MUNICIPAL CORPORATION OF GREATER MUMBAI (MCGM)

CONSULTANCY SERVICES FOR ENGINEERING REPORT FOR GOREGAON MULUND- LINK ROAD

ENGINEERING & GEOTECHNICAL REPORT

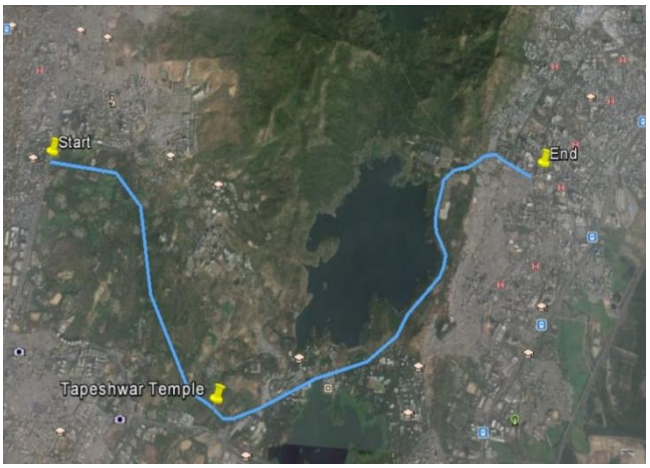
Submitted to:

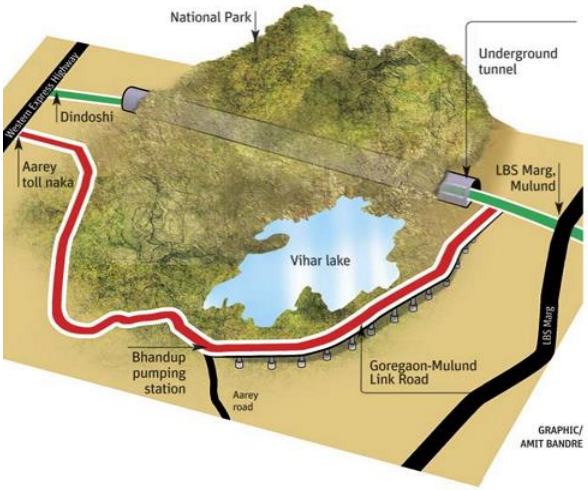
Office of the
Chief Engineer (CTI & RC),
Civic Training Institute & Research Center
Abhinav Nagar near National Park, Borivali (E) Mumbai, 400018

Submitted by:

PADECO

PADECO CO Ltd	
Client:	Municipal Corporation of Greater Mumbai
Project:	Consultancy Services for Peer Review of the Draft Project Report, finalization of most suitable alignment for Goregaon Mulund- Link Road and its bid process management
Title:	**Engineering and Geotechnical Report**
Document No:- PAD-GMLR-EGR-001	**Rev:-** 01





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IRC 89-1983	Geometric Design Standards for Urban Roads in Plains
IRC 106-1990	Guidelines for Capacity of Urban Roads in Plain Areas
IRC 108-2015	Guidelines for Traffic Forecast on Highways
IRC: SP-91-2010	Guidelines for road tunnels
IRC: SP- 87-2013	Manual of Specification and Standards for 6 laning of Highways HCM 2000
RES IRC: SP: 19 IND	Manual for Survey, Investigation and Preparation of Road Projects
Research Paper - Urban Mobility Forecasts: Emissions Scenarios for Three Indian Cities. Authors - Lisa Rayle, Madhav Pai; November 15, 2009	
Yang, X. and Zhang, N. (2005). "The marginal decrease of lane capacity with the number of lanes on highway." Proc. International Conference of Eastern Asia Society for Transportation Studies (EASTS), Vol. 5, pp. 739 - 749.	
IS 1892:	Code of Practice for Subsurface investigation for foundations
IS 2131	Method of Standard Penetration Test for Soils
IS 2132:	Code of Practice for Thin Walled Tube Sampling of Soils
IS 4078:	Code of Practice for Indexing & storage of drill cores.
IS 4464:	Code of Practice for Presentation of drilling information and core description in Foundation investigation.
IS 5313:	Guide for core drilling observations
IS 5529:	Code of Practice for In-situ Permeability Tests
IS 6926	Code of Practice for Diamond Core Drilling for site investigation for river valley projects.
IS 7974	Symbols and Abbreviations for Geological maps, Sections and sub-surface Exploratory Logs
IS 7422	Symbols and Abbreviations for Geological maps, Sections and sub-surface

	Exploratory Logs.
IS: 1124	Method of test for determination of water absorption, apparent specific gravity and porosity of natural building stones"
IS 13030	Method of test for laboratory determination of water content, porosity, density and related properties of rock material.
ASTM D2938	Standard Test Method for Unconfined Compressive Strength of Intact Rock Core Specimens
IS: 10050	Standard Method to determine slake durability tests on rock specimens.
IS 10082	Method of test for the determination of tensile strength by indirect tests on rock specimens.
ASTM (2010): D7625-10	Standard Test Method for Laboratory Determination of Abrasiveness of Rock Using the CERCHAR Method
IS: 91	
IS: 8764	Method for determination of point load Strength index of rocks
ASTM D 2664	Standard Test Method for Triaxial Compressive Strength of Undrained Rock Core Specimens Without Pore Pressure Measurements
IS 9221	Method For The Determination Of Modulus Of Elasticity And Poisson's Ratio Of Rock Materials In Uniaxial Compression
ASTM C1721	Standard Guide for Petrographic Examination of Dimension Stone
IS: 2720 (Part 26, 27)	Method of Test for Soils: Part - 26 Determination of pH Value Methods of Test for Soils: Part - 27 Determination of Total Soluble Sulphates
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LIST OF ACRONYMS

Acronyms	In Full-words
AGLR	Andheri - Ghatkopar Link Road
BODR/DDR	Basis of Design Report/ Detail Design Report
CTS	Comprehensive Transportation Study
DEM	Digital Elevation Module
DP	Development Plan
DPR	Draft Project Report
EEH	Eastern Express Highway
EIA	Environmental Impact Assessment
GAD	General Arrangement Drawing
GIS	Geographical Information System
GL	Ground Level
GMLR	Goregaon Mulund Link Road
IL	Invert Level
IRC	Indian Road Congress
JVLR	Jogeshwari - Vikhroli Link Road
Km	Kilometre
LBS	Lal Bahadur Shastri Marg
LOS	Level of Service
m	Metre
MCGM	Municipal Corporation of Greater Mumbai
MMR	Mumbai Metropolitan Region
MMRDA	Mumbai Metropolitan Region Development Authority
MSRDC	Maharashtra State Road Development Corporation
MUIP	Mumbai Urban Infrastructure Project
MUTP	Mumbai Urban Transport Projects
Nos.	Numbers
O-D	Origin - Destination

PADECO	M/s Padeco Company Limited
RL	Reduced Level
SCLR	Santacruz Chembur Link Road
SGNP	Sanjay Gandhi National Park
SqKm	Square Kilometre
Sqm	Square Metre
SV	Swami Vivekananda Road
TAZ	Traffic Analysis Zone
TBM	Temporary Bench Mark
TIN	Triangulated Irregular Network
TOR	Terms of Reference
WEH	Western Express Highway
BH	Bore hole
SPT	Standard penetration test
MPa	Mega pascal
UDS	Undisturbed soil sample
DS	Disturbed or wash soil sample
CR	Core Recovery
DBR	Design based report
PCC	Plain cement concrete
WG	Weathering grade
GSI	Geological strength index
UCS	Unconfined compressive strength
PLT	Point load test
RQD	Rock quality designation
ASTM	American society for testing and materials
GRM	Generalised reciprocal method
ERT	Electrical resistivity test

EXECUTIVE SUMMARY

ES 1. Background

This document provides an Engineering report carried-out by M/s Padeco Company Limited (PADECO), who has been appointed by Municipal Corporation of Greater Mumbai (MCGM) for "Consultancy Services for Peer Review of the Draft Project Report, finalization of most suitable alignment for Goregaon Mulund- Link Road and its bid process management". Letter of Award for this Project was issued vide ChEng/8582/Bridges 8th February 2016. This is the second Deliverable as identified in the Consulting assignment.

The objective of this Study is to carry-out the Engineering Survey and Geotechnical Investigation on GMLR proposed Tunnel Alignment including approach road at Entry and Exit points and finalization of most suitable alignment and its bid process management.

The Scope of the Consultant's assignment is divided into 2 parts, namely:

Part 1

Peer Review of the Earlier Proposal (as suggested by M/S Pentacle) and to finalise a more suitable Alignment, including tunnelling (if required and recommended) with suggestions, improvements and alternatives, if any

Part 2

Provide Pre-tender activities including Engineering Survey/Finalisation of Most-suitable Alignment/Preparation of General Arrangement Drawing (GAD)/Design & Specification/Environmental Impact Assessment (EIA) and obtaining all regulatory clearances/Preparation of Tender, up to award of the Contract. The total time period allowed for assignment is 10 months.

Terms of Reference (TOR) provided to the Consultants identifies a total of 7 deliverables:

i. Peer Review of DPR Prepared by M/S Pentacle
ii. Engineering Survey and Geotechnical Investigations Report
iii. Finalization of Most Suitable Alignment
iv. GAD of Suitable Alignment
v. Design and Specifications of the suitable Alignment
vi. EIA of Suitable Alignment

vii. Bid Process Management of Suitable Alignment

ES 2. Consultant's Mobilization:

Upon receipt of Work Order dated 25th February 2016, the Consultants (PADECO) have mobilized the Team and due to delay in approval for carrying out second deliverable, we have received the extension for completion of project till 30th September 2017 The team has had a number of consultative meeting and site-visits in association with the concerned MCGM officials.
All of the technical experts and support-personnel, including Environmental and Tunnel experts, have also been made available to support the assignment.

ES 3. Summary of Review and Findings:

The Consultant presented "Peer Review of Draft Project Report" and the suggestions/Observations of MCGM were noted and incorporated in this Engineering Report, Further to assess the feasibility of preliminary approved alignment by MCGM following Engineering Survey were carried out.

a. Topographical Survey for approach road
b. GIS Survey for National Park portion
c. Traffic Survey
d. Geotechnical Survey

a. Topographical Survey

The scope and objective of Topographical survey is to establish the centre line for Tunnel at grade road and finalization of Tunnel Vertical and Horizontal Alignment along with approach road. Topographical Survey was carried out on Alignment away from Sanjay Gandhi National Park premises namely to identify the profile of existing ground, identify the exact Boundary of National Park as per coordinate available from Notification, Availability of Overburden for Tunnel Portal , Structure affected and Nos. of Tree affected.

b. GIS Survey

Sanjay Gandhi National Park (SGNP), previously identified as Borivali National Park, is a large protected area in the northern part of Mumbai city (preferably called Mumbai Suburban district) in Maharashtra State in India. It encompasses an area of 104 Km^2 (40 sq. mi) and is surrounded on three sides by India's most populous city. It is notable as one of the major national parks existing within a metropolis limit and is one of the most visited parks in the world. Due to dense vegetation and Trees the Topo Survey for the alignment passing through SGNP area was not possible. As a part of this

project Bhugol GIS Pvt. Ltd (firm opened by IIT professor) was consulted by PADECO, to undertake project for "Contour Generation for a surface area above the proposed tunnel of Goregaon-Mulund Link Road (GMLR), Mumbai" and perform the following tasks. The project is to generate contours at 10 meter vertical intervals using satellite data analysis for an area of 1.00 Km buffer around the proposed Goregaon-Mulund Link Road passing through Sanjay Gandhi National Park (SGNP).

As a part of this project, elevation levels at locations in and around the SGNP surveyed earlier were using Differential GPS (DGPS) and Survey of India Toposheet Bench Mark locations were used along with Cartosat 2.5m stereo images. Using the collected elevation data, Survey of India Toposheet and Satellite data the Digital elevation model (DEM) was generated for this area. Further as a part of the project, contours were extracted using GIS analysis for an area of 1.00 Km buffer around the proposed GMLR alignment.

c. Traffic Survey

The Goregaon-Mulund link road currently exists on the eastern side and western side of Sanjay Gandhi National Park. In existing scenario, the Jogeshwari-Vikhroli Link Road (JVLR) and Aarey road south of Sanjay Gandhi National Park and Ghodbunder road and Western Expressway north of Sanjay Gandhi National Park, offer connectivity to the eastern and western parts surrounding the Sanjay Gandhi National Park. The proposed GMLR road will provide direct connectivity to the eastern and western areas surrounding the Sanjay Gandhi National Park.

The proposed new GMLR corridor is expected to connect the Eastern Expressway to the Western Expressway via a tunnel section under the Sanjay Gandhi National Park. The study aims to document traffic volumes that would be diverted from the existing vicinity corridors to the proposed new GMLR corridor. The report also aims to identify the corresponding geometry required for the proposed GMLR corridor carriageway to accommodate the projected 10-year (Year 2032) and 20-year (Year 2042) horizon years.To capture traffic likely to use the new corridor, classified turning movement counts and origin-destination surveys were carried out at six locations in the MMR region surrounding the Sanjay Gandhi National Park. Based on the collected data, origin-destination matrix and desire line diagrams were prepared using ArcGIS software. Traffic projections for the future year scenarios were projected using an Elastic Demand Growth Model.

A 6-lane divided roadway segment (3-lanes in each direction) is expected to operate within the projected capacity thresholds for the Year 2032 and Year 2042 projections. Although operations with the 6-lane divided geometry under Scenario 2 (a more conservative scenario) for the Year 2042

projection is expected to operate at near maximum capacity, a comparison with international standards suggests that a 6-lane divided section will operate well within acceptable LOS limits. Alternatively, the tunnel section is expected to operate under uninterrupted flow conditions (freeway segment) and therefore a capacity analysis based on freeway thresholds was additionally considered for the tunnel sections. Since the 6-lane geometry under uninterrupted flow conditions was projected to operate within LOS C thresholds for the Year 2042 projections, a 6-lane divided two-way roadway section (3-lanes in each direction) was recommended for the proposed GMLR. Based on the available right-of-way identified for the proposed GMLR, this 6-lane corridor can be accommodated within the proposed ROW (Right-Of-Way).

d. Geotechnical Survey

As a statutory requirement & to identify required design parameters for safe design, PADECO decided to carry out geotechnical investigation at SGNP (Sanjay Gandhi National Park) Mumbai. Geotechnical investigation work consisted of seven boreholes to examine subsurface profile. Depth of boreholes to be drilled was determined using IS: 1892- 1979 section 2.3.2. The lateral extent of exploration and the spacing of boreholes depend mainly on the variation of the strata in horizontal direction. M/s JAY GAJANAN, Thane (W) carried out fieldwork of boreholes from 20th Dec, 2016 to 01st March, 2017. Selected rock samples were tested in Soil Laboratory of M/s OCE PROJECT Pvt. Ltd., & IIT Bombay Laboratory test results were received on 07th April, 2017. Objective of the site investigation was to obtain the information that may be useful for one or more of the following purposes:

1. To select the type and depth of foundation for a given structure, to access the critical locations along the alignment for tunnel design.

2. To determine the bearing capacity & ground improvement techniques for soil/rock layer.

3. To establish the ground water level & seepage estimation in the tunnel area/section.

4. To select the suitable construction technique.

5. To predict potential foundation problems.

6. To ascertain the suitability of the soil as a construction material.

7.To collect and transport the selected samples of soil and rock in testing laboratory and conduct relevant tests to determine properties.

8.Recommendations for soil-related construction conditions such as site preparation, earthwork construction, excavation slopes, and difficult excavation.

ES 4. Hindrances

After careful analysis and consideration of the above objectives, the following Engineering Survey for Tunnel Alignment review is as follows

a. Based on the Topographical and GIS Survey Tunnel Portals can be accommodated outside of SGNP boundary;
b. On the proposed Goregaon Mulund Link Road alignment approx. 600 nos. of trees will be affected on the Film City (Goregaon Side);
c. On the proposed Goregaon Mulund Link Road alignment Approx. 14340.59 Sqm of Structures will be affected in Khindipada (Mulund Side);
d. 3 m diameter Underground Water tunnel at 48.00 RL I.L from Bhandup Complex to Charkop passing through SGNP and it is crossing below proposed Goregaon Mulund Link Road Tunnel Alignment;
e. TATA Overhead Electric Lines is passing on surface above the proposed Tunnel Alignment;

Based on the findings of the study and the anticipated traffic projections, a 3+3 -lane two-way divided arterial roadway was recommended for the ten-year horizon year (Year 2032 - 42) scenario.

ES 5. Way Forward

Sr. No.	Deliverables	Remarks
1	Finalization of Suitable Alignment	Preliminary Alignment finalised by MCGM on February 20, 2016. Final submission expected by 30th April, 2017.
2	Finalization of GAD	Expected by 10th May 2017 subject to finalisation of approval of final Alignment.
3	Preliminary Design and Design Based Report	expected by 10th May 2017 subject to approval of GAD
4	EIA report & Regulatory Approvals	Target to submit till 30th April 2017
5	Preparation of Tender Document & Assisting in Bid Process Management	PADECO had a discussion with Chief Engineer for formalising the criteria for Tender document. Some Points to be finalize after discussing with AMC

1. Introduction

Mumbai is popularly known as Commercial Capital of India and also known as city of seven islands. The city's position as on industrial and port city, along with its cultural and economic facilities, has caused the MCGM and immediately surrounding areas to grow at a much faster rate than any other area of India.

Mumbai City district is spread over an area of 527 SqKm The population of Mumbai Metropolitan Region increased from 19.3 million in 2001 to 22.8 million in 2011 - a decadal growth rate of 17.8%. Mumbai's position as on industrial and port city, along with its cultural and economic facilities, has caused the Municipal Corporation of Greater Mumbai (MCGM) and immediately surrounding areas to grow at a much faster rate than other area of Maharashtra and India. As a result, the metropolitan area is developed more rapidly than its ability to provided adequate and attractive facilities. The population within the MCGM limit increased from 2.8 million in 1951 to 4.2 million in 1961. As on today the population of Mumbai is 12.47 million (As per 2011 Census). Thus, it can be seen that the population of the Mumbai which has area of 527 SqKm, has increased tremendously leading to numbers of traffic related problems. In order to resolve the above traffic related problems, the MCGM has decided to take up the work of construction of Goregaon Mulund Link Road (GMLR) as a major East-West link.

1.1. Project Definition

This report is prepared to bring out Engineering Surveys and Geotechnical investigation. Our findings and views in a concise manner but comprehensively addressing all aspects of TOR and our recommendations after discussing with MCGM authorities.

1.2. Background

With industries and ports, and being major economic epicentre of the world, Mumbai grew exponentially faster than any other regions of the nation. With the fivefold increase of population in the last five decades, the accompanying demands too grew; and transportation industry was no exception to this. Traffic too grew with population, and the City now has close to 2.5 million vehicles, with add-on of more than 500 vehicles/day. With the present road network of only 2000.00 Km, it is becoming difficult to handle the traffic. In order to improve the level of service, MCGM has carried out varies studies in the past through reputed consultants and have identified new road links that would de-congest the existing road network. Commercial areas being developed across city and demand for

connectivity between residential areas has increased, the need for connecting city along east-west at regular compelling intervals has become a necessity. One such major connectivity is GMLR.

Following are major studies conducted for GMLR

- MMRDA appointed M/s CES India Pvt. Ltd. in the year 2003 to prepare a Master Plan for Road Network Improvement and Traffic Dispersal in Greater Mumbai.
- CES's Report suggested some alternatives to MGCM's original proposal in the DP, and taking into consideration these alternatives, MCGM awarded the work to Pentacle to prepare a DPR.
- The preferred option of Elevated Corridor proposed by Pentacle to connect WEH with EEH via Aarey Colony, Powai and Bhandup Complex along trunk-main pipeline is studied. PADECO's observations and research, including in terms of level of Service to the road-users, constraints during/after construction and environmental impact during/after construction are presented in this Report. Several disadvantages observed and measures to mitigate them led PADECO to propose a new HYBRID CORRIDOR, which includes a twin-tunnel in SGNP area connecting the segment from Goregaon/ Dindoshi to Mulund. The advantages of "Tunnel" over "Elevated Corridor" are discussed below :-

1. Travel-time is considerably reduced, to an extent close to half the time than the elevated option. As there is no intermediate loop; the through traffic will have free flow from one end to the other;
2. Tree-cutting will be much lesser in Tunnel portion compared to the Elevated-option;
3. As there are different activities like tunnelling, at-grade works, elevated viaducts, work is proposed to be split into different packages and construction activities will be carried-out in parallel.

Considering all the advantages and disadvantages of earlier proposed Elevated Alignment and our interactions, discussions and correspondence with MCGM it is concluded that the alternative shortest route as mentioned in the MCGM Development Plan is found to be the most suitable alignment for GMLR, except the portion passing through Sanjay Gandhi National Park area, which is proposed as tunnel in lieu of existing alignment to avoid negative impact on environment.

Based on the approval from MCGM on 23rd November 2016 for preliminary Tunnel Alignment and the Engineering survey and Geotechnical Investigation were commenced.

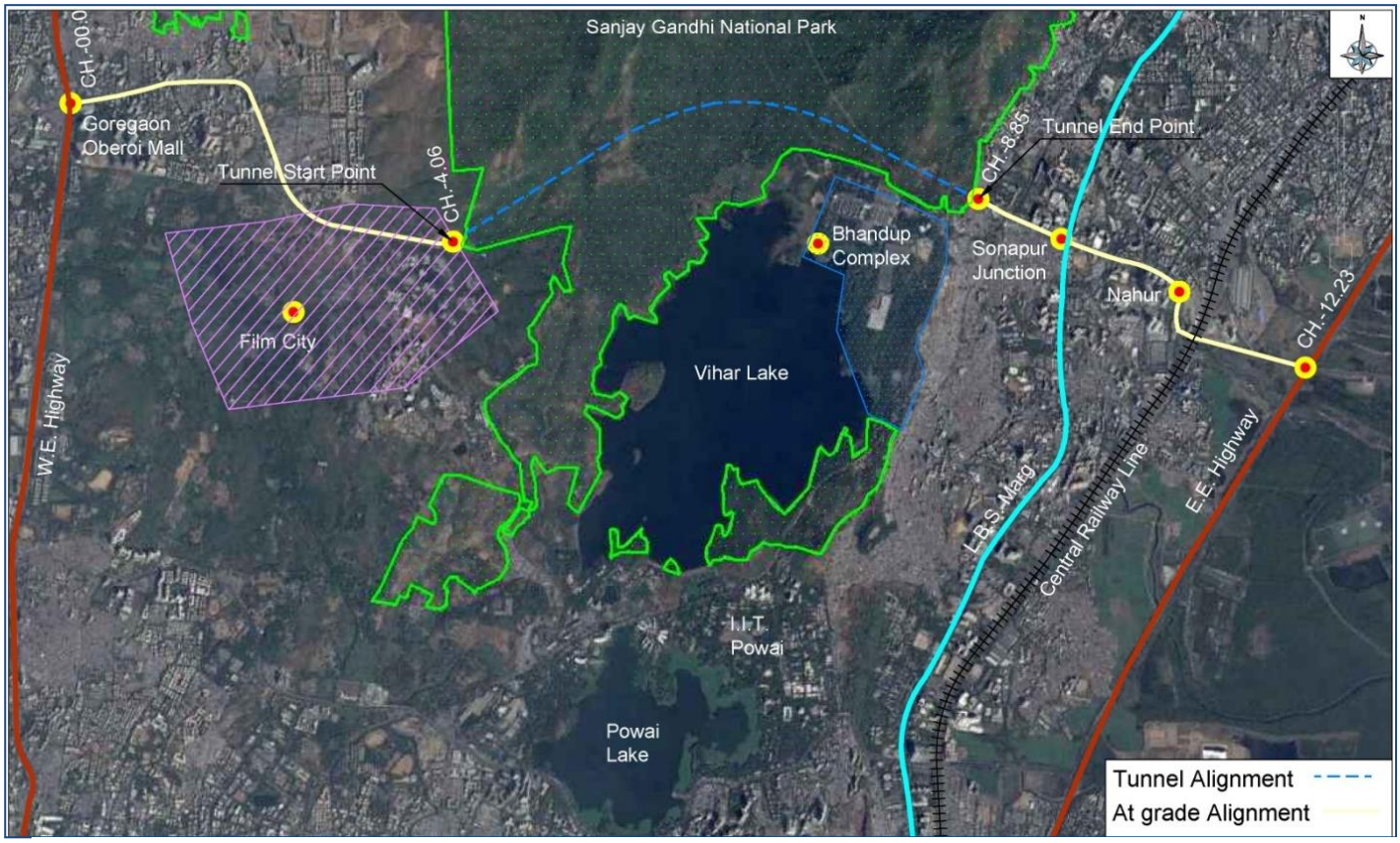

Figure 1-1 Proposed GMLR Alternative Tunnel Alignment

1.3. Objective

MCGM have appointed PADECO to review the concept prepared by Pentacle and propose improvements/ new most-suitable alignment. Accordingly, the scope of services will include Peer Review, Finalisation of most-suitable alignment including tunnelling (if required and recommended) with suggestions, improvements and alternatives, if any, details of which are:

1. Peer Review of Proposal, Finalisation of most-suitable alignment including tunnelling (if required and recommended) with suggestions, improvements and alternatives, if any
2. Engineering Survey/Geotechnical Investigation and any additional tests/changes, etc.
3. Finalisation of most-suitable alignment from point view of traffic-study and dispersal view of considering PAP (Project Affected People), Land Acquisition. Minimum cutting of trees, shortest routes, effect of Draft *DP 2014-2034 and effects of on-going/proposed infrastructural projects by MMRDA, MSRDC, Railway Projects, etc.
4. Preparation of GAD
5. The Design and Specification from point of view of the safety, smooth flow of traffic and cost effectiveness, including preparation of Design Based Report.
6. EIA and obtaining all regulatory clearances at the State and Union levels.
7. Bid Process Management including pre-tender activities, preparation of tender and all associated activities up to the award of Contract.

1.4. Scope of the Study

Scope of the Study under this Consultancy Services are as detailed below, those of which are basically Pre-contract Works before the actual award of Percentage-rate Contract

Completed Works

1. Acquaint and review available data with MCGM such as Feasibility Study 'Master Plan BODR/DDR' of the proposed works.
2. Review Reports submitted by Pentacle.

Balance Works

1. Provide complete service for the tender proceedings, pre-tender meetings and clarifications on any related queries raised thereof.
2. Prepare answers to Bidder's queries, Pre-bid minutes, Addendum/Corrigendum, etc.
3. Complete Evaluation of the bids received by MCGM and recommendations thereof.

4. In case of re-invitation of Tender for any reason, Consultant shall modify tender documents; in such circumstance, provide all the tender stage services as listed in 3, 4and5 above at no extra cost to MCGM, if required.
5. On award of Contract, assist MCGM in preparing the Contract documents for the Percentage-rate Contract.

1.5. Structure of the Engineering Survey and Geotechnical Investigation Report

Based on our recommendation for Tunnel Alignment for GMLR passing through Sanjay Gandhi National Park Engineering Survey and Geotechnical Investigation Reports prepared is studied by PADECO with respect to physical infrastructure, level of service to the road users, accessibility, constructability, environmental issues etc. and our review remarks, observations, etc. are detailed. The Engineering Survey and Geotechnical Investigation Report comprise of six chapters. The contents of these chapters are:

Chapter 1-Introduction

Chapter2– Topographical Survey

Chapter3– Traffic Survey

Chapter4– Geotechnical Investigation

Chapter 5- Project Hindrances

Chapter 6- Utility Survey

2. Topographical Survey

2.1. General

In this Chapter, we have explained the scope, objective, methodology and finding of Topographical Survey carried out for Goregaon Mulund Link Road

2.2. Scope and Objective

To establish the centre line of the Tunnel Alignment at Grade and for preparation of Design Base Report, Alignment Design (Vertical and Horizontal Alignment), the following aspects are considered to maximise accuracy during Topographical Survey.

- Availability of Overburden
- Availability of land for Portal location;
- Number of Tree affected;
- Number of Structure affected;
- Demarcation of Forest Boundary;
- Accessibility of Approach Road;
- Availability of Land for Construction Yard.

Further this Chapter is broadly divided into 2 parts:

- **Part 1 -** focuses on topographical survey carried out outside SGNP with Total Station;
- **Part 2** - focuses on topographical survey carried out inside SGNP with Remote Sensing Technology.

2.3. Topographical Survey outside SGNP

2.3.1. Survey Location

Topographical Survey was carried out using Total Station on Western and Eastern Side outside SGNP to identify the profile of existing ground, identify the exact Boundary of National Park as per coordinate available from Notification, Availability of Overburden for Tunnel Portals on both the sides. On western side survey was conducted from Film City entrance passing through Film City along the DP Road alignment till Whistling Woods from where our alignment diverts towards north east to connect with the identified Portal Location on the western Side till the forest Boundary with buffer of 50m along the alignment on both the side. On the eastern side, Survey was commenced from Culvert

Crossing Tans Pipeline passing through Khindipada along GMLR Alignment till Forest Boundary through Amir Nagar Slums with the Buffer Zone of 50m on both the side of the alignment. Topographical Survey inside SGNP was avoided as SGNP has a dense forest which would have affected visibility and increased the time period and effect productivity.

Figure 2-1 TBM Locations in Film City and Khindipada

2.3.2. Methodology

For the Completion of Toposurvey and finalization of Tunnel Centre Line we adopted following methodology:-

a. Reconnaissance Survey
b. Establishment of Horizontal and Vertical Control Points
c. Topography Survey
d. Alignment Survey
e. General Topography

2.3.2.1. Reconnaissance Survey

Prior to initiating a Topography Survey a thorough search and recovery of existing horizontal and vertical control monuments in the immediate area of the project is required. Also, a field reconnaissance will be required before final control net planning is accomplished and field work is begun. Recovered control monuments must be evaluated before being used as a basis for new control surveys. All recovered points should be fully described in the survey notes. In this Regard Team of Sr. Surveyor, Project Engineer and Project Manager had a visit with client and identified the Nature of

Terrain, Bench Mark Location, Easiest & shortest way for bench-mark transfer, approach roads for site & Suitable Locations of Ground control points & secondary control points.

2.3.2.2. Establishment of Horizontal and Vertical Control Points

For horizontal and vertical control, grid co-ordinates of existing site given by Client were used.

