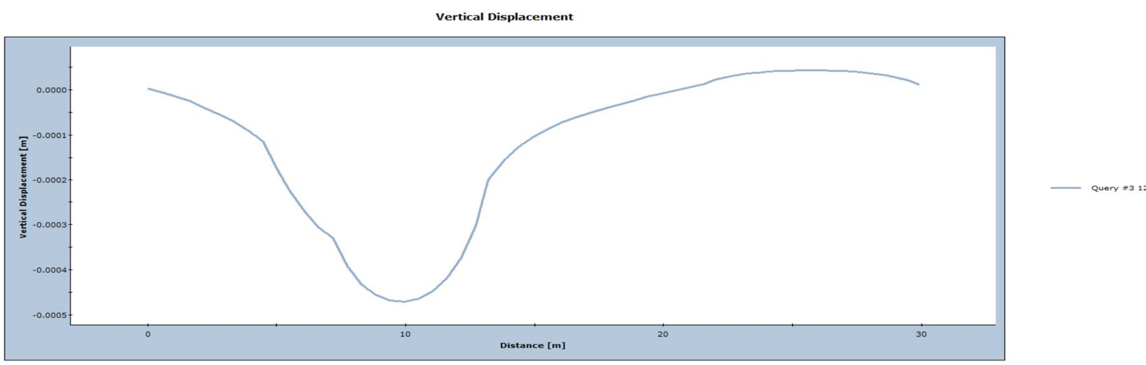


Figure 15. Support Element

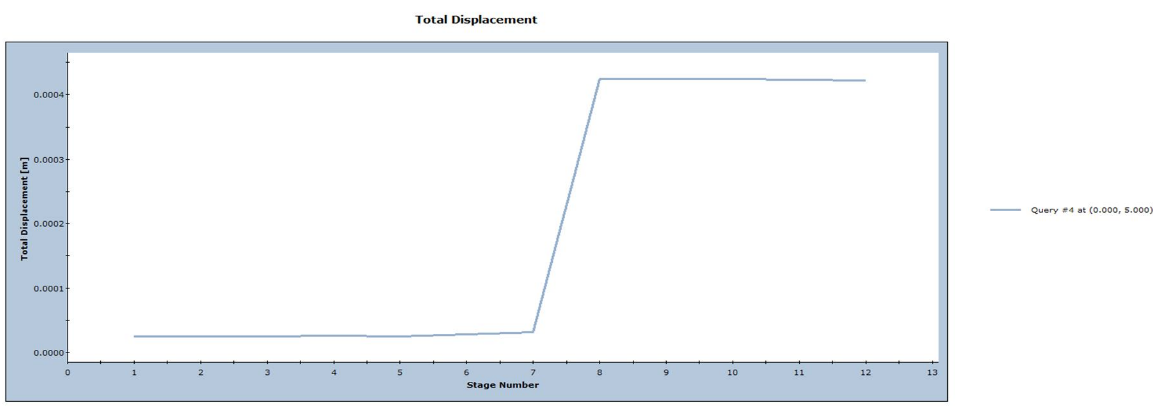
The maximum settlement at tunnel is about 0.40 mm with proposed support system. Thus, provided support is sufficient to safe guard the excavation as initial support.

E. Case Five



Graph 9. Vertical Displacement

The graph shows the vertical displacement for distance from 0 to 30m. The horizontal axis represents the distance and the vertical axis represents vertical displacement. The graph presents both the increase and decline in displacement, as vertical displacement fluctuated between 0 – 10 distance and maximum vertical displacement was at 10m.



Graph 10. Total Displacement

The graph shows the number of total displacement for stages from 1 to 13. The horizontal axis presents the stage number and the vertical axis shows the total displacement. The graph indicates that number of displacement on each stages have fluctuated. There was a stable in total displacement from stage 1 – 7 and 8 - 12 also there was straight increase in displacement from stage 7- 8 over the period.

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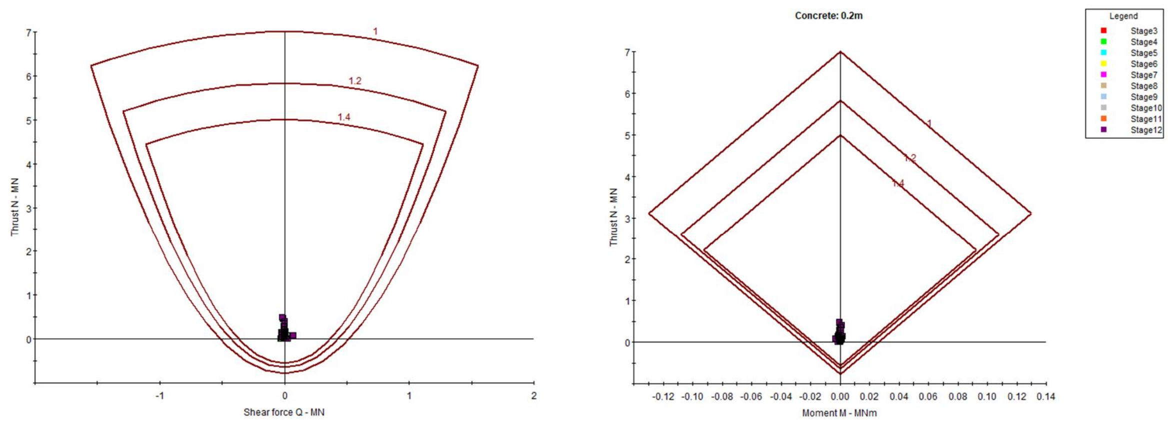

Support Element: Liner 1

Figure 16. Support Element

The maximum settlement at tunnel is about 0.44 mm with proposed support system. Thus, provided support is sufficient to safe guard the excavation as initial support.

