Effect of Existing Nearby Structures in Tunnel Excavation at TSC Area

Fuad Bin Nazrul

Mohaimenul Islam

Mohammad Abu Umama

Mahdi Mansur

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Fuad Bin Nazrul (155404)

Mohaimenul Islam (155405)

Mohammad Abu Umama (155413)

Mahdi Mansur (155422)

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2019

PROJECT REPORT APPROVAL

The thesis titled "Effect of Existing Nearby Structures in Tunnel Excavation at TSC area" submitted by Fuad Bin Nazrul, Mohaimenul Islam, Mahdi Mansur and Mohammad Abu Umama, St. No. 155404, 155405,155422 and 155413 has been found as satisfactory and accepted as partial fulfillment of the requirement for the Degree Bachelor of Science in Civil Engineering.

SUPERVISOR

Dr. Hossain Md. Shahin
Professor
Department of Civil and Environment Engineering (CEE)
Islamic University of Technology (IUT)
Board Bazar, Gazipur, Bangladesh

DECLARATION OF CANDIDATE

We hereby declare that the undergraduate research work reported in this thesis has been performed by us under the supervision of Professor Dr. Hossain Md. Shahin and this work has not been submitted elsewhere for any purpose (except for publication).

Dr. Hossain Md. Shahin

Professor,
Department of Civil and Environmental Engineering (CEE)
Islamic University of Technology (IUT)
Board Bazar, Gazipur, Bangladesh

Fuad Bin Nazrul
Student No: 155404
Academic Year: 2018-2019
Date :

Mohaimenul Islam
Student No: 155405
Academic Year: 2018-2019
Date :

Mohammad Abu Umama
Student No: 155413
Academic Year: 2018-2019
Date :

Mahdi Mansur
Student No: 155422
Academic Year: 2018-2019
Date :

DEDICATION

Our combined thesis work is dedicated to our respective parents, family and friends. We also express our gratitude to our respected supervisor Professor Dr. Hossain Md. Shahin. It is a small token of appreciation towards all those who supported us throughout our endeavor and encouraged us to continue our work until the end.

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"In the name of Allah, Most Gracious, Most Merciful."

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ABSTRACT

Keywords: *Tunnel lining, Soil Parameters, Finite Element Method, Plaxis-2D, Surface Settlement, Numerical Analysis, Mohr Coulomb Model, Constitutive Model.*

Urban underground structures e.g. construction of subway tunnels, are a crucial part of Geotechnical Engineering. Existing nearby structures have a significant impact on construction and excavation work. Until starting the key construction sequences, proper investigation and accurate analysis are needed. This study addresses the TSC area tunnel project. The tunnel should be placed considering the impacts and risks associated with building loads. In this perspective, numerical analysis can be classified as an important tool to evaluate the ground deformations, surface settlements and stress that occurred during the tunnel construction sequences.

In this work, PLAXIS 2D, a finite element analysis application has been used to analyse finite elements. In the simulation, Mohr Coulomb Model model has been used as a constitutive model of the soil. Laboratory tests have defined soil parameters that characterize physical and strength properties. Triaxial tests and consolidation tests obtained design parameters. It needs only a few integrated material parameters and can take into account the effect of the principal intermediate stress on soil deformation and strength, surface settlement, displacement vector, stress path influence on plastic flow direction and density and/or including pressure influence. It was found that the simulation of soil-structure interaction and behavior according to the field scenario in the Plaxis 2D system allows for the higher safety factor. Therefore, with an advanced simulation tool Plaxis 2D, a subway tunnel network can be designed for Dhaka city after a proper prediction of ground movement and tunneling effect.

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CHAPTER 1 : INTRODUCTION

1.1 General

Tunneling has been widely used during the past decades. Due to the fast population growth and industrial activity, such type of infrastructures becomes a common technique in the urban area providing a wide range of facilities (transportation, electric line, ditches, etc.). To satisfy the increasing demand for tunneling, advances in the technology of tunneling are necessary. For high-rise buildings supported by deep or shallow foundations, the construction of tunnel induces ground movements, which in turn affect the bearing capacity as well as the settlement of the existing foundations. To overcome this particular problem of the surface settlement many researchers have performed various tests to keep the settlement within allowable limits. Engineers are always concerned about the responses of soil behavior throughout the construction phases. Several studies have been undertaken to understand the mechanisms of the soil– tunnel–pile interaction and to reduce the risk of possible adverse effects of tunneling on existing foundations. To ensure that excessive ground movement does not damage structures adjacent to tunnel constructions, care must be taken.

The interaction between loaded foundation and tunnel under construction is a three-dimensional problem and modeling the influences of the tunnel is only possible if tunneling-induced ground movements are assessed accurately. In practice the tunneling-induced ground movements are assessed by using empirical methods (Peck, 1969; Mair 1993; Clough and Schmidt, 1981; O'Reilly and New, 1982), analytical methods (Sagaseta, 1987; Verruijt and Booker, 1996) and Finite element methods (Gunn, 1993; Rowe and Kack, 1983). Each method is subject to some limitations.

When the portion of the soil above the tunnel crown touches the tunnel lining, the soil at the side of the tunnel displaces towards the bottom of the tunnel. Therefore, the upward movement of the soil below the tunnel is limited. Centrifuge model tests carried out by Stallbrass et al. (1996) revealed similar results. Loganathan et al., (2001) assumed that about 75% of the vertical ground movement occurs within the upper annulus of the gap around the tunnel. (Ref: N. Loganathan, H. G. Poulos, K.J. Xu: Ground and Pile-group responses due to tunneling, Japanese Geotechnical Society, Japan)

For designing the tunnel lining engineers have to be concerned about the surrounding earth pressures of tunnel as well. Earth pressure in tunneling is usually estimated by using rigid plastic theory in which the deformation properties of the soil and the sequence of the excavation are not considered. In real cases, however, earth pressure depends on both properties of the ground and excavation sequences of tunnel. Elastic analysis also cannot properly explain such dependence of earth pressures in tunneling. Hence a more accurate deformation analyses is required to get realistic results of earth pressures. It is evident that meaningful numerical analysis can be made only If the stress distribution and density within the ground be predicted reliably. Therefore, a suitable constitutive model that the engineer can comprehend and apply easily is required. The constitutive model should consider typical soil behaviors including positive and negative dilatancy of soils, dependency of density and or confining pressure of soils. Mohr-Coulomb model is one of the constitutive models, which can describe different important characteristics of soils.

1.2 Background

1.2.1 Project Background

One of the largest growing megacities in the world is the capital of Bangladesh, Dhaka. The population is increasing every year, inflicting serious problems like stagnant traffic conditions throughout the city. Outdated traffic maneuvering methods, lack of law-abiding tendencies, narrow road spaces are the main causes of elongated traffic jam situations. Economic losses that are sustained from these congestions are beyond negligence. It is also causing serious air pollution and noise pollution and thus worsens the overall environmental condition.

The plan of the subway in Dhaka city is not limited only in the plan or in the paper. As per the plan of the Government, the initiatives are being implemented and it will be done shortly.

The Bangladesh Road Transport and Bridges Ministry and Spanish consulting body TYPSA have signed a contract for the construction of a subway system in Dhaka in July 2018. TYPSA, a leading consulting engineering group in transport, urban development, and renewable energy, will examine four possible routes for the subway. The first phase of construction for the subway will have an estimated cost of $5.62 billion. Once completed, about 4 million out of around 8 million working population of Dhaka city would be able to use the subway on four routes and there will be a significant improvement in the traffic condition of Dhaka city.

1.2.2 Project Details

Primary selected proposed routes of a subway in Dhaka*:*

- The first route will be around 32 kilometers in length; it will be from ***Tongi – Airport – Kakali – Mohakhali – Moghbazar – Paltan – Motijheel Shapla Chattar – Sayedabad***, which will be extended to Narayanganj in the future. For this, the potential construction cost is estimated to be US$ 5.66 billion.
- Secondly, a 16 km long subway line-2 will be from ***Aminbazar – Gabtali – Shyamoli – Asadgate - New Market – TSC - Ittefaq Moor - Sayedabad***. Later it will extend on both sides. The possible construction cost will be US$ 2.87 billion.
- Thirdly, route-3 will be conducted from ***Gabtali – Mirpur 1 – Mirpur 10 – Kakoli – Gulshan 2 – Natun Bazar - Rampura TV Station – Khilkhet – Motijheel Shapla Chattar - Jagannath Hall - Keraniganj***.
- Under route-4, the probability route of the subway will be from ***Rampura TV station – Niketan – Tejgaon - Sonargaon Hotel – Panthapath - Dhanmondi 27 – Jigatala – Azimpur - Lalbagh - Sadarghat***.

The length of root-3 and root-4 has not finalized yet. The underground depth of these subways will be from 20 to 40 meters. Sophisticated Tunnel Boring Machine (TBM) will be used to construct these subways. So, during the implementation of the project, people will not suffer due to dig on the soil.

In this particular study, TSC area is considered from the second route of the subway line. Proposed tunnel will be passing underneath the selected area. All the building loads are taken from Teacher Student Center (TSC) of Dhaka University. This building is the most nearby structure in the area.

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1.2.3 Study Area

Figure 1.2.3.1: Study area (TSC area) from google map marked by a red circle

There is a 50 ft wide road, and from the footpath distance of the TSC building is 50 ft. From the soil report project "Feasibility Study and Preliminary Design for construction of Dhaka Subway" there is a borehole (BH 12) in TSC area whose location is in X direction 234472.8125 and Y direction 2627007.679. The foundation of TSC building is the footing foundation.

1.2.4 Technical Considerations

We have considered the first two footings of TSC building in one section.

Footing	**Length (ft)**	**Loading area (ft^2)**
First (Exterior)	4.5	144
Second (Interior)	8.0	216

Table 1.2.4.1 Footing details of TSC building

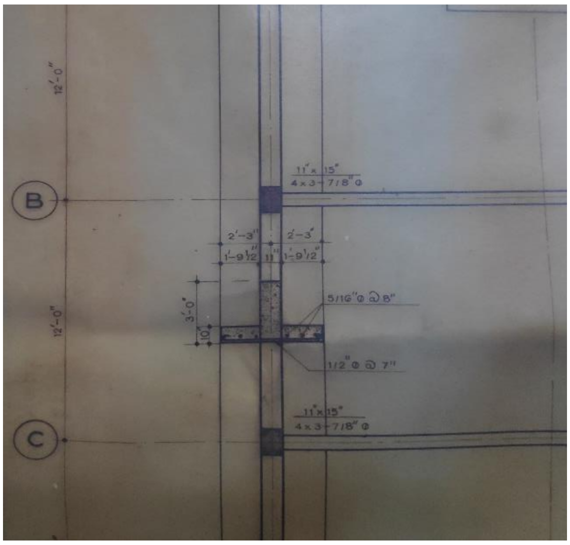


Figure 1.2.4.1: Exterior footing

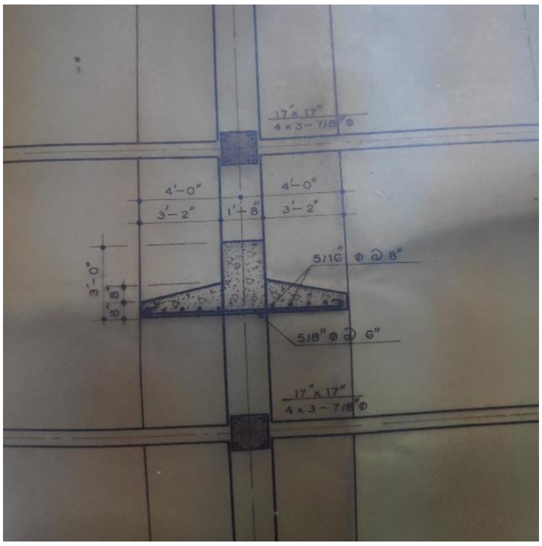


Figure 1.2.4.2: Interior footing

Reference:

- Plan view of TSC building, Engineering department of TSC building.

1.2.5 Objectives

- Evaluating the effect of existing nearby structures in tunnel excavation
- Surface settlement induced by the existing structure and by the excavation of the tunnel
- Determining the stress development on tunnel lining
- Water pressure and stress development due to the excavation of the tunnel

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

Around the world, there are many examples of subway tunnels. But this is a new technique in Bangladesh, and very few studies have been done so far. PLAXIS 2D design has been used in this research to simulate subway tunnels for the proposed route under Dhaka City. The literature review was done to identify the studies related to this field that have been carried out already.

2.2 Tunnel Construction

A tunnel construction method depends on ground and surface water conditions, excavation depth, surface loadings, tunnel drive length and diameter, tunnel lining width, tunnel excavation techniques, final use, and tunnel structure etc.

For common uses, two basic forms of tunnel construction are the following:

1. Cut and cover tunnels built in a shallow trench and then paved over
2. Bored tunnels, built in-situ, without scraping the above ground. Typically they are circular, or horseshoe cross-section is known as shield tunneling.

2.3 Past Research on Underground Tunneling System

- **Shahin et al. (2011)** Conducted a study which proposed that the displacement applied at the tunnel crown greatly influences the surface settlement and the earth pressure around a tunnel for the same volume loss and the same surcharge.

During tunneling loads from existing structures, control the surface settlement and the zone of deformation. The maximum surface settlement happens beneath the existing structures**.**

- **Ghaboussi et al. (1983)** Stated that for similar situations, the liner stresses generally decrease when radial displacements at the heading are allowed to take place prior to the ground and liner coming into contact.
- **Mair and Taylor (1979)** Observations from practice have shown that the distribution of the developing longitudinal settlement trough due to tunnel excavation is a s-like-curve.
- **Shahin et al. (2016)** Showed that due to the arching effect earth pressure decreases at the tunnel excavation boundary while excavating a single tunnel.
- **Zhang et al. (2015)** Analyzed the effect of multilayered soil on tunnel lining by using FEM. The relation between the numerical model and real measurement was convincing and satisfactory.
- **Eric Leca (2007)** The response of existing structures to tunneling induced ground movements depends on their geometry, construction type and overall structural condition.

  Typically, the construction of an unsupported tunnel opening in soft ground would generate large ground displacements which, in turn could lead to the formation of a failure zone behind the face.

- **Meguid M. A. et al. (2002)** To evaluate the effects of construction on the tunnels, it is important to assess the current state of stress in the lining so that incremental changes due to construction would not lead to stresses exceeding the allowable limits.