Table 2-1 Details of Bench-Mark for Location 1 (Goregaon Film City)

Sr. No	Northing	Easting	RL. (m)	Desc.	Location
	2120243.492	277790.975	56.333	B-13	On South Side Road
2	2120254.214	277714.271	54.159	B-12	On South Side Road
3	2120274.88	277619.9816	51.756	B-11	On South Side Road

Table 2-2 Details of Bench-Mark for Location 2 (Mulund Khindipada Site)

Sr. No.	Northing	Easting	RL. (m)	Desc.	Location
1	2120594.0288	282518.6839	35.437	GPS 17	On Junction
2	2120614.2711	282473.0272	38.284	STN 43	Near Junction
3	2120619.2830	282401.9224	44.529	STN 44	Near Junction

We had used the Bench-Mark situated on B-13 and GPS 17. The same Bench-Mark has used to transfer to Project area along the road by running a double tertiary level line established on control points & permanent structures, which act as temporary bench mark for vertical control & also we transferred the same on Temporary Benchmark stations given below.

Table 2-3 Temporary Bench-Mark for Location 1 (Goregaon Aare Colony Site)

Sr. No.	Northing	Easting	RL. (m)	Desc.	Location
1	2120321.776	277633.907	49.843	D-1	Mark in drawing
2	2120318.934	277729.271	59.507	D-2	Mark in drawing
3	2120319.955	277742.907	60.080	D-3	Mark in drawing

4	2120299.942	277751.555	59.606	D-4	Mark in drawing
5	2120286.256	277761.708	58.227	D-5	Mark in drawing
6	2120269.693	277798.295	55.466	A-2	Mark in drawing
7	2120299.360	277804.970	55.004	D-6	Mark in drawing
8	2120322.790	277807.302	56.608	D-7	Mark in drawing
9	2120306.755	277892.284	59.050	D-8	Mark in drawing
10	2120354.415	278004.125	65.928	D-9	Mark in drawing
11	2120378.407	277993.414	69.703	D-10	Mark in drawing
12	2120395.958	277986.181	71.259	D-11	Mark in drawing
13	2120356.808	278050.698	69.545	D-12	Mark in drawing
14	2120394.738	278091.628	69.725	D-13	Mark in drawing
15	2120405.768	278163.615	69.465	R-7	Mark in drawing
16	2120438.663	278307.930	87.591	D-14	Mark in drawing

Table 2-4 Temporary Bench-Mark for Location 2 (Mulund Khindipada Site)

Sr. No.	Northing	Easting	RL. (m)	Desc.	Location
1	2120629.595	282466.682	36.295	D-1	Mark in drawing
2	2120639.465	282448.790	36.295	D-2	Mark in drawing
3	2120642.582	282444.517	36.295	D-3	Mark in drawing
4	2120657.138	282413.439	36.295	D-4	Mark in drawing
5	2120675.311	282411.402	36.295	D-5	Mark in drawing
6	2120652.990	282414.005	36.295	D-6	Mark in drawing
7	2120653.637	282400.083	36.295	D-7	Mark in drawing
8	2120651.064	282399.241	36.295	D-8	Mark in drawing
9	2120649.963	282393.534	36.295	D-9	Mark in drawing

10	2120663.862	282389.317	36.295	D-10	Mark in drawing
11	2120666.106	282381.532	36.295	D-11	Mark in drawing
12	2120671.818	282381.995	36.295	D-12	Mark in drawing
13	2120676.265	282364.643	36.295	D-13	Mark in drawing
14	2120700.878	282367.938	36.295	D-14	Mark in drawing

2.3.2.3. Topography Survey

The purpose of a topography survey is to gather survey data about the natural and man-made features of the land, as well as its elevations. From this information a Three-dimensional map is prepared. The topography map was generated in the office after collecting the field data. The process for generating the Topographical Map is follows:-

1. Establishing horizontal and vertical control that will serve as the framework of the survey.
2. Determining enough horizontal location and elevation (usually called side shots) of ground points to provide enough data for plotting when the map is prepared.
3. Locating natural and man-made features that may be required by the purpose of the survey.
4. Computing distances, angles, and elevations
5. Drawing the topographic map Topographic surveys is commonly identified with horizontal and/or vertical control of third and lower order accuracies. Accordingly we had completed the topography survey boundary.

2.3.2.4. Alignment Survey

Alignment Survey has been carried out for fixed alignment location and topographical survey prepared around surrounding right of way (ROW). Topographical surveys make it possible to measure the steepness of slopes as well as details of terrain.

Contour survey has been carried out by observing spot levels at 10 m X 10 m. Grid, and/or as per the client's specification. They are plotted on the drawings and the contours are drawn using the Auto CIVIL or Auto Plotter Software. Contours are interpolated at 0.5 006D intervals and/or as specified by the clients. Generally, additional levels are taken to show the exact profile of the land.

2.3.2.5. Data Collection

The data collection work was conducted with the use of Total Station. Boundary Details, Elevations within the plot, outside the plot, Road details for the road around the plot, Utility details in and around the plot, Field boundary & other Important Topographic features are collected. The data was collected in various formats, and produced in specified / derived formats to the satisfaction of Client.

2.3.3. Findings of Topography survey (Total Station)

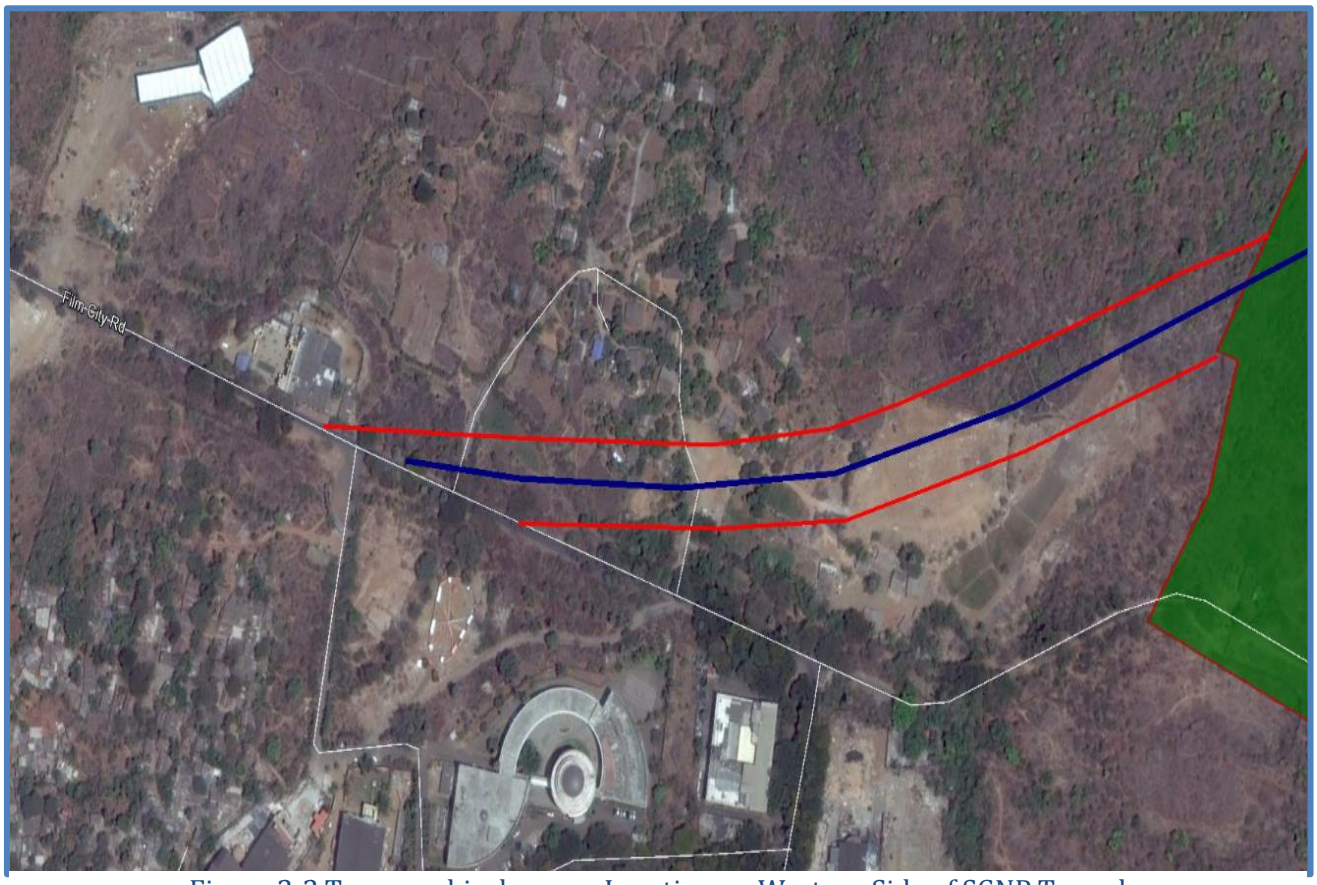

Figure 2-2 Topographical survey Location on Western Side of SGNP Tunnel

Topography survey outside SGNP gave a brief idea about the Existing Ground Level on the approach Roads and the Tunnel Portals on Both the side viz. Eastern and western.

On the Western Side the TBM considered from the set Bench Mark of MCGM. A variation in Slope was observed along the existing DP Road alignment till Whistling woods which was carried out by MCGM nominated Surveyor, further with reference of established BM the survey was carried on preliminary approved Alignment from Whistling wood Gate toward Sanjay Gandhi National Park boundary at the buffer of 50m on both side . 30 m before Forest Boundary we got a RL of 78 m which was appropriate for Tunnel Portal with an overburden of 15m. It was also observed that approx. 600 nos. of Trees were affected on the western side in Film City.

Figure 2-3 Film City Side Twin Tunnel Location

Figure 2-4 Aerial View of Twin Tube Tunnel Location Goregaon End

On the Eastern Side a gentle slope is observed till Guru Govind Singh Road and a gradual slope till Bhandup Complex. Flat vertical portion with a very steep slope was identified in Khindipada a perfect location for tunnel portal outside SGNP. However it also affects approx.14340.594sqm. Structures in Khindipada area.

Figure 2-5 Khindipada Side Toposurvey Location

Figure 2-6 Khindipada Side Twin Tunnel Location

2.4. Topography survey inside SGNP

2.4.1. Introduction

As a part of this project Bhugol GIS Pvt. Ltd was consulted by PADECO, to undertake project for "Contour Generation for a surface area above the proposed tunnel of Goregaon-Mulund Link Road (GMLR), Mumbai" and perform the following tasks. The project is to generate contours at 10 meter vertical intervals using satellite data analysis for an area of 1.00 Km buffer around the proposed Goregaon-Mulund Link Road passing through Sanjay Gandhi National Park (SGNP).

As a part of this project, elevation levels at locations in and around the SGNP surveyed earlier were using Differential GPS (DGPS) and Survey of India Toposheet Bench Mark locations were used along with Cartosat 2.5m stereo images. Using the collected elevation data, Survey of India Toposheet and Satellite data the Digital elevation model (DEM) was generated for this area. Further as a part of the project, contours were extracted using GIS analysis for an area of 1.00 Km buffer around the proposed GMLR alignment.

2.4.2. Methodology

2.4.2.1. Project Site description

Sanjay Gandhi National Park (SGNP), previously identified as Borivali National Park, is a large protected area in the northern part of Mumbai city (preferably called Mumbai Suburban district) in Maharashtra State in India. It encompasses an area of 104 Km^2 (40 sq. mi) and is surrounded on three sides by India's most populous city. It is notable as one of the major national parks existing within a metropolis limit and is one of the most visited parks in the world.

The park occupies most of the northern suburbs of Mumbai. To the west lie the suburbs of Goregaon, Malad, Kandivali, Borivali and Dahisar. To the east lie the suburbs of Bhandup and Mulund. To the south lie the Aarey Milk Colony and the university campus of IIT Bombay. The northern reaches of this forest lie in Thane city. The park and these areas surrounding it, except Thane city are all part of Mumbai.

The terrain in this region is hilly with elevations between 30.00 m (98 ft.) and 480.00 m (1,570 ft.). The park encompasses two lakes, Vihar Lake and Tulsi Lake, which meet part of the city's water requirements. Further, The Park is said to be the lungs of the city as it purifies much of the air pollution of the city.

2.4.3. Data used

There are two Cartosat-1 scenes which cover the Sanjay Gandhi National Park (SGNP) area.

These data sets are provided in Orthokit GeoTiff format and referenced to the WGS84 ellipsoid and datum. Cartosat-1 carries two high-resolution imaging cameras: the afterward looking camera (Aft) and the foreword looking camera (Fore), both the cameras are able to collect panchromatic images with a spatial resolution of 2.5 m on the ground. Thus, each set of data is composed of two images namely band A and band F images. Soft-Photogrammetric Suit has been used to generate DEM from Cartosat-1 stereo data.

2.4.4. Step involved in the process

The process of DEM generation in soft photogrammetry is carried by creating a block project file and defining the geometric model as RPC model. Cartosat-1 stereo scenes with Rational Polynomial Coefficient (RPC) within Rational Function (RF) sensor model is used in creating a block file. The Rational Polynomial Coefficient (RPC) file is used to relate the image. The block project is assigned the horizontal and vertical coordinates with UTM projection and WGS 84 datum. The stereo pair images band A and band F are added to the frame.

RPC (Rational Polynomial Coefficients) files contain rational function polynomial coefficients that are generated by the data provider (e.g. NRSC for cartosat-1 data) based on the position of the satellite at the time of image capture. Cartosat-1 RPC files (banda_rpc.txt and bandf_rpc.txt) are encrypted metadata files. Hence, it is not readable.

The software allows selecting a matching point in one image, finding its conjugate point in the other (stereo) image. Once the tie points are generated in the overlapping area additional surveyed ground points are added to the images. The X, Y, and Z values for CGP points are provided. The triangulation is done after adding GCPs and tie points to check the accuracy for GCPs and tie points. Then the resultant data is used to generate the DEM.

2.4.5. DEM extraction

The verified data is used with the output cell size 7m considering the Ground Sampling Distance (GSD) of the original stereo pair is 2.5 m. with which the DEM is extracted.

A digital elevation model represents the elevation or attributes value of each grid in a raster format. DEM is normally generated using spatial interpolation from regularly or irregularly spaced data points. Data sources for the input data include direct measurement on the ground using GPS, stereo air photo

or satellite images, digitized contour lines, radar data, LIDAR (light detection and ranging) data etc. The quality of DEM can influence the accuracy of terrain measures such as slope, aspect and relief and in deriving the drainage network. DEMs are quite useful for calculating contours, slope, aspect, hill shading and automatic watershed delineation. The limitations are that large amount of data redundancy in the areas of uniform terrain and cannot handle data of high relief area without changing the grid size. The vector based TIN model helps to overcome these limitations.

2.4.6. Generation of buffer around the proposed GMLR tunnel alignment

The proposed alignment of GMLR provided by PADECO was converted first to GIS understandable format. The buffer of 1.00 Km around the alignment was generated using GIS analysis and generated DEM was also extracted according to buffer of the alignment.

2.4.7. Extraction of contour

Once the DEM was extracted as per the buffer, the extracted DEM was used as an input to extract contours at 10 m interval using GIS analysis.

The most common method for terrain mapping is contouring. Contour lines connect points of equal elevation and the contour interval or vertical resolution is the elevation difference between two adjacent contours. Contour lines are closely spaced in high relief terrain. Contour lines do not intersect one another and do not stop in the middle of the map. Contour lines can be generated from a DEM or TIN. In TIN model, the triangles are divided into smaller triangles and using linear interpolation technique, contour lines are generated. Vertical profiling method helps to show the elevation values along a linear feature such as a road and it can be plotted on a graph. The vertical profile is very useful to estimate the volume of material needed to be removed or to be filled while proposing a road or a canal construction work.

Hill shading simulates how the terrain looks with the interaction between sunlight and the surface. A hill slope facing the sunlight will be bright and a slope opposite to the light will be dark. Hill shading helps to recognize the shape of landform features. The factors that control the visual effect of hill shading are the sun's azimuth angle (ranging from 0^o due north to 360^o in clockwise direction), sun's altitude (angle of the incoming light measured above the horizon between 0^o and 90^o), terrain slope (ranging from 0^o and 90^o) and aspect.

Perspective views are 3D views where the terrain appears as being viewed with an angle from a height. The parameters that control the appearance of a 3D view are viewing azimuth (direction from the observer to the surface ranging from 0^o to 360^o in clockwise direction), viewing angle (the angle from the horizon to the altitude of the observer ranging from 0^o to 90^o), viewing distance (the distance between the viewer and the surface) and z scale (ratio between the vertical scale and horizontal scale

additionally known as vertical exaggeration factor. Using perspective view option in GIS packages, one can view the surface in various rotations and also navigate through the surface.

Once the contours were extracted they were compared with the Toposheet provided by PADECO and necessary correction was made wherever required to make the final data. The final generated contours were additionally draped over the google earth data after converting them into .kmz file which is additionally provided as one of the outputs. Final Result

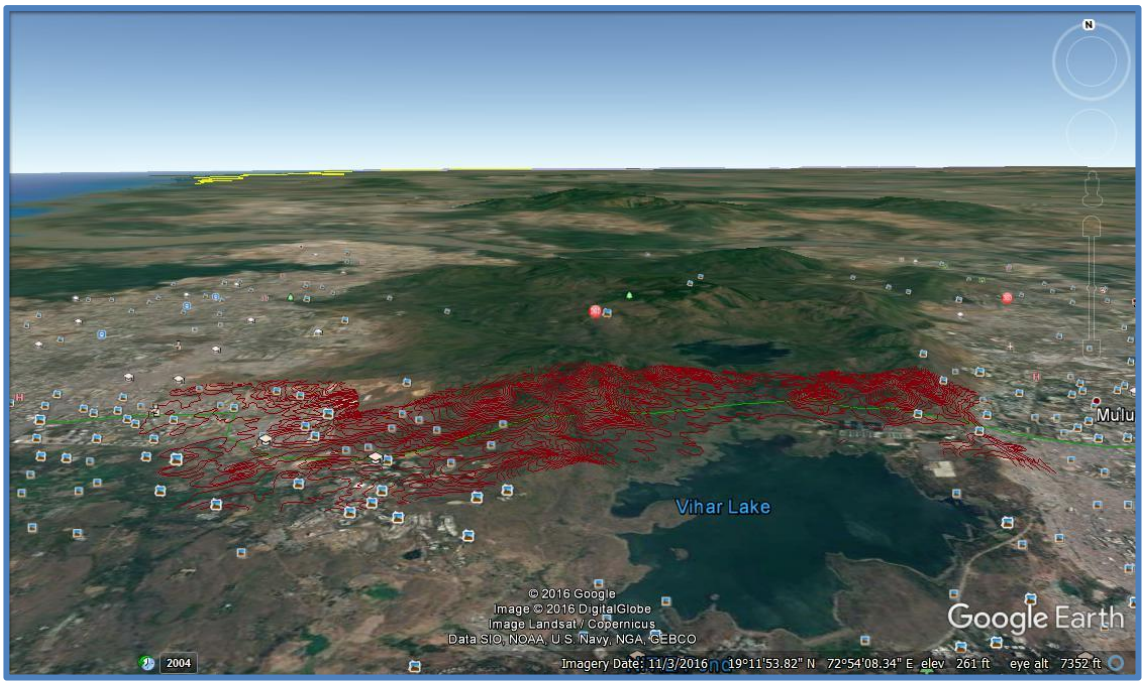

Figure 2-7 Google Earth draped contours of the proposed GMLR over SGNP

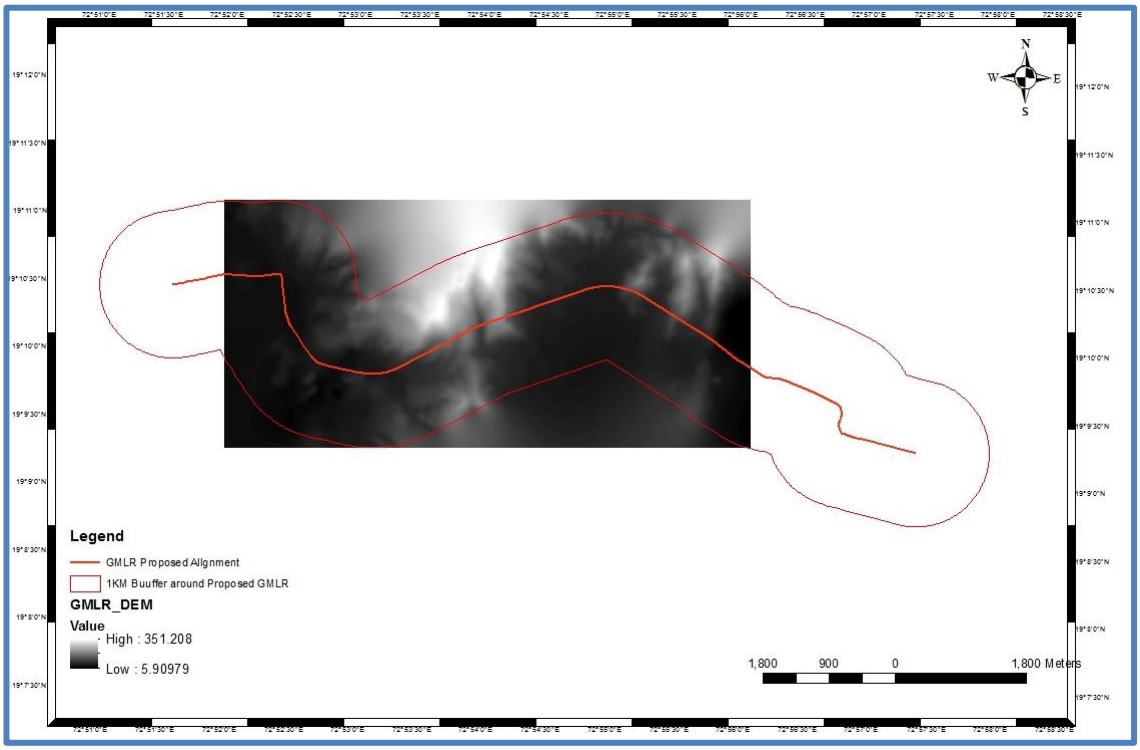

Figure 2-8 Proposed GMLR alignment with DEM inside SGNP

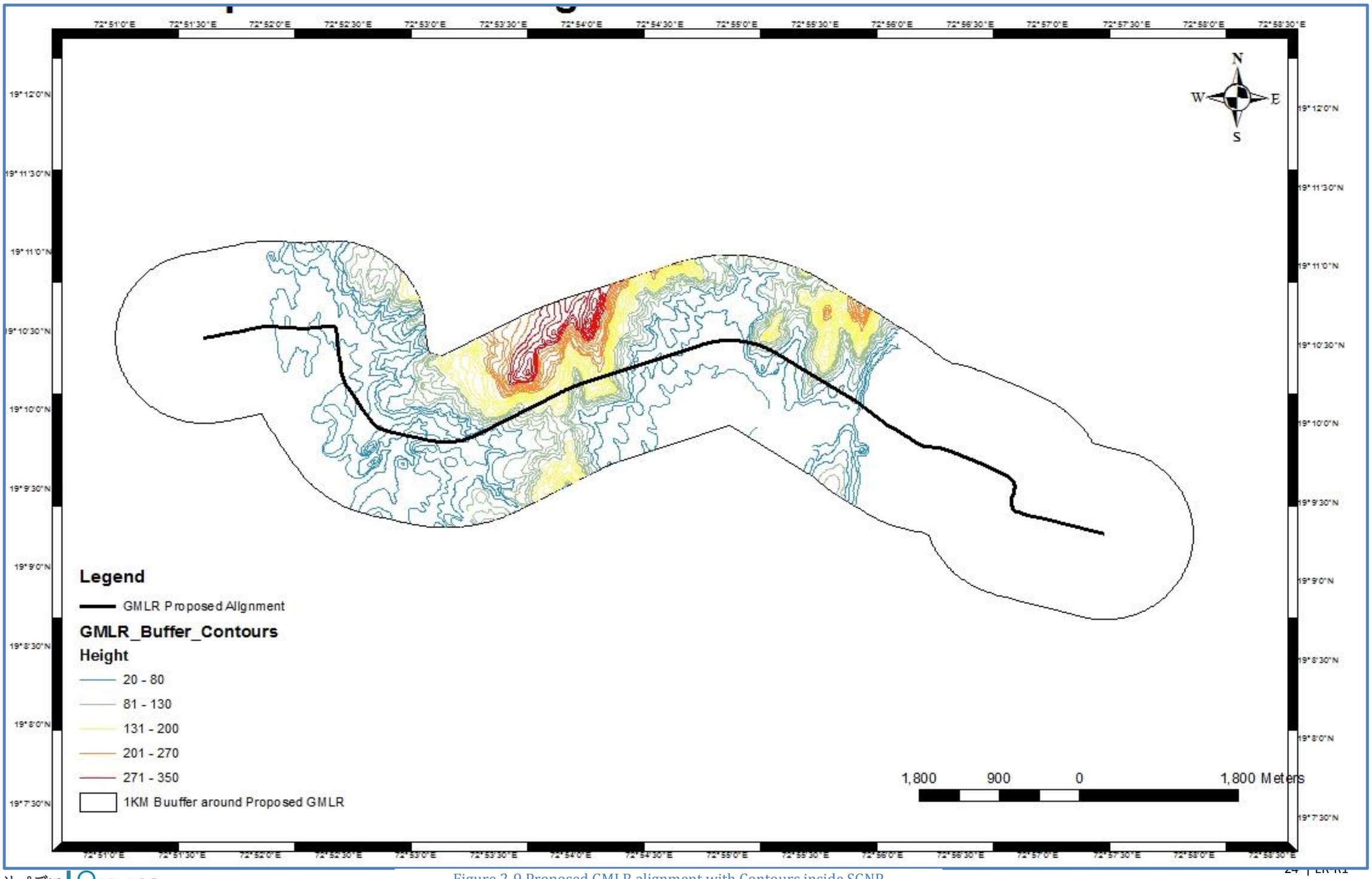

Figure 2-9 Proposed GMLR alignment with Contours inside SGNP

3. Traffic Survey

3.1. General

In this Chapter, we have explained the scope, objective, methodology and finding of Traffic Survey Carried Out for Goregaon Mulund Link Road

3.2. Introduction

In consultation with M/S Global Traffic Solutions conducted a traffic study for the proposed Goregaon Mulund Link Road (GMLR) for the Municipal Corporation of Greater Mumbai (MCGM).

The proposed new GMLR corridor is expected to connect the Eastern Expressway to the Western Expressway via a tunnel section under the Sanjay Gandhi National Park. The study aims to document traffic volumes that would be diverted from the existing vicinity corridors to the proposed new GMLR corridor. The report also aims to identify the corresponding geometry required for the proposed GMLR corridor carriageway to accommodate the projected 10-year (Year 2032) and 20-year (Year 2042) horizon years.

United Nation's Year 2014 revision of the World Urbanization Prospects report identified Mumbai as the second most populous city in India with an estimated population 0f 20.7 million people in its urban agglomeration. Mumbai is connected to the national highways system by National Highway 3, National Highway 4, National Highway 8 and National Highway 17.Public transport systems in Mumbai include the Mumbai Suburban Railway, Monorail, Metro, Brihan Mumbai Electric Supply and Transport (BEST) buses, black-and-yellow meter taxis, auto rickshaws and ferries.

In 2008, the Mumbai Metropolitan Regional Development Authority (MMRDA) with the assistance of the Word Bank under the Mumbai Urban Transport Project (MUTP) carried out a Comprehensive Transport Study to identify short term and long term improvements for transportation facilities in the Mumbai Metropolitan Region (MMR). The recommendations of this study identified new highway links in the MMR region. Goregaon Mulund Link Road (GMLR) was one of the proposed new roads in this MUTP. The following report summarizes the findings of the proposed Goregaon Mulund Link Road (GMLR) traffic study.

3.3. Alignment of Proposed Road

The Goregaon-Mulund link road currently exists on the eastern side and western side of Sanjay Gandhi National Park. In existing scenario, the Jogeshwari-Vikhroli Link Road (JVLR) and Aarey road south of Sanjay Gandhi National Park and Ghodbunder road and Western Expressway north of Sanjay Gandhi National Park, offer connectivity to the eastern and western parts surrounding the Sanjay Gandhi National Park. The proposed GMLR road will provide direct connectivity to the eastern and western areas surrounding the Sanjay Gandhi National Park.

The alignment of the proposed road is through Sanjay Gandhi National Park. Owing to the environmentally sensitive nature of this region, the proposed alignment of the GMLR would be through a tunnel under the existing forest area. East of the tunnel, the proposed GMLR would extend up to the Eastern Express Highway. West of the tunnel, the proposed GMLR would extend up to the Western Express Highway. Thus, the proposed GMLR alignment would provide a direct connection between the Eastern and Western Express Highways. **Figure 3-1** below illustrates the vicinity roadway network and the proposed GMLR alignment.

3.3.1. Existing Eastern Alignment

The existing eastern alignment of the Goregaon Mulund Link Road (GMLR) commences from the Eastern Express Highway, where the GMLR meets Mulund–Airoli Road. The GMLR on eastern side of Sanjay Gandhi National Park runs for about 3.00 Km. travelling in the westbound direction, GMLR has a mixed lane configuration of 4-lane and 6-lane geometry till it reaches Dr. Hedgewar Chowk. LB S Marg which is oriented in the north-south direction meets existing GMLR at Doctor Hedgewar Chowk, which is a four-legged signalized junction located approximately 2.50 Km from the Eastern Express Highway. **Figure 3-2** illustrates the location of **Figures 3-3** through **3-9** where **Figure 3-3** and **Figure 3-4** illustrate the existing road geometry on GMLR between the Eastern Express Highway and Dr. Hedgewar Chowk. **Figure 3-5** illustrates the intersection at Dr. Hedgewar Chowk. The GMLR runs for about 750 m in the westbound direction and merges with Guru Gobind Singh Road. The lane configuration on GMLR, is a 2-lane undivided roadway section as illustrated in **Figures 3-6** & **3-8**. Prior to its merger with Guru Gobind Singh Road, a 2-lane undivided bridge exists on GMLR as shown in **Figure 3-7**. The intersection of GMLR and Guru Gobind Singh Road is a T intersection as shown in **Figure 3-9**.