VIII. CONCLUSION

The analysis was performed for predictions of the ground condition around the tunnel area in different excavation patterns in NATM construction to find out the maximum displacement using Roc science2 software and applying different field conditions.

A. Total Displacement For All Cases

1) Case 1: 0.35mm
2) Case 2: 0.37mm
3) Case 3: 0.42mm
4) Case 4: 0.40mm
5) Case 5: 0.44mm

We can see that after excavating the crown portion of tunnel by NATM method and in each cases the displacement increases.
From this observation, as the geology is very good around the tunnel I found that there was slight increases in displacement as we kept on excavating different parts of tunnel.
NATM construction in urban area is a challenging activity considering the construction sequence, monitoring and safety aspects. The maximum permissible limit allowed in urban area is 5mm/s and from the observation we found that the conditions are safe.

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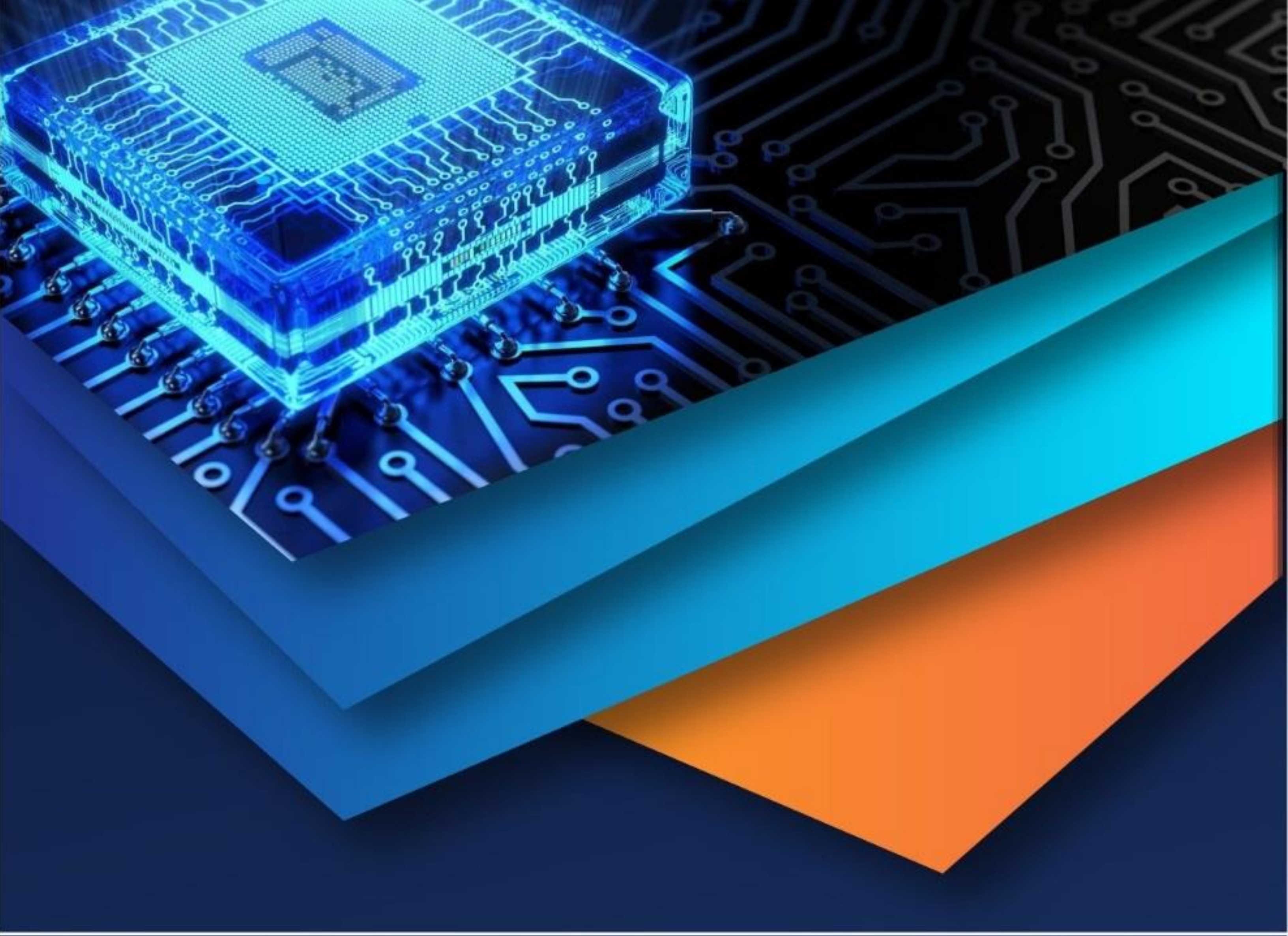

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