2.4 Researches in the perspective of Bangladesh:

Very few research work on the underground tunneling network in Bangladesh has been carried out.

- **Waheed et al. (2008)** used the method of cut-and-cover excavation along with the current railway crossings from Uttara junction to Kamalapur junction based on the traditional analysis process. In this situation, he suggested doing FEM.
- **Farazandeh et al. (2010)** reported that in Bangladesh's viewpoint, SHIELD tunneling is the safest method.

CHAPTER 3: METHODOLOGY

3.1 Methods of Analysis of the tunneling system

There are generally two approaches to the analysis of a system. The first is the conventional analysis, and the second is the Finite Element Method (FEM) numerical analysis. A numerical analysis or FEM developed numerical formulas and gives an accurate result based on computer programming.

3.2 Numerical Analysis

Numerical analysis involves using approximation techniques to answer mathematical problems, taking into consideration the extent of possible errors. Although this analysis is an approximation, it is possible to produce results as accurately as desired.
In geotechnical engineering, numerical analysis is commonly used for the following:

- The simulation process is fast and simple to perform.
- The analysis is more reliable and realistic.
- Practically understanding and determining structural behaviour.
- The best analytical approach is to look at each structural behavioural step of the construction process.
- Resolve non-linear equation roots.
- Solve large equation systems.
- In this form of analysis, soil-structure interaction is adequately accounted for.
- In this study, interaction between soil and water can be modelled accurately.
- It is possible to accurately assess the settlement and deformation of the soil and structures.

Using PLAXIS 2D (2019 Version) software for numerical analysis there are several steps. In general settings we define the section. In definition of soil stratigraphy we set the soil parameters and in definition of the structural elements we define the footing, tunnel lining, plates parameters. Basically for numerical analysis there are 5 phases. Phase 1 : Building, Phase 2: Tunnel, Phase 3: Contraction, Phase 4: Grouting, Phase 5: Final Lining.

3.3 Finite Element Method (FEM)

With different analytical method, it cannot be solved irregular structures accurately. But using the Finite Element Method (FEM), one can solve irregular structures accurately and easily. According to O. O. Ochoa and J. N. Reddy, Finite Element Analysis of Composite Laminates, 2nd ed. (1992) FEM has two features that no other method shares-

i. The domain of the problem is represented by a collection of simple sub-domains, called finite elements. The subdivision of a domain into elements is termed finite element discretization. The collection of finite elements is called finite element mesh.

ii. Over each finite element, the solution of the governing equations is approximated by a linear combination of undetermined parameters and preselected approximation functions, almost always polynomials. Since the solutions is represented by polynomial on each element, a continuous approximation of the solution of the whole can be obtained only by imposing the continuity of the element solution and possibly its derivatives, at element interfaces. The procedure of putting the elements together is called the assembly of elements.

The algebraic equations relating physical quantities at selective points, called nodes. (J. N. Reddy, An Introduction to the Finite Element Method, 3rd ed.(2005))

The solution of the element analysis and the system analysis is required for Finite Element Method (FEM). The relationship between nodal forces and nodal displacements from equilibrium conditions at nodes in element analysis is expressed in terms of a stiffness matrix for the element. A system of equilibrium equations come from assembling all individual elements to form the complete structure from the stiffness matrices.

Then application of the prescribed boundary conditions to solve these equilibrium equations. The method gives sufficiently accurate results when the selected displacement patterns for the elements are able to produce constant stress fields inside the elements.

In this research, using PLAXIS 2D (software version 2019) two-dimensional finite element analyses have been carried out. Soil ground is divided into a certain number of elements with six nodes. For simplicity, considering plane strain condition for 2D Ground Model.

3.4 Soil Model

There are various kinds of soil model in PLAXIS 2D. The name of the soil models are:

- Linear Elastic Model (LE)
- Mohr-Coulomb Model (MC)
- Hardening Soil Model (HS)
- Hardening Soil Model with small stress-strain stiffness (HS small)
- Soft Soil Model (SS)
- Soft Soil Creep Model (SSC)
- Jointed Rock Model (JR)
- Modified Cam-Clay Model (MCC)
- NGI-ADP Model (NGI-ADP)

- UDCAM-S Model (UDCAM-S)
- Sekivguchi-Ohta Model (Seki guchi-Ohta)
- Hoek-Brown Model (HB)
- UBC3D-PLM Model (UBC3D-PLM)
- Concrete Model (Concrete)

In this research work, materials are modelled with Mohr Coulomb model in PLAXIS 2D software. This model has some advantages over other soil model:

- ❑ A straightforward method for soils and it is simpler in Mathematical expression.
- ❑ It’s physical quantities more clearly understandable.

CHAPTER 4: MODEL CONSIDERATIONS, TUNNEL GEOMETRY AND SOIL BOUNDARY

4.1 Introduction

Based on the literature review following considerations have been taken

- Finite Element Modelling of Tunnel Excavation
- Nearby Existing Structure

4.2 Selection of Construction Method

- Plaxis 2D Software 2019 version
- Consider element with 6 nodes
- Consider plane strain condition for 2D Ground Model
- Materials are modelled with Mohr Coulomb model
- Microsoft Excel for generating tables and graphs
- AutoCAD 2016 for drawing figures.

4.3 Tunnel Geometry

- Tunnel depth : Tunnel crown is 33 meters down from the surface of the soil
- Tunnel diameter (B) : 11 meter
- Tunnel centre : (10.5B, 3.5B) or (115.5,38.5) from the left side of the section
- Contraction : 5%

4.4 Lining and Footing

- Lining Thickness : 0.35 meter (From global database of PLAXIS 2D)
- Lining bending modulus (EI) : $14.3x10^4$ kN/m^2/m (From global database of PLAXIS 2D)
- Lining axial modulus (EA) : $14x10^6$ kN/m (From global database of PLAXIS 2D)
- Lining other values: From the global database of PLAXIS 2D
- Footing bending modulus (EI) : $24x10^3$ kN/m^2/m (From the global database of PLAXIS 2D)
- Footing axial modulus (EA) : $7.6x10^6$ kN/m (From global database of PLAXIS 2D)
- Footing other values : From global database of PLAXIS 2D

4.5 Section Geometry

- Section type : Two dimensional
- Length : 10B+B + 10B = 21B = 231 meter (Where tunnel diameter, B = 11 meter)
- Depth : 6B = 66 meter (Where tunnel diameter, B = 11 meter)

4.6 Soil Parameters

Soil sample are collected from TSC area (Borehole 12) and the parameters are considered as the basic design input for the model. Soil parameters are extracted from the USCS soil classification, SPT values and different co-relations. From the soil report of Prosoil Foundation Consultant we get different important parameters for different co-relation.

Following tests are performed :

i. Particle size analysis-sieve

ii. Particle size analysis-Hydrometer

iii. Atterberg limits test

iv. Natural moisture content

v. Dry and apparent density

vi. Particle density

vii. Unconfined compressive strength

viii. Triaxial test (CU)

ix. Consolidation test

Figure 4.6.1: Tri-axial test at Prosoil Foundation Consultant laboratory

Layers		Borehole_TSC	
#	Material	Top	Bottom
1	Layer 1	0.000	-3.750
2	Layer 2	-3.750	-6.750
3	Layer 3	-6.750	-9.750
4	Layer 4	-9.750	-11.75
5	Layer 5	-11.75	-28.00
6	Layer 6	-28.00	-60.00

Figure 4.6.2: Bore-log of the model (From PLAXIS 2D software)

Basic parameters:

E = Modulus of elasticity

C = Cohesion

Φ = Angle of internal friction

υ = Poisson's ratio.

Ψ = Angle of dilatancy

From the soil report we get Standard penetration test (SPT) values for different depth. We took the average of them then modified it close to the lowest value. Then from USCS soil classification and different co-relation from books we get the soil parameters.

For simplicity we have considered the soil as pure clay r pure sand. But in clay soil we gave angle of friction value 1 degree for make in Undrained B condition in the software.

Layer	Depth (m)	Classification of soil (USCS)	Description	Avg SPT	Modulus of elasticity (E) MPa	Cohesion (c) Kpa	Angle of friction (Φ) Degree	Angle of dilatancy (Ψ) Degree	Poisson's Ratio (υ)
1	0.00 to 3.75	CL	Reddish Brown, medium stiff to stiff, Lean Clay	5	9	30	1	0	0.4
2	3.75 to 6.75	CH	Reddish Brown, stiff to very stiff, Fat Clay	13	14	65	1	0	0.4
3	6.75 to 9.75	CL	Reddish Brown, stiff to very stiff, Lean Clay	12	12	60	1	0	0.4
4	9.75 to 11.75	CL	Reddish Brown, very stiff, Sandy Lean Clay	22	30	80	1	0	0.4
5	11.75 to 28	SM	Brown,medium dense to very dense,Silty Sand	24	20	0	31	1	0.3
6	28 to 66	SM	Brown,medium dense to very dense,Silty Sand	57	30	0	34	4	0.3

Table 4.6.1 : Basic parameters of soil for model simulation.

4.7 Load Calculation

For estimating the footing load we have considered the service load only.

Service Load = Dead Load + Live Load

From BNBC 2006 we took the values of Dead Load and Live Load for TSC building.

Dead Load: **Weight of all materials of construction incorporated into the building**			
Material		Weight per unit area(kN/m^2)	
Floor (Concrete slab) solid, 150 mm thick		3.540	
Roof concrete , 25 mm thick		0.527	
Walls and Partitions sand-lime, per 100 mm thickness		2.475	
Ceiling Cement plaster, 13 mm thick		0.287	
Miscellaneous Plaster-cement, per 10 mm thickness		0.230	
Live Loads for Various Occupancies			
Building	Occupancy	Use of floor	Weight per unit area (kN/m^2)
Educational, Institutional Building	B,C,D	Class room, lecture room, lounge. cafeteria, restaurant	3.0

Table 4.6.2 : Dead Loads and Live Loads occurring in TSC building.

Calculation of load for the exterior footing:

Number of floor = 4

Footing length = 4.5 ft = 1.3716 m

Loading area = 144 ft^2 = 13.3780 m^2

Service load = Dead Load + Live Load = 10.059 kN/m^2

Load acting on the exterior footing = (4*10.059*13.3780) kN = 538.2772 kN

So, in exterior footing load acting per length = (538.2772/1.3716) = **392.4447 kN**

Calculation of load for the interior footing:

Number of floor = 4

Footing length = 8 ft = 2.4384 m

Loading area = 216 ft^2 = 20.0671 m^2

Service load = Dead Load + Live Load = 10.059 kN/m^2

Load acting on the exterior footing = (4*10.059*20.0671) kN = 807.418091 kN

So, in exterior footing load acting per length = (807.418091/2.4384) **= 332.1261 Kn**

4.8 Mesh Generation

There are different types of finite element meshes in PLAXIS 2D software for FEM analysis.

For meshing we have used element distribution very fine.

4.9 Displacement Boundary and Water table

4.9.1 Displacement Boundary

The displacement boundary conditions are as follows:

At bottom: Both vertical and horizontal displacements are fixed.

At left edge: The horizontal displacement is fixed but vertical movement is allowed; i.e., vertical displacement is pinned.

At right edge: The horizontal displacement is fixed but vertical movement is allowed; i.e., vertical displacement is pinned.

4.9.2 Water table

Water table is at the top of the soil layer (from the borelog of the soil report).

4.10 Cases Considerations

In this research work we have considered two cases.

CASE 1	Tunnel under 1st footing of the building
CASE 2	Tunnel under the center of the road (22.86m distance from CASE 1)