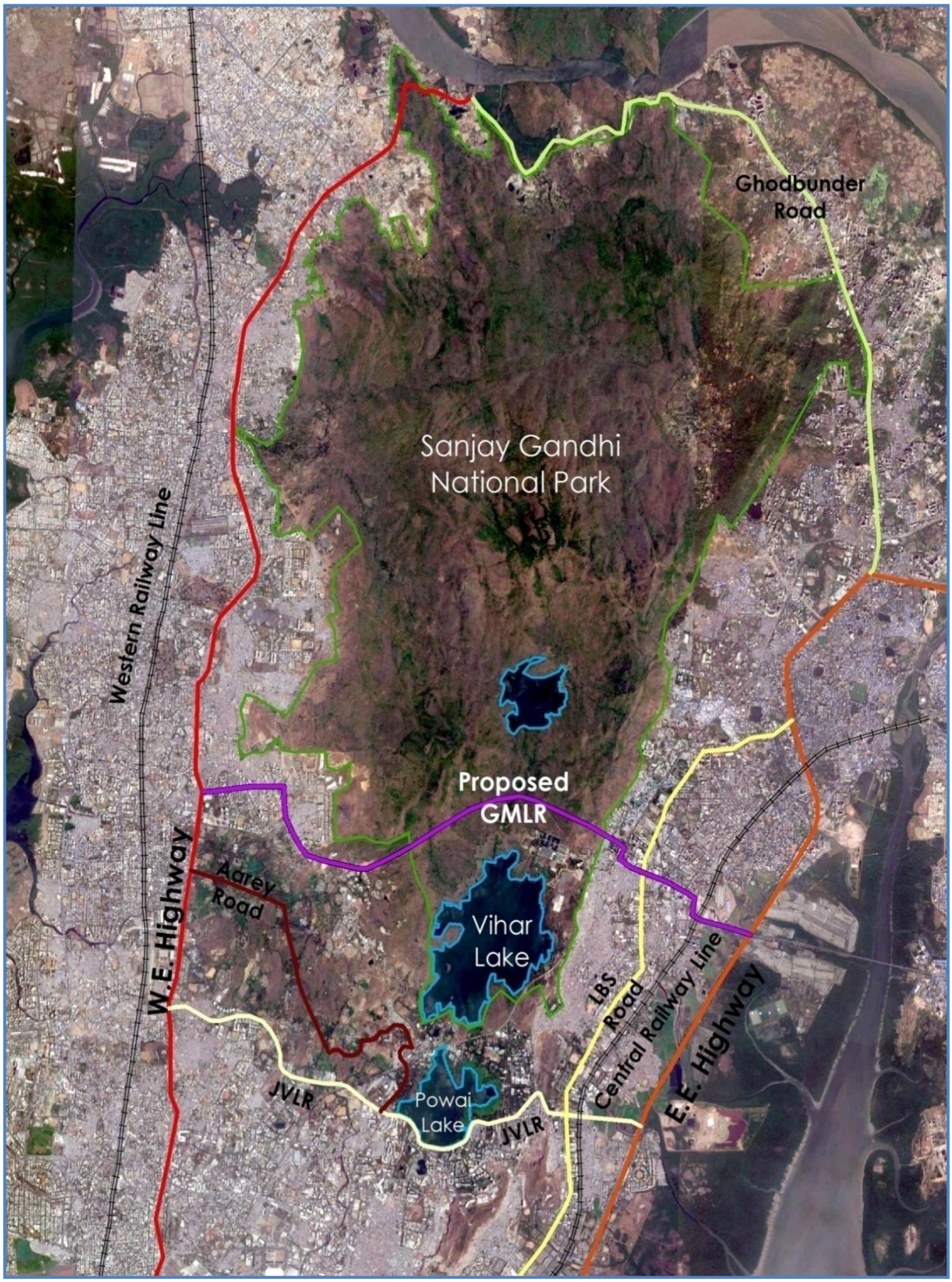

Figure 3-1 Alignment of Proposed GMLR

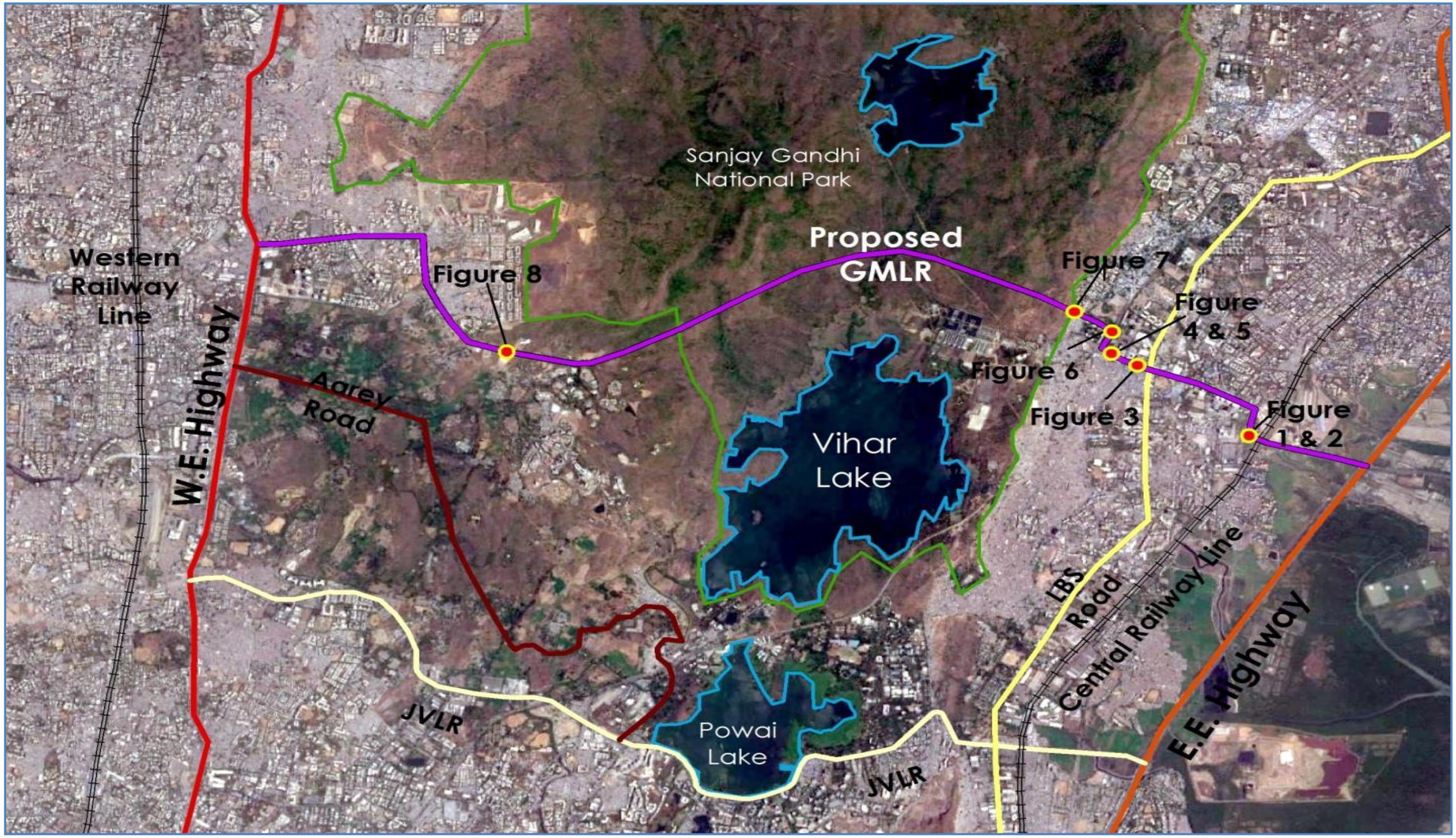

Figure 3-2 Locations of Photos of Existing Alignment

Figure 3-3: Westbound GMLR (6-Lane divided road section with 3-lanes in each direction)

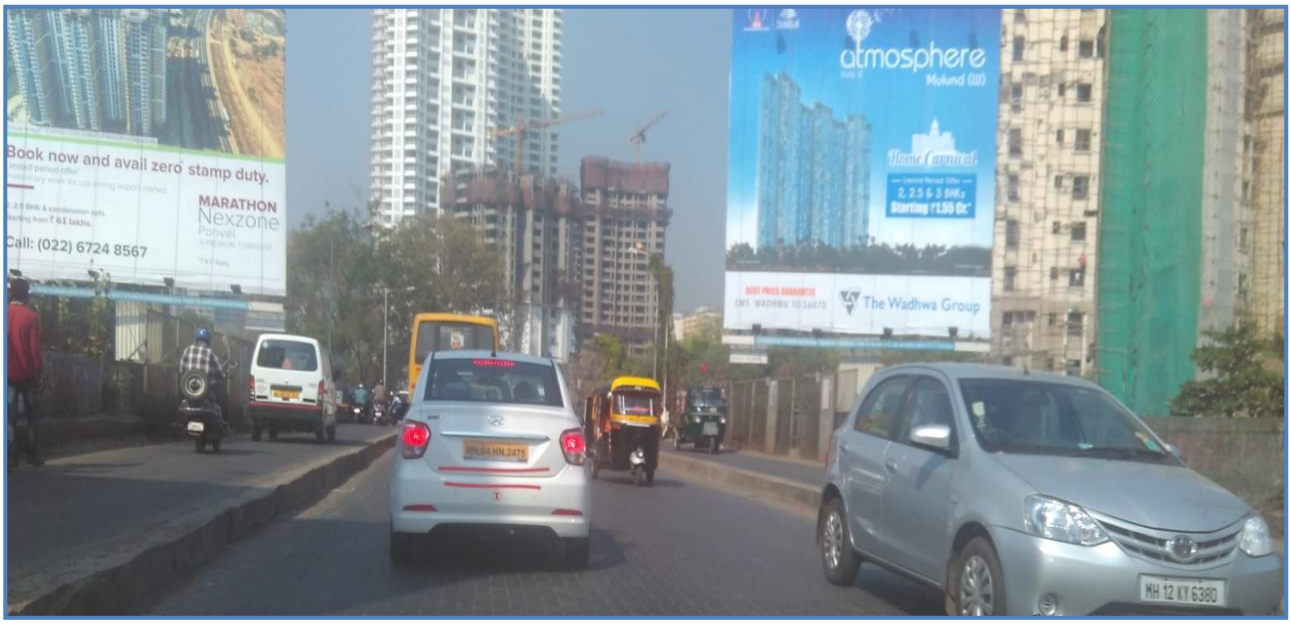

Figure 3-4: Westbound GMLR (4-lane road)

Figure 3-5: Dr. Hedgewar Chowk (at intersection of GMLR and Lal Bahadur Shastri road)

Figure 3-6: Westbound GMLR at Hedgewar Chowk towards guru Gobind singh road (2-lane undivided road)

Figure 3-7: Existing Bridge on GMLR (2-lane undivided road)

Figure 3-8: GMLR and Guru gobind singh road

Figure 3-9: T-intersection at Guru Gobind singh road

3.3.2. Existing Western Road Alignment

The western alignment commences from Western Express Highway, where GMLR meets with General Arun Kumar Vaidya Marg. The western alignment runs for about 3.00 Km. It is a combination of General Arun Kumar Vaidya Marg and Film City Road. The eastbound General Arun Kumar Vaidya Marg runs for 1.50 Km and meets the Film City Road. A T intersection is formed at the location of meeting. From the intersection Film City Road runs for approximately 1.50 Km to reach the proposed tunnel. The existing roadway geometry on Film City Road is a 2-lane undivided road as illustrated in **Figure 3-10** below.

Figure 3-10: Eastbound film city road (2-lane undivided road)

3.4. Methodology

To determine the existing travel patterns in the study area and to project the future traffic volumes onto the proposed new corridor, the vicinity areas were divided into traffic zones. The roadway network in the vicinity of the Sanjay Gandhi National Park was studied to identify the appropriate locations for data collection. The locations for traffic volume counts and O-D surveys were selected so as to capture maximum relevant data for the study in an efficient manner. Tabulation of the collected data was carried out in Microsoft excel while the preparation of desire line diagrams was carried out using the network analysis tool in ArcGIS software. An Elastic Demand Model was used to arrive upon the anticipated traffic projections for the future year scenarios. On the basis of these traffic projections for the year 2032 and 2042 `scenarios, carriageway geometry for the proposed GMLR was recommended. The traffic projections for private vehicles (2 wheelers and 4 wheelers) were done with the data obtained from the latest CTS report for Mumbai region. **Figure 3-11** below illustrates the methodology used for this traffic study.

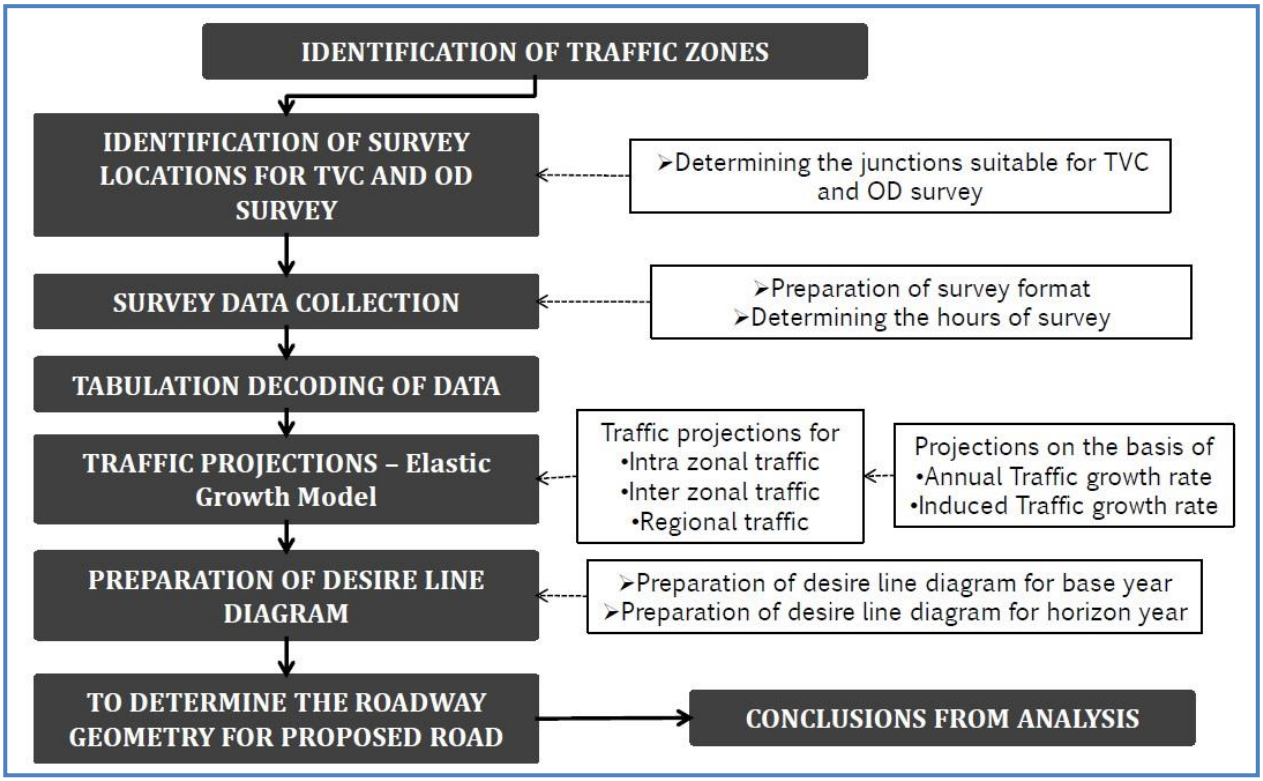

Figure 3-11: Study methodology

3.5. Traffic analysis zones (TAZ)

The project influence area (PIA) was identified with respect to the alignment of the proposed road in the vicinity of the Sanjay Gandhi National Park. The PIA was divided into 27 traffic analysis zones (TAZs). The ward map of Greater Mumbai, map of Mumbai suburban area, and the map of Thane district and Navi Mumbai were used to delineate the boundaries of the TAZs as shown in **Appendix A.** The respective boundaries were overlaid using AutoCAD software to prepare the overall map. **Figure 3-12** below illustrates the TAZs. The purpose of these zones was to help analyse the nature of trips operational within the study area. These trips would later be used to calculate the traffic diversion once the proposed GMLR becomes operational.

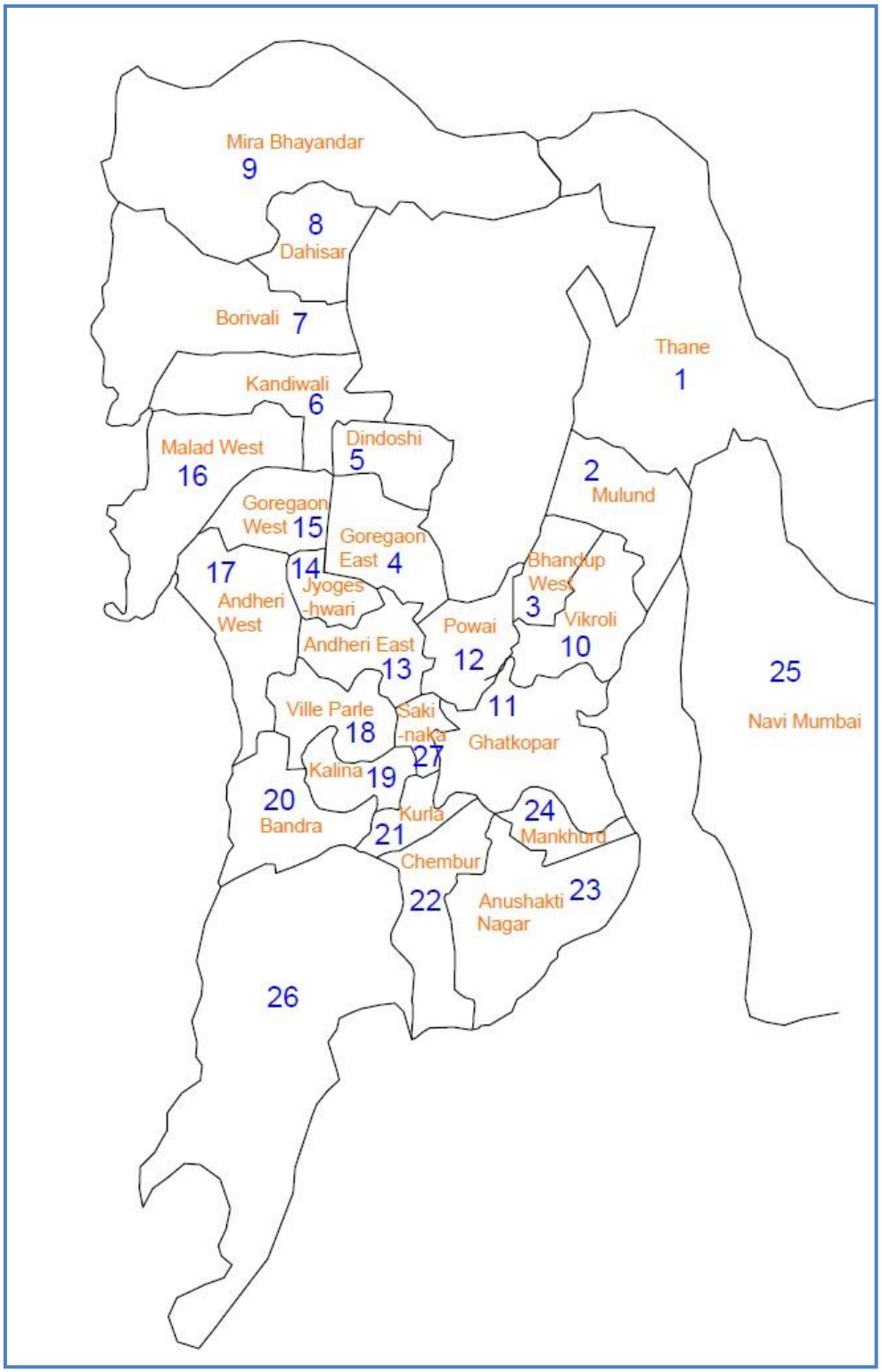

Figure 3-12 Map of Traffic Analysis Zone (TAZ)

3.6. Survey details

Traffic counts and Origin-Destination surveys were conducted at six locations in the vicinity of the Sanjay Gandhi National Park. The locations were selected to assist in determining the existing traffic volumes and travel patterns operating in the study area corridor network. **Figure 3-13** below illustrates the location of the study junctions while **Figure 3-14** highlights the junction details.

Figure 3-13 Junctions Identified for Study With respect To Proposed GMLR

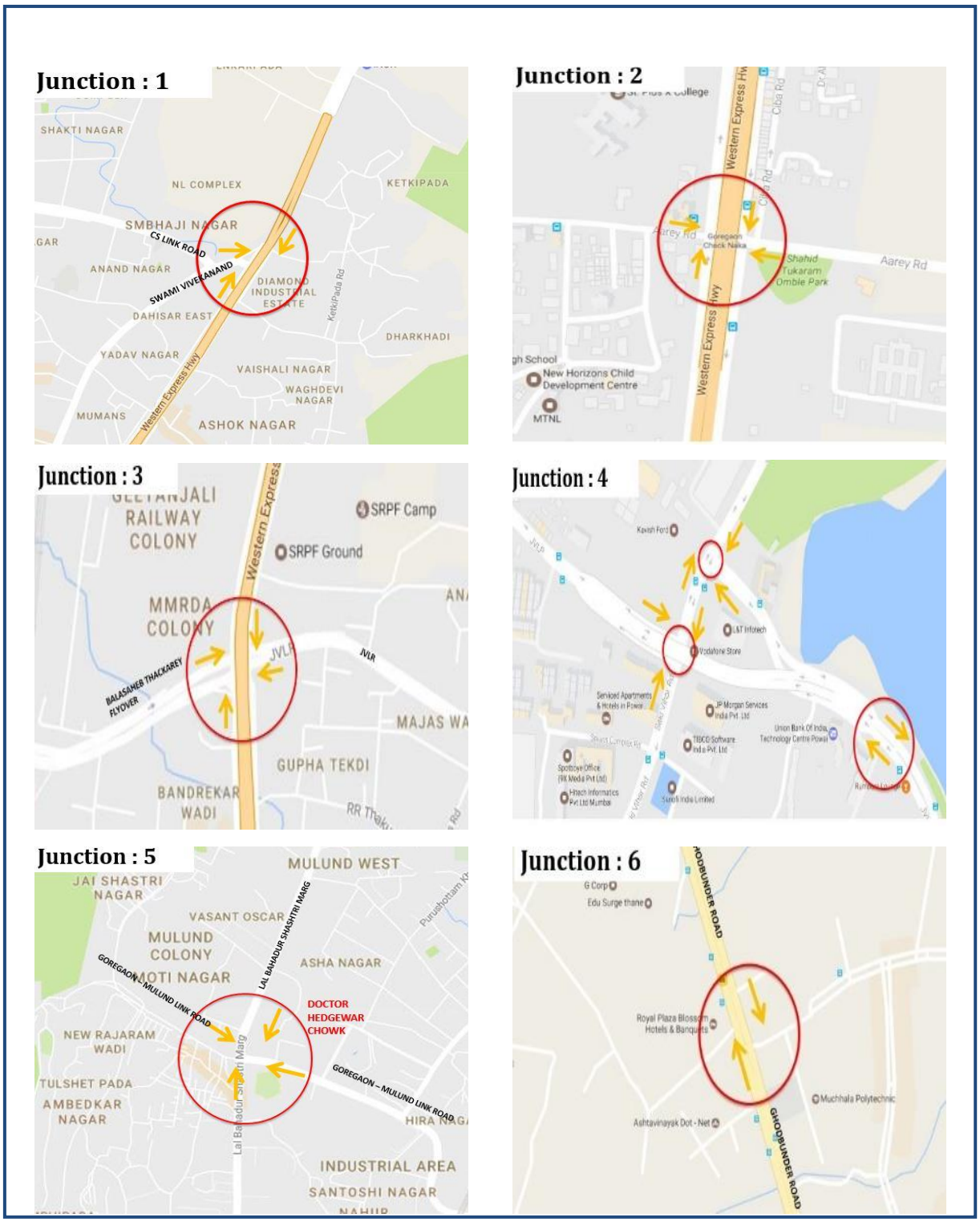

Figure 3-14 Survey Location Details

Junction 1

Junction 1 is located on Western Express Highway where Swami Vivekananda road (**Figure 3-15**) meets with the Western Express Highway. Three-way traffic at the junction was considered, which includes the traffic on Swami Vivekananda Road and service lanes of Western express highway (**Figure 3-16**). With reference to the zone map, this junction is located in zone 8.

Figure 3-15 Swami Vivekananda road

Figure 3-16 Service lane of western express highway near junction 1

Junction 2

Junction 2 is located on the Western Express Highway where Aarey road (**Figure 3-17**) meets with the Western Express Highway. Four-way traffic at the at-grade junction was considered, includes the two way traffic on Aarey roads and service lanes of western express highway (**Figure 3-18**). With reference to the zone map, this junction is located in zone 4.

Figure 3-17 Aarey Road

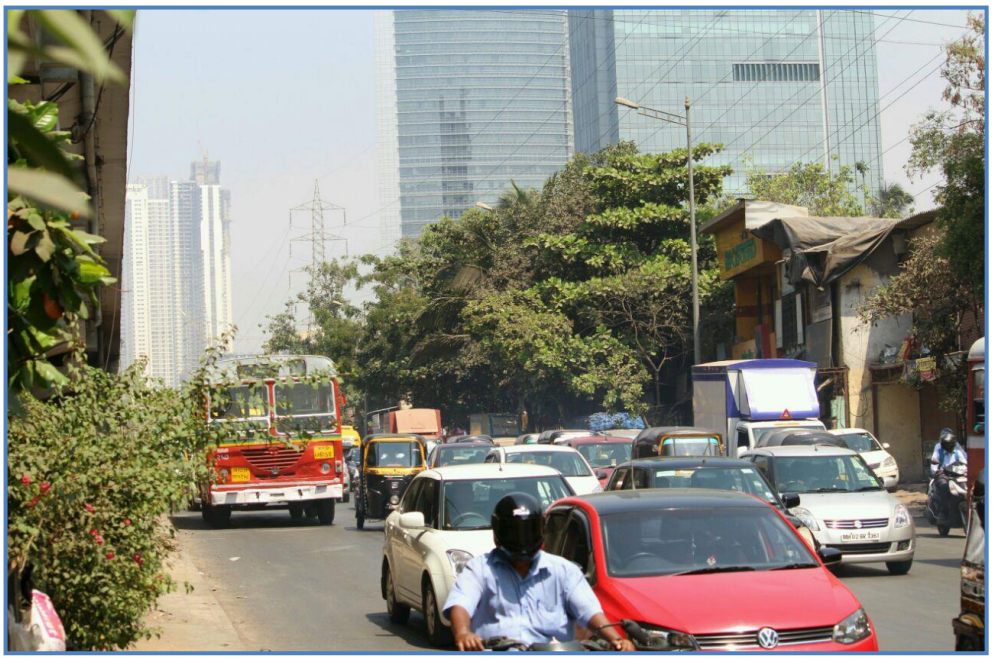

Figure 3-18 Service Lane of Western Express Highway near Junction 2

Junction 3

Junction 3 is located on Western Express Highway where Balasaheb Thackeray flyover &Jogeshwari–Vikhroli Link Road (JVLR) (**Figure 3-19**) meet with the Western Express Highway. At this junction, the traffic from Balasaheb Thackeray flyover, JVLR & service roads, which runs along the Western Express Highway, was considered. With reference to the zone map, this junction is located in zone 14.

Figure 3-19 Jogeshwari - Vikhroli Link Road

Figure 3-20 Service Lane of Western Express Highway near Junction 3

Junction 4

Junction 4 is located on the intersection at which Saki Vihar Road (**Figure 3-21**) meets Adi Shankaracharya Marg. The junction was divided into 4A, 4B and 4C for survey. 4A is a T intersection at which the traffic from west bound JVLR meets with Saki Vihar Road. The traffic from both the roads was considered. At 4B the east bound JVLR meets with Saki Vihar Road. Traffic from both the roads was considered. 4C is composed of two way traffic from JVLR. With reference to the zone map, this junction is located in zone 12.

Figure 3 21 Saki Vihar Road

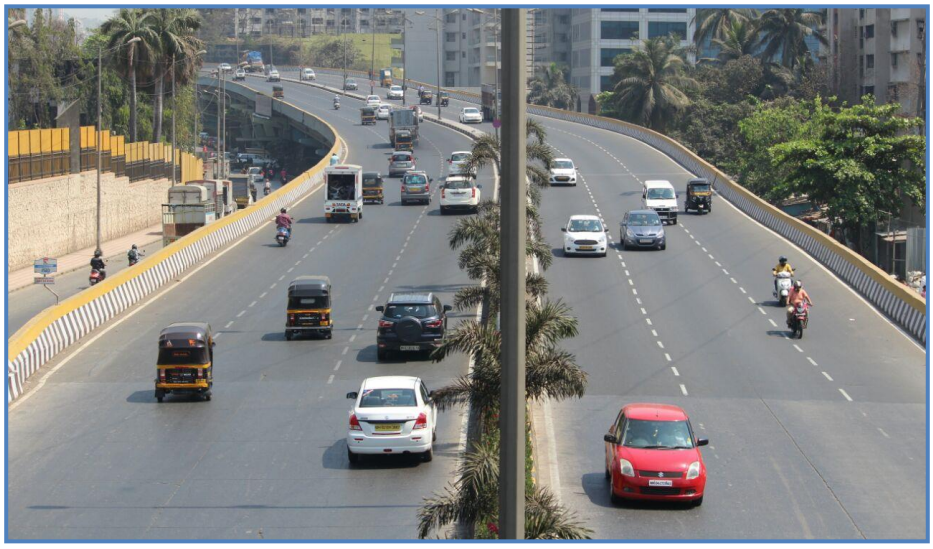

Figure 3-22 JVLR and Service Lane near Junction 4

Junction 5

Junction 5 is located at the Doctor Hedgewar Chowk. It is a four-legged junction. At this junction Goregaon-Mulund Link Road (GMLR) (**Figure 19**) meets with Lal Bahadur Shastri Marg (**Figure 18**). Traffic from both the roads was considered. With reference to the zone map, this junction is located in Zone 2.