Table 4.10.1 : Cases that has been considered

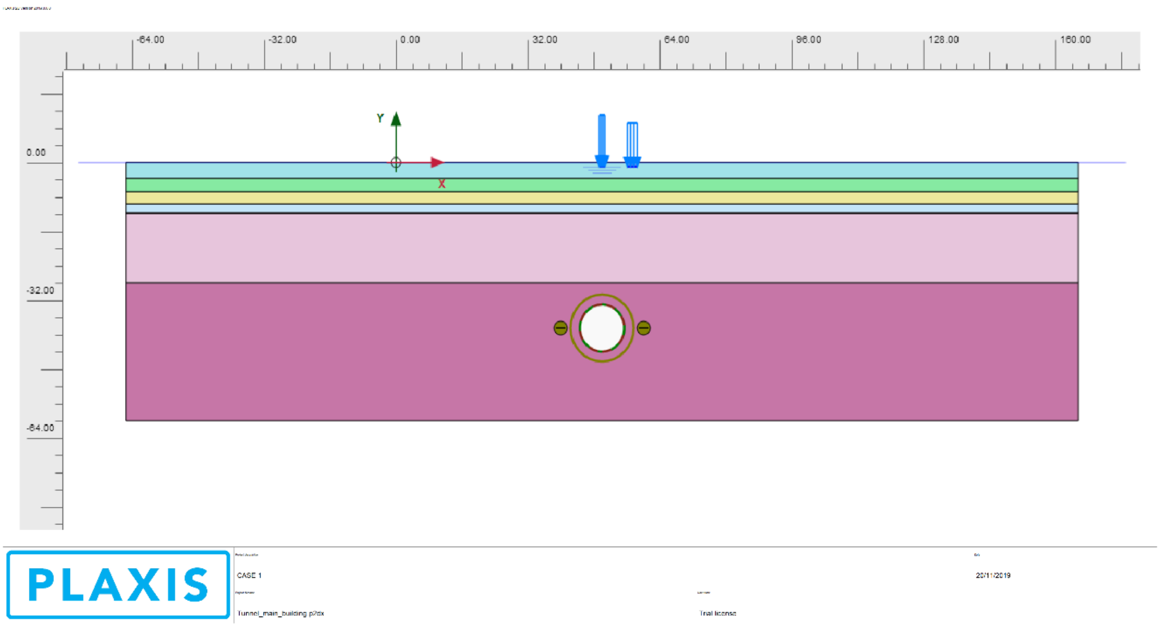


Figure 4.10.1 : CASE 1 – Tunnel under 1st footing of the building

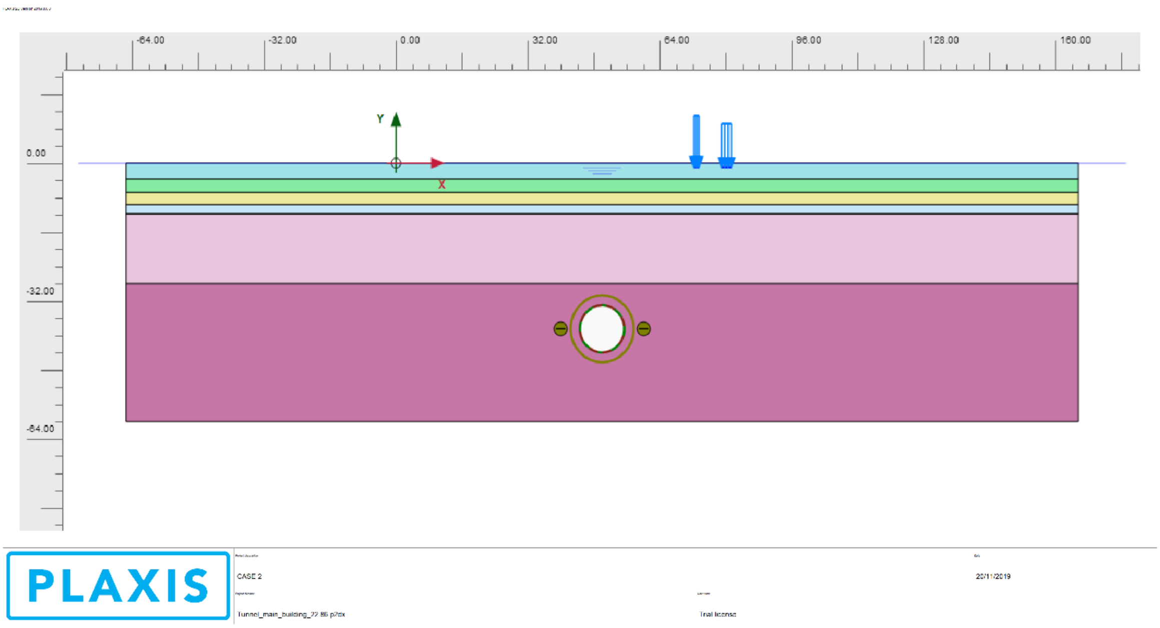


Figure 4.10.2 : CASE 2 – Tunnel under center of the road (22.86m distance from CASE 1)

CHAPTER 5: RESULTS AND DISCUSSIONS

5.1 Introduction

Results of different cases and scenarios are mentioned in this section:

The deformed mesh, total displacement, horizontal displacement, vertical displacement of soil behavior and bending moment, shear force, axial force for tunnel behavior are mentioned in this section.

For this research work, we have moved the tunnel by 10 meters repeatedly. So, we have got 6 scenarios. Total nine scenarios we have got considering tunnel without any surface load, CASE 1 and CASE 2.

5.2 Ground Condition

5.2.1 Deformed mesh

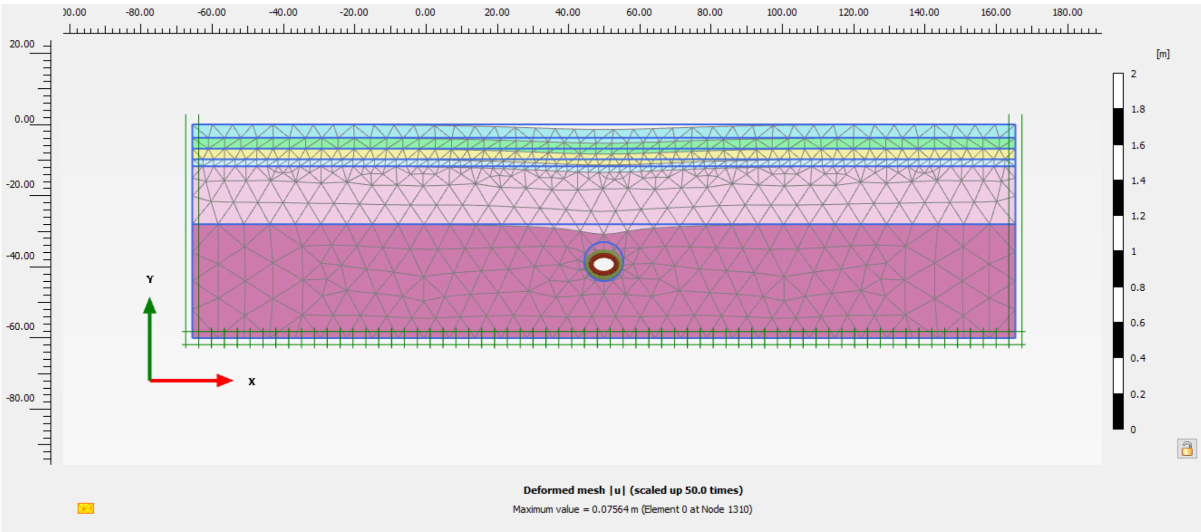


Figure 5.2.1.1 : Deformed mesh (Tunnel without any existing structure)

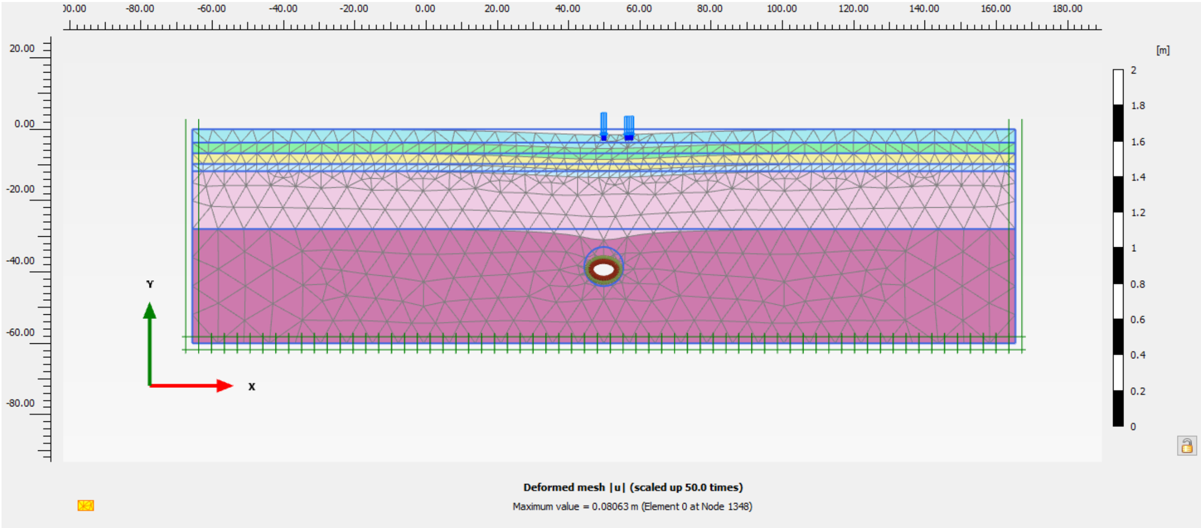


Figure 5.2.1.2: Deformed mesh (CASE 1 - Tunnel under 1st footing of the building)

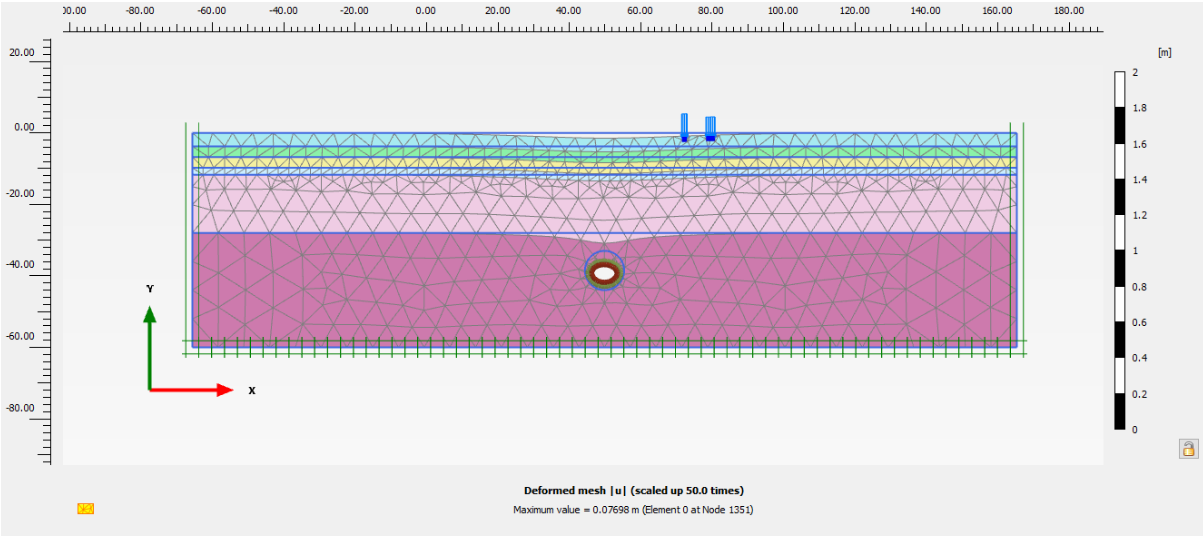


Figure 5.2.1.3: Deformed mesh (CASE 2 – Tunnel under center of the road)

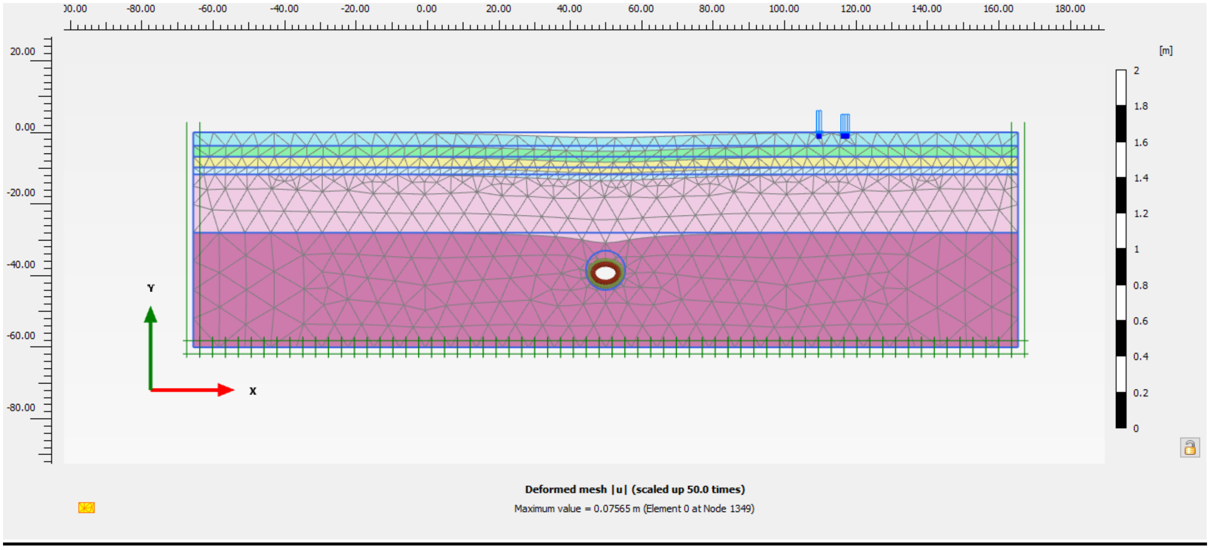


Figure 5.2.1.4: Deformed mesh (Tunnel at 60m distance from CASE 1)

5.2.2 Total displacement

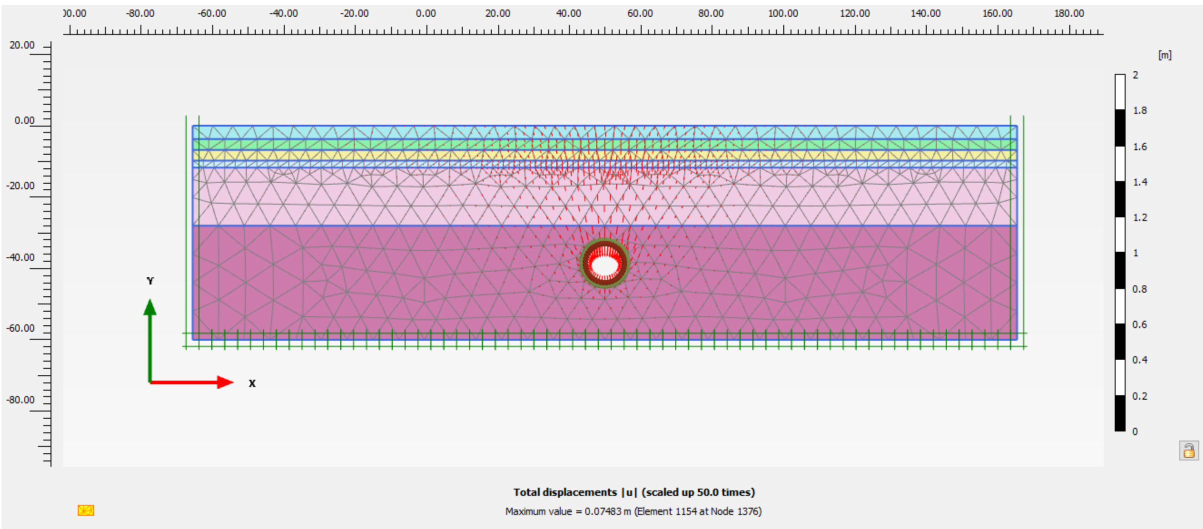


Figure 5.2.2.1.: Total displacement (Tunnel without any existing structure)