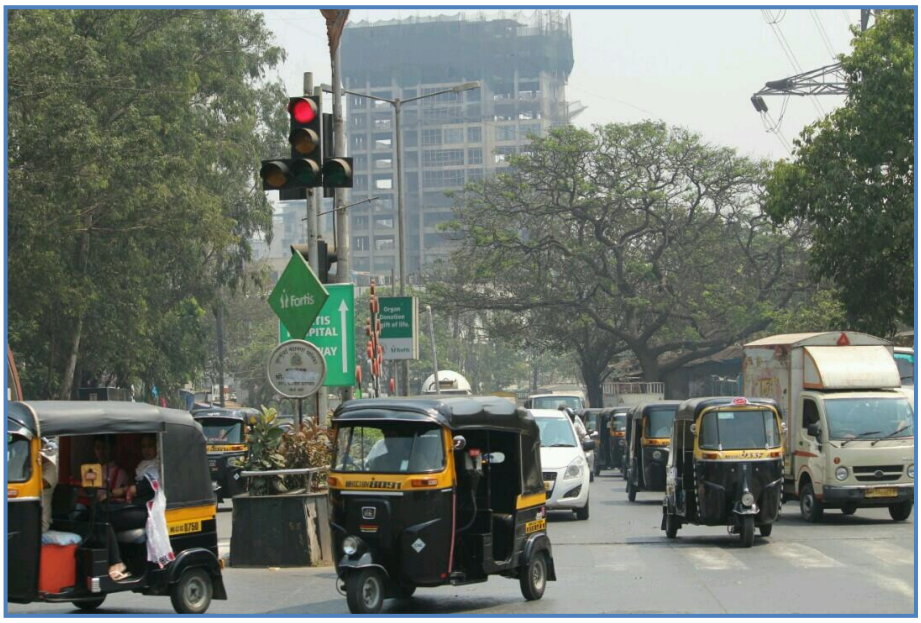

Figure 3-23 Lal Bahadur Shastri Marg near junction 5

Figure 3-24 Existing GMLR near junction 5

Junction 6

Junction 6 is located at the intersection of Bhavani Nagar Road and Ghodbunder Road. Two-way traffic at Ghodbunder road (**Figure 20**) was considered. With reference to the zone map, this junction is located in zone 1.

Figure 3-25 Ghodbunder Road

3.7. Data collection

Six-hour peak duration traffic volume counts were conducted at the 6 study junctions highlighted in **Figure 3-4** and **Figure 3-5**. Traffic counts were conducted on weekdays for the morning and evening peak periods for 3 hour durations (800hrs-1100hrs and 1800hrs – 2100hrs). The peak hour volumes for both morning and evening peak hours were obtained. The classified volume counts were converted into Passenger Car Units (PCUs). **Figure 3-26** below illustrates the peak hour traffic counts at the 6 study locations. The junction numbers shown are with reference to location map of junctions **Figure 3-4.**

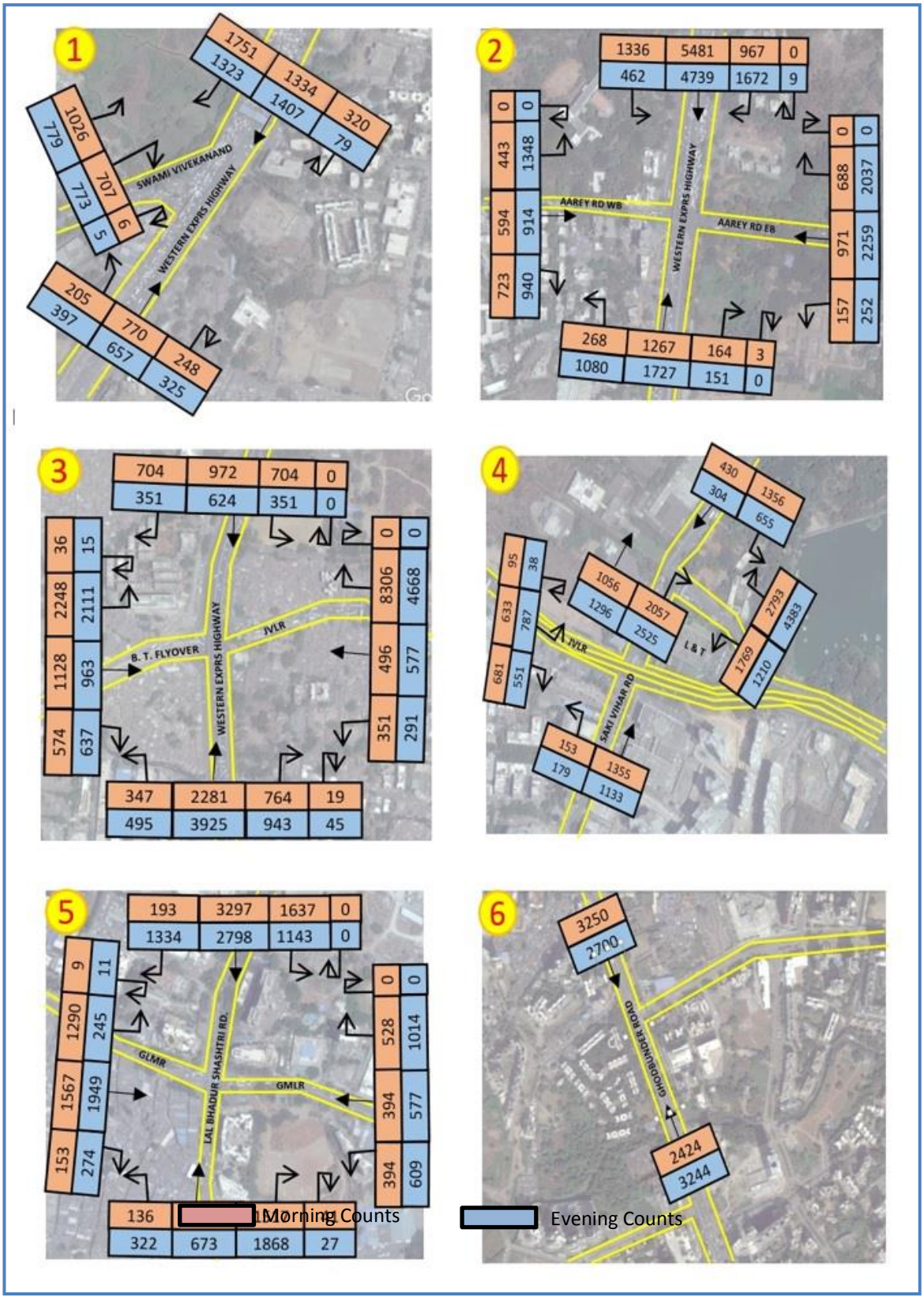

Figure 3-26 Existing Peak Hour Traffic Volume Counts

In addition to the traffic volume counts, O-D surveys were conducted for the morning and evening peak traffic durations. These O-D surveys were carried out at the 6 locations where traffic volume counts were conducted. To improve the quality of sample data being collected, every attempt was made to capture O-D data in the same proportion as the modal split observed during the classified volume counts at that particular location. A total of 3232 samples were collected as a part of this exercise. A total of 5771 trips were captured during the OD survey. **Table 3-1** below illustrates a blank sample table that was populated in the field with information collected from the morning and evening commuters. The data collected from O-D survey is shown in **Appendix D.**

Table 3-1 Survey format for O-D survey

Origin Destination Survey									
Name of surveyor				Direction		Date			
Junction ___						Time		:00	:15
Sr No	Origin	Destination	Mode of vehicle	Occupancy	Frequency	Travel time	Route taken	Puprose	Opinion
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

3.8. Data analysis

The data collected from the traffic volume count surveys and origin destination surveys was analysed using Microsoft Excel and Arc GIS software. ArcGIS is a geographic information system based software used for working with maps. It is generally used for creating and using maps, compiling geographic data, analysing mapped information and managing geographic information for database sharing. As mentioned earlier, ArcGIS software was used for preparation of desire line diagram consistent with the methodology adopted for this project.

3.9. Traffic volume count and trips generated

The data obtained from 6 hours of traffic volume counts is summarized below. **Table 3-2** summarizes the traffic volume counts according to the modal split. The traffic volume counts with mode classification are significant to ascertain the travel behaviour of trips corresponding to the respective modes.

Table 3-2 : Traffic volume at each junction

JUNCTIONWISE TOTAL TRAFFIC VOLUME							
Junction	**2-Wheelers**	**3-Wheelers**	**4-Wheelers**	**LCV**	**Trucks**	**Bus**	**Total Traffic Volume of 6 hours**
1	18148	12079	7841	1794	1753	1287	42902
2	44297	22478	38441	1848	1283	3351	111698
3	36419	19084	46437	3770	3730	3385	112825
4	16297	9153	20958	1158	1405	1515	50486
5	36470	16482	27815	1375	1559	2589	86290
6	13359	4488	15213	1376	1245	1104	36785
Total	**164990**	**83765**	**156705**	**11321**	**10975**	**13230**	**440986**

Table 3-3 summarizes the total traffic volume during the peak hour for each junction. The hourly volume at each junction was used for calculating the average daily traffic at each junction. Based on IRC 89-1983 the peak hour volume was considered to be 12% of the average daily volume.

Table 3-3 : Total traffic volume at peak hour

TOTAL TRAFFIC VOLUME OF PEAK HOUR	
Junction	**Peak Hour Volume**
1	7002
2	20748
3	21017
4	9589
5	17525
6	6369
Total	**82250**

The traffic volumes were converted into trips by using vehicle occupancy factors. Vehicle occupancy is defined as the average number of passengers in a vehicle during a trip. **Table 3-4** below summarizes the average vehicular occupancy based on comprehensive traffic study conducted by MCGM.

Table 3-4 : Calculated vehicular occupancy

Calculated Vehicular Occupancy					
Mode of Vehicle	**2-Wheelers**	**3-Wheelers**	**4- Wheelers**	**LCV**	**Trucks**
Vehicle Occupancy	1.4	2.3	2.5	2	2

As summarized in Table 3-5 below, traffic volumes were converted into the trips generated with their respective modes, using the vehicular occupancy for that particular mode as shown in Table 3-4. The 2-wheeler and 4-wheeler trips are important to ascertain the share of trips made by private vehicles. The freight traffic was assessed on the basis of trips made by LCV and trucks. These trips were used for generating the origin and destination matrix.

Table 3-5 : Total trips

SUMMARY OF TOTAL TRIPS GENERATED (Peak hour)						
Junction	**Total Number of Trips**					
	2-Wheelers	**3-Wheelers**	**4- Wheelers**	**LCV**	**Trucks**	**Total Trips**
1	3921	4831	3501	700	700	13654
2	10747	10498	17117	2905	415	41683
3	9121	9184	19441	3363	2102	43211
4	4162	3970	7911	1918	1534	19494
5	9078	8868	14020	2454	701	35120
6	3032	2051	6210	1019	637	12948
Total	**40061**	**39403**	**68200**	**12358**	**6089**	**166110**

3.10. O-D Matrix for existing scenario

Based on the total vehicles interviewed during roadside O-D survey, the origin destination matrix for the corresponding trips was prepared using the pivot table tool in Microsoft Excel. This matrix was converted into an O-D matrix for peak hour trips using the traffic volume count for peak hour. Table 3-6 summarizes the traffic surveys based on which the origin and destination matrix was prepared.

Table 3-6 Summary of O-D survey

SUMMARY OF VOLUME COUNTS AND TRIPS	
Total vehicles Interviewed in OD Survey	3232
Total No. of Trips -OD Survey	5771
Total Volume Count for Peak hour	82250
Total No. of Trips through volume Count Peak Hour	166110
% of Trips captured for OD Survey	5%

Peak hour traffic generally ranges from 10% to 12% of the daily traffic as per IRC 89-1983. For the purpose of this report a 12% value was considered. Accordingly, the peak hour traffic volumes obtained from the traffic volume survey were converted to daily traffic volumes as summarized in **Table 3-7.** The private vehicles considered for the analysis included 4-wheelers and 2- wheelers, public transport vehicles included auto rickshaw, etc., and freight vehicles include LCV and trucks. With respect to the average daily traffic volume calculations, the corresponding O-D matrix was prepared for the average daily trips. Tables summarizing the origin and destination matrix are included in the **Appendix E**.

3.11. Desire line analysis

A desire line analysis is a tool used for determining the level of interaction between zones. In case of traffic studies the level of interaction is generally in terms of the number of trips between the Traffic Analysis Zones (TAZs).

In this study the desire line analysis was performed to determine the number of trips between the TAZs obtained from the origin and destination survey.

Table 3-7 Average daily traffic volume calculations

JUNCTION	PEAK HOUR TRAFFIC VOLUME	DAILY TRAFFIC VOLUME	DAILY TRAFFIC VOLUME ACCORDING TO MODAL SPLIT		
			PRIVATE VEHICLES	PUBLIC TRANSPORT VEHICLES	FREIGHT VEHICLES
1	7002	58350	35347	18179	4824
2	20748	172900	128072	39981	4847
3	21017	175142	128620	34879	11642
4	9589	79908	58967	16885	4057
5	17525	146042	109531	32277	4234
6	6369	53075	41225	8068	3782
Total	**440986**	**685417**	**501762**	**150270**	**33385**

A desire line diagram was prepared using the Network analysis tool in ArcGIS software. The steps followed for preparation of desire line diagram were as follows:

- Mapping of zones and creation of Shape file showing zones.
- Mapping basic road network.
- Using OD matrix tool in Network analysis for creation of desire lines.
- Assigning values of number of trips to desire lines.

In addition to the local trips, the route taken by external trips was analysed. External trips were identified as those trips either going to or coming from other parts of the Maharashtra state or other states. Such trips were classified as trips going through or coming through the traffic analysis zone of Mira Bhayander, Thane or Navi Mumbai.

Figure 3-27 below shows the desire line diagram based on peak hour trips. It illustrates the trips between the zones of the study area. The centroids of the respective zones are denoted by the red points. The colour of the lines determines the number of trips between the zones. Green lines denote higher number of trips.

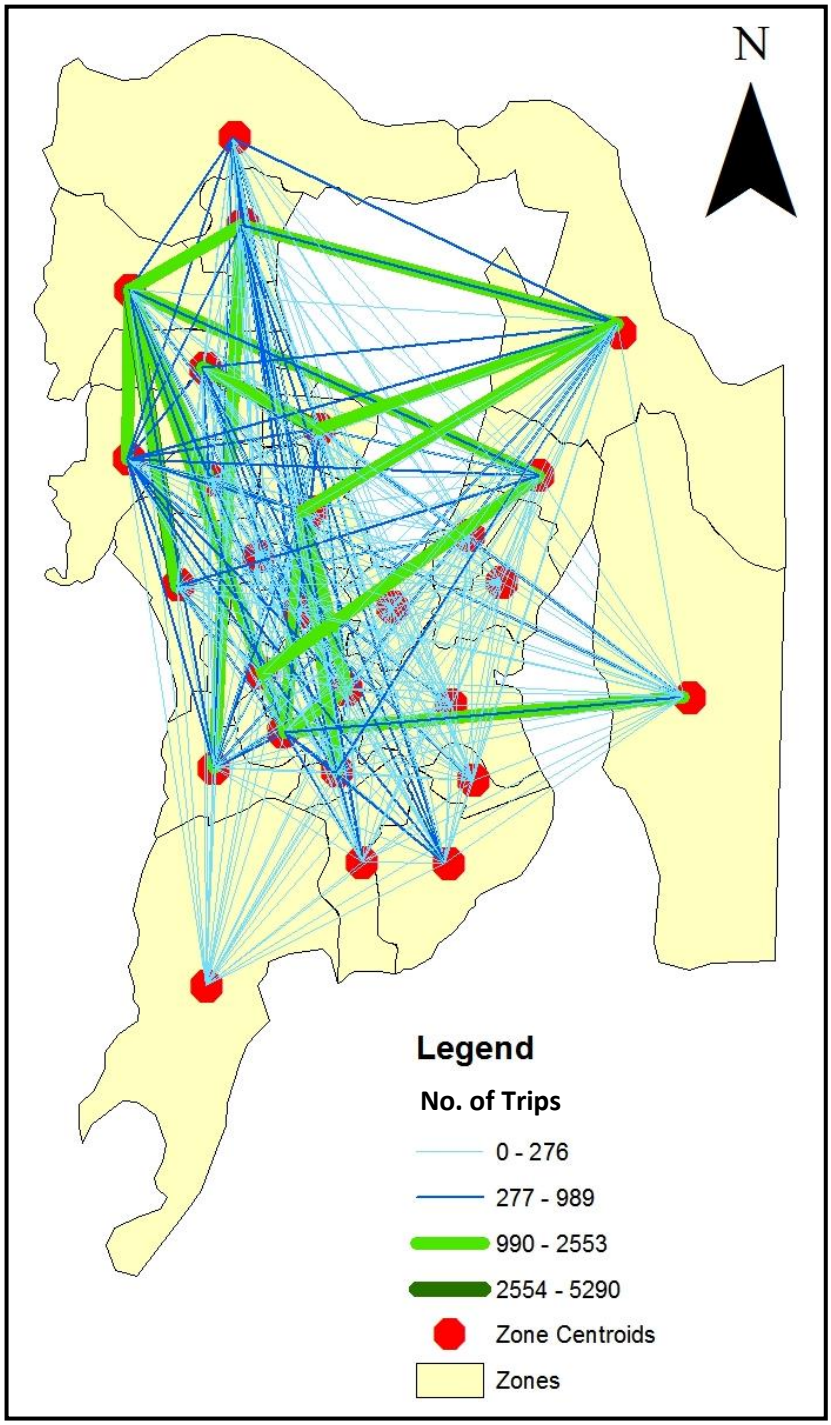

Figure 3-27 Desire Line Diagram (Existing Peak Hour Scenario 2017)

Figure 3-28 below shows the desire line diagram based on the daily trips. The lines show the number of trips between the zones. Darker lines denote the zones having higher interaction.

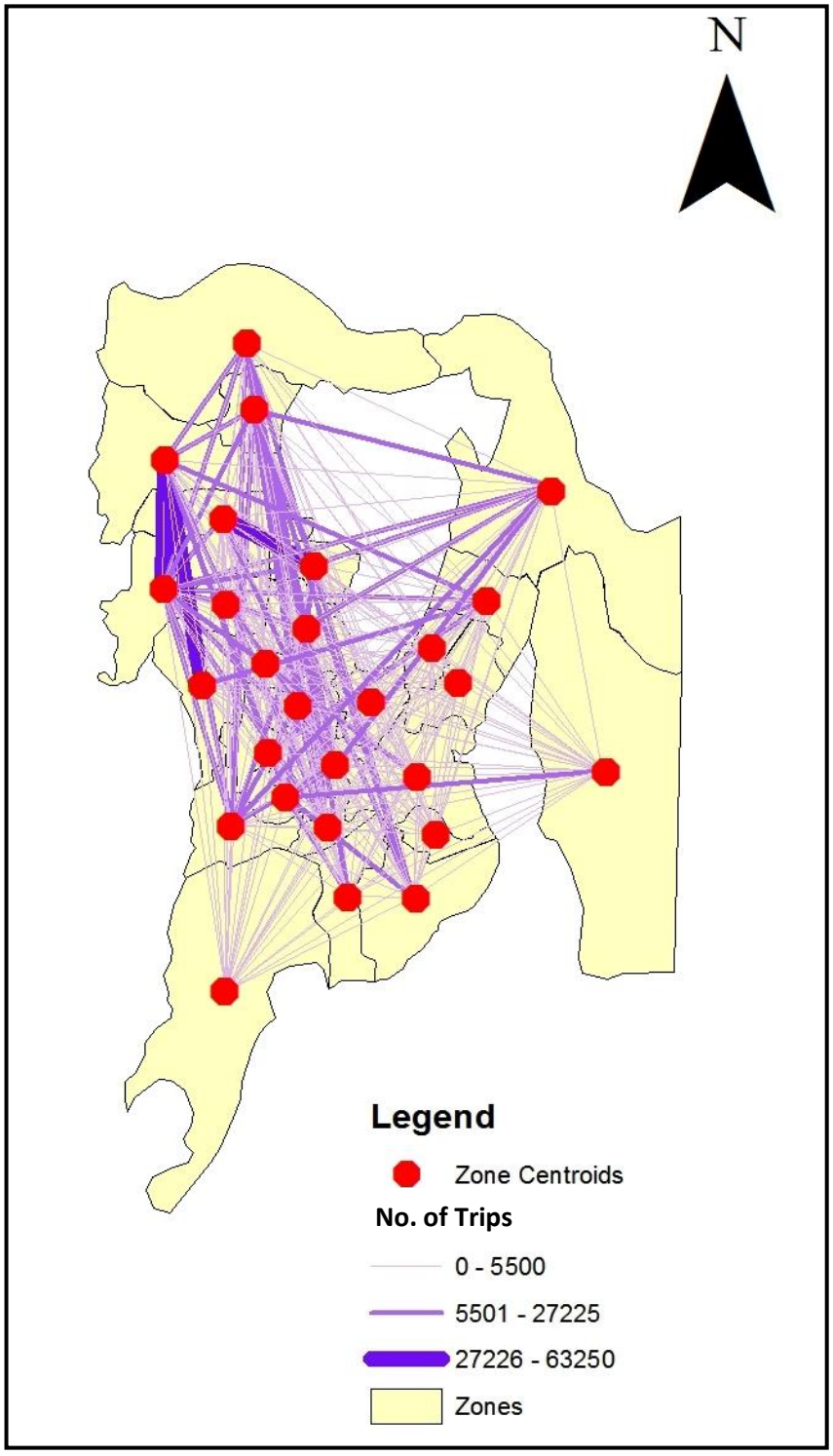

Figure 3-28 Desire line diagram (Existing daily trips scenario 2017)

3.12. Traffic projections

Elastic Travel Demand Modelling was undertaken for estimating the future year scenario. In this method, growth factors based on elasticity of transport demand were calculated. As per IRC 108-2015, vehicle population was related with one or more logically derived independent variables to derive the elasticity of transport demand. The growth rate of private vehicles was obtained from the latest comprehensive traffic study for Mumbai done by LEA Associates.

The data of Net State Domestic Product of Maharashtra State and the increase in registered vehicles for last 10 years was considered for the purpose of modelling. Using this method, the yearly % increase in the traffic volume was calculated as shown in the **Table 3-8**. For detailed calculations refer **Appendix F**.

Table 3-8 Projected yearly % increase in traffic volume

Period	PRIVATE VEHICLES	PUBLIC TRANSPORT VEHICLES	FREIGHT VEHICLES
Up to 2017	18	5.8	7.8
2017-2022	16	6.8	9.3
2022-2032	10.5	5.15	6.9
2032-2042	7.5	2.7	3.5

Table 3-9 summarizes the calculated traffic volumes for the future years. The 2032 scenario (after 10 years) and 2042 scenario (after 20 years) are shown in the Table 10.

Table 3-9 Projected traffic volume

YEAR	2017 - 2022	2022-2032	2032-2042
PRIVATE VEHICLES	516222	602259	627564
PUBLIC TRANSPORT VEHICLES	122743	143200	149217
FREIGHT VEHICLES	133313	155531	162066
TOTAL TRAFFIC VOLUME	**772278**	**900990**	**938847**

The scenario for the future years 2032 and 2042 trips were built on the basis of the projected traffic volumes as shown in **Table 3-10**. Tables summarizing the origin and destination matrix for the future projections are included in the **Appendix E**.

3.13. Desire line diagram for scenario 2032 and 2042

On the basis of the traffic volume projections, desire line diagrams for future year 2032 and 2042 scenario were created. Desire lines are indicators of the amount of trips between the TAZs. On the basis of the trips shown by the desire lines, the numbers of trips to be shifted to the proposed road was ascertained. **Figure 3-29** shows the desire line diagram for 2032 scenario.

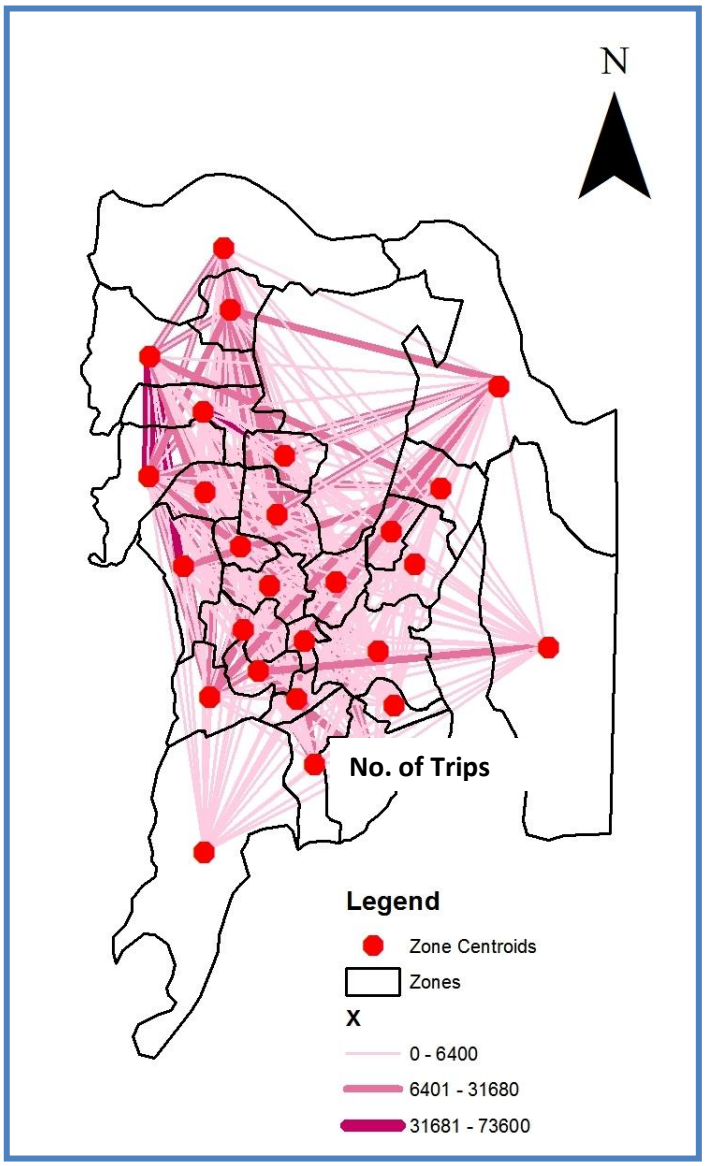

Figure 3-28 Desire Line Diagram 2032 Scenario

Figure 3-30 shows the desire line diagram for 2042 scenario.

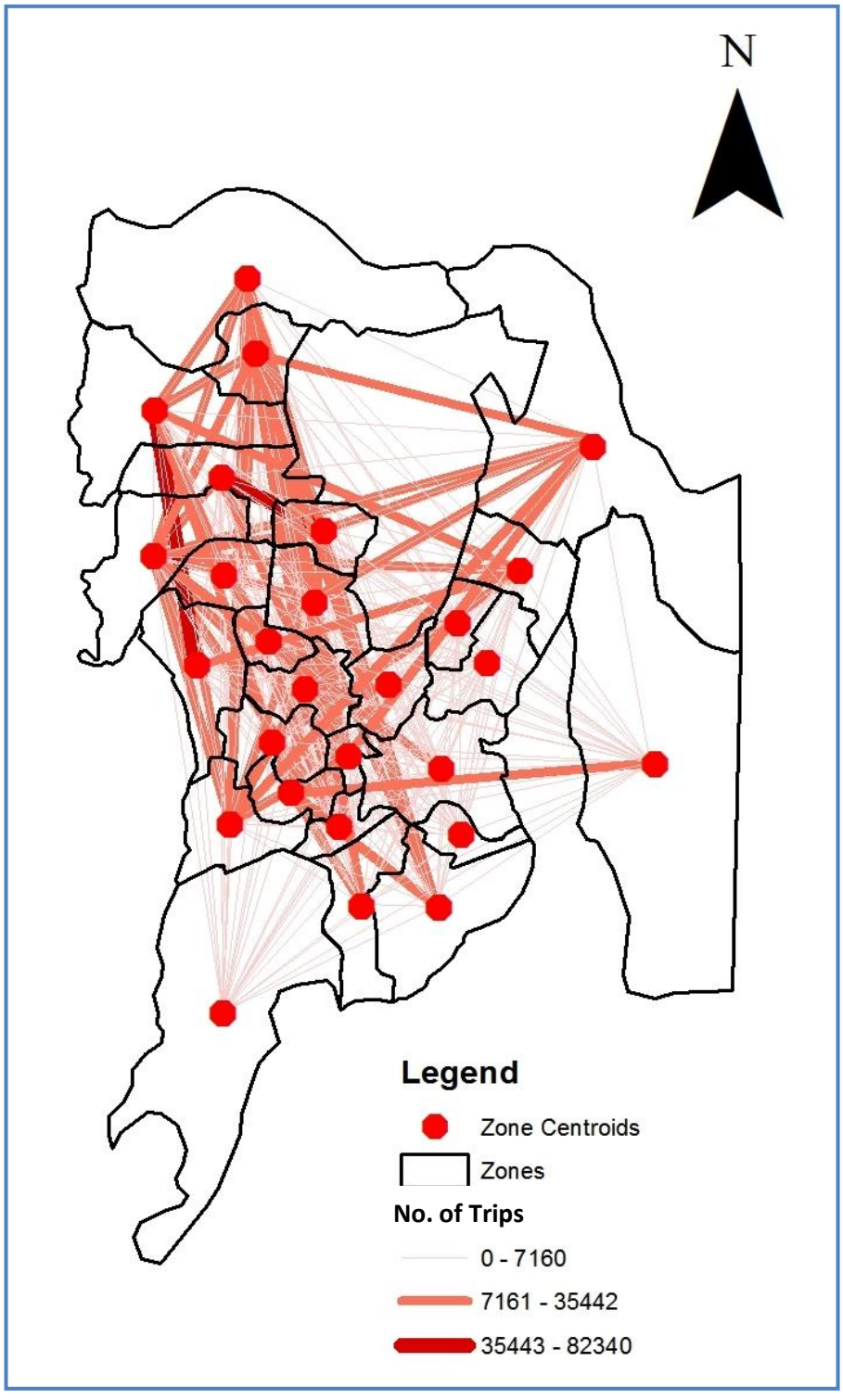

Figure 3-30 Desire Line Diagram 2042 Scenario

3.14. Determination of roadway geometry for proposed road

As per the projections for the origin and destination of trips and with due considerations for the impact of metro corridors, the total trips between the TAZs were classified into 3 categories:

- Trips that would surely shift to the proposed GMLR
- Trips that would probably shift to the proposed GMLR, and
- Trips that would not shift to the proposed GMLR in any case

Figure 3-31 illustrates the trips that are expected to surely shift to the proposed GMLR as well as those trips that may shift to the proposed GMLR.

Considering the trips that may probably shift to proposed GMLR, 2 scenarios were built –

Scenario 1: 20% of trips that may probably shift were considered as shown in **Table 3-10**

Scenario 2: 40% of trips that may probably shift were considered as shown in **Table 3-11**

In **table 3-11** and **3-12** the total trips were those obtained from conversion of the projected traffic volumes to trips. These were summarized in **Table 3-9** earlier.

The daily volume, peak duration volume and peak hour volume was calculated for the 2032 scenario and 2042 scenario. Daily trips for future scenario were calculated based on these projected traffic volumes. In **Table 3-10** 20% of the trips that may probably shift to the new corridor were considered and in **Table 3-11** 40% of the trips that may probably shift were considered.

On the basis of the total trips that would shift to the proposed GMLR, the daily traffic volume for the year 2032 and 2042 were calculated. Since future year scenarios were being analysed, it is expected that the peak traffic volume would be spread over a longer peak duration i.e. future traffic volumes would be spread out more evenly throughout the day. Thus, the peak hour of traffic would experience a lower proportion of the total daily traffic volume. Consistent with IRC 106-1990, peak hour volumes for the future year 2032 and 2042 scenarios were considered to be 8.5 % of the daily

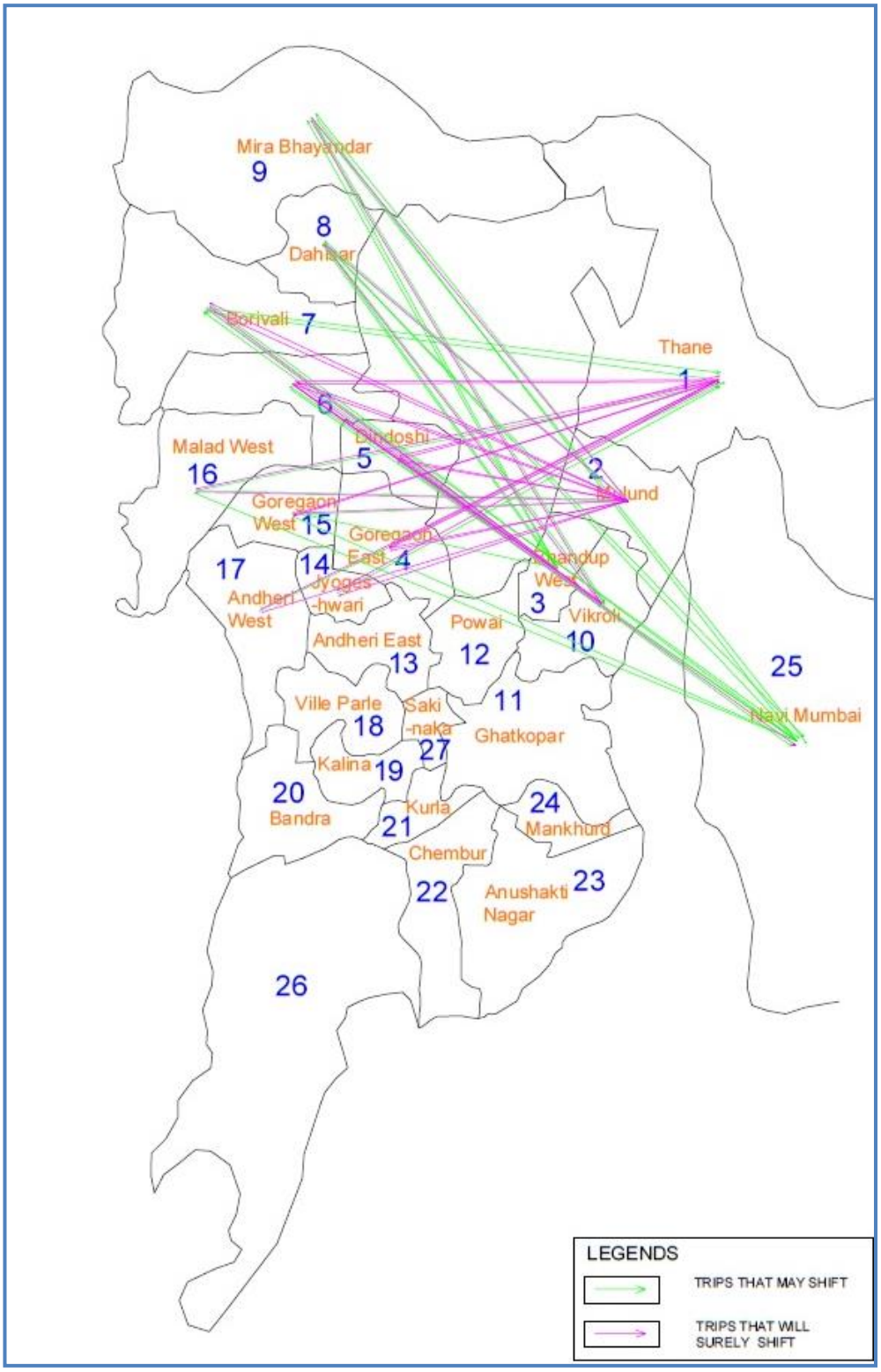

Figure 3-31 Figure Showing the Trips between the Zones That Will Shift to the Proposed GMLR

Traffic volumes. Further, traffic volume in terms of number of vehicles per hour was converted into passenger car units (PCUs) per hour as per the corresponding modal split. IRC 106-1990 guidelines were used for the PCU conversion factors.

LOS values in terms of their corresponding Volume/Capacity ratios for multilane roadways were calculated. LOS C volumes corresponding to IRC 106-1990 were used to calculate the capacity of the roadway facility. Since the Indian Highway Capacity Manual is still in the final stages of development and yet to be published, LOS values in terms of their corresponding Volume/Capacity ratios for multilane roadways at midblock locations based on the US Highway Capacity Manual, Special Report 209 were used to determine the Level of Service corresponding to the Volume/Capacity ratios. LOS C or better was considered to be an acceptable level of service for the future 10 year scenario and LOS D or better was considered to be an acceptable level of service for the future 20 year scenario.

Traffic in the tunnel section is expected to operate under uninterrupted flow conditions. The freeway capacity guidelines for Indian urban conditions are yet to be framed. In the absence of Indian capacity values for uninterrupted flow conditions, capacity values based on the Highway Capacity Manual (USA) were used for determining the projected level of service. LOS thresholds were calculated based on density criteria. The free flow speeds required for density calculation were calculated based on Ministry of Road Transport and Highway (MORTH) guidelines.

Traffic density is defined as the number of vehicle occupying a unit length of roadway. For a free flow speed (FFS) of 100, 90, 80, 70 Km/hr. HCM table provides the maximum density for each LOS. The FFS was calculated by applying suitable reduction factors to the Base Free Flow Speed (BFFS). BFFS was assumed to be 100 Km/hr. for an urban freeway as per MORTH guidelines for expressways. FFS was determined using the equation given below:-

$$FFS = BFFS - f_{LW} - f_{LC} - f_M - f_A$$ .... (MORTH Guidelines for expressways)

Table 3-10 Scenario 1 traffic volume to be shifted to the proposed GMLR

Sr. No.	Scenario 1			
1	Year	2022	2032	2042
2	Total Volume(PCU)	710605	829038	884772
3	Volume to be shifted(PCU)	49008	57175	61019
4	Volume that may shift	30045	35052	37409
5	Peak hour Volume (12%)	85273	99485	106173
6	Peak hour volume to be shifted	5881	6861	7323
7	Peak hour volume that may shift	3606	4206	4490
8	Percentage volume that may shift	20%	20%	20%
9	Total shifted volume	6602	7702	8221
10	Recommended width of road	6 lane divided	6 lane divided	6 lane divided
11	Capacity as per IRC	7714	7714	7714
12	Capacity for tunnel (IRC)	9257	9257	9257
13	V/C ratio	0.71	0.83	0.89
14	Level of service	**B**	**D**	**D**
15	IRC Capacity for tunnel(8 lane)	12343	12343	12343
16	Level of service (8 lane)	**C**	**C**	**C**

Table 3-11 Scenario 2 traffic volume to be shifted to the proposed GMLR

Sr. No.	Scenario 2			
1	Year	2022	2032	2042
2	Total Volume(PCU)	710605	829038	884772
3	Volume to be shifted(PCU)	49008	57175	61019
4	Volume that may shift	30045	35052	37409
5	Peak hour Volume (12%)	85273	99485	106173
6	Peak hour volume to be shifted	5881	6861	7323
7	Peak hour volume that may shift	3606	4206	4490
8	Percentage volume that may shift	40%	40%	40%
9	Total shifted volume	7323	8543	9119
10	Recommended width of road	6 lane divided	6 lane divided	6 lane divided
11	Capacity as per IRC	7714	7714	7714
12	Capacity for tunnel (IRC)	9257	9257	9257
13	V/C ratio	0.79	0.92	0.98
14	Level of service	**D**	**D**	**E**
15	IRC Capacity for tunnel(8 lane)	12343	12343	12343
16	Level of service (8 lane)	**C**	**C**	**D**

Appendix G includes the calculation of FFS. On calculating FFS, the level of service criteria applicable to that category was determined. The density thus obtained was compared with HCM density thresholds and the corresponding LOS was obtained.

Density values were determined using the following equation

$$D = \frac{V}{S} \quad \text{.... (HCM 2000)}$$

D = Density

v = flow rate (PCU/hr./lane)

s = average passenger car travel speed

Table 3-12 below summarizes the findings of the density analysis.

Table 3-12 Comparative capacity analysis determining los based on density

LOS CORRESPONDING WITH DENSITY FOR MULTI LANE HIGHWAY (SCENARIO 1)

Projected Year	Lane Configuration	Hourly Volume (PCUs) (Q)	v/c	Average Speed(km/hr) (V)	Density(km/hr/ln) (Q/V)	LOS
2022 (Opening year)	6-LANE DIVIDED	6602	0.4	100	11.00	C
2032 (10 years)	MULTILANE	7702	0.48	100	12.84	C
2042 (20 years)	ARTERIAL SECTION	8221	0.51	100	13.70	C
2022 (Opening year)	8-LANE DIVIDED	6602	0.31	100	8.25	B
2032 (10 years)	MULTILANE	7702	0.36	100	9.63	B
2042 (20 years)	ARTERIAL SECTION	8221	0.39	100	10.28	B

LOS	DENSITY*(PCU/Km/ln)
A	<7
B	>7-11
C	>11-16
D	>16-22
E	>22-25
F	>25

LOS CORRESPONDING WITH DENSITY FOR MULTI LANE HIGHWAY (SCENARIO 2)

Projected Year	Lane Configuration	Hourly Volume (PCUs)	v/c	Average Speed(km/hr) (V)	Density(km/hr/ln) (Q/V)	LOS
2022 (Opening year)	6-LANE DIVIDED	7323	0.46	100	12.21	C
2032 (10 year)	MULTILANE	8543	0.54	100	14.24	C
2042(20 years)	ARTERIAL SECTION	9119	0.58	99.5	15.27	C
2022 (Opening year)	8-LANE DIVIDED	7323	0.35	100	9.15	B
2032(10 years)	MULTILANE	8543	0.4	100	10.68	B
2042 (20 years)	ARTERIAL SECTION	9119	0.43	100	11.40	C

*DENSITY is carried out from Highway Capacity Manual 2000, 3rd Ed.

3.15. Assessment of the Impact of Proposed Mumbai Metro Corridors on the Proposed Link Road

The proposed GMLR is expected to provide excellent connectivity in the east-west direction via a direct link through the Sanjay Gandhi National Park. In order to project future volumes operating on the GMLR corridor, the proposed methodology incorporated a few assumptions to arrive upon the 10 year and 20 year scenarios with a certain level of confidence.

Although there are 8 metro routes proposed for the MMR region, the north-south metro corridors are not expected to impact trips that would occur via the proposed GMLR link which operates in the east-west direction.

As shown **Figure 3-32** below, 3 Metro corridors have been proposed to improve the east-west connectivity across the MMR.

- **Line 6** **(**Lokhandwala-SEEPZ-Kanjurmarg Corridor)
- **Line 1** (Versova-Andheri-Ghatkopar Corridor)
- **Line 8** (Sevri-Prabhdevi Corridor)

Based on proximity to the proposed GMLR alignment, Metro Line 6-6 and Metro Line 1-1 could have an impact on the proposed GMLR link.

A research paper published by Dr. Geetam Tiwari, IIT Delhi and Dr. Mukti Advani, CRRI Delhi titled "Evaluation of Public Transport Systems: Case Study of Delhi Metro" suggests that metro ridership generally comprises of trips originating within a 500m walking distance of a metro line. Trips outside the 500m radius trips continue to use the regular modes of transport.

For the purpose of this report, two types of trips were considered to project the likely traffic volumes expected to be diverted onto the new GMLR corridor.

- ***Type 1 Trips:*** The first assumption was that if a trip was originating from or concluding at one of the zones which could provide the shortest path via the GMLR, it was assumed that this trip would use the GMLR for commuting in the east-west direction.
- ***Type 2 Trips:*** The second assumption was that there would be trips which would originate from or conclude in one of the zones wherein the path via the GMLR would not necessarily be the shortest path; however it could be a path which offers faster route or a better driving experience as an alternative to the original route.

The proposed Metro corridor would have no impact on freight traffic regardless of the freight trip being a Type 1 trip or a Type 2 trip.

For **Scenario 1**, a liberal assumption of 20% was made for these Type 2 trips. The remaining 80% of these Type 2 trips could be assumed to be the ones that could contribute to the Metro trips and other

link road projects in the vicinity of the proposed GMLR. These trips were excluded from the design volume calculations for Scenario 1.

For **Scenario 2**, a conservative assumption of 40% was made for these Type 2 trips. The remaining 60% of these Type 2 trips could be assumed to be the ones that could contribute to the Metro trips and other link road projects in the vicinity of the proposed GMLR. These trips were excluded from the design volume calculations for Scenario 2.

Although Metro operations in the vicinity of GMLR are expected to have an impact on existing mode share; the conservative assumptions made in the report to estimate the future traffic volumes, account for this mode shift.

Figure 3-32 Master Plan of Mumbai Metro

3.16. Conclusion of Traffic Survey

The Goregaon Mulund Link Road (GMLR) via Sanjay Gandhi National Park was proposed in the Comprehensive Transport Study for Mumbai Metropolitan Region in July, 2008. The purpose of this traffic study was to identify the typical roadway geometry for the proposed Goregaon Mulund Link Road (GMLR). The proposed GMLR will offer connectivity to the eastern and western region surrounding Sanjay Gandhi National Park. Traffic volume counts and O-D surveys were conducted to identify trips most likely to use the proposed new GMLR connection. An elastic travel model was used to determine the 10-year and 20-year traffic projections on the new GMLR connection.

A 6-lane divided roadway segment (3-lanes in each direction) is expected to operate within the projected capacity thresholds for the Year 2032 and Year 2042 projections. Although operations with the 6-lane divided geometry under Scenario 2 (a more conservative scenario) for the Year 2042 projection is expected to operate at near maximum capacity, a comparison with international standards suggests that a 6-lane divided section will operate well within acceptable LOS limits. Alternatively, the tunnel section is expected to operate under uninterrupted flow conditions (freeway segment) and therefore a capacity analysis based on freeway thresholds was additionally considered for the tunnel sections. Since the 6-lane geometry under uninterrupted flow conditions was projected to operate within LOS C thresholds for the Year 2042 projections, a 6-lane divided two-way roadway section (3-lanes in each direction) was recommended for the proposed GMLR. Based on the available right-of-way identified for the proposed GMLR, this 6-lane corridor can be accommodated within the proposed ROW (Right-Of-Way).

4. Geotechnical Investigation

4.1. Introduction

4.1.1. Objective of Geotechnical Investigation

MCGM have appointed PADECO to review the concept prepared by Pentacle and propose improvements/ new most-suitable alignment. Accordingly, the scope of services will include Peer Review, Finalisation of most-suitable alignment including tunnelling (if required and recommended) with suggestions, improvements and alternatives, if any.

Site investigations or sub-surface explorations are done for obtaining information about subsurface conditions at the site of proposed construction. Site investigation in one form or the other is required for every engineering project. Information about the surface and subsurface features is essential for the design of structures and for planning construction techniques.

As a statutory requirement & to identify required design parameters for safe design, PADECO decided to carry out geotechnical investigation at SGNP (Sanjay Gandhi National Park) Mumbai. Geotechnical investigation work consisted of seven boreholes to examine subsurface profile. Depth of boreholes to be drilled was determined using IS: 1892- 1979 section 2.3.2. The lateral extent of exploration and the spacing of boreholes depend mainly on the variation of the strata in horizontal direction. M/s JAY GAJANAN, Thane (W) carried out fieldwork of boreholes from 20th Dec, 2016 to 01st March, 2017. Selected rock samples were tested in Soil Laboratory of M/s OCE PROJECT Pvt. Ltd., & IIT Bombay Laboratory test results were received on 07th April, 2017. Objective of the site investigation was to obtain the information that may be useful for one or more of the following purposes:

1. To select the type and depth of foundation for a given structure, to access the critical locations along the alignment for tunnel design.
2. To determine the bearing capacity & ground improvement techniques for soil/rock layer.
3. To establish the ground water level & seepage estimation in the tunnel area/section.
4. To select the suitable construction technique.
5. To predict potential foundation problems.
6. To ascertain the suitability of the soil as a construction material.
7. To collect and transport the selected samples of soil and rock in testing laboratory and conduct relevant tests to determine properties.
8. Recommendations for soil-related construction conditions such as site preparation, earthwork

construction, excavation slopes, and difficult excavation.

4.1.2. Report limitations

This geotechnical investigation report is based on the data collected from seven boreholes data, from laboratory results & judgement of undersigned based on his experience. Scope of this investigation report is limited to defining factual geotechnical data, geotechnical design parameter & geological profile for the system.

Subsurface and ground water conditions between and beyond the explored locations may differ from those encountered at the explored locations, and conditions may become apparent during construction, which we could not detect or anticipate at the time of the site investigation. We intend the comments we make in this report relating to potential construction problems and possible methods of construction only for guidance of the designer. The scope of this investigation report did not include an environmental assessment or investigation for the presence or absence of hazardous or toxic materials in the soil or groundwater or surface water within or beyond the site. Any statements in this report or on the soil test, boring logs regarding odours, staining of soils, or other unusual conditions observed are strictly for the information of our client.

The present document assesses the available geotechnical investigation data and establishes the geotechnical profile and engineering parameters to be used in subsequent design stages. The present document is a controlled document and as such it shall be updated and/or revised if and when the need appears.

Professional judgments and recommendations are presented in this report. They are based partly on evaluation of the technical information gathered, partly on historical reports and partly on our general experience with sub-surface condition in the area. We do not guarantee the performance of the project in any respect other than that our engineering work and the judgments rendered meet the standards and care of our profession. It should be noted that the borings/trial pits may not represent potentially unfavourable subsurface conditions between borings. If during construction soil conditions are encountered that vary from those discussed in this report or historical reports of if design loads and/or configuration change, we should be notified immediately in order that we may evaluate effects, if any, on foundation performance. The recommendations presented in this report are applicable only to this specific site. These data should not be used for other purposes.

4.1.3. Scope of the Study

Scope of the Study under this Consultancy Services is basically Pre-contract Works before the actual award. The scope of services included a site reconnaissance, site soil test, borings and soil sampling, laboratory soil testing, engineering evaluation of the field test data, and preparation of this report. Specifically, the scope of our engineering work for this site was to provide the following:

1. Soil nature and origin, including changes resulting from man's activities
2. Depths, thickness, and composition of soil strata that will be appreciably stressed by the intended construction.
3. Depths to encountered groundwater, dense soil strata, and rock that could affect the proposed construction. Collect ground water sample from borehole for chemical analysis. Collect undisturbed soil samples from cohesive soil stratum.
4. Conduct standard penetration tests at an interval of 1.0 to 1.5 meter and collect disturbed soil samples.
5. To prepare a geotechnical investigation report by compiling data collected from field, bore logs, and results of laboratory tests.
6. Recommendations & design parameters for tunnel design, allowable bearing pressures, estimated settlements, footing sizes and depths.

The following investigation programmes have been performed in the project area. The first stage consisting of drilling of 7 boreholes to get the geological & geo mechanical (Lab Testing) information of the project area, in general drilling of 30 to 50 m in depth. The second investigation stage is in-situ testing such as Permeability & Pressure meter Tests in soil & Rock strata. Field tests such as Electricity Resistivity & Seismic Refraction at the selected locations. Details of the available investigations are presented in Table 1 and complete factual data described in the next section.

Table 4-1 Summary of Boreholes

Structure	Bore Hole No	Ground RL (m)	Occurrence of Rock Strata (m)	Final Depth of Borehole (m)	Ground Water Table (m)
Portal Location	BH 1	87.00	85.00	57.00	N.A
	BH 7	86.00	86.00	56.00	78.8
Tunnel Area	BH 2	117.00	117.00	67.00	104.70
	BH 3	112.00	109.50	61.50	102.80
	BH 4	89.00	87.50	47.00	80.70
	BH 5	71.00	69.3	23.50	N.A
	BH 6	89.00	87.50	46.00	N.A

4.1.4. Structure of the Report

This Report describes the overall approach and methodology used by PADECO for this study. The details are given in the following sections.

Chapter 4.1 - Introduction (This chapter)
Chapter 4.2 –Investigation Procedure and Standard Code Provisions
Chapter 4.3 - Regional Geology
Chapter 4.4 - Results of Investigation & Geotechnical Evaluation
Chapter 4.5 – Lab Test Results

4.2. Investigation Procedure and Standard Code Provisions

4.2.1. Project Location

The proposed project corridor is from Goregaon in Western Suburbs to Mulund in Eastern Suburbs, Mumbai.

4.2.2. Planning

A subsurface exploration programme depends upon the type of structure to be built and also upon variability of the strata at proposed site. Sub-surface explorations are generally carried out in three stages.

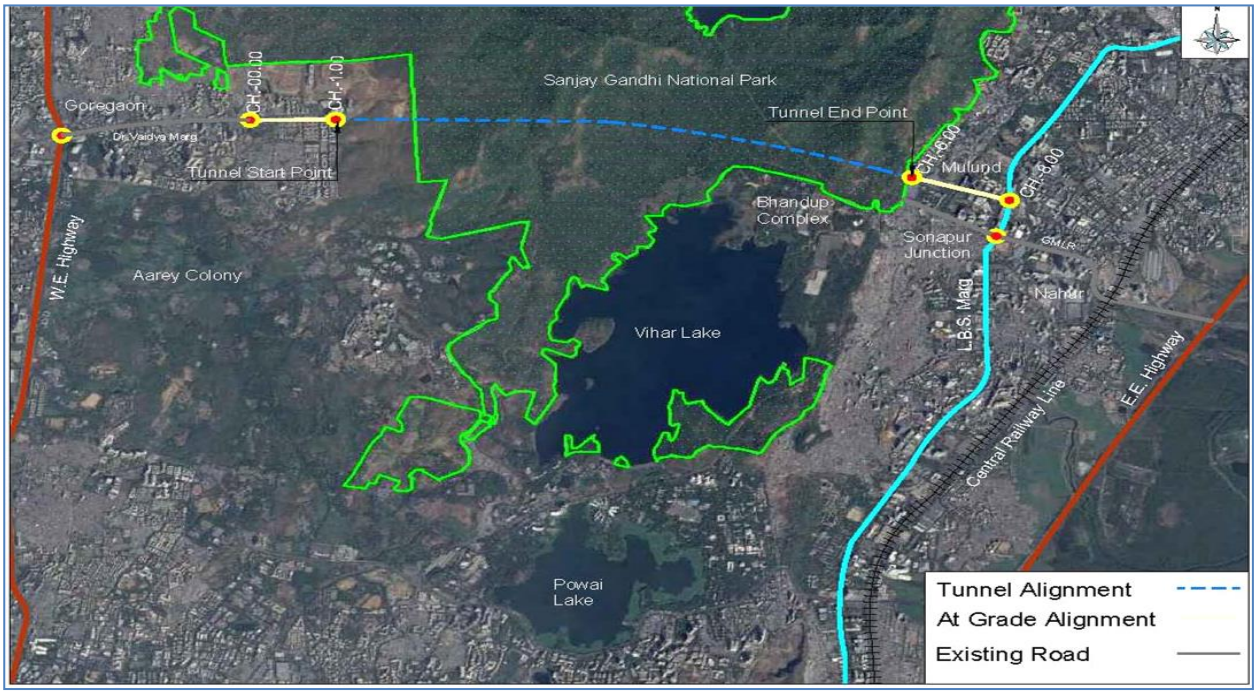

Figure 4-1 Tunnel Corridor Section for Geotechnical Investigation

4.2.2.1. Reconnaissance:

Prior to our field exploration, the site and surrounding areas were visually evaluated by M/s JAY GAJANAN, Thane (W), and Engineer. His observations were used in planning explorations, in determining areas of special interest, and in relating site conditions to known geologic conditions in the proposed project area. Subsurface exploration programme includes visit to a site and study the map and other relevant records. The information about the following features is obtained:

1. General topography of the site.
2. Existence of underground water mains, power conduits, etc. at the site.
3. Existences of settlement cracks in structure already build near site.
4. The evidence of landslides, creep of slope and shrinkage cracks.
5. The stratification of soil observed from deep cuts near the site.
6. Depth of ground water table as observed in wells and drainage pattern.
7. Type of vegetation existing at the site.

4.2.2.2. Preliminary Exploration:

The aim of a preliminary exploration is to determine the depth, thickness, extent and composition of each soil stratum at the site. The depth of bedrock and the ground water table is also determined. The preliminary explorations are generally in the form of trial pits. Trial pits were not considered for these sub-surface investigations.

Trial Pit

Trial pits are excavated at the site to inspect the strata. The size of the pit should be sufficient to provide necessary working space. IS: 4453 – 2009 recommends a clear working space of 1.2 m x 1.2 m at the bottom of the pit. The depth of the pit depends upon the requirement of the investigation. Shallow pits up to a depth of 3 m can be made without providing any lateral support. For deeper pits especially below the ground water table the lateral support in the form of sheeting and bracing system is required. Tests pits can be excavated manually or mechanically. The sides of the pits should be cleaned by chipping continuously in vertical bands or by other appropriate methods so as to expose a clean face of rock or soil. Measurements should be taken and recorded documenting the orientation, plan dimension, depth of the pit, and thickness of each stratum exposed in the pit. Adequate precaution should be taken against possible accidents due to caving of the ground.

4.2.2.3. Detail Exploration:

The purpose of detail exploration is to determine engineering properties of soil in different strata. It includes an extensive boring programme, sampling and testing. Field test such as vane shear test, SPT, PLT, Permeability test (Whenever required by client) to be conducted to determine properties of soil in natural state. The tests for the determination of dynamic properties are also carried out, if required.

4.2.3. Drilling

Locations of the boreholes are indicated on the attached Boreholes Location Plan. Onsite locations of boreholes were specified by client. The borings were performed to maximum depths of 50 m below the existing ground surface elevations. For drilling rotary type drilling rig was used. Rig was coupled with diesel engine, tripod and all drilling accessories. Drilling rig have tripod with suitable arrangement for driving as well as extracting casing. It was also used for conducting Standard Penetration Test (SPT), collection of Undisturbed Soil Sample (UDS) and Disturbed or wash Soil Sample (DS).

Initially casing of adequate diameter to suit boring of 100 mm borehole was lowered and boring was commenced. When rock was encountered, size of borehole was changed to Nx (76 mm) diameter. A core barrel and Nx sized bits are used for drilling and recovering rock cores. Recovered rock cores were numbered serially and preserved in good quality sturdy wooden core boxes. Rock core recovery (CR) and Rock Quality Designation (RQD) were computed for every run of length drilled. Rock samples have been selected for laboratory test based on the probable founding elevation of the proposed structure.

4.2.3.1. Technical Specifications for Drilling Work:

IS 1892: Code of Practice for Subsurface investigation for foundations.

IS 2131: Method of Standard Penetration Test for Soils

IS 2132: Code of Practice for Thin Walled Tube Sampling of Soils

IS 4078: Code of Practice for Indexing & storage of drill cores.

IS 4464: Code of Practice for Presentation of drilling information and core description in Foundation investigation.

IS 5313: Guide for core drilling observations

IS 5529: Code of Practice for In-situ Permeability Tests

IS 6926: Code of Practice for Diamond Core Drilling for site investigation for river valley projects.

IS 7974: Symbols and Abbreviations for Geological maps, Sections and sub-surface Exploratory Logs.

IS 7422: Symbols and Abbreviations for Geological maps, Sections and sub-surface Exploratory Logs.

4.2.3.2. Equipments for Drilling

- Theodolite Levels
- Total station.
- Rotary drilling rigs

4.2.3.3. Method for Rotary Drilling in Overburden soils

The machine shall be set-up at the borehole locations as indicated by client. In overburden soil the borehole shall be drilled by using rotary drilling machine. The borehole shall be made of 'SX' diameter in overburden soil. In loose or very soft soils or whenever there is chance of cave in of soil, temporary casing shall be used to support the sides of the borehole.

Standard Penetration Test (Ref.IS: 2131-1981):

Tests will be conducted at intervals of 3 m depth and/or change of strata up to depth the soil depth or change of strata. Tests may be conducted at lesser intervals, if specified or considered necessary. The sampler will be lowered to the bottom of the borehole. The following information will be noted and recorded:

- Depth of bottom of borehole below ground level.
- Penetration of the sampler into the soil under the combined weight of sampler and rods (to be noted from readings of the scale over the drill rod at the top)
- Water level in the borehole and
- Depth of bottom of casing below ground level.

The split spoon sampler resting on the bottom of borehole will be allowed to sink under its own weight; then the split spoon sampler will be seated 15 cm with the blows of the hammer freely falling through 75 cm. Thereafter the split spoon sampler will be further driven by 30 cm or 50 blows (except that driving shall cease before the split spoon sampler is full). The number of blows required to affect each 15cm of penetration will be recorded. The first 15 cm drive will be considered to be seating drive. The total blows required for the second and third 15cm of penetration will be termed the penetration resistance 'N'; if the split spoon sampler is driven less than 45 cm (total), then the penetration resistance will be for the last 30 cm of penetration (if less than 30 cm is penetrated, the logs should state the number of blows and the depth penetrated). The entire sampler may sometimes sink under its own weight when very soft sub-soil stratum is encountered. Under such conditions, it may not be necessary to give any blow to the split spoon sampler and SPT value should be indicated as zero. If, on lowering the sampler by means of a string of rods, it is found to rest at a level above the bottom of the casing, the penetration test and sampling should not be carried out at that stratum. The drive hammer will be of the type incorporating an automatic trip mechanism to insure free fall.