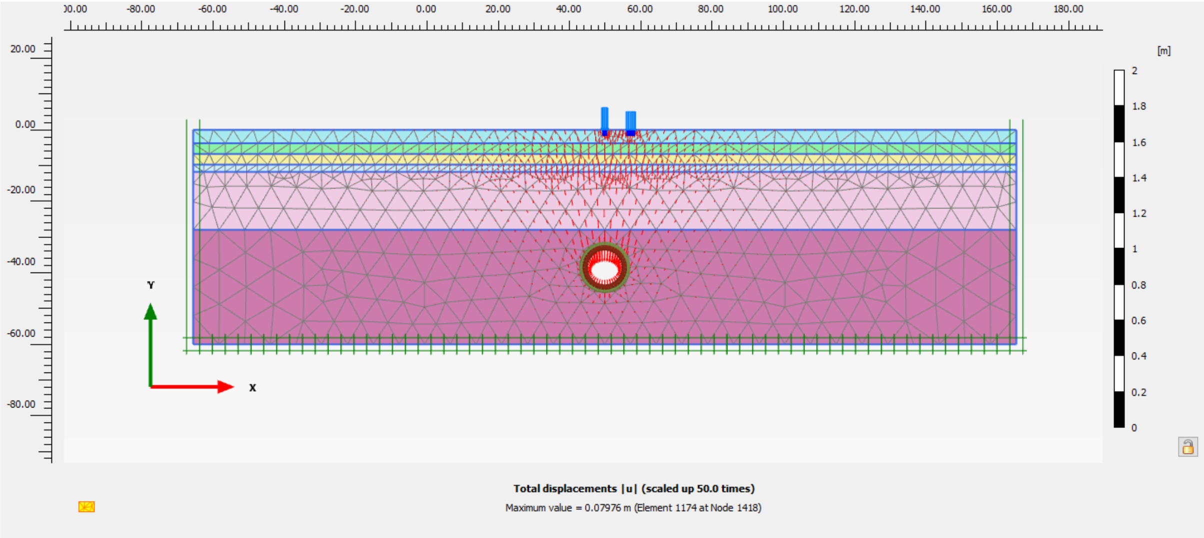


Figure 5.2.2.2: Total displacement (CASE 1 - Tunnel under 1st footing of the building)

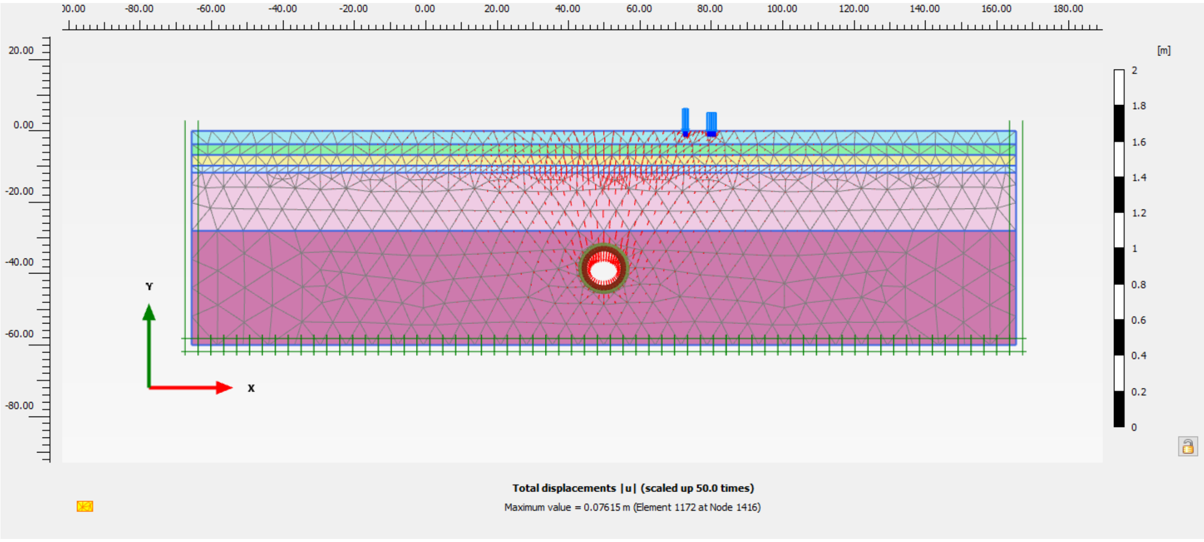


Figure 5.2.2.3: Total displacement (CASE 2 – Tunnel under center of the road)

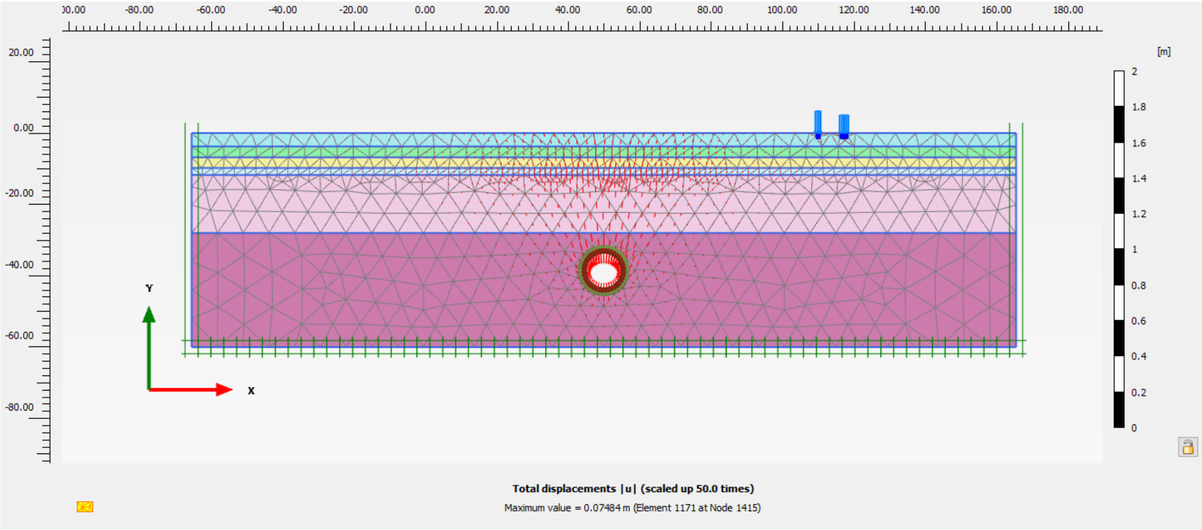


Figure 5.2.2.4: Total displacement (Tunnel at 60m distance from CASE 1)

5.2.3 Horizontal displacement

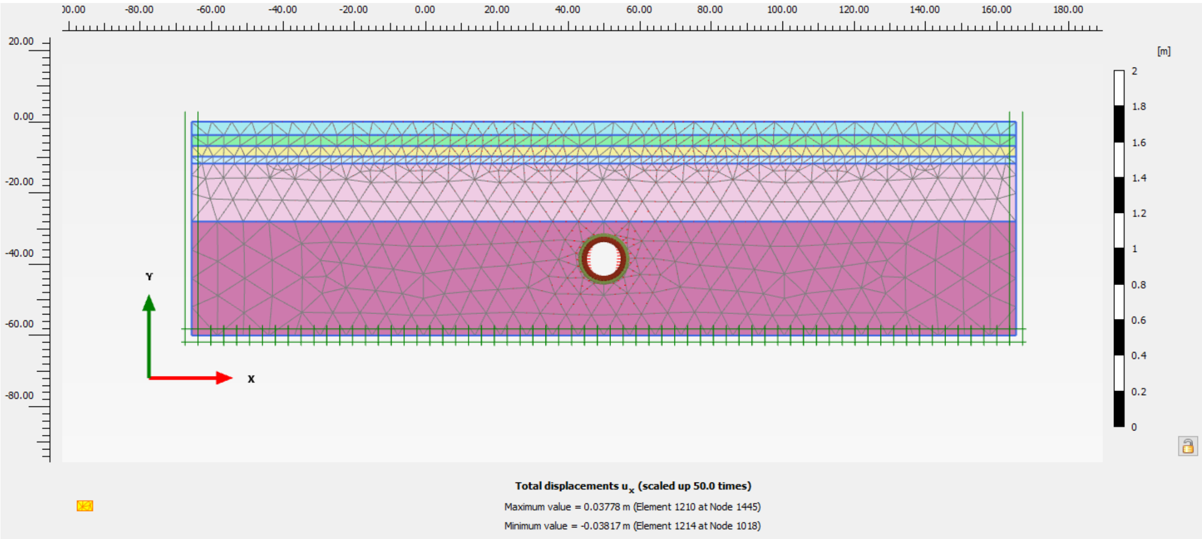


Figure 5.2.3.1: Horizontal displacement (Tunnel without any existing structure)

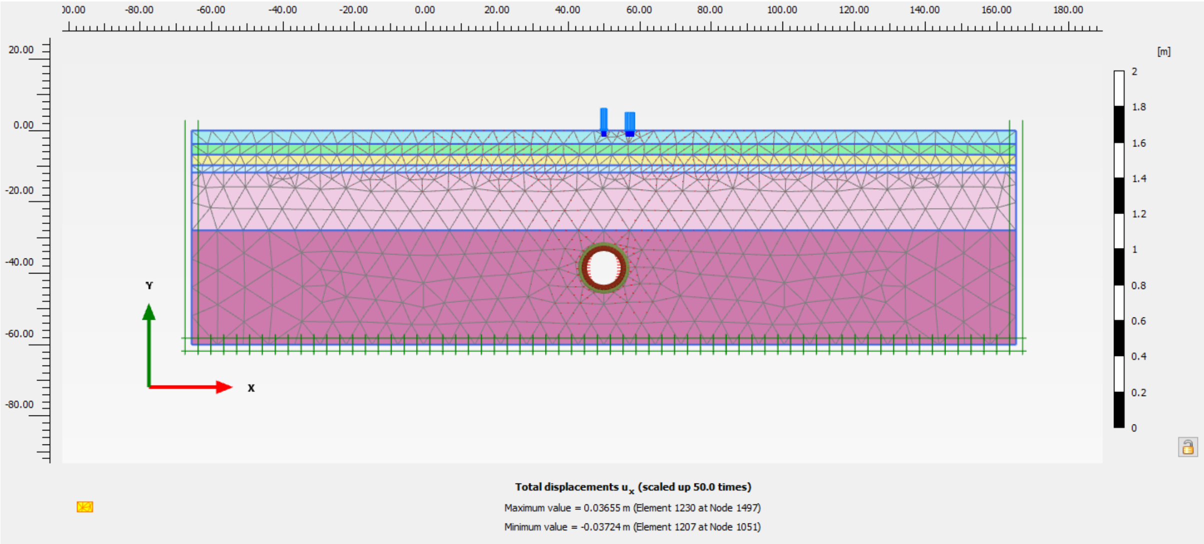


Figure 5.2.3.2: Horizontal displacement (CASE 1 - Tunnel under 1st footing of the building)

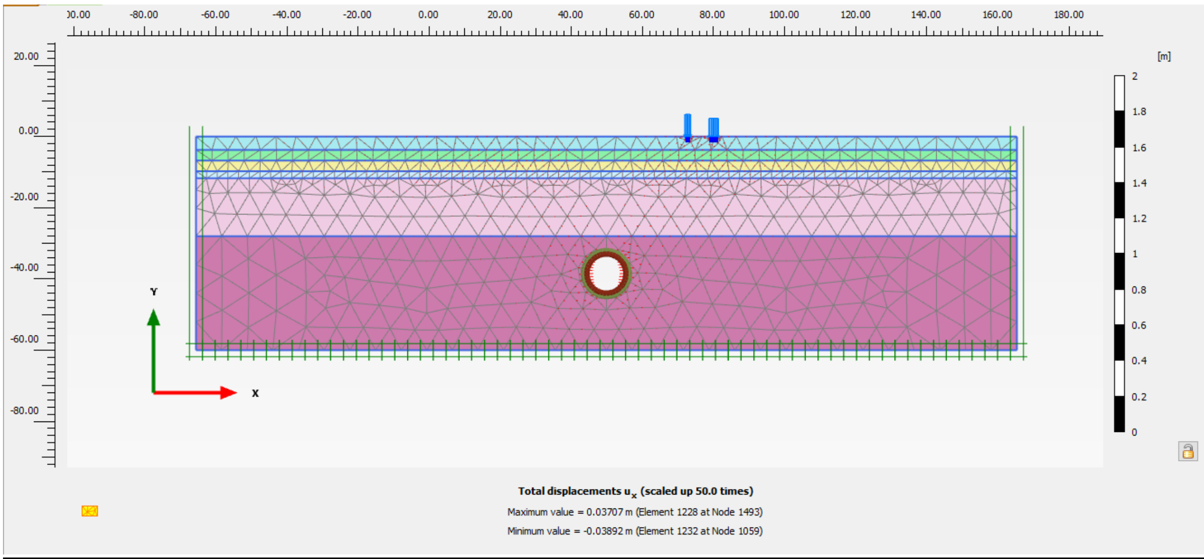


Figure 5.2.3.3: Horizontal displacement (CASE 2 – Tunnel under center of the road)

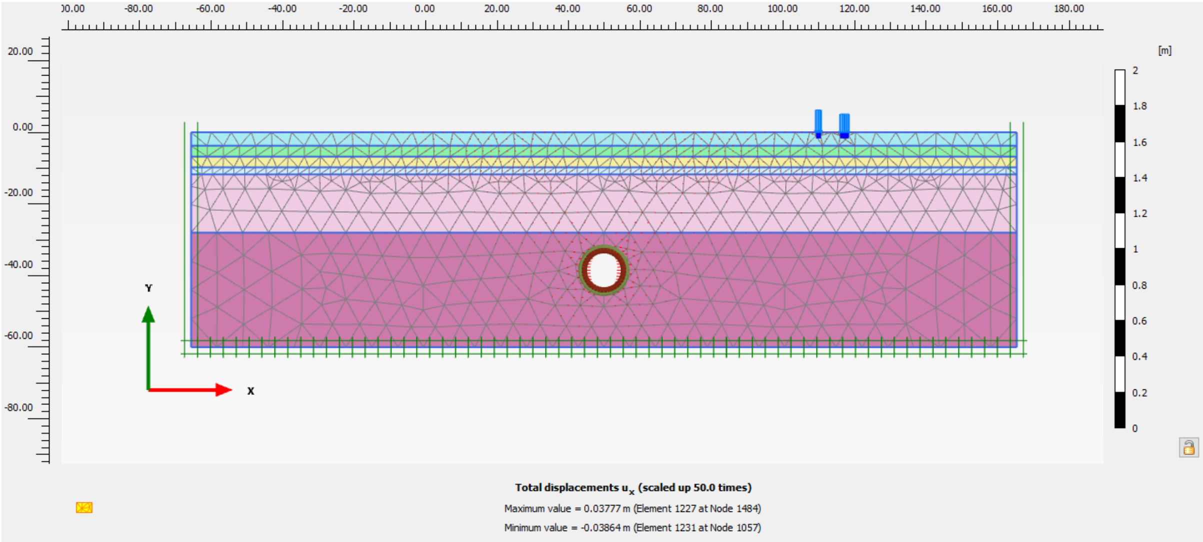


Figure 5.2.3.4: Horizontal displacement (Tunnel at 60m distance from CASE 1)

5.2.4 Vertical Displacement

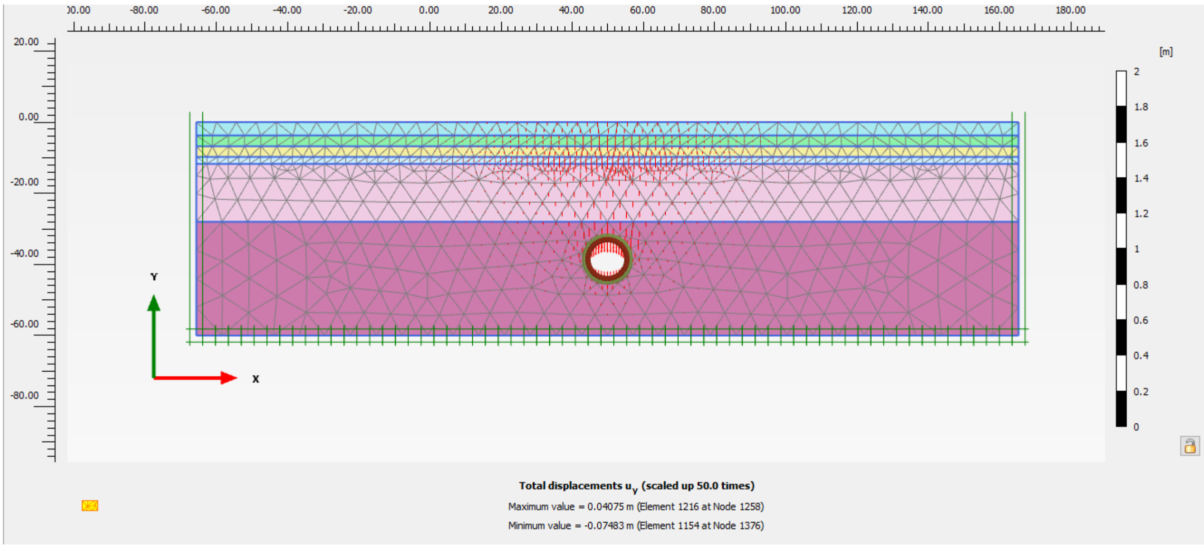


Figure 5.2.4.1: Vertical displacement (Tunnel without any existing structure)

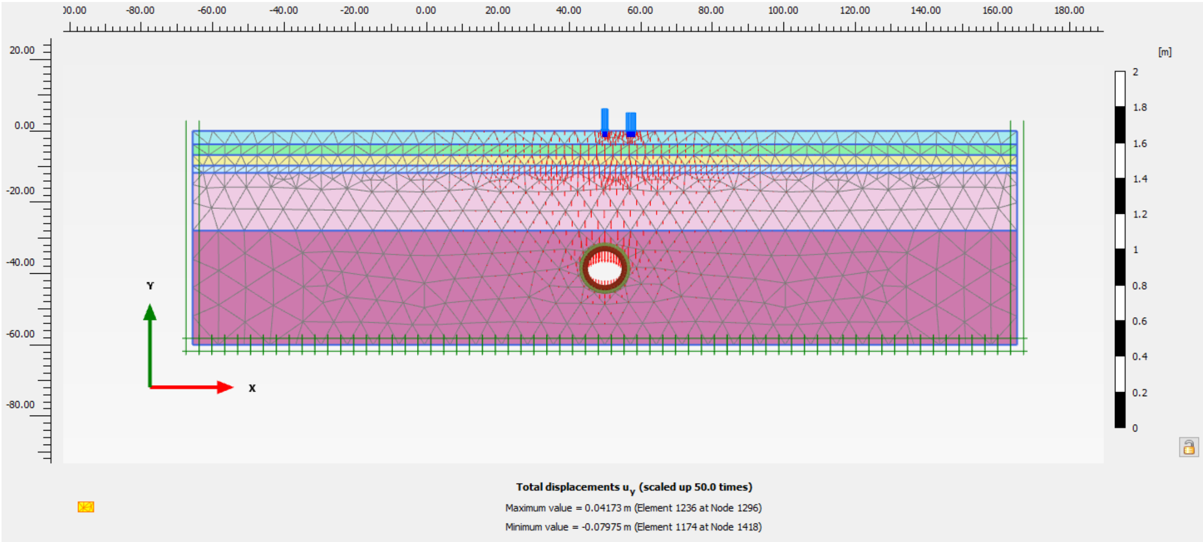


Figure 5.2.4.2: Vertical displacement (CASE 1 - Tunnel under 1st footing of the building)

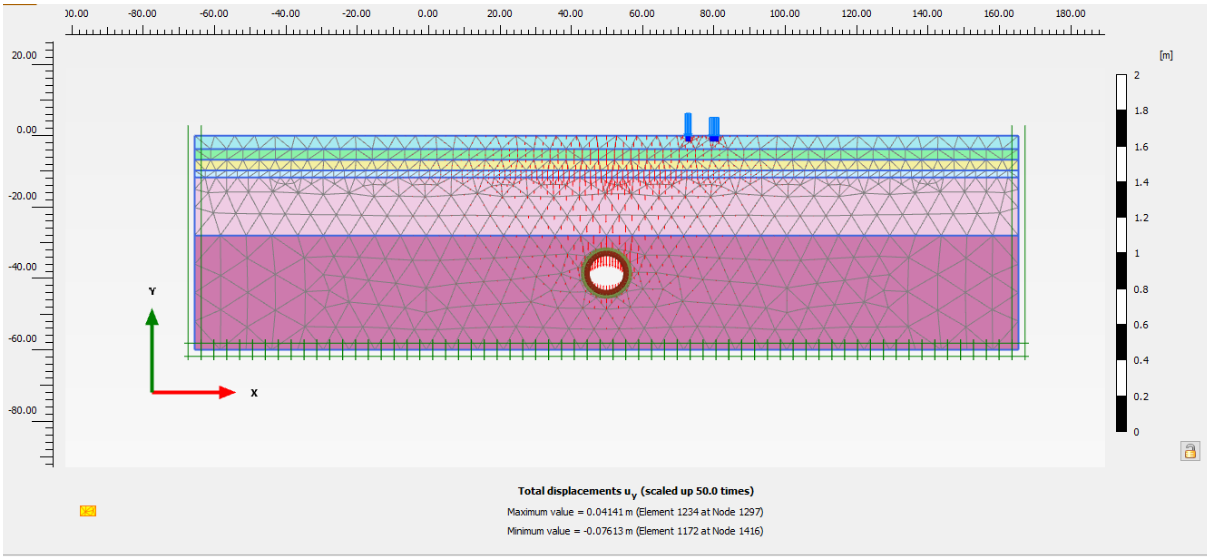


Figure 5.2.4.3: Vertical displacement (CASE 2 – Tunnel under center of the road)

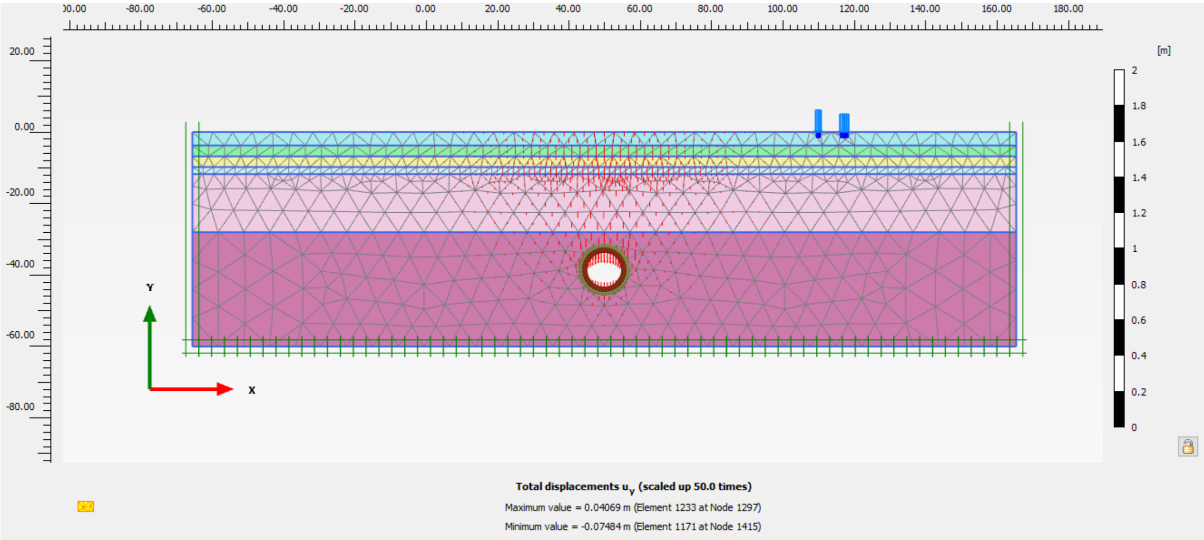


Figure 5.2.4.4: Vertical displacement (Tunnel at 60m distance from CASE 1)

5.3 Tunnel lining condition

5.3.1 Bending Moment

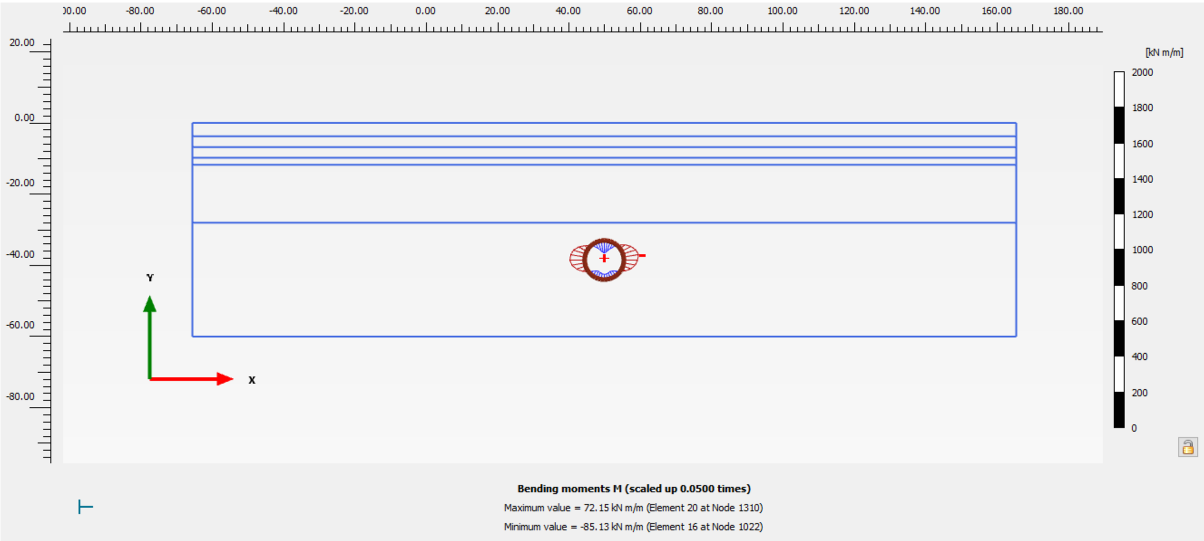


Figure 5.3.1.1: Bending moment diagram of tunnel (Tunnel without any existing structure)

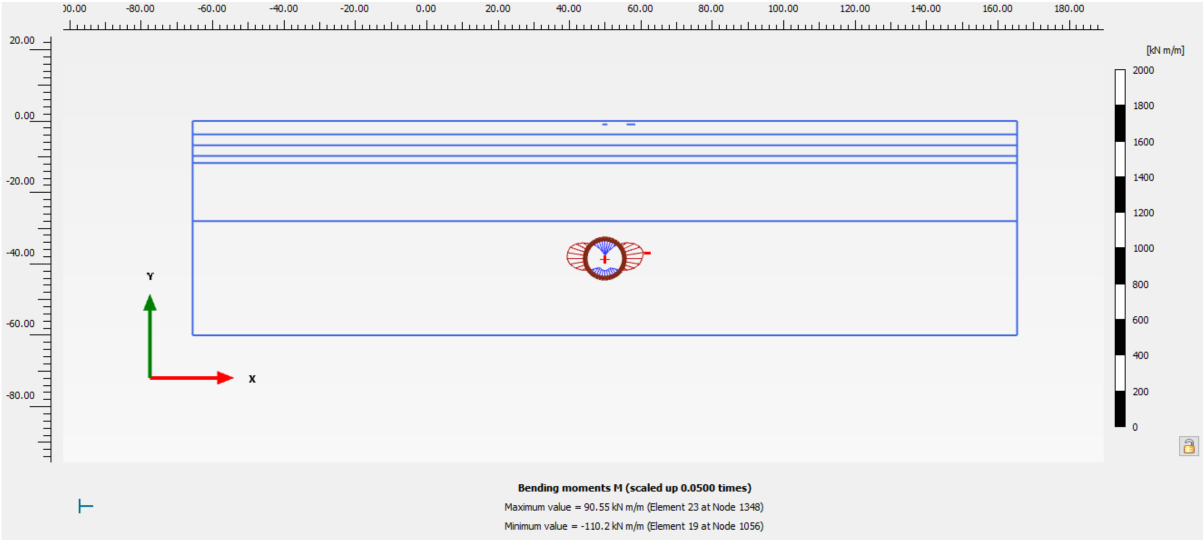


Figure 5.3.1.2: Bending moment diagram of tunnel (CASE 1)