Thin-Walled Tube Sampling Of Soils (Ref. IS: 2132-1981):

1. **Driving the Casings:** Where casing is used it will not be driven below the sampling level, and casing pipe should be in such a way that it does not disturb the soil to be sampled.
2. **Cleaning the hole:** The hole will be cleaned to sampling elevation using whatever method is preferred that will ensure that the soil to be sampled is not disturbed. In saturated sandy and silty soils the drilling equipment should be withdrawn slowly to prevent loosening of the soil around the hole. Where casing is used, the hole will be cleaned out to the bottom or just below the casing. A clean-out auger should be used to clean the bottom of the hole, when necessary.
3. The depth of bottom of the casing, if used, below ground level and the water level in the borehole will be noted. Sampling will be done as soon as after the clean-out operation of the bore hole.
4. The assembled sampling tube of diameter 90 mm and 450 mm long, will be lowered to the bottom of the hole; and the following information will be noted:
   - Depth of bottom of bore hole below ground level;
   - Amount of penetration of the sampling tube into the soil, under the combined weight of the tube and the rods; and
   - Water level in the borehole.
5. The sampling tube will then be pushed into the soil by a continuous and rapid motion. In no case the tube will be pushed farther than the length provided for the sample. About 50 mm will be allowed for cuttings and sludge. A clearance of 10 to 20 mm will be allowed below the sampled head in the tube. The depth of penetration of the tube will also be noted. Before pulling out the tube, at least 5 minutes will be allowed to elapse after pushing the tube after which the tube will be turned at least for two revolutions to shear the sample off at the bottom.

4.2.3.4. Preparation for Shipment:

Upon removal of the sampling tube, the length of the sample in the tube and the length between the top of the tube and the top of the sample into the tube will be measured and recorded. The disturbed material into the upper end of the tube will be completely removed before applying wax for sealing. The length and type of the sample so removed will be recorded.

The Soil at the lower end of the tube will be reamed to a distance of about 20 mm. After cleaning both ends will be sealed with wax applied in a way that will prevent wax from entering the sample. Wax used for sealing should not be heated too more than a few degrees above its melting temperature.

4.2.3.5. Stabilisation of Bore Hole:

Stabilization of borehole shall be done by bentonite slurry and/or providing suitable temporary steel casing as necessary and which can be removed and taken back after completion of borehole as required for preventing caving in of soil/weathered rock.

4.2.3.6. Storage of Soil Samples:

All the soil Samples (Disturbed and SPT) of one bore hole shall be kept in Wooden Box of required size & easy to handle. These Boxes shall be kept at Site Offices or any other suitable location as per directions of the Engineer.

For Soil & Weathered Rock samples, Identification Labels shall be fixed on the Plastic Pouches, indicating Bridge location, bore hole No., Depth and Visual Soil classification.

4.2.3.7. Rotary Drilling In Rocks:

In the rotary drilling method, the hole shall be advanced by rotating a drill string consisting of a series of hollow drill rods to the bottom of which shall be attached either a cutting bit or a core barrel with a coring bit. Cutting bits shears off chips of the material penetrated and thus shall be used primarily for penetrating overburden between the level at which samples are required. Coring bit on the other hand shall be used to cut an annular hole in the rock mass, thereby, creating a cylinder or core of rock that enters the barrel and is retrieved. Thus the core barrel shall primarily be used in rock which under most circumstances shall be cored continuously. As the rods with the bit or barrel are rotated, downward pressure shall be applied to the drill string to obtain penetration and drilling fluid under pressure shall be introduced into the bottom of the hole through the hollow drill rods and passages in the bit or barrel.

1. Drilling Run:

Drill runs shall not exceed 3 m in length and the core barrel shall be removed from the drill hole as often as may be required in order to get the best possible core recovery. When any recovery is less than 80% for a full length drill run then the next run shall be reduced to 1 m. Where a geological feature has to be accurately determined, short runs of 30 cm or even smaller lengths, as required, shall be taken as directed by the Engineer-in-charge. However, under no circumstances shall coring be continued when it is obvious that the core barrel is blocked. This will result in grinding down of the rock and loss of core. In zones of highly fractured rock or where the barrel continually becomes blocked, use of short run is essential.

2. Observations During Drilling:

The ease or difficulty of drilling and speed of drilling at different depths shall be carefully recorded during drilling. The returning drill water shall be kept constantly under observation and its character such as, its clarity or its turbidity; its colour etc. shall be recorded. If the returning drill water is turbid, the same shall be collected and the suspended matter is allowed to settle. The settled matter shall be preserved in a suitable container and kept in the core box at the appropriate place corresponding to the depth from which it is obtained. Depth of drill water losses, partial or full shall be accurately recorded during drilling. Whenever a new diamond bit is taken for use, the change of bit shall be indicated appropriately in the Daily Report. Drilling time or penetration time for each bit shall be recorded and indicated in the column for time required for drilling.

3. Extraction of Cores:

Core barrel will be held horizontally, while cores are extruded, which will be by applying a constant pressure without vibration and in a manner to prevent disturbance to cores. Each and every piece of core shall be sequentially numbered from top downwards as soon as the core pieces are removed from the core barrel. The serial number of each piece shall be neatly painted on the respective piece with good quality paint/ permanent marker. Arrows indicating the lower end of the piece and the number of drill hole shall also be painted on each core piece. Sketch pens, marker pens, ball pens, lead pencils etc. shall not be used for marking the core pieces. Length of each core piece shall be measured and recorded.

4.2.3.8. Storing of Core Pieces and Core Boxes

All core pieces shall be placed in core boxes in a serial order in correct sequence from top downwards. For each bore hole there will several core boxes. Core shall be placed in the box with the shallowest core to the top left-hand corner and for every compartment the shallower core shall be to the left, the top being considered adjacent to the hinged section. Core boxes at the end of each day's work shall be stored. Core boxes shall be made according to specifications laid down in IS 4078:1980. If the cores of size larger than NX are extracted, these cores shall be kept in core boxes of appropriate size. Each of such boxes shall be sequentially numbered in the sequence in which the boxes are to be used to store core pieces. The following shall be neatly painted on the lid of the core boxes, both on outside and inside and inside surfaces using pre-cut stencils and good quality enamel black paint.

Name of the project:	Goregaon Mulund Link Road
Location of bore hole:	19⁰__'__._"N 72⁰__'__._"E
Core Box No. :	BH__ CB__
Depth of core contained:	From __m to __ m

The bore hole number and the core box number shall be painted on all four vertical sides outside, with good quality enamel black paint.

4.2.3.9. Photographing of Core Boxes

Colour photographs of cores in each box shall be obtained as soon as practicable after completion of a borehole. Photographs are necessary to permit the engineer or geologist to review the nature of rock as required at subsequent times. Further photographs will provide a record of the correct sequence of the core pieces in case the core box is spilled accidentally or cores are not returned to the proper place after examining them. The photographs shall be taken from directly above the box with the lid open. The format for reference number for each photograph shall be given below

Photograph No. /Borehole No/ Core box No __ of__

4.2.4. Examination of Soil Samples, Rock Cores & Final Bore Hole Log

On completion of each bore hole, the soil samples and cores examined and logged by his Engineering Geologist. For each bore hole, the final log of sub-surface explorations shall be prepared Engineering Geologist, which shall comprise of the following:

- Bore log in overburden soil:
- Geological log of the Rock.

These final logs shall be prepared on the basis of the Daily Drill Reports, the Consolidated Drilling Log, visual examination of the soil samples and rock cores and laboratory testing data. Boring logs shall contain the date when the boring was made, the location of the boring with reference to the co-ordinate system used for the site, the depth of the boring and the elevation with respect to a fixed datum. The logs shall also include the elevation of the top and bottom of boring and the level at which water table and the boundaries of soil and rock strata were encountered. The classification and description of soil and rock layer, percentage recovery of rock core, quality of core lost or not recovered for each core interval or drill run and Rock Quality Designation (RQD). Results of field permeability tests and bore hole logging shall also be included on logs. The type of tools used in

making the boring shall be noted. Notes shall be provided of everything significant to the interpretation of sub-surface conditions such as lost drilling fluid, rod drops and changes in drilling rate. Incomplete or abandoned boring shall be described with the same care as successfully completed borings. The geological log of bore holes shall be prepared in line with IS: 4464-1985.

4.2.5. Plugging Of Bore Holes:

The boreholes except that meant for future monitoring of ground water level, shall be backfill with available soil in such a manner that no subsequent depression is formed at the ground surface due to settlement of the backfill.

4.2.6. Ground Water

Ground water table was observed after dewatering the borehole by suitable method and waiting for time period of 24 hours to allow for recuperation of ground water. Ground water samples were collected for chemical analysis [IS: 3025 (Part - 24 and 32)] to determine their pH, Sulphate and Chloride content. This is useful to predict corrosive effect of ground water on structures.

4.2.7. Field Tests

Following field tests were conducted to evaluate design parameters,

1. In-situ permeability test by Pump-in Test
2. Pressure meter test in rock/soil
3. Standard Penetration Test
4. Seismic Refraction Test
5. Electrical Resistivity

4.2.7.1. In-Situ Permeability Test

Field Permeability test are carried out to determine permeability of each subsurface strata encountered up to bed rock as well as to ascertain overall permeability of strata. The tests shall be carried out in standard drill holes where subsurface explorations for foundations will be carried out by drilling. The tests carried are either pumping in or pumping out type. When the stratum being tested is above water table, the pumping in test is carried out and when it is below water table then either pumping in or pumping out test may be conducted.

There are a number of methods of determining field permeability in overburden.

1. Pumping In Tests
   a) Constant head method
   b) Falling head method
2. Pumping Out Tests

Applicable Standards

1. IS 5529: Code of Practice for In-Situ Permeability, (Part I) – Tests in Overburden.
2. Section-V, Technical Specifications, Tender No-NPCIL/CIVIL/GAPP-1&2/2011/TEN/16

A. Pumping-In Test

The tests give permeability of the material in the immediate vicinity of the bottom of the drill hole. It may thus be used for determining the permeability of different layers in stratified foundations and thus check the effectiveness of grouting in such formulations.

B. Falling Head Method

The test may be conducted both above and below water table but is considered more accurate below water table. It is applicable for strata in which the hole below the casing can stand and has low permeability; otherwise the rate of fall of the head may be so high that it may be difficult to measure.

1. Equipment

- A drilling or boring set
- Driving pipe casing
- A pumped water supply or a number of drums of 100 litres capacity full of water
- Delivery hose pipe
- Arrangement for measuring water level in the test holes by water level indicator.
- Miscellaneous equipment- stop watches graduated cylinders pressure gauges, water meter and enamelled bucket for measuring discharge.

2. Test depth & Test Section:

Test section shall be selected between 1m and 3m based on the soil strata encountered.

3. Procedure:

The procedure is accordance with IS-5529 (Part I)

- Borehole should be drilled up to the bottom of the test horizon and the casing should be simultaneously driven upto top of the test section as the drilling of the hole is in progress.
- Wash the bore hole.
- Measure the depth of natural water table if any prior to the test.
- Fill the casing with water upto the top.

- Using stop watch and water level indicator, measure drop of water level in the casing after 1, 2, 5, 5.0, 7.5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 and 60min.
- If permeability of soil is relatively high, fill up the casing with water before each observation and average permeability is worked out.

4. Records and Calculations:

The permeability by falling head method in an uncased hole should be obtained from the following relation determined by,

$$K = (d^2/8L) \times \log_e (L/R) \times \{(\log_e (h_1/h_2))/(t_2-t_1)\}$$

Where,

K = coefficient of permeability in cm/sec,

d = diameter of stand pipe in cm

L = length of test zone in cm

h1 = head of water in casing pipe at time t1 minutes in cm

h2 = head of water in casing pipe at time t2 minutes in cm

R = radius of hole in cm.

4.2.7.2. Pressure meter Test in Soil & Rock

The objective of the tests is to determine the deformation modulus, shear modulus, creep pressure and limiting pressure of in-situ soil stratum. The aim of the tests is to determine the in-situ deformation modulus of soil using an expanding probe to exert pressure on the wall of a drill hole. The resulting diametric hole expansion (dilation) is determined from measurements of the volumetric expansion of the probe. Deformability characteristics of the soil stratum at the dilatometer location may be calculated from the relation between pressure and dilation.

Applicable Standards: IS 12955: (Part 1&2) - In-Situ Determination of Rock Mass Deformability Using A Flexible Dilatometer.

1. Site Calibration:

The internal displacement callipers and the rubber membrane will be calibrated at regular, appropriate interval throughout the field work. The callipers will be calibrated over the membrane displacement/expansion range using calibration ring. A thickness variation calibration will be regularly performed on rubber membrane, pressurized over the testing pressure range within a rigid steel calibration sleeve.

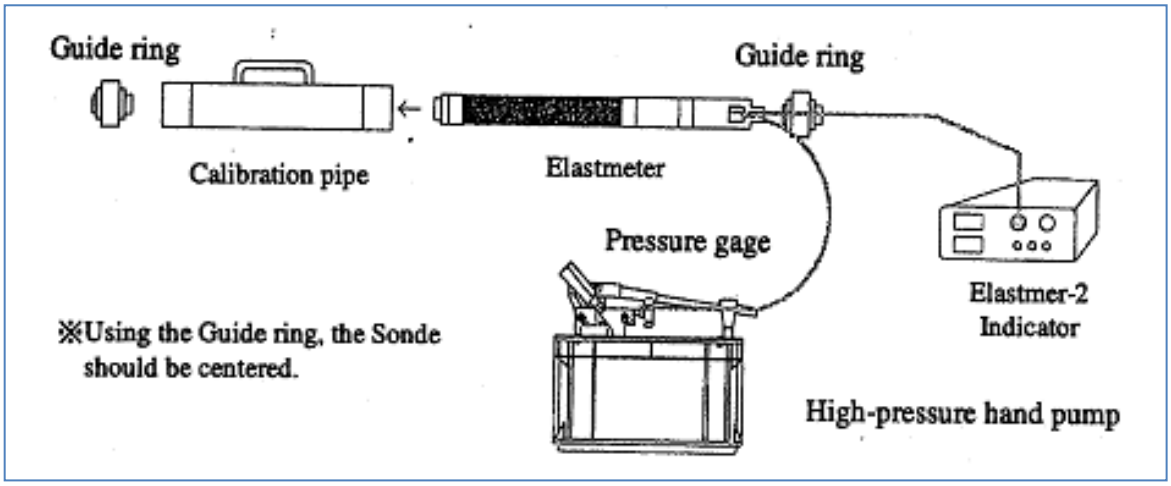

Figure 4-2: Calibrating the Pressure output

The internal displacement callipers and the rubber membrane will be calibrated at regular, appropriate interval throughout the field work. The callipers will be calibrated over the membrane displacement/expansion range using calibration ring. A thickness variation calibration will be regularly performed on rubber membrane, pressurized over the testing pressure range within a rigid steel calibration sleeve. The results of the calibrations shall be used, in accordance with manufactures calculations procedures, to apply correction to the borehole wall deformation readings, to account for membrane thickness variation during testing.

2. Test Procedure:

- NX size bore hole will be drilled up to the desired depth. Casing will be provided up to suitable depth in the borehole.
- Calibrated probe will be placed at desired test depth and pressure will be applied in equal increment of 0.5 MPa.
- At each load increment the pressure will be held constant for the period of 60 second.
- Application of pressure increment will be up to failure point or maximum specified pressure (100 bars).
- The test will be terminated at the maximum pressure were no further increase in the pressure observed with increase in the deformation reading.

3. Interpretation:

- The ground coefficient (K) & Pressure-meter modulus (Ep) will be determined from the liner a pseudo elastic deformation zone of the load deformation curve as follows

$$K = \Delta P/\Delta R$$

$$E_p = (1+\mu)*R_{av}* K$$

Where,

K = Ground coefficient ($MN/m^{2)}$

ΔP = Pressure interval (MPa)

ΔR = Radius interval (m)

E_p = Pressure-meter Modulus (MPa)

μ = Poisson's Ratio

R_{av} = Intermediate Radius (m)

- The volume changes at 60 sec. Vs. pressure will be plotted gives in situ stress strain curves.
- Recommendations will be given regarding deformation modulus.

4.2.7.3. Standard Penetration Test

Explained in the Drilling section.

4.2.8. Geophysical Test

1. Objectives of Seismic Refraction Test

To carry out geophysical investigations (ERT and SRT) for GMLR Road tunnel Project through Sanjay Gandhi National Park.

- Length of the twin tunnel : 4.5 km (approx.)
- Depth of interest: Minimum 30 m.

There will be 2 parallel lines (One line on each tunnel) along the tunnel alignment for SRT. The main objectives required are:

Soil/Rock Interface:

Precise determination of Soil layer thickness and the rock head level, The bedrock profile, quality of rock with respective to depth & Precise determination of Water table.

Rock quality:

Weathering of rock, fractured and weak zones, To detect anomalous zones or water bearing formation (any localized area where large volume of water inflows expected during excavation), Loose pocket of rock OR Inter trappean beds (Completely weathered/ clay pocket/shale rock between two continuous basalt flows), Discontinuities or jointing nature of rock (Like Highly/moderately jointed rock) & Information on weak zones/buried channels in b/w the competent rock.

Rippability Assessment:

Velocity profile with respect to depth, Localization and identification of different lithological/geological units, A drawing showing till what depth, rock can be excavated and from which depth, blasting is required, A continuous rock profile for tunnel length & Q value estimation w.r.t depth (Empirical correlation).

Note: A 3-D profile at the end showing all the anomalous zones/ water bearing formation with respect to depth.

4.2.8.1. Seismic Refraction Test

The seismic refraction method is a geophysical method to determine the subsurface velocity structure through an analysis of the seismic waves that return to the ground surface after refraction at the boundaries of subsurface layers with different seismic velocities. It has been widely used for many years in civil engineering applications.

Although there are several types of seismic refraction methods depending on the survey objectives or targets, the most common methods are based on the first arrivals of P-waves. The digital measuring equipment for seismic refraction surveying is becoming increasingly more compact and offers multi-channel recording capability.

Data processing techniques increasingly employ automated analysis. In addition, seismic tomographic data processing techniques have to derive more detailed velocity structures. The seismic refraction method is based on the analysis of artificially created seismic waves that are generated from the surface. Those waves travel to a particular depth and return to the surface after refraction at the boundaries of layers with different seismic velocities.

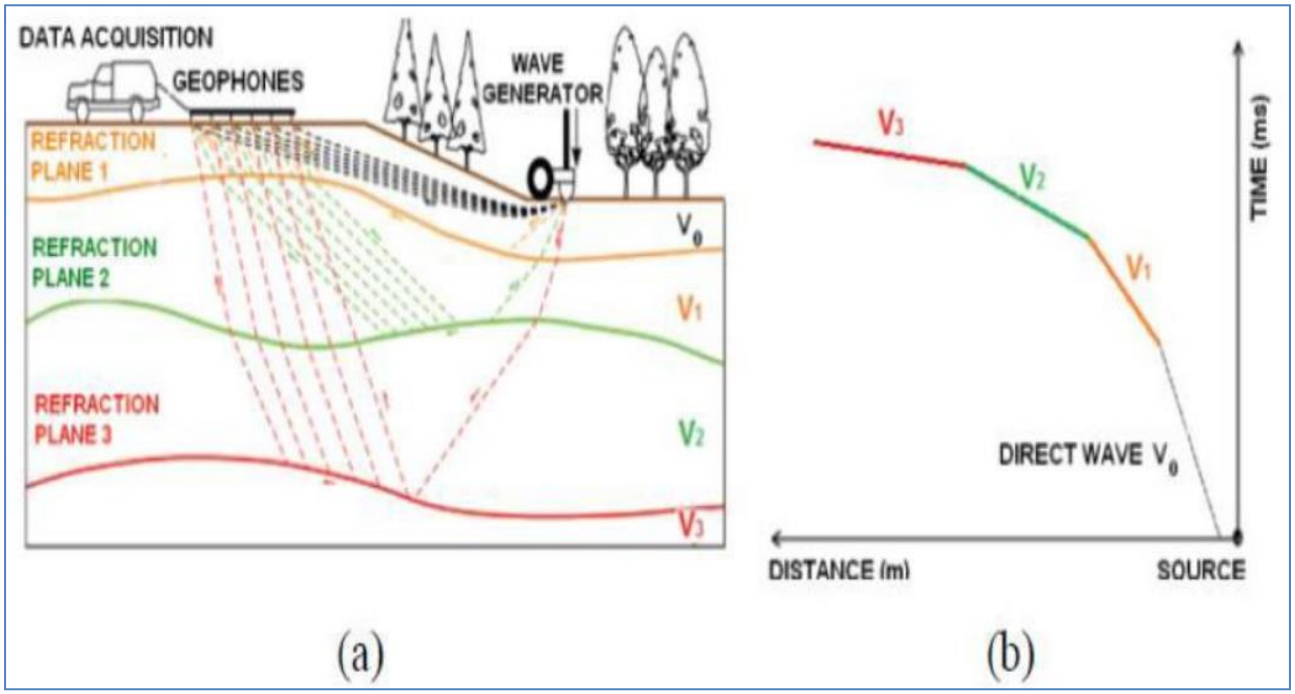

Figure 4-3: Seismic Refraction Method (a) Data Acquisition (b) Distance -Time diagram

1. Applicability

The seismic refraction method is applicable in situations where the P-wave velocity increases with depth. Since this is the usual situation in the near surface in a rock site, the method has been used widely for site characterization in road construction, dam construction and tunnelling projects.

The depths to the various layers can be determined and the seismic velocities estimated by the method can be utilized to determine lithology, rock strength, and crack density, degree of weathering or metamorphism, and locations of fault zones. Some of the applications are:

- Stratigraphic mapping, Estimation of depth to bedrock.
- Estimation of depth to water table, predicting the Rippability of specific rock types.
- Locating sinkholes, Landfill investigations & Geotechnical investigations

2. Planning

A. Study of existing information

In this study, a review should be made of existing information including borehole data, the topography, the geology, the depth to the water table, the degree of weathering, the possibility of thin layers and layers associated with velocity inversions, and dips of possible faults at the survey site.

B. Arrangement of the survey line(s)

The survey lines should be prepared in consideration of the survey objectives, the depth of investigation, the geological conditions and the topography. The location and length of the survey

lines, the source and receiver intervals and the maximum offset distance between sources and receivers are basic parameters in planning a seismic refraction survey.

The seismic refraction method can accommodate rough topography but it is desirable to arrange survey line(s) to avoid extremely rough terrain.

Because the seismic refraction method derives two-dimensional (2-D) depth profiles, the survey lines should be arranged perpendicular to the strike of the target geological structures and boundaries. Setting up a survey grid will provide tie lines and facilitate delineation of targets in three dimensions.

The minimum length of the survey line is determined by the depth of the expected targets and the velocity structure. As a rule of thumb, this is generally around 5–10 times of the depth of investigation.

C. Intervals of source and receiver points

In most civil engineering applications for the seismic refraction method, the depth of investigation is within several tens of meters. In these cases, 10-m geophone intervals are usually adequate but for shallower targets, this interval can be reduced to 5 m or less.

During the survey, the geophones will be arranged in spreads of typically 12 or 24 geophones. These will be used to simultaneously measure the seismic waves arriving from a single source. For long lines, spreads should be run end to end.

For the deepest layer (the main refractor), this coverage is mainly achieved by the remote shots. For the intermediate layers, the coverage is obtained using sources within the spread. It is generally recommended that these source points should be at intervals of 30-60 m.

D. Types of seismic sources

Dynamite is an excellent seismic source, especially for deeper exploration. Shots need to be buried to ensure maximum coupling of energy into the ground and to ensure that there is no blow-out causing surface damage and creating safety issues.

During last two decades, powerful mechanical seismic energy devices like weight drops accelerated by rubber bands or vacuum and mini-vibrators have been developed. These devises may be used for surveys where the depth of investigation is up to several hundreds of metres.

In case of shallow surveys where the depth of investigation is less than 20 m, hammers and weight drops can be used as alternate, non-explosive sources.

3. Field operation

A. Equipment:

Survey equipment generally consists of geophones (receivers), geophone cables with connecting take outs, extension cables, a data acquisition system (including amplifiers, display and recording facilities), and a detonating box (blaster). Geophones typically have a natural frequency of 30 Hz or less and are damped to ensure that there is not a strong resonance at the natural frequency. All instruments should undergo routine checks prior to use.

B. Positioning of the survey line

The locations and elevations of the survey line, the geophones and shot points need to be determined by appropriate surveying. If there is more than one spread of geophones in a line, the ends of each spread should overlap so that continuity in the travel time data can be preserved.

C. Preparation for the measurement

To obtain good signals, all geophones should be planted firmly into the ground. They should be connected via take-outs to the geophone cable so that there is the same polarity for all geophones. The instant of shot detonation starts the recording process. This time can be transmitted from the shot point via radio or via a cable.

D. Measurement

The observer needs to maintain an observer's log detailing the locations of all geophones within a spread, the locations of the shots, the shot record numbers and the depth of each shot hole. The observer needs to monitor amplifier gains and/or filtering parameters to ensure the quality of the recorded data. If necessary, repeated measurements should be made to obtain better quality data.

E. Completion of survey

At completion of the survey, all equipment needs to be retrieved and cleaned. The site needs to be rehabilitated in accordance with the client's requirements. The observer needs to ensure that all seismic data, observer's logs and relevant survey information is properlyarchived and available for data processing and interpretation.

4. Data processing

A. Arrangement of the field data

All field data—seismic recordings (shot records), observer's logs and survey information need to be organized and compiled for a processing sequence of the type illustrated in Fig. 4-4. This is a standard processing sequence. There are other ways of processing and interpreting data, for example by using ray tracing techniques and through tomographic inversion.

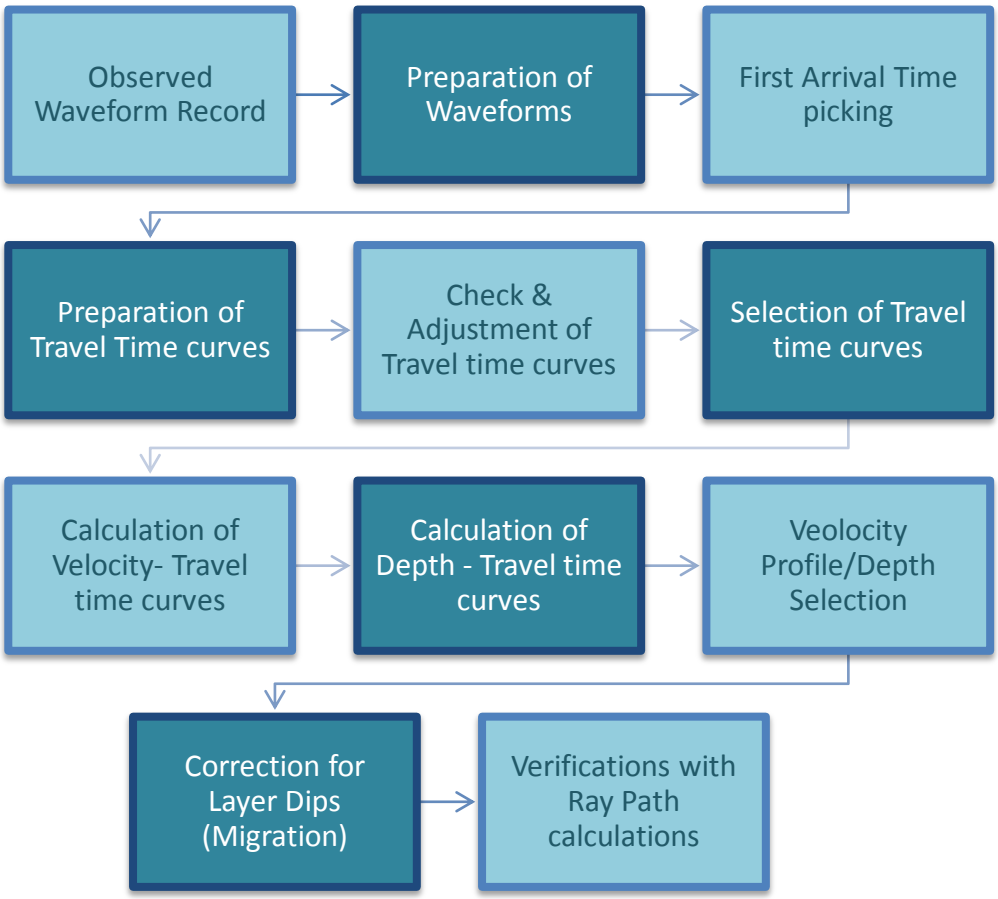

Figure 4-4: Flow chart for Data Processing

B. Picking first arrivals

First of all, the first arrival times of the refracted P-waves are picked on the shot records in order to construct travel time curves. Usually, first arrival times are picked with a time resolution of around 1 ms. For a high precision survey, time resolution is often less than 0.1ms. Picking can be done manually on printed seismic records or using automatic and interactive computer techniques. An up hole correction is required to compensate for the burial of the shot.

C. Construction of the travel time curves

Based on the distance along the survey line, the receiver intervals (geophone spacing) and the first arrival times, travel time curves are plotted with the horizontal axis being distance and the vertical axis travel time. For hard copy travel time curves, typical scales are 1/500 or 1/1000 for the distance axis and 5 or 10ms to the cm for the vertical axis, see Fig. 4-5.