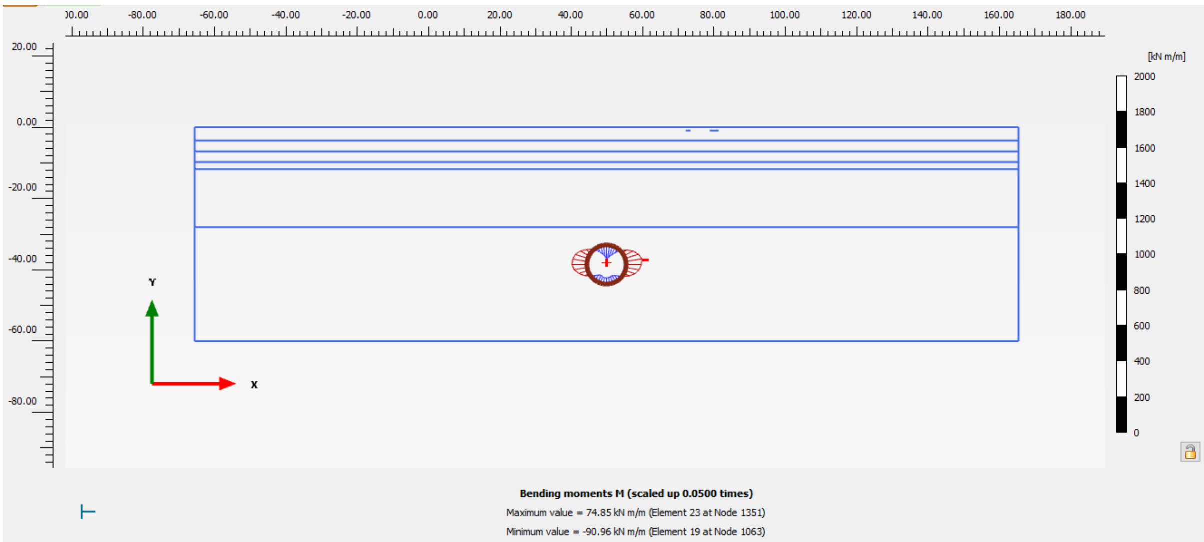


Figure 5.3.1.3: Bending moment diagram of tunnel (CASE 2)

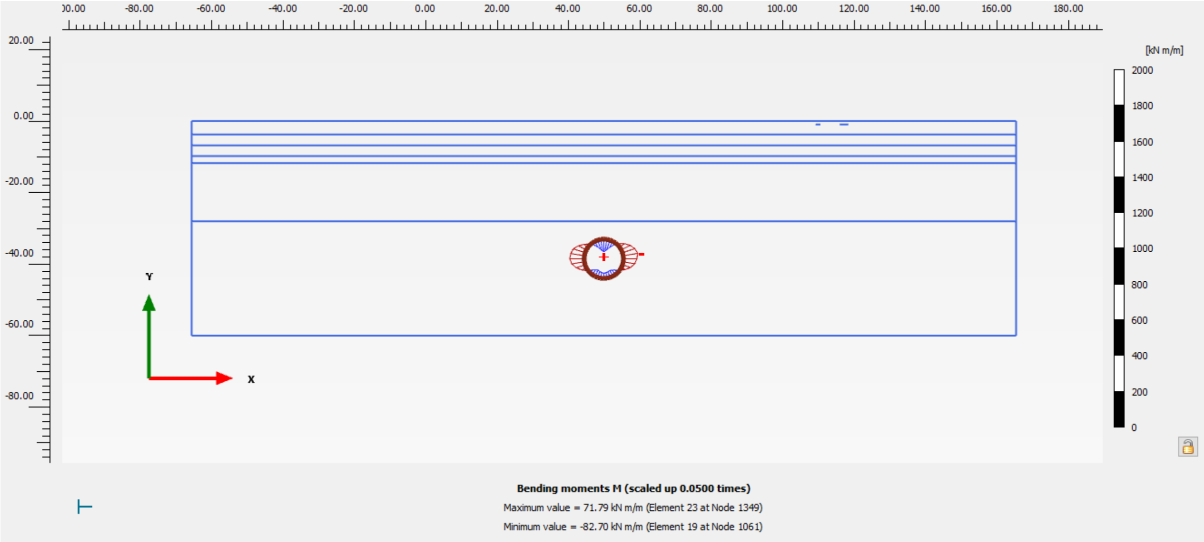


Figure 5.3.1.4: Bending moment diagram of tunnel (Tunnel at 60m distance from CASE 1)

5.3.2 Shear force

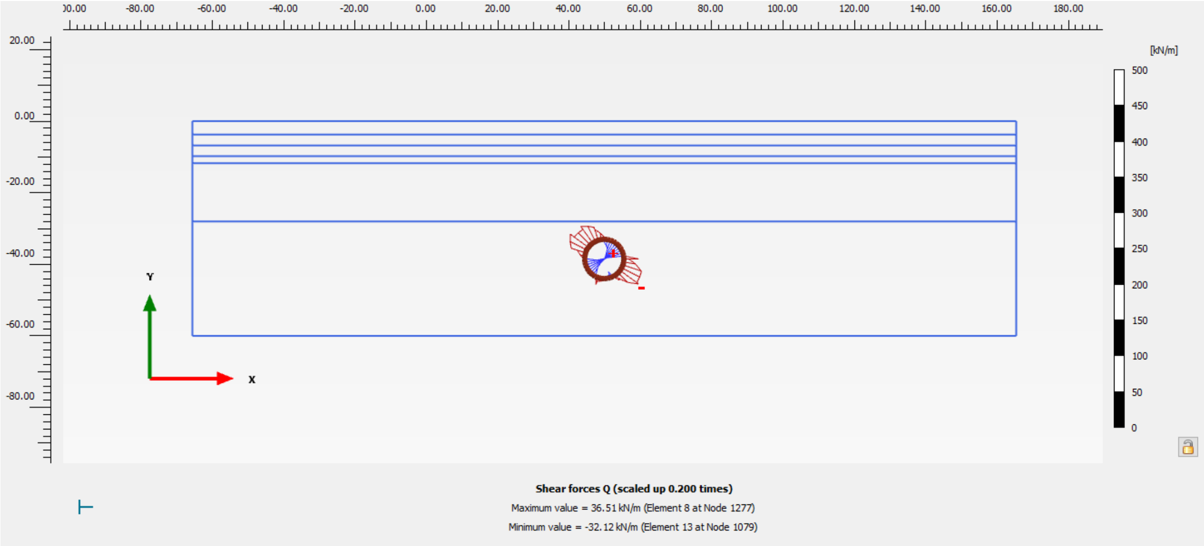


Figure 5.3.2.1: Shear force diagram of tunnel (Tunnel without any existing structure)

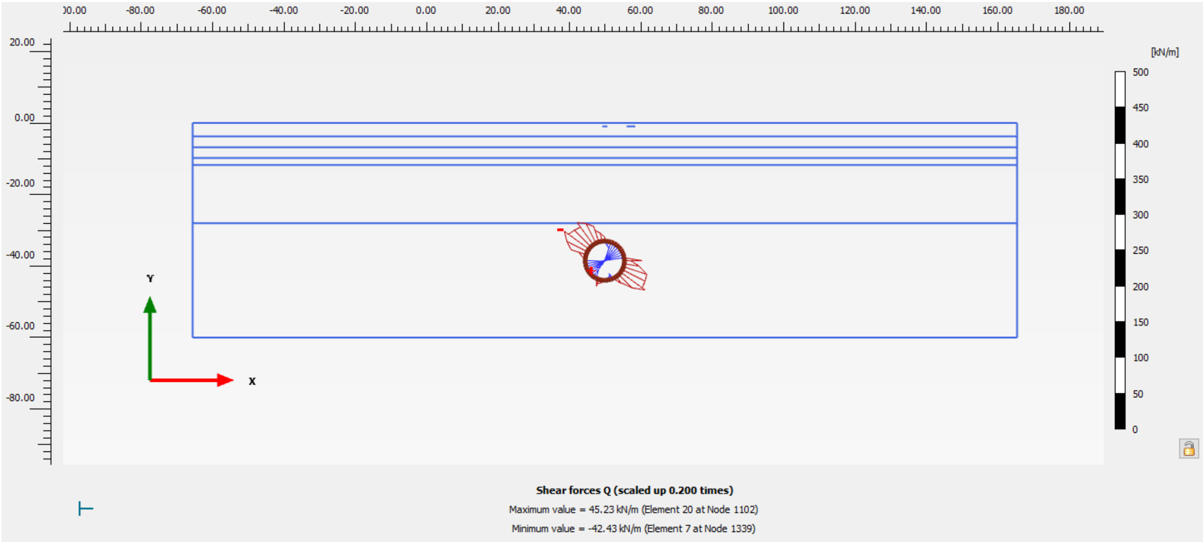


Figure 5.3.2.2: Shear force diagram of tunnel (CASE 1)

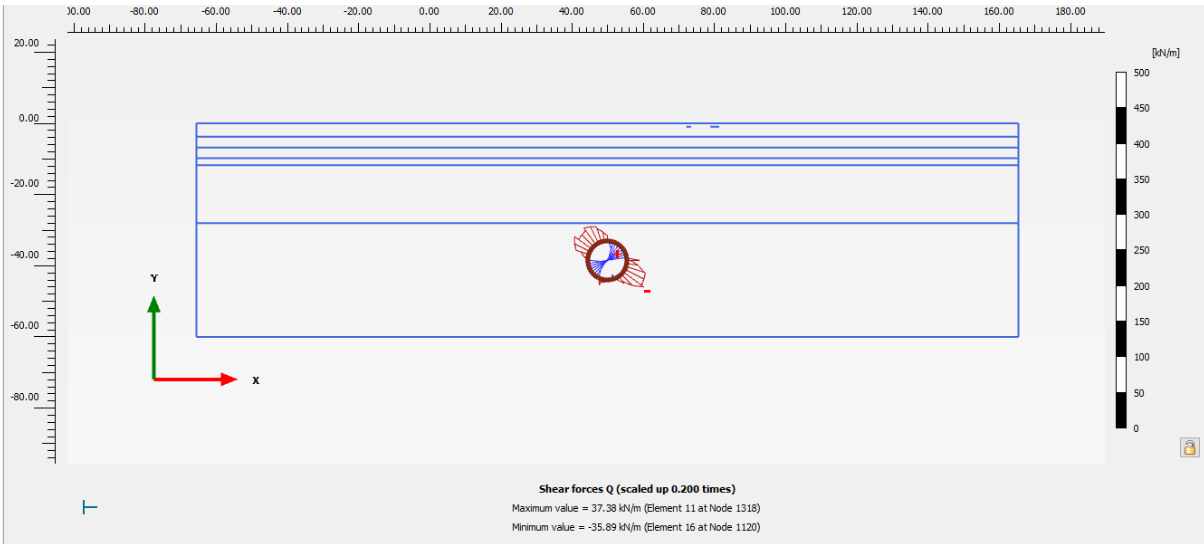


Figure 5.3.2.3: Shear force diagram of tunnel (CASE 2 – Tunnel under center of the road)

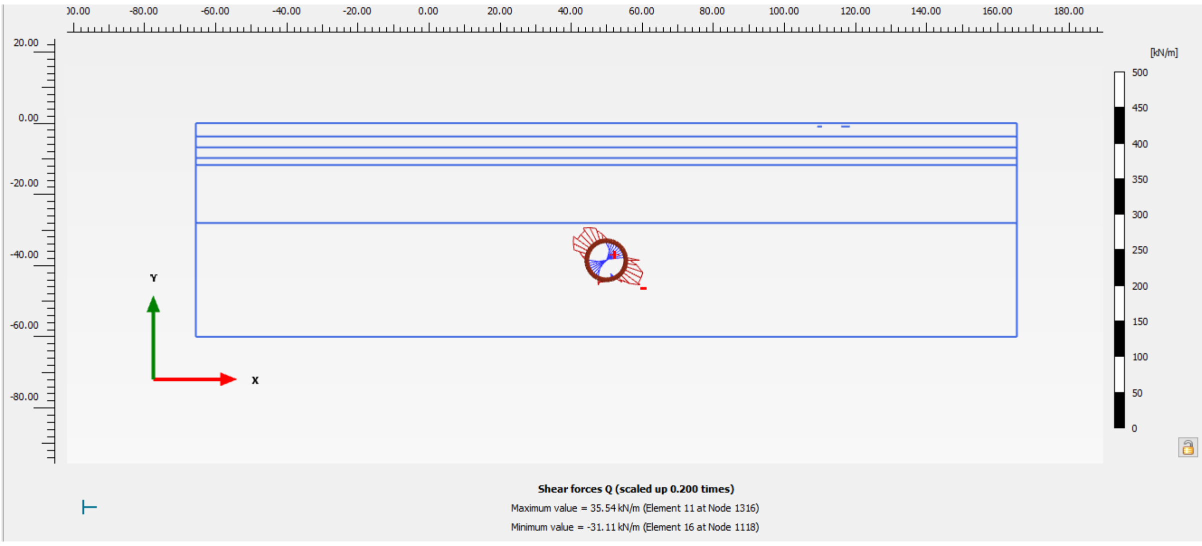


Figure 5.3.2.4: Shear force diagram of tunnel (Tunnel at 60m distance from CASE 1)

5.3.3 Axial force

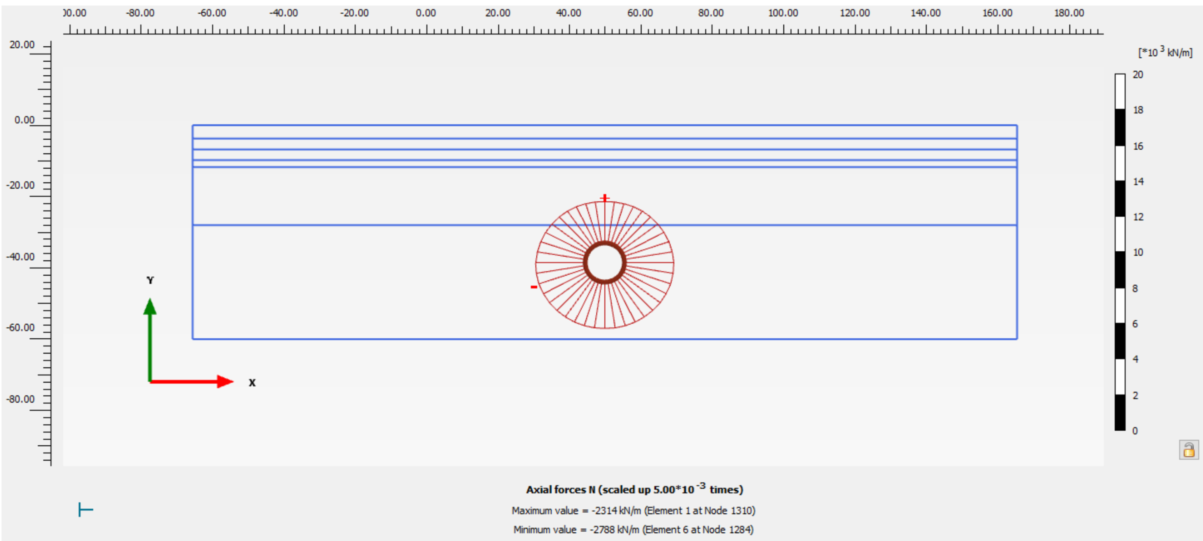


Figure 5.3.3.1: Axial force diagram of tunnel (Tunnel without any existing structure)