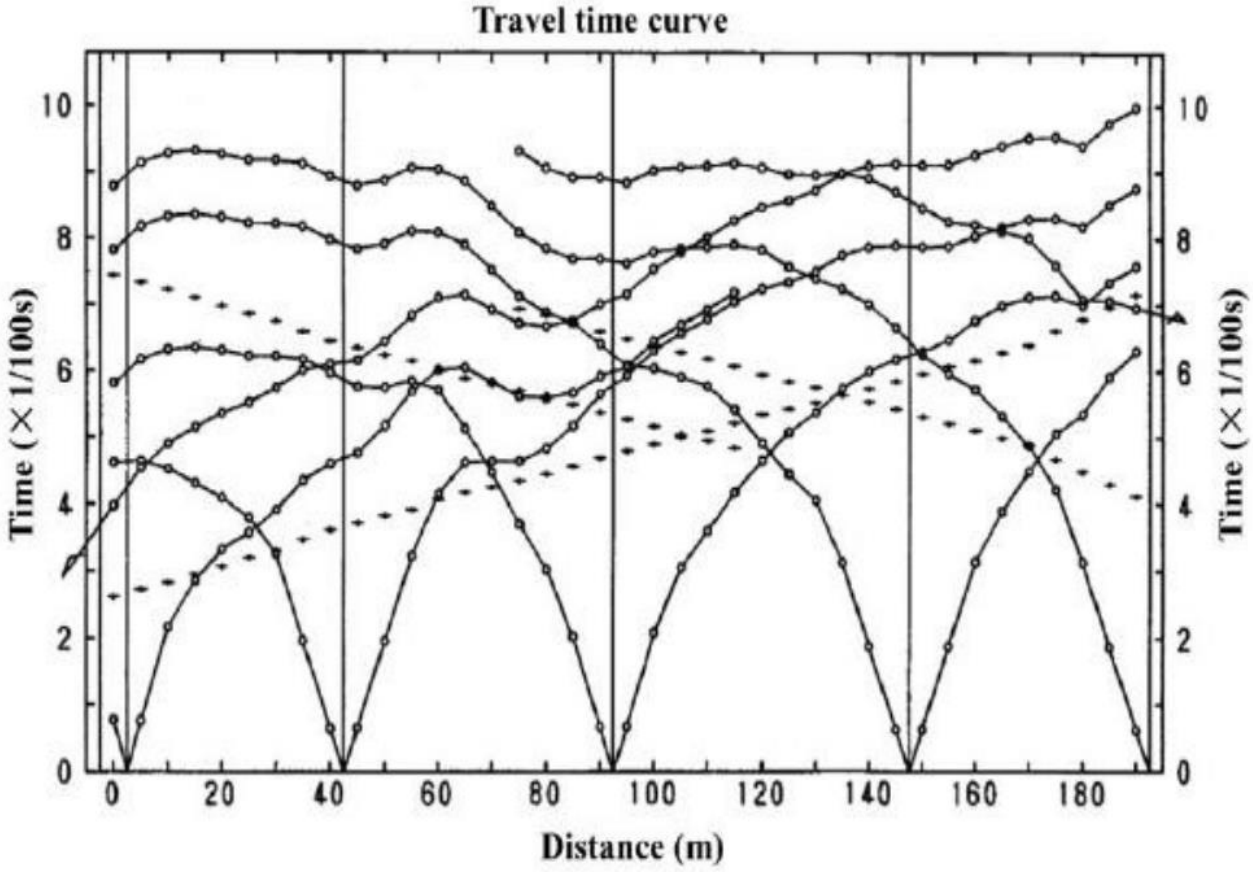

Figure 4-5: Example of travel time curves

D. Checking of the travel time curves

The travel time curves should be checked and corrected if necessary, on the basis of the following:

- Reciprocity of the travel times. (Travel times between a pair of shot points should be equal.
- At each shot point, coincidence of intercept times from each of the refractors.
- Parallel travel time curves when different shots provide travel times to the same refractor at the same locations. Bulk shifts in travel times can be used if it is decided that there is a constant delay,

due to errors in the up hole correction. Individual travel times may need to be adjusted after further consideration of the shot records.

E. Derivation and verification of the velocity profile

The number of refractors present in the travel times is determined on the basis of the number of changes in slope and the degree of parallel behaviour observed on the travel time curves. The 2-D velocity profile (depth section) under the survey line is then obtained by analysing the travel time curves using techniques such as the generalized reciprocal method (GRM) and Hagiwara's method.

An intermediate step for these methods involves determining the velocities of the P-waves in each of the refracting layers present. Verification of the depth section using ray tracing to calculate synthetic travel time curves is desirable. These can be plotted on the corresponding observed travel time curves.

5. Interpretation

I. The depth section thus obtained is generally interpreted in consideration of the survey objectives, existing data and additional or supplemental profiles if available.
II. If the travel time curves can be interpreted by two or more different models, it is desirable to report on all possible interpretations. These situations typically arise when hidden layers and velocity inversions are present.
III. The P-wave velocities obtained with a seismic refraction survey can be used as an indicator of rock quality for designing a construction such as a tunnel and a dam in rock engineering applications.
IV. Fig 4.6 shows an example of the resultant depth section.

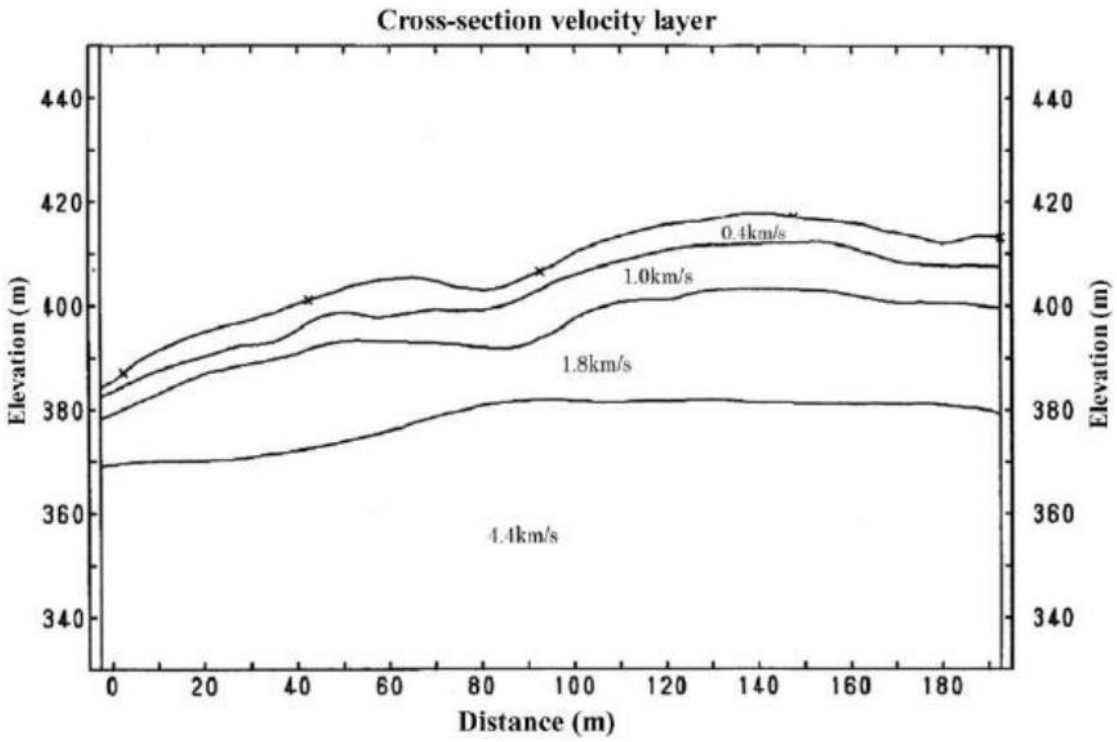

Figure 4-6: Resultant velocity/depth profile

6. Output and report

Outputs of a seismic refraction survey should include at least the following:

I. Location map of the survey site;
II. Layout of survey lines;
III. Observer's logs;
IV. Shot records (in digital form);
V. Travel time curves;
VI. Velocity profile verified with ray paths.

4.2.9. Laboratory Tests

Lab tests were conducted (as per relevant IS & ASTM code) on soil and rock samples to determine their properties which may be used for design and geotechnical evaluation.

Table 4-2 Relevant Codes for Lab Tests

Sr. No	Test Description	Relevant IS/ASTM code
A	**Rock Tests**	
1	Water absorption	IS:1124
2	Moisture Content	IS 13030
3	Porosity	IS: 13030 / IS 1124
4	Dry density	IS 13030 / IS 1124
5	Crushing strength (UCS)	ASTM – D2938
6	Point load test	ASTM – D
7	Tensile strength (Brazilian)	IS 10082
8	Durability-	IS: 10050
9	Specific gravity	IS 13030 / IS 1124
10	Abrasivity Test (Cercher Abrasivity Test)	ASTM (2010): D7625-10
11	Unconfined compression	IS: 9143
12	Point load tests	IS: 8764
13	Triaxial compressive strength	ASTM D 2664
14	Young's Modulus and Poisson ratio	IS 9221
15	Petrographic Study (Including Thin Sections)	ASTM C1721
B	**Chemical Tests**	
1	Soil Chemical Test	IS : 2720 (Part 26, 27)
2	Water Chemical Test	IS 3025 Method of Sampling & Testing

Point load strength index is often used to predict uniaxial compressive strength. On average, uniaxial compressive strength is 20 to 25 times point load strength. However, the ratio can vary between 15 and 50, especially for anisotropic rocks.

4.2.10. **Logging Procedures:**

In logging the exploration pit/borehole, a vertical profile should be made parallel with one pit wall or borehole. The contacts between geological units should be identified and drawn on the profile, and the units sampled as recommended by geotechnical consultant. Sampling should be made as per SP: 36 (Part – 2) – 1988 for disturbed samples and IS: 8763 – 1978 (sand), IS: 10108 – 1982 (fine grained soil) for undisturbed samples. Characteristics and type of soil or lithologic contacts should be noted. Variation within the geologic unit must be described and identified, and indicated on the pit /borehole log wherever the variation occurs. The sample locations should be shown in the respective log and their location written on a sample tag showing the station location and elevation. Ground water should also be noted on the exploration pit/borehole log.

4.3. REGIONAL GEOLOGY

Mumbai & nearby region are located in the great volcanic formation building up the Deccan plateau. The broad physiographic feature of the Mumbai region is broad and flat terrain flanked by north – south trending hill ranges. The hill ranges from almost parallel ridges in the eastern and western part of the area. The Powai – Kanheri hill ranges are the other hill extending in the eastern and central part running NNE – SSW.

Malbar, Colaba, Worli and Pali hills are the isolated small ridges trending north – south in the western part of the district. There are a number of creeks, dissecting the area. Among them, Thane is the longest creek. Other major creeks are Manori, Malad and Mahim which protrude in to the mainland and give rise to mud flats and swamps.

A wide variety of basalts and associated rocks such as volcanic breccias, black tachylytic basalts, red tachylytic basalts etc. occur in the area covered by Deccan trap basalts.

Most basalts are either compact i.e., with no gas cavities, or amygdaloidal with gas cavities filled with secondary minerals, and vesicular basalts with empty gas cavities are rare. Zeolites are the commonest secondary minerals filling gas cavities, though silica, calcite and chlorophacite also occur as infillings. The basalt flows are essentially horizontal over most of the area and it is only at a few places such as Panvel, Mumbai, Western Saputaras, Khandesh etc., that the flows have been disturbed from their original horizontality and show gentle dips. A major monoclinal flexure called the Panvel flexure is supposed to be existing along the west coast, though there is no field evidence to prove its existence. However, lavas in large areas, which should have been dipping west if the flexure existed, have actually been observed to be horizontal, and over large areas, there are no observations of dips at all. Hence there is no field evidence to prove westerly dipping lavas and the Panvel flexure obviously does not exist at all.

Though faults are rare, vertical or steeply inclined fractures along which movement has taken place are widespread in the western parts of the Deccan trap outcrop. Water seeping along the crack brings about decomposition of basalts on both sides and the fracture is marked by a band of decomposed material 3 to 30 mm wide.

Because of the closely spaced vertical planes of separation of the sheet jointing, the zone of decomposition of a fracture looks superficially like the shear zones of tectonic areas, and as a result, the fractures are commonly described as shear zones. However it must be borne in mind that the vertical planes of separation seen in the fractures are not planes of shear but are planes of sheet

jointing resulting by the decomposition of basalts, and no true shear zones occur in the Deccan trap area. The geological map of the area is shown in Fig. 4-9. After this discussion on the general geology of the Deccan trap area on a macro scale, it is only appropriate to discuss the engineering geology of Project area and its peculiar features.

Geologically, of the project area presents a complex lithological combination showing large heterogeneity. Major rock types occurring in the area are fine grained, greenish basalt to black colored, aphastilite. Compact basalt and weathered amygdaloidal basalt are also found, characteristic of the Deccan trap. They are associated with acidic and basic tuffs, volcanic breccia with fullaceous matrix, Trachytes and also occasionally, rhyolites. Inter trappean beds representing breaks in the tectonic volcanic activities are seen in the western ridges. Basaltic flows and inter trappean beds show westerly dip of 5° to 12°. These flows and pyroclastic rocks have been intruded by dolerite and basaltic dykes.

Kordiwadi Kandivali, Marve and Manori area. Marve Manori area is separated by a creek. Eastern hill ranges show the presence of yellowish brown volcanic breccia lateralized at the top. Basaltic fragments appear to be embedded in this rock.

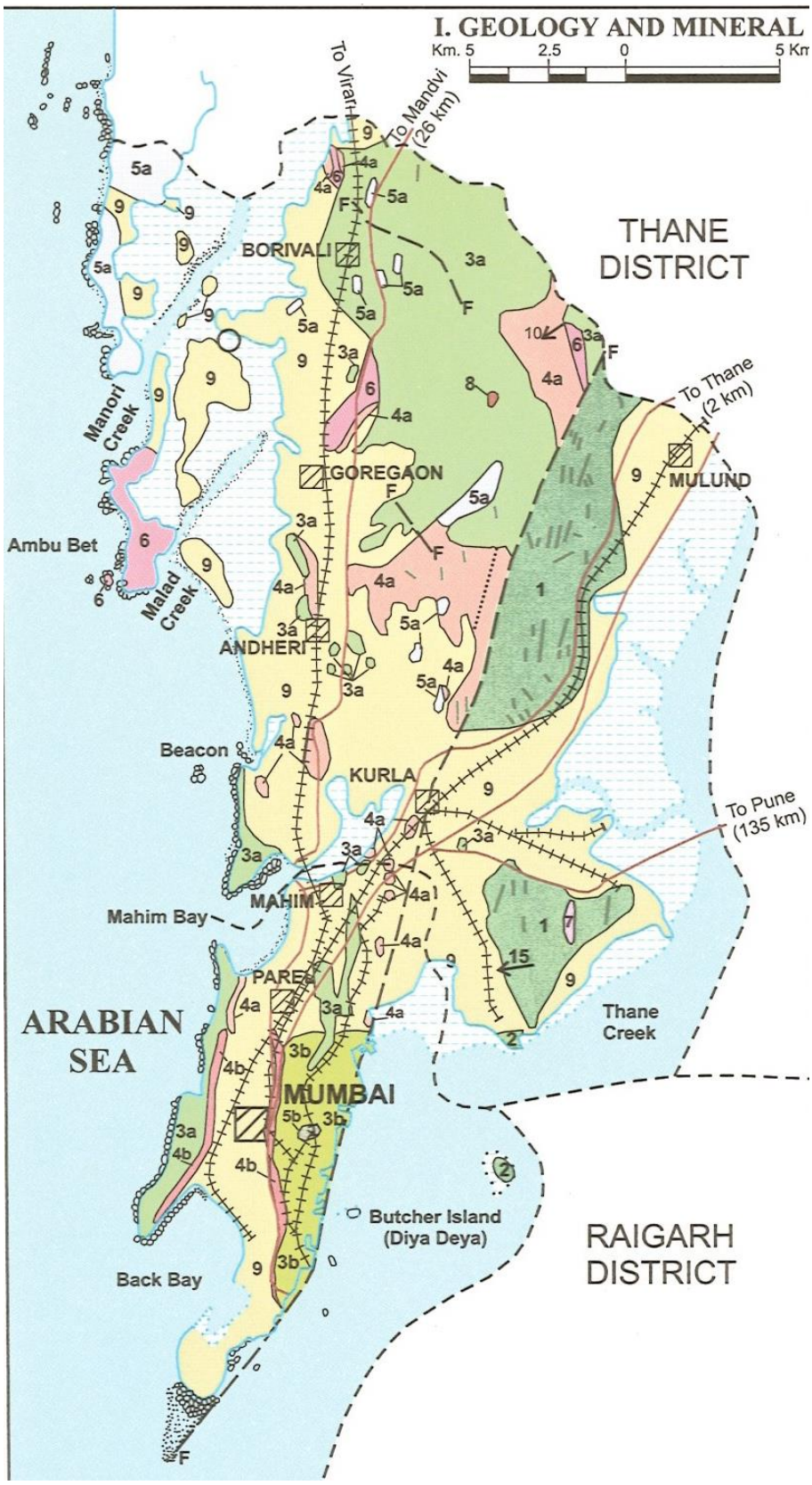

Figure 4-7: Project area Geology

Legend			
F F	Fault	9	Alluvial
	Fracture/ Shear Zone	8	Laterite
15	Gradient/ Dip of Flow		Basic Dykes
	Drainage	7	Pyroxene megacryst Rock
	Mud	6	Trachyte
	Rock	5a 5b	Rhyolite hybridised acid
	Shoal	4a 4b	Agglomerates & Tuff Intetrappean

Other types of rocks are volcanic grey ash, grey ash, hard and soft tuffs. Small basaltic dyke appears shows the presence of basalt and volcanic breccia.

Though the low lands lying between the two ridges do not show any exposures, cutting and excavations made for various purposes reveal brownish and grey clay, greyish, brownish and greenish tuff, breccia, ash and other pyroclastic material along with highly weathered basalts and inter trappean.

Coastal areas on the western shore of Mumbai consist of sandy beaches mixed with silt with shale fragments. The western shore is exposed to intense wave action of Arabian Sea resulting in the formation of sandy and rocky beaches. It is known that near the Gateway of India, the sea meanders inside, and in the process intense wave action as noted on the western coast of Mumbai Island calms down. The relatively clam eastern shore line particularly, north of Mazagaon exhibits mud flats and salt pans. The thick blue clay layer, very soft in nature is the result of silting over the geological years as a consequence of relatively calm sea which allowed finer clay particles to settle, a fact clearly observed during the investigations. This clay layer is followed by a very thin layer of coarse black sand at places, hardly about meter in thickness. By the nature of its deposition the clay is unconsolidated and very soft in nature.

Based on the assessment of boreholes, the sub strata can be marked in following lithological units.

- Soil Overburden

- Rock Strata

4.3.1. Soil Overburden

From existing ground level till 2.5 m, layer consists, medium dense sandy clay or stiff clay having light brown colour and is located majorly at 2.5 to 4m below ground level. The fore mentioned is underlain by stiff to very stiff sandy clay. This layer has found to have small amount of sand/ gravel at inception. Further, presence of residual soil due to complete weathering of In-Situ rock strata has been observed and is expected to behave as soil.

4.3.2. Rock Strata

Below Soil overburden, rocky strata of different weathering grades, ranging from Fresh (Grade I) to completely weathered (Grade V) have been encountered, consisting predominantly Breccia and Basalt. A typical feature of the lava flows in the area is a highly vesicular bottom layer having closely spaced horizontal joints and low thickness. The vesicles are generally filled with secondary minerals and green earths. In such cases, they do not serve as aquifers. However, if such vesicular zones are weathered (as the case is, in several parts), they become moderately permeable, and if the vesicles are not filled, they become highly permeable aquifers. This typical 'Pahoehoe' flow comprises of a basal vesicular zone, followed by a middle relatively massive portion followed by a vesicular top. These vesicles are generally not inter-connected and thus there is a variation in the water holding capacity from the base to the top of the flow. Ground water exists in fractures, joints, vesicles and in weathered zones of Basalt. The occurrence and circulation of ground water is controlled by vesicular unit of lava flows and through secondary porosity and permeability developed due to weathering, jointing, fracturing etc. of Basalt. The ground water occurs under phreatic, semi confined and confined conditions. Generally, the phreatic aquifer ranges down to the depth of 15.0 m below ground level.

Classification of the Weathering Grades have been made as per IS 4464- 1985. GSI has been estimated based on the discontinuity logs and bore logs and presented in this section. The Geological Strength Index (GSI) is a system of rock-mass characterization that has been developed in engineering rock mechanics to meet the need for reliable input data related to rock-mass proper-ties required as input for numerical analysis or closed form solutions for designing tunnels, slopes or foundations in rocks. The geological character of the rock material, together with the visual assessment of the mass it forms, is used as a direct input for the selection of parameters for the prediction of rock-mass strength and de-formability. This approach enables a rock mass to be considered as a mechanical continuum

without losing the influence that geology has on its mechanical properties. It also provides a field method for characterizing difficult-to-describe rock masses.

Table 4-3: Description of Rock Strata with Weathering Grade and GSI Range

Rock Mass Type (RMT)	Description of Rock Strata	Weathering Grade	Geological Strength Index Range
Basalt	Moderately Strong to Strong, Very fine Grained, Moderately to widely spaced joints, hard, compact, slightly weathered Dark Greenish to Dark Greyish Basalt	II	50-66
Breccia	Moderately Strong to Strong, moderately to widely spaced joints, hard, compact, Unweathered to Slightly weathered Dark Greyish Volcanic Breccia	I	53-67
	Moderately Strong, moderately to widely spaced joints, hard, having Good Strength, Slightly weathered Grey to Dark Greyish Volcanic Breccia	II	47 - 64
	Moderately Strong to moderately weak, moderately to closely spaced joints, moderately weathered Dark Greyish Volcanic Breccia	III	32 - 58
	Weak to very weak, Highly weathered Dark Greyish Volcanic Breccia	IV	27-38

4.3.2.1. Deccan Trap Geology

A wide variety of Basalts and associated rocks such as volcanic breccia, black trachytic Basalts, red trachytic Basalts etc. occur in the area covered by Deccan trap Basalts. Most Basalts are either compact i.e., with no gas cavities, or amygdaloidal with gas cavities filled with secondary minerals, and vesicular Basalts with empty gas cavities. Zeolites are the commonest secondary minerals filling gas cavities, though silica, calcite and chlorophacite also occur as infillings.

The Basalt flows are essentially horizontal over most of the area and it is only at a few places such as Panvel, Mumbai, Western Saputaras, and Khandesh etc., that the flows have been disturbed from their original horizontality and show gentle dips. A major monoclinal flexure called the Panvel flexure is supposed to exist along the west coast, though there is no field evidence to prove its existence.

However, lavas in large areas, which should have been dipping west if the flexure existed, have actually been observed to be horizontal, and over large areas, there are no observations of dips at all. Hence there is no field evidence to prove westerly dipping lavas and the Panvel flexure obviously does not exist at all. Though aults are rare, vertical or steeply inclined fractures along which movement has taken place are widespread in the western parts of the Deccan trap outcrop. Water seeping along the cracks brings about decomposition of Basalts on both sides and the fracture is marked by a band of decomposed material 3 to 30 mm wide.

The zone of decomposition of a fracture looks superficially like the shear zones of tectonic areas, because of the closely spaced vertical planes of separation of the sheet jointing, and as a result, the fractures are commonly described as shear zones. However, it must be borne in mind that the vertical planes of separation seen in the fractures are not planes of shear but are planes of sheet jointing resulting by the decomposition of Basalts, and no true shear zones occur in the Deccan trap area. The geological map of the area is attached.

4.3.3. Hydrogeology

Hydrogeology data was obtained from the ground water information report of the Greater Mumbai District published by the Ministry of Water Resources, Central Ground Water Board, and Government of India. As per this report, the hydrogeology of the Mumbai region is summarized as follows:

Table 4-4: Water table level Mumbai Region by Ministry of Water Resources, Central Ground Water Board, and Government of India

Water bearing formation	Basalt – Jointed/Fractured/ Weathered/Vesicular and Massive. River/Marine alluvium
Pre-monsoon Depth of water level (May 2007)	2.77 to 6.42 m BGL
Post-monsoon Depth of water level (Nov 2007)	1.80 to 7.10 m BGL
Pre-monsoon water level trend (1998 – 2007)	Fall: 0.11 to 0.38 m/year
Post-monsoon water level trend (1998 – 2007)	Fall: 0.02 to 0.26 m/year

The entire area is underlain by Basaltic lava flows of upper Cretaceous to lower Eocene age. The shallow Alluvium formation of recent age also occurs as a narrow stretch along the major rivers flowing in the area. A

map depicting the hydrogeological features is shown in the next figure. It is convenient to study the hydrogeology of the area segregated as per the type of water bearing strata.

4.4. Factual Data and Laboratory Testing

Boreholes observations and laboratory testing results for proposed Goregaon Mulund Link Road are presented in this section. A preliminary site model was developed using the information obtained from existing data and the site visit. The model should be divided into zones of interest (i.e., geotechnical units) based on the necessary design parameters and objectives. This model will obviously change as results of the detailed investigation are collected. Following information was collected during the site reconnaissance stage.

Sr. No	Checklist Item	Sub-Item	Description
1	**Accessibility**		Easy
2	**Visit to site**	Date and time	20th Dec to 02nd March 2017
		Visitors	M/s Jay Gajanan Engineers
		Weather condition	Sunny Season
		Temperature	28 to 32^0 Centigrade
3	**Ground Cover**		Grass & Small Bushes
4	**Existing Terrain**		Hilly Terrain
5	**Site Hydrology**	Surface water conditions	N.A
		Subsurface water	Encountered in boreholes
6	**Site Drainage**		Existing drainage system
7	**Soil and rock conditions**	Surface soil	Hard Brownish Clayey Sand mixed with boulders
		Subsurface soil	Stiff Clay with Gravels
		Rock features	Weathering Basalt
8	**Investigative Operation**		Seven Boreholes
9	**Prior information**		Site Observations

10	**Geological information**		NA

Total Seven boreholes were drilled for GMLR Tunnel in present investigation. Out of Seven borehole two boreholes were drilled at Portal Locations & Five boreholes along the tunnel alignment. Boreholes were drilled up to maximum 40.0 m depth from the existing ground level. Ground water table were observed in all boreholes. Fieldwork is summarised in the following table.

Table 4-5: Summary of Boreholes

Structure	Bore Hole No.	Ground RL (m)	Coordinates		Occurrence of Rock Strata below G.L.	Final Depth of Borehole below G.L. (m)	Ground Water Table below G.L.
			Easting	Northing			
Portal Locations	BH 1	87.00	19⁰09'54.4"	72⁰ 53'26.7"	2.00	30.00	N.A
	BH 7	86.00	19⁰ 10'05.8"	72⁰ 55'45.6"	3.00	30.00	7.20
Tunnel Alignment	BH 2	117.00	19⁰ 10'08.6"	72⁰ 53'59.7"	3.00	50.00	12.30
	BH 3	112.00	19⁰ 10'17.1"	72⁰ 53'17.2"	3.50	50.50	9.20
	BH 4	89.00	19⁰ 10'24.4"	72⁰ 54'35.1"	3.00	42.00	8.30
	BH 5	71.00	19⁰ 10'29.4"	72⁰ 54'54.7"	3.00	47.50	N.A
	BH 6	89.00	19⁰ 10'21.7"	72⁰ 55'21.8"	2.10	43.00	N.A

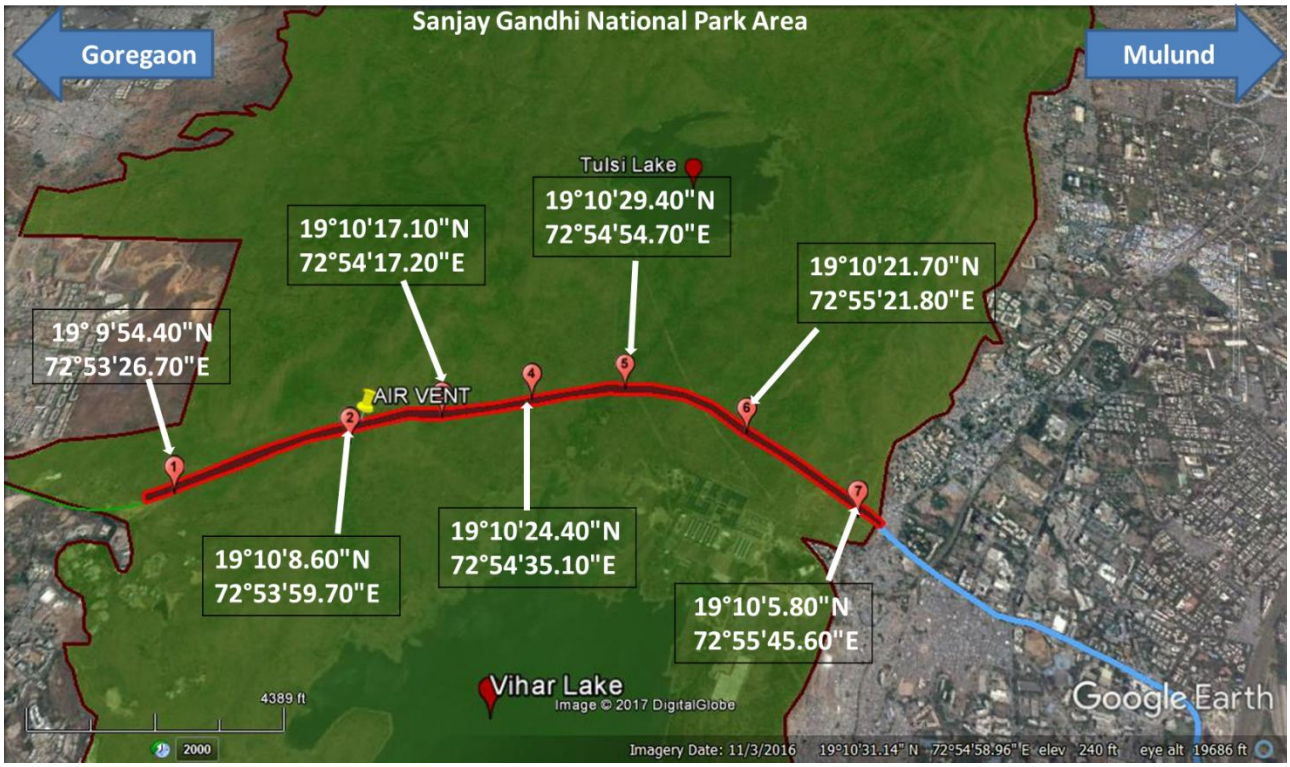

Figure 4-8: Project Location Plan

4.4.1. Geotechnical Information at Portal Location:

Review of Two borehole logs i.e. BH 01 & BH 07 indicates that the subsurface profile consists of 4 layers were inferred up to final depth of boreholes at Portal Locations. Following are the subsoil Layers.