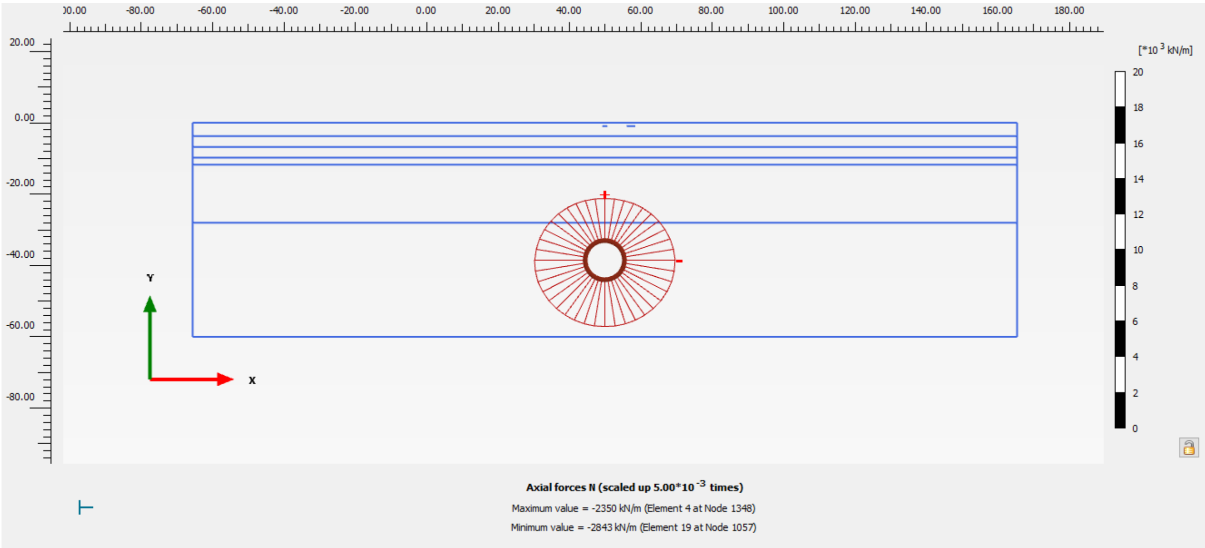


Figure 5.3.3.2: Axial force diagram of tunnel (CASE 1)

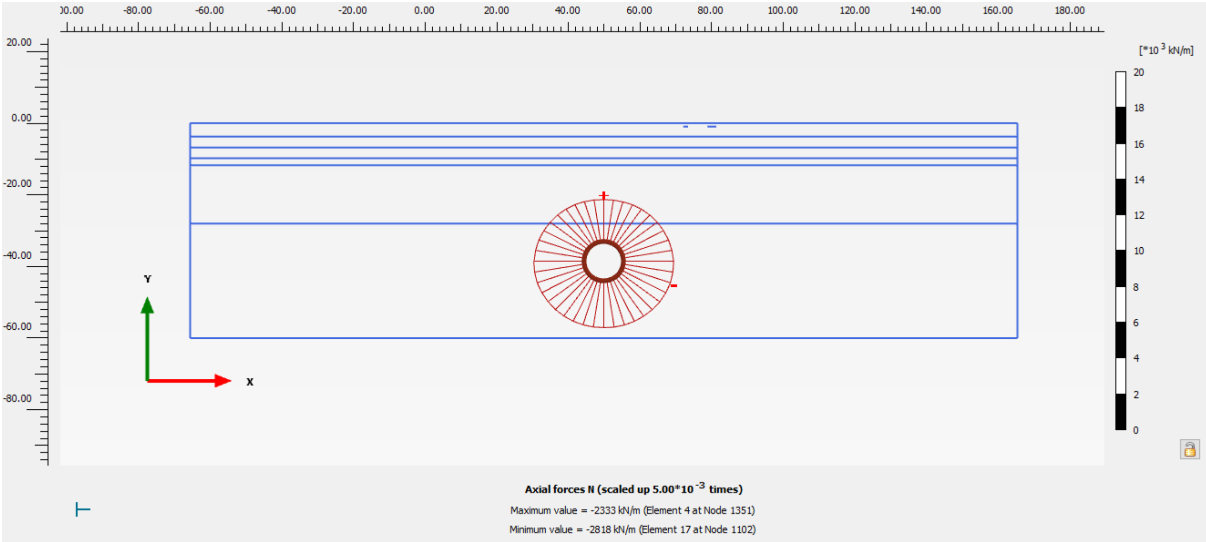


Figure 5.3.3.3: Axial force diagram of tunnel (CASE 2 – Tunnel under center of the road)

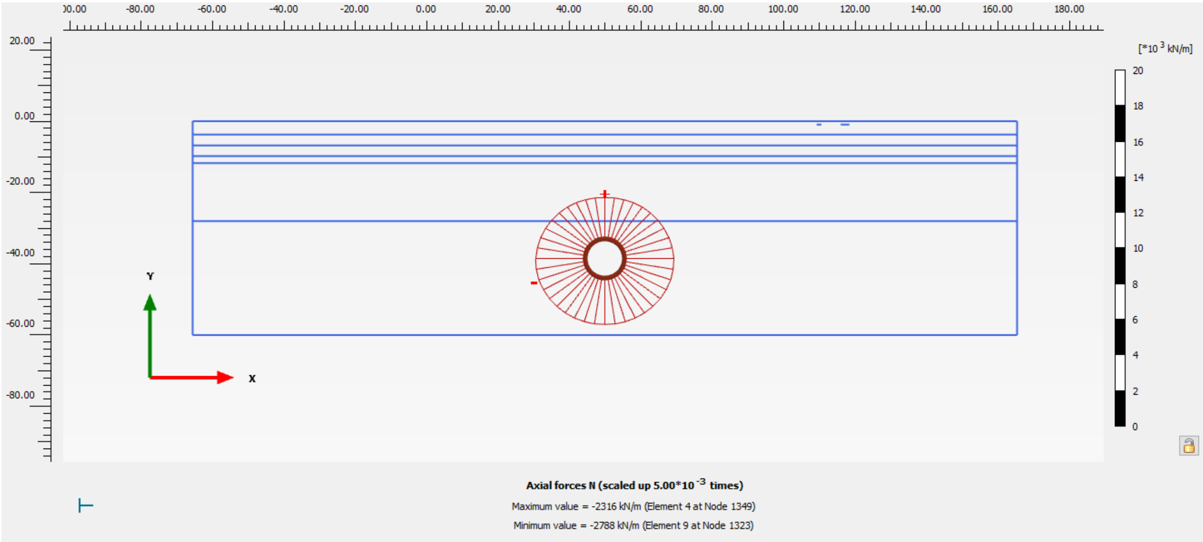


Figure 5.3.3.4: Axial force diagram of tunnel (Tunnel at 60m distance from CASE 1)

5.4 Graphs

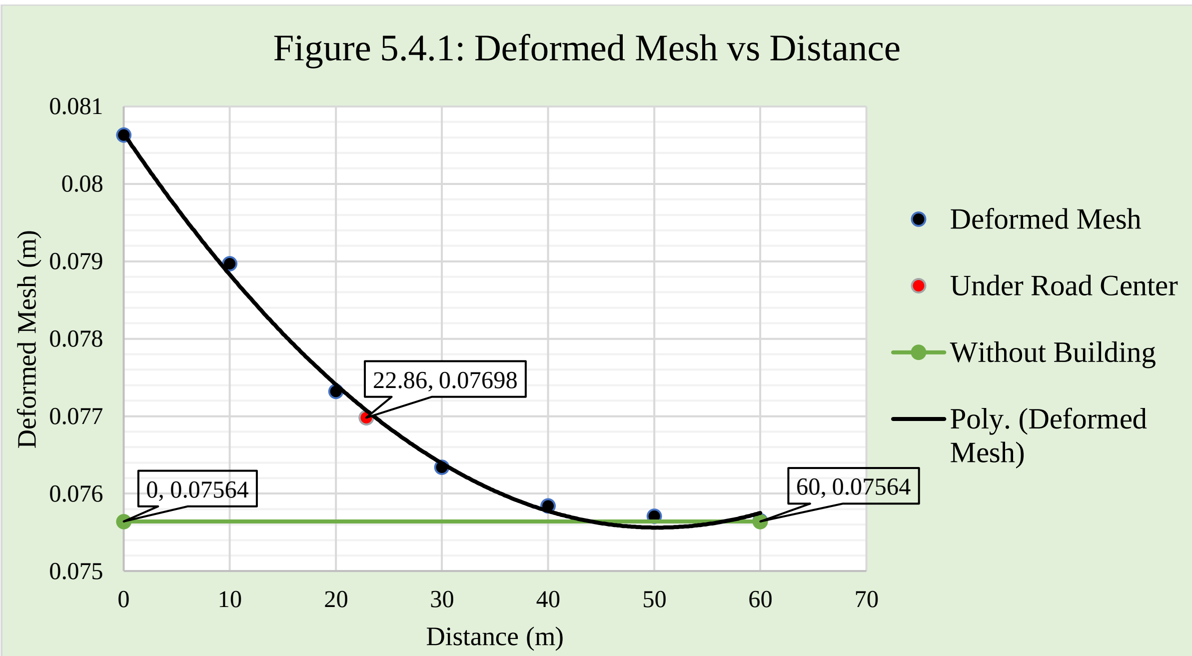


Figure 5.4.1: Deformed Mesh vs Distance

Figure 5.4.2: **Total Displacement** vs **Distance**

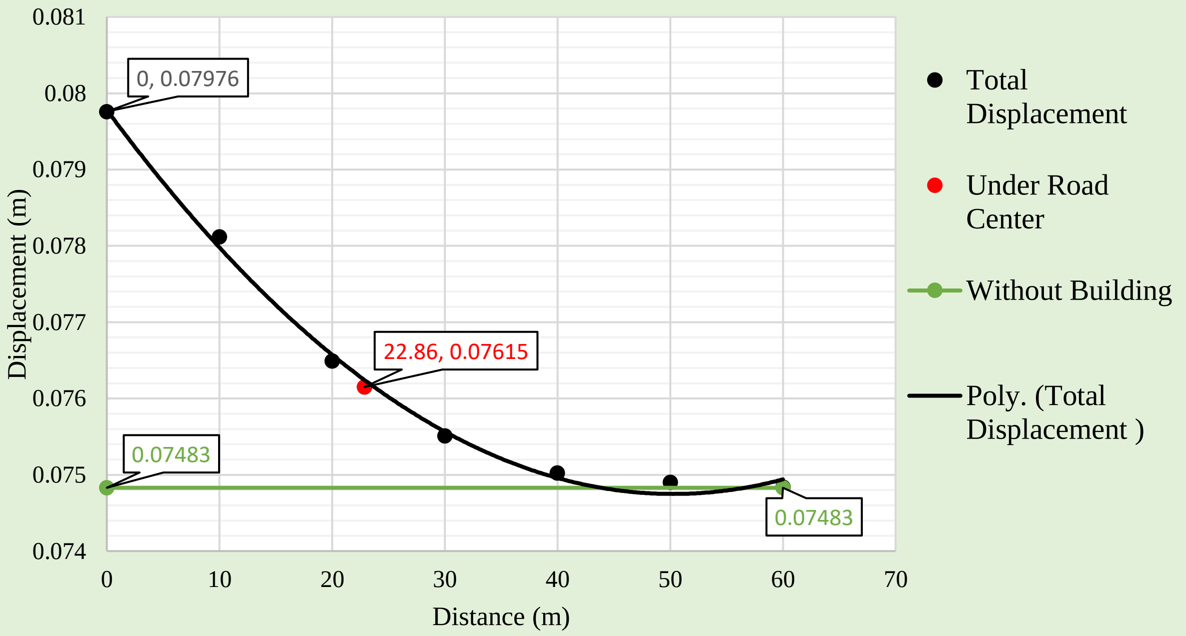


Figure 5.4.3: **Maximum Horizontal Displacement** vs **Distance**

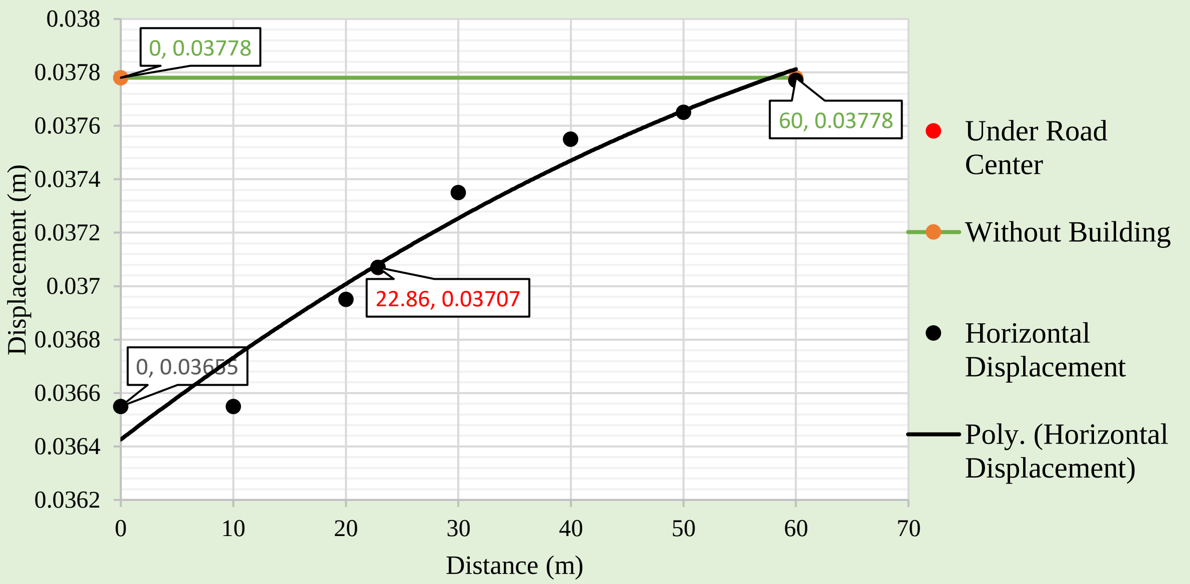


Figure 5.4.4: **Maximum Vertical Displacement** vs **Distance**

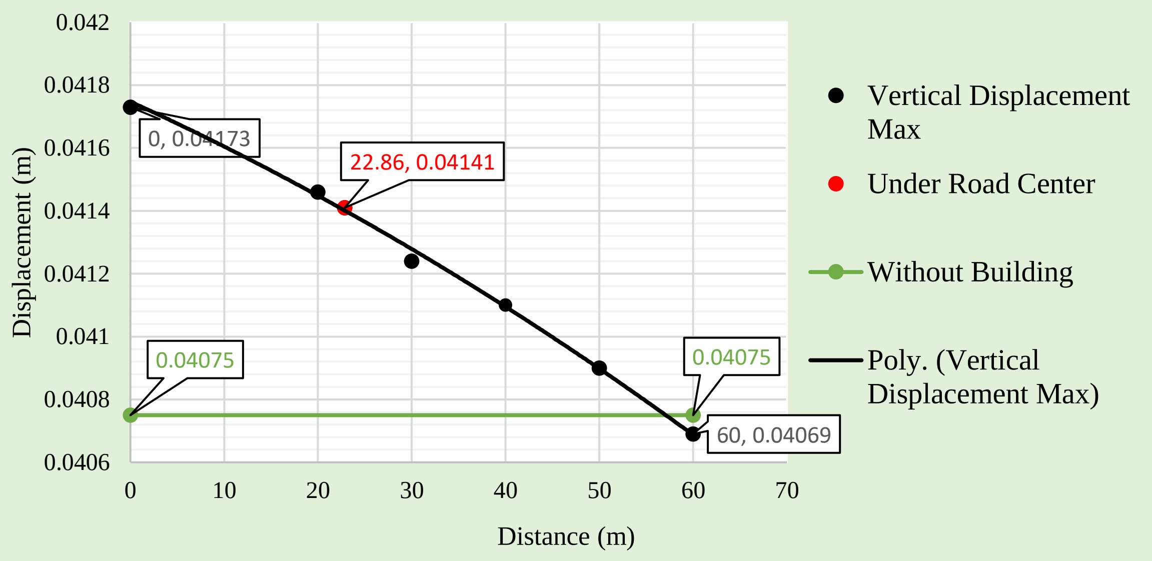


Figure 5.4.5: **Maximum Bending Moment** vs **Distance**

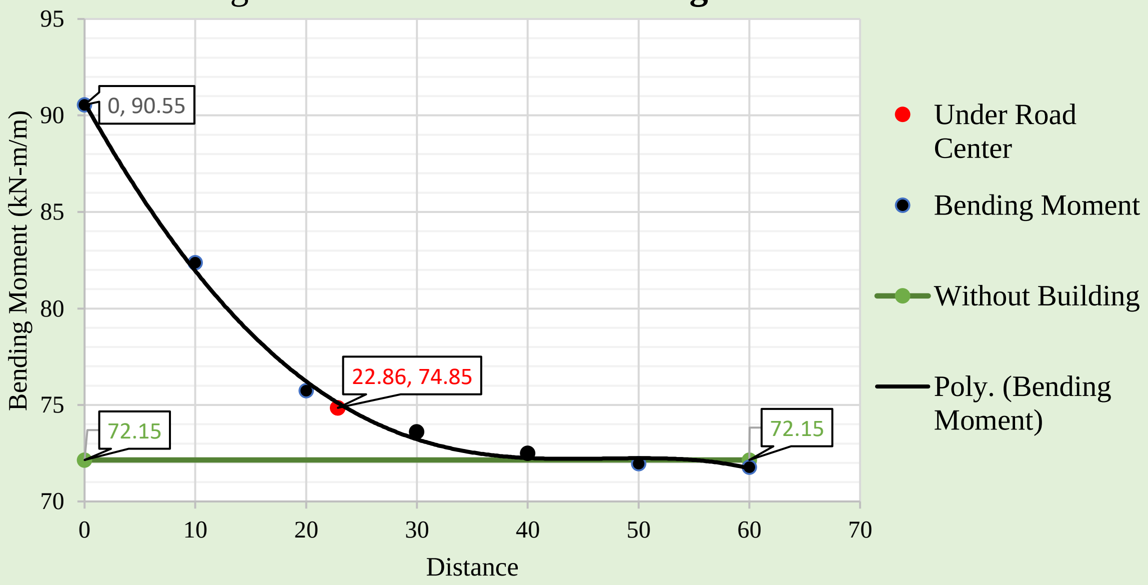


Figure 5.4.6: **Maximum Shear Force** vs **Distance**

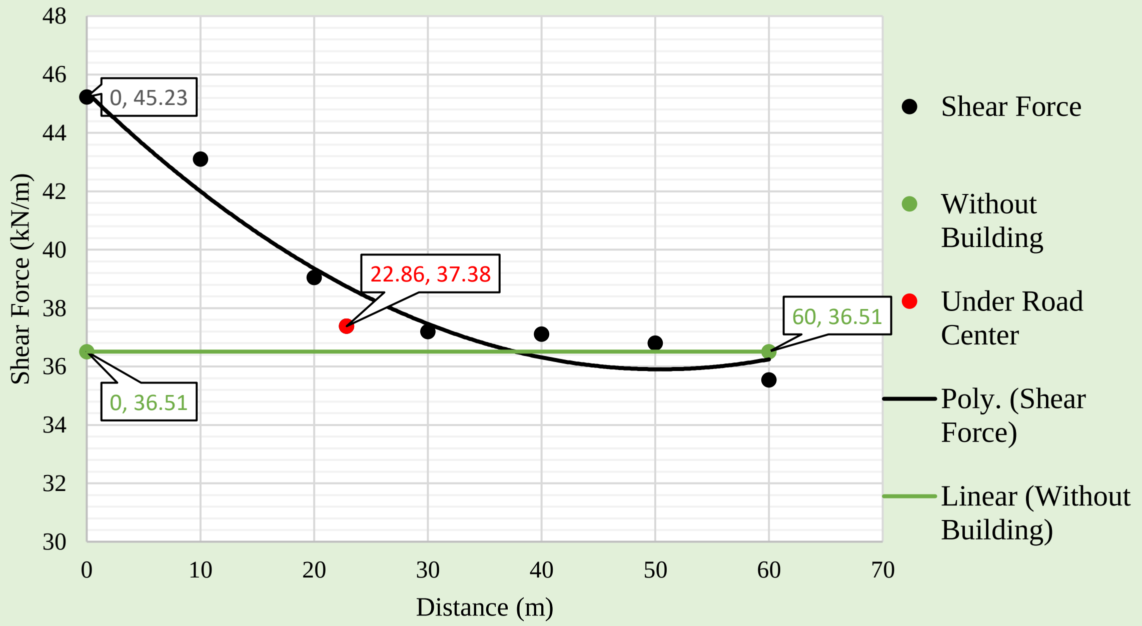
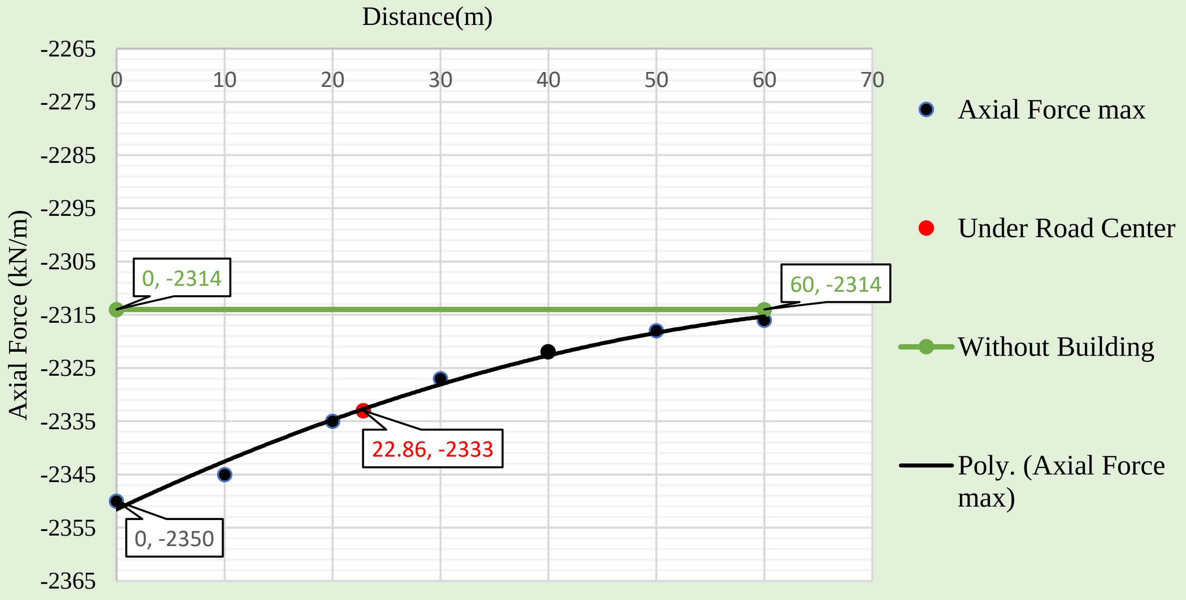


Figure 5.4.7: **Maximum Axial Force** vs **Distance**



5.5 Discussion

Conditions		Tunnel without any surface load	CASE 1	CASE 2	Tunnel at 60m distance from CASE 1	Comment
Ground condition	Deformed mesh (m)	0.07564	0.08063	0.07698	0.07565	Very close
	Total Displacement(m)	.07483	0.07976	0.07615	0.07484	Very close
	Horizontal displacement (m)	.03778	0.03655	0.03707	0.03777	Very close
	Vertical displacement (m)	.04075	0.04173	0.04141	0.04069	Closely enough
Tunnel lining condition	Bending moment (kN-m/m)	72.15	90.55	74.85	71.79	Closely enough
	Shear force (kN/m)	36.51	45.23	37.38	35.54	Meets early
	Axial force(kN/m)	-2314	-2350	-2333	-2316	Very close

Very close : Values are very close to the baseline values.

Closely enough : Values have little difference from the baseline values.

Meets early : Values meets the basline values before tunnel placed at 60 m distance from CASE 1.

Table 5.5.1 : Results and comments for all scenarios

From the results we can discuss that if we consider the base values are for all conditions (ground and tunnel lining) the values extract from the tunnel without any surface load for every cases then most of the condition's values meets the base values ((Tunnel at 60m distance from CASE 1).

There were some limitations and unwanted shapes in the graphs for creating the best line curves. Some values were unrealistic. Because of

- Soil parameters are extracted from USCS soil classification, SPT values, and different co-relations.
- The modeled soil parameter was not similar to the actual field soil parameters.
- The plates and tunnel lining data are collected from global database of PLAXIS 2D software.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- Similarities were found in soil behavior and tunnel lining behavior between the initial condition (without nearby structure) -
  - For CASE 1 – its suggested to placed the tunnel around 60 m from the initial phase.(CASE 1)
  - For CASE 2 – it is suggested to placed the tunnel around 37.14m from the initial phase (CASE 1).
- In case of similar soil layers, similar ground behavior can be speculated in tunnel construction in Dhaka city.

6.2 Future work and recommendations

- In this study, we have considered only the distance of the tunnel where there was no effect of surface loading. A proposal can be made on the lining thickness of the tunnel in the future.
- We have used the modified soil parameters. In the future, using real field data is suggested.
- In the future, instead of using Mohr-Coulomb criteria, other material models e.g. Hardening Soil Model, Soft Soil Model etc. can be used and compared with various models.
- In our study, we have considered the 2D effect only. In addition, 3D effect of soil and tunnel lining behavior can be an advanced topic of research for this project.
- Finally, though parametric values are obtained from SPT, in case of the accuracy of the model triaxial test or direct shear test is suggested.

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APPENDIX A

The result and values for different scenarios

Tunnel without any surface loading						
Deformed Mesh (m)	Total Displacement (m)	Horizontal Displacement Maximum (m)	Vertical Displacement Maximum (m)	Bending moment Maximum (kN-m/m)	Shear Force Maximum (kN/m)	Axial Force maximum (kN/m)
0.07564	0.07483	0.03778	0.04075	72.15	36.51	-2314

CASE 1 - Tunnel under 1st footing of the building						
Deformed Mesh (m)	Total Displacement (m)	Horizontal Displacement Maximum (m)	Vertical Displacement Maximum (m)	Bending moment Maximum (kN-m/m)	Shear Force Maximum (kN/m)	Axial Force maximum (kN/m)
0.08063	0.07976	0.03655	0.04173	90.55	45.23	-2350

CASE 2 - Tunnel under the center of the road (22.86m distance from CASE 1)						
Deformed Mesh (m)	Total Displacement (m)	Horizontal Displacement Maximum (m)	Vertical Displacement Maximum (m)	Bending moment Maximum (kN-m/m)	Shear Force Maximum (kN/m)	Axial Force maximum (kN/m)
0.07698	0.07615	0.03707	0.04141	74.85	37.38	-2333

Tunnel has been moved 10 meters repeatedly. So, we get 6 scenarios.

Tunnel moved from CASE 1							
Tunnel movement distance (m)	Deformed Mesh (m)	Total Displacement (m)	Horizontal Displacement Maximum (m)	Vertical Displacement Maximum (m)	Bending moment Maximum (kN-m/m)	Shear Force Maximum (kN/m)	Axial Force maximum (kN/m)
0	0.08063	0.07976	0.03655	0.04173	90.55	45.23	-2350
10	0.07897	0.07812	0.03655	0.04163	82.38	43.11	-2345
20	0.07732	0.07649	0.03695	0.04146	75.75	39.05	-2335
30	0.07634	0.07551	0.03735	0.04124	73.6	37.2	-2327
40	0.07584	0.07502	0.03755	0.0411	72.48	37.1	-2322
50	0.07571	0.0749	0.03765	0.0409	71.96	36.8	-2318
60	0.07565	0.07484	0.03777	0.04069	71.79	35.54	-2316