Table 4-6: Description of Layers Portal Area

Layer Number	Description	Average Thickness (m)
Layer 1	Stiff to Hard Brownish Clayey Sand Mixed with Gravel	0.00 to 3.00
Layer 2	Moderately Weathered Basalt Rock	3.00 to 7.50
Layer 3	Slightly Weathered Basalt Rock	6.50 to 9.00
Layer 4	Fresh Basalt	13.50 to 15.00

Layer – 1 Stiff to Hard Brownish Clayey Sand Mixed with Boulders

First layer of subsoil profile is hard Brownish Clayey Sand Mixed with Boulders. This layer consists of sand and clay in varying percentage of boulders or gravels. This layer were present in all boreholes of Portal, and has an average thickness layer is 2.00 to 3.00 m in BH 01 & BH 07. Examination of sample collected that it was completely weathered rock having yellowish medium-

stiff to stiff clay mixed with gravels and boulders/ residual rock structure, which is locally known as murrum. Rock core recovery value recorded in boreholes is NIL in all drill runs. These values of rock recovery show completely weathered condition of rock stratum. Rock quality designation values recorded are zero percentage in all drill run. These indicate very poor state of fractures in rock mass. Three Standard penetration tests were conducted in this stratum to check consistency of the stratum. Reported 'N' values are varying from 10 to 21. SPT values indicate Stiff to hard consistency of the stratum. Due to the limited sample thickness Grain sieve analysis, was not conducted.

Layer – 2 Moderately Weathered Basalt

Second stratum of subsoil profile is Moderately Weathered Basalt Stratum mixed with Boulders & clay. Average thickness of this stratum is varying between 3.00 to 7.50 m in all boreholes. Examination of sample collected that it was greyish moderately weathered basalt. Rock core recovery value recorded is from 57% to 77%, these values of rock recovery show moderately weathered condition of rock stratum. Rock quality designation values recorded are from 29% to 68% in all drill runs. These indicate poor state of fractures in rock mass. One rock core was tested in laboratory. Reported Saturated crushing strength value is 299.38 Kg/cm^2. These values indicate that rock has Medium strength. The available laboratory data such compressive strength, Tensile Strength, Rock Triaxial, Slake Durability & Young Modulus test results corresponding to intact rock samples are presented here as a function of depth. Strength test results corresponding to intact rock samples are presented here as a function of depth. The available data derives from 2 sources: a) Directly, measured from the Unconfined Compressive Strength (UCS) device (IS: 9143) and b) indirectly via Point Load Tests (PLT, IS: 8764). The PLT results were correlated with the UCS results in order to obtain indirectly the σ_{ci} value of the rock samples. Correlation was implemented by comparing the UCS and PLT results from tests performed on the same rock sample. The ratio between UCS and PLT results was determined to vary between 14 and 22.

Sr No	Description of Test	Unit	Test Results
1	Unconfined Compressive Strength	Kg/cm^2	299.38
2	Water absorption	%	0.60
3	Porosity	%	1.62
4	Density	gm/cc	2.69
5	Young's Modules	Gpa	32.6
6	Poisson's ratio	--	0.23

Layer – 3 Slightly Weathered Basalt Rock

Third stratum of subsoil profile is Slightly Weathered Basalt Rock Stratum. Average thickness of this stratum is varying between 4.70 to 12.00 m in borehole. Rock core recovery value recorded is from 55% to 76%, these values of rock recovery show moderately weathered condition of rock stratum. Rock quality designation values recorded are from 30% to 75% in drill runs. These indicate moderate state of fractures in rock mass. Examination of sample collected that it was greyish colour moderately weathered basalt. One rock core was tested in laboratory. Reported Saturated crushing strength value is 272.20 Kg/cm2. These values indicate that rock has Low to Medium strength. One Pressure meter field test was conducted in these strata to get the Insitu parameters such as Subgrade Modulus, Field Young Modulus & Shear Modulus etc. One Packer Permeability test was conducted in these strata, Field Test result presented in the Lab & Field Test section. The available laboratory data such compressive strength, Tensile Strength, Rock Triaxial, Slake Durability & Young Modulus test results corresponding to intact rock samples are presented here as a function of depth.

Sr No	Description of Test	Unit	Test Results
1	Unconfined Compressive Strength	Kg/cm^2	272.20
2	Water absorption	%	1.04
3	Porosity	%	2.83
4	Density	gm/cc	2.73
5	Tensile Strength	MPa	12.88
6	Rock Triaxial Cohesion	MPa	7.86
	Angle of Internal Friction	Degree	51
7	Slake durability index I^{st} Cycle SDI	%	88.37
	Slake durability index I^{st} Cycle SDI	%	87.24
8	**Pressure Meter Test**		
	Deformation/ Pressure-meter Modulus E_p	MPa	27306.50
	Ground coefficient K	kg/cm^2	5000
	Shear Modulus	kg/cm^2	17749.22
9	Packer Permeability Test	Lugeon	4.336

Petrographic Analysis:

- BH 01, Core Sample No 51, Depth 12.0-13.50 m;
- Method of Analysis: Optical microscopy
- Rock Type: Igneous Rock
- Rock Name: Basalt

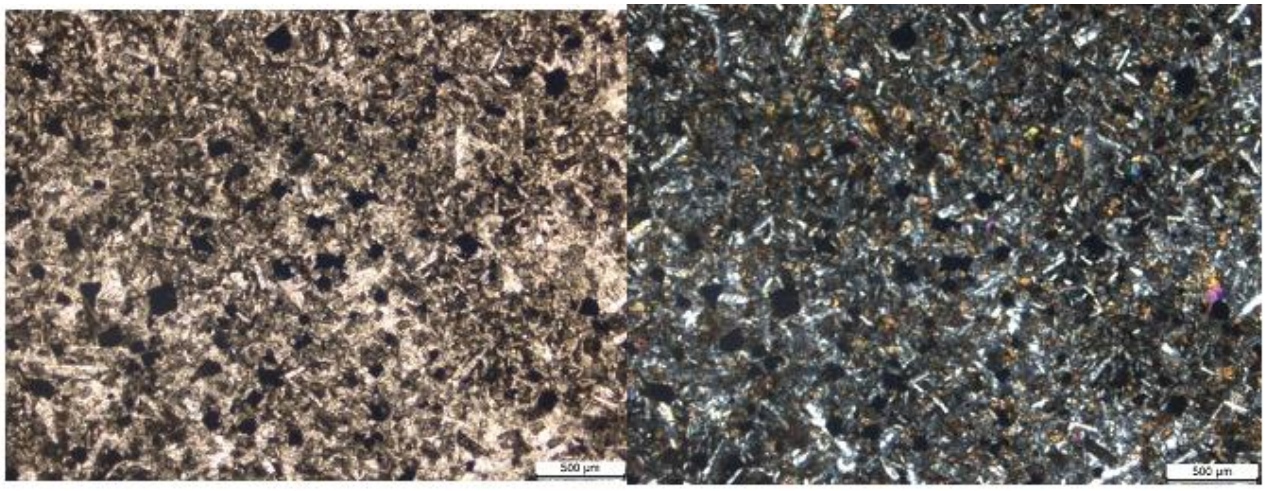

Figure 4-9: Petrographic Analysis of Slightly Weathered Core Samples

Thin section description: Under optical microscope, basaltic rock showed fine grained groundmass that was predominantly composed with plagioclase feldspar and augite minerals. Minor olivine grains and opaque minerals were also present in the groundmass. The compound silica is estimated to be 52-56%.

Minerals in the sample	Modal Analysis (%)	Granulometry		
		Max size (µm)	Min. size (µm)	Avg. size (µm)
Plagioclase	70	700	75	270
Augite	20	350	45	80
Olivine	3	-	-	-
Opaque	4	-	-	-
others	3	-	-	-

Layer – 4 Fresh Basalt Rock

Forth stratum of subsoil profile is Fresh Basalt Rock & borehole were terminated into this strata. Average thickness of this stratum is varying between 13.50 to 15.00 in boreholes. Rock core recovery value recorded is from 90% to 97%, with one value of 87% in BH 07. These values of rock recovery show slightly weathered condition of rock stratum. Rock quality designation values

recorded are from 35% to 93% in drill runs. These indicate moderate to slightly state of fractures in rock mass. Examination of sample collected that it was Fresh basalt. The basalt is fine-grained and sometimes vesicular, with principal minerals of olivine, augite and plagioclase. The volcanoes make basalt, and have formed long and persistent Deccan trap. Basalt is commonly very fine grained, and it is nearly impossible to see individual minerals without magnification. Basalt found in boring is amygdaloidal basalt with deposition of silica/quartz. Amygdaloidal basalt is formed when minerals are deposited in the almond shaped gas bubbles that were trapped in the basalt as it was cooling. These vesicles or pores were later the site for mineral precipitation. Five rock cores were tested in laboratory. Reported Saturated crushing strength value is from 283 Kg/cm^2 to 1071 Kg/cm^2. These values indicate that rock has moderate to strong strength. The available laboratory data such compressive strength, Tensile Strength, Rock Triaxial, Slake Durability & Young Modulus test results corresponding to intact rock samples are presented here as a function of depth.

Sr No	Description of Test	Unit	Test Results
1	Unconfined Compressive Strength	Kg/cm^2	283.79 to 1071.90
2	Water absorption	%	0.27 to 0.75,
3	Porosity	%	0.80 to 2.02
4	Density	gm/cc	2.71 to 3.01
5	Tensile Strength	MPa	11.52 to 12.68
6	Rock Triaxial Cohesion	MPa	6.62
	Angle of Internal Friction	Degree	52
7	Cercher Abrasion Index	--	1.06 to 1.39
8	Young's Modules	Gpa	50.29
9	Poisson's ratio	--	0.24
10	Slake durability index Ist Cycle SDI	%	95.42
	Slake durability index IInd Cycle SDI	%	94.39
11	Packer Permeability Test	Lugeon	3.586

Soil laboratory testing of the soil/ rock samples collected was carried out in laboratory of M/s OCE Projects Pvt. Ltd. Navi Mumbai & IIT Bombay. Layer wise laboratory tests results were given in the respective tables. Ground water table were encountered in the borehole at a depth of 7.20 m from EGL.

4.4.2. Borehole Log: Portal Location

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO.	: BH-1	SHEET NO.	: 1 OF 3
LOCATION	: --	DATE	: 30/01/2017 TO 12/02/2017
CO-ORDINATES	: N 19°10'21.7", E72°55'54.7"	METHOD	: ROTARY DRILLING
GROUND R. L.	: 87.00m.	CASING	: 100mm 1.50m & NX mm Ø UPTO BGL.
GROUND W. T.	: --		

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
1.00	100 mm		Brownish, CLAY with gravel	0.00	DS1								
				1.50/		15	05	--	--				
2.00			Completely weathered, brownish, ROCK	1.70	SPT1	35	55	07	09	14			
				2.00									
3.00				3.00							73	63	
4.00			Moderately weathered, greyish, BASALT								77	68	
				4.50									
5.00	NX										74	44	
6.00				6.00									
7.00											88	85	
				7.50									
8.00			Slightly weathered, greyish, BASALT								79	76	
9.00				9.00									
10.00											85	67	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-1 | SHEET NO. : 2 OF 3

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
11.00	NX		Slightly weathered, greyish, BASALT	10.50							85	67	
12.00				12.00							88	73	
13.00				13.50							87	43	
14.00													
15.00				15.00							80	39	
16.00			Fresh, greyish, BASALT	16.50							90	52	
17.00													
18.00				18.00							93	73	
19.00				19.50							97	73	
20.00											90	63	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-1 | SHEET NO. : 3 OF 3

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
21.00	NX		Fresh, greyish, BASALT	21.00							90	63	
22.00				22.50							93	69	
23.00													
24.00				24.00							91	72	
25.00				25.50							92	52	
26.00													
27.00				27.00							91	45	
28.00				28.50							97	35	
29.00													
30.00				30.00							97	48	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : BORE HOLE IS TERMINATED AT DEPTH 30.00 m. BELOW G. L.

CLIENT : **GMLR-PADECO-MCGM**			
PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP			
BORE HOLE NO.	: BH-7	SHEET NO.	: 1 OF 3
LOCATION	: --	DATE	: 15/02/2017 TO 27/02/2017
CO-ORDINATES	: N 19°10'05.8", E72°55'45.6"	METHOD	: ROTARY DRILLING
GROUND R. L.	: 86.00m.	CASING	: 100mm 1.50m & NX mm Ø UPTO BGL.
GROUND W. T.	: 7.20m Below GL.		

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm				SPT N	C R %	RQD %	OTHER TESTS
						15	15	15	15				
1.00	100 mm		Completely weathered, brownish, ROCK	0.00	DS1								
				1.50/		15	05	--	--				
2.00				1.70	SPT1	32	52	--	--	R			
3.00				3.00		05	--	--	--				
4.00			Moderately weathered, greyish, BASALT	3.05	SPT2	52	--	--	--	R	73	67	
				4.50									
5.00	NX		Fresh, greyish, BASALT with white infillings								92	92	
6.00				6.00									
7.00											99	75	
				7.50									
8.00			Moderately weathered, greyish, BASALT with white infillings								69	47	
9.00				9.00									
10.00											57	29	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-7 | SHEET NO. : 2 OF 3

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
11.00	NX		Moderately to slightly weathered, greyish, BASALT with white infillings	10.50							57	29	
12.00				12.00							73	47	
13.00				13.50							81	68	
14.00				15.00							68	53	
15.00				16.50							79	33	
16.00				18.00							87	80	
17.00				19.50							91	71	
18.00			Fresh, greyish, BASALT with white infillings								94	54	
19.00													
20.00													

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-7 | SHEET NO. : 3 OF 3

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
21.00	NX		Fresh, greyish, BASALT with white infillings	21.00							94	54	
22.00				22.50							96	93	
23.00				24.00							91	80	
24.00				25.50							96	83	
25.00				27.00							91	71	
26.00				28.50							97	60	
27.00				30.00							99	99	
28.00													
29.00													
30.00													

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : BORE HOLE IS TERMINATED AT DEPTH 30.00 m. BELOW G. L.

2.1. Core Box Photo: Portal Location

Figure 4-10: Borehole No 01 Portal Goregaon Side

Figure 4-11: Borehole No 01 Portal Goregaon Side

Figure 4-12: Borehole No 07 Portal Goregaon Side

Figure 4-13: Borehole No 07 Portal Mulund Side

Figure 4-14: Borehole No 01 Location

Figure 4-15: Borehole No 07 Location

4.4.3. Lab Test Results: Portal Location

SGS SOIL INVESTIGATION

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Test Report No: OCEPPL/TPM/12

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan Geotechnic
Thane

Sample Description : Rock,BH No-1, piece No -77- Depth 16.50 to 18.00 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	1008.20
2	Water Absorption (%)	0.28
3	Porosity (%)	0.80
4	Density (g/cc)	2.80

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Quality Manager

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Test Report No: OCEPPL/TPM/13

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock, BH No-1,piece No -99-Depth 19.50 to 21.00 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	1071.90
2	Water Absorption (%)	0.28
3	Porosity (%)	0.80
4	Density (g/cc)	2.85

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Test Report No: OCEPPL/TPM/14

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock,BH no-1,piece No -139- Depth 24.00-25.50 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	433.04
2	Water Absorption (%)	0.28
3	Porosity (%)	0.80
4	Density (g/cc)	2.85

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Page : 1 of 1

Test Report No: OCEPPL/TPM/15

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock,BH No-1,piece No -182- Depth 28.50-30.00 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	753.36
2	Water Absorption (%)	0.27
3	Porosity (%)	0.81
4	Density (g/cc)	3.01

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Test Report No: OCEPPL/TPM/37

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock, BH No-7,Piece No -38A-Depth 10.50-12.00 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	299.38
2	Water Absorption (%)	0.60
3	Porosity (%)	1.62
4	Density (g/cc)	2.69

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Test Report No: OCEPPL/TPM/36

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock,BH No-7,Piece no-78- Depth 15.00-16.50 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	272.20
2	Water Absorption (%)	1.04
3	Porosity (%)	2.83
4	Density (g/cc)	2.73

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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ISO/IEC 17025 : 2005
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Test Report No: OCEPPL/TPM/35

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock,BH No-7,Piece No-97- Depth 18.00-19.50 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	283.79
2	Water Absorption (%)	0.75
3	Porosity (%)	2.02
4	Density (g/cc)	2.71

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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OCE Project Pvt. Ltd. Navi Mumbai

Geo-mechanical tests:

Cerchar, slake durability, Rock triaxial, young modulus tests were conducted in IIT Bombay Laboratory, Summary of the tests results are as follows

Table 4-7: Tensile strength of the samples Portal Locations

Bore hole No	Depth (m)	Sample No	Tensile Strength (MPa)
BH 01	27.00-28.50	159	12.68
BH 07	11.50-12.00	45	12.88
BH 07	15.00-16.50	56	5.79
BH 07	18.00-19.50	91	11.52

Table 4-8: Cerchar Abrasion Index of the samples

Bore hole No	Depth (m)	Specimens	CAI
BH 01	22.50-24.00	R-125	1.06
BH 07	18.00-19.50	R-96	1.39

Table 4-9: Triaxial Compressive Strength (Shear strength parameters) of the samples

Bore hole No	Depth (m)	Sample No	Cohesion strength (MPa)	Angle of internal friction(Phi), degree
BH 01	15.0 - 16.50	106	7.86	51
BH 01	19.50 - 21.00	107		
BH 07	18.00 - 19.50	94	6.62	52

Table 4-10: Young's modulus and Poison's ratio of the samples Portal Locations

Bore hole No	Depth (m)	Sample No	Young's Modules (GPa)	Poisson's ratio
BH 01	6.00-7.50	23	32.6	0.23
BH 07	15.00- 16.50	79	50.29	0.24

Table 4-11: Slake durability index of the samples Portal Locations

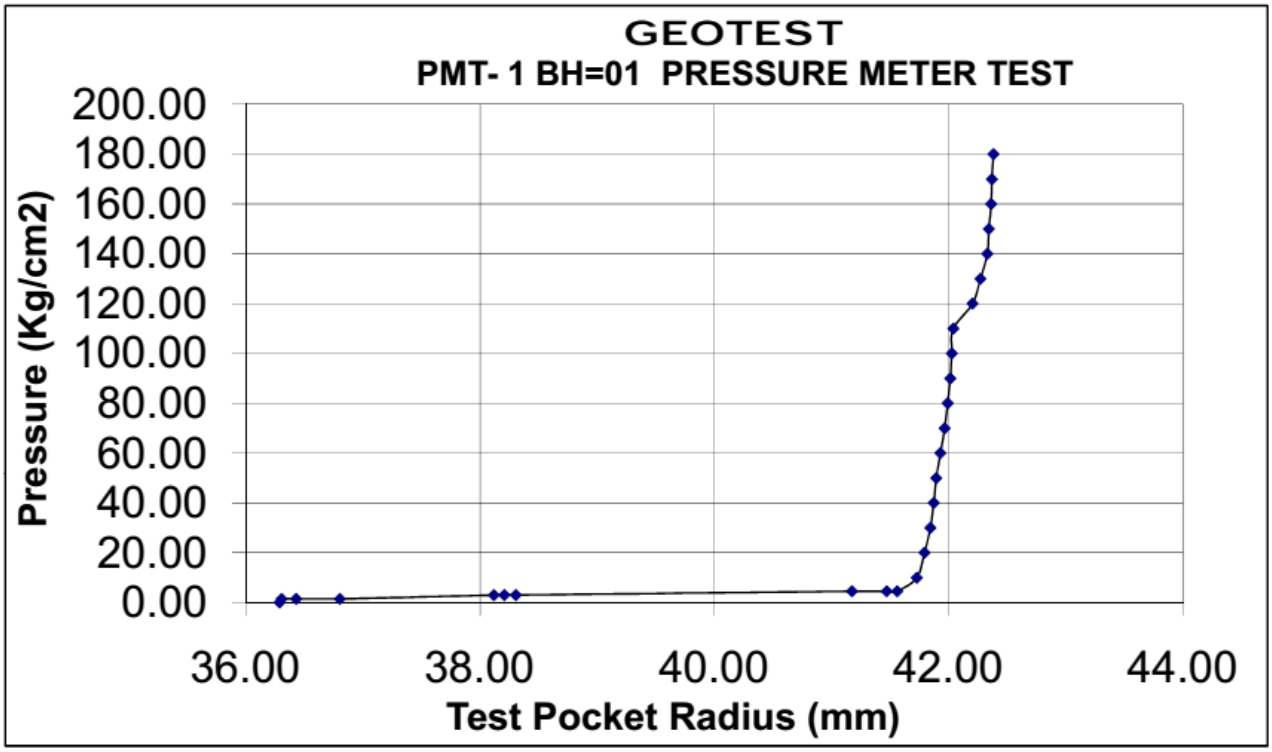
Bore hole No	Depth (m)	Sample No	Ist Cycle SDI (%)	IInd Cycle SDI (%)
BH 01	22.50-24.00	121	95.42	94.39
BH 07	10.50-12.00	44	88.37	87.24
BH 07	18.00-19.50	94	92.76	90.77

4.4.4. Field Test Results: Portal Location

4.4.4.1. Pressure Meter Test at Portal

PRESSURE METER TEST

PROJECT			G.M.L.R.					
NAME OF CLIENT			MCGM / PADECO		SIZE OF BOREHOLE (mm)			Nx
BOREHOLE NO.			BH=01		DATE			17.02.2017
LOCATION			N=191010.6 E=725339.2		TEST DEPTH (m)			13.00-14.50
RL (m)			87		FINAL DEPTH (m)			50.00
TYPE OF STRATA			Moderately to Slightly weathered		CASING (m)			5.00
Sr No.	Time in sec.	Pressure P (MPa)	Pressure P' (Kg/Cm2)	Displacement Display Value Rn	Inner Radius Display Value Ri =Rn+23.5	Thickness Correction Volume PG= P"/K	Reference inner Radius Rs =Ri-PG	Test Pocket Radius R= SQRT (Rs2+S/π)
		(Mpa)	(Kg/Cm2)	(mm)	(mm)		(mm)	(mm)
1	0	0.00	0.00	0.00	23.50	-0.01	23.51	36.29
2	15	0.15	1.50	0.03	23.53	-0.01	23.54	36.31
3	15	0.15	1.50	0.22	23.72	-0.01	23.73	36.43
4	15	0.15	1.50	0.79	24.29	-0.01	24.30	36.81
5	15	0.30	3.00	2.74	26.24	-0.01	26.25	38.12
6	15	0.30	3.00	2.87	26.37	-0.01	26.38	38.21
7	15	0.30	3.00	3.01	26.51	-0.01	26.52	38.31
8	15	0.45	4.50	7.01	30.51	-0.01	30.52	41.18
9	15	0.45	4.50	7.41	30.91	-0.01	30.92	41.47
10	15	0.45	4.50	7.53	31.03	-0.01	31.04	41.56
11		1.00	10.00	7.76	31.26	0.00	31.26	41.73
12		2.00	20.00	7.86	31.36	0.01	31.35	41.79
13		3.00	30.00	7.94	31.44	0.03	31.42	41.85
14		4.00	40.00	7.99	31.49	0.04	31.45	41.87
15		5.00	50.00	8.03	31.53	0.05	31.48	41.89
16		6.00	60.00	8.09	31.59	0.06	31.53	41.93
17		7.00	70.00	8.15	31.65	0.08	31.58	41.97
18		8.00	80.00	8.20	31.70	0.09	31.61	41.99
19		9.00	90.00	8.24	31.74	0.10	31.64	42.01
20		10.00	100.00	8.27	31.77	0.11	31.66	42.03
21		11.00	110.00	8.30	31.80	0.13	31.68	42.04
22		12.00	120.00	8.53	32.03	0.14	31.89	42.20
23		13.00	130.00	8.63	32.13	0.15	31.98	42.27
24		14.00	140.00	8.72	32.22	0.16	32.06	42.33
25		15.00	150.00	8.75	32.25	0.18	32.08	42.34
26		16.00	160.00	8.79	32.29	0.19	32.10	42.36
27		17.00	170.00	8.81	32.31	0.20	32.11	42.37
28		18.00	180.00	8.84	32.34	0.21	32.13	42.38
Calculation Notes:					Type Of Probe	A		
Membrane Calibration Constants					Thickness Correction K :Mn/m2/mm=80			
					Expansion Correction S (mm2)= 2399.35			
GEOTEST						Job No	Prepared by	Cheked By
						2001	Vaibhav	Prasad



PMT: 1 PRESSURE METER TEST

Observation from Graph

Intial Pressure P1 (Kg/ cm2) =	80.00
Final Pressure P2 (Kg/ cm2) =	100.00
Δ P (Kg/cm2) =	20.00
Intial Radius (mm) =	41.99
Final Radius (mm) =	42.03
Δ R(cm) =	**0.004**
r(cm)=	4.201

γ = 0.3

Calculations

K= ΔP/ΔR =	5000	
E=(1+γ)rK=	27306.5000	(kg/cm2)
G= E/2(1+γ)=	17749.2250	(kg/cm2)

GEOTEST

4.4.4.2. Packer Permeability Test at Portal

PACKER PERMEABILITY TEST

Project : **Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP**

Elevation : 86.00m.
Location : --
Coordinate : N 19°10'05.8", E72°55'45.6"
Inclination : 90 (Deg. With Horizontal)
Test Section : **15.00** To **16.50** m
Length of Test Section : 1.50 m
Type of Test : **Double Packer Test**
Test Location : Test Below Water Table

Date : **07/03/2017**
Bore Hole : **BH 7**
Depth of Bore Hole(m) : **30.00**
Diameter (mm) : **NX-76.00**
Water Table (m) : **7.20**
H_1 (m) : **1.25**
H_2 (m) : **7.20**

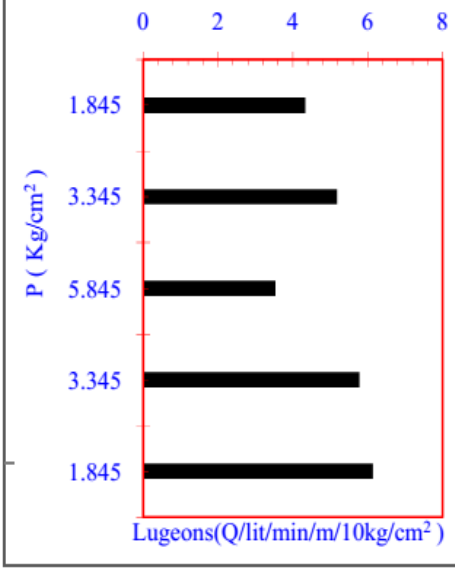
Sr. No.	L (m)	H_1 (m)	H_2 (m)	P_0 Kg / cm²	P Kg / cm²	t (min)	Q_t (lit)	Q_o (lit/min)	Q lit/min/m	Lugeon	k (cm/sec)
1	1.50	1.25	7.20	1.00	1.845	10.0	12.00	1.20	0.800	4.336	4.34E-05
2	1.50	1.25	7.20	2.50	3.345	10.0	26.00	2.60	1.733	5.182	5.18E-05
3	1.50	1.25	7.20	5.00	5.845	10.0	31.00	3.10	2.067	3.536	3.54E-05
4	1.50	1.25	7.20	2.50	3.345	10.0	29.00	2.90	1.933	5.780	5.78E-05
5	1.50	1.25	7.20	1.00	1.845	10.0	17.00	1.70	1.133	6.143	6.14E-05

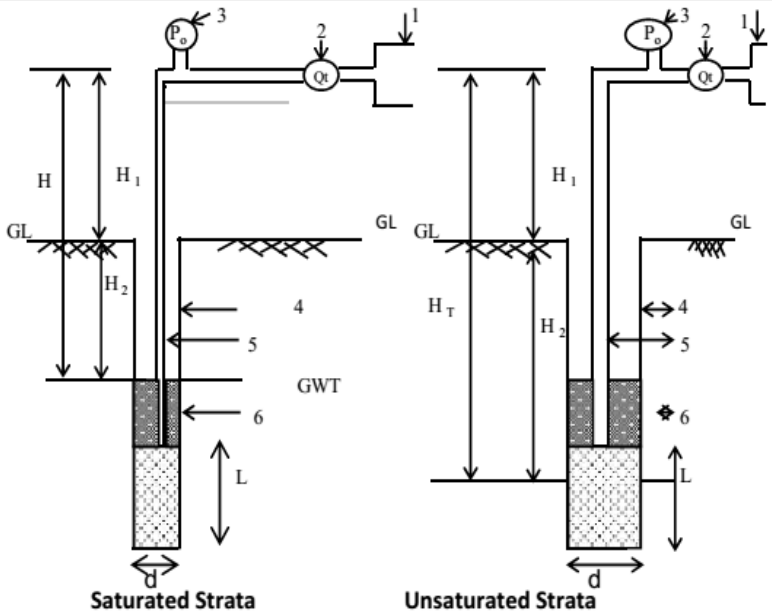
Sample Calculation :-
As per IS - 5529

P : $P_0 + (H_1 + H_2)/10$: 1.845 Kg/cm²
Q_0 : Q_t / t = 1.200 lit / min
Q : Q_0 / L = 0.800 lit/min/m

Lugeon :- $\frac{Q * 1\ Mpa}{\text{Test Pressure i.e. P}}$ = **4.336**

Group : --
Classification : --
Permeability Value : **4.336** Lugeon





Saturated Strata

1 :- Pump
2 :- Flow Meter
3 :- Pressure Gauge
4 :- Drill Hole
5 :- Injection Pipe
6 :- Packer
Lugeon :- Lugeon Value in lit/min/m/10Kg/cm²
k :- Permeability in cm/sec

Unsaturated Strata

P_o :- Gauge Pressure
H_1 :- Height of Pressure Gauge
H_2 :- Depth of Ground Water or Mid of Test Section to Ground Surface
P :- Effective Pressure
P :- P_0+H/10 or H = $H_1 + H_2$
t :- Injection Time
Q_t :- Water Volume During time
Q_0 :- Water Volume / min.

PACKER PERMEABILITY TEST

Project : **Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP**

Elevation : 87.00m.
Location : --
Coordinate : N 19°10'21.7", E72°55'54.7"
Inclination : 90 (Deg. With Horizontal)
Test Section : **27.00** To **28.50** m
Length of Test Section : 1.50 m
Type of Test : **Double Packer Test**
Test Locatior : Test Below Water Table

Date : **06/03/2017**
Bore Hole : **BH 1**
Depth of Bore Hole(m) : **30.00**
Diameter (mm) : **NX-76.00**
Water Table (m) : **9.20**
H_1 (m) : **1.25**
H_2 (m) : **9.20**

Sr. No.	L (m)	H_1 (m)	H_2 (m)	P_0 Kg / cm^2	P Kg / cm^2	t (min)	Q_t (lit)	Q_o (lit/min)	Q lit/min/m	Lugeon	k (cm/sec)
1	1.50	1.25	9.20	1.00	2.045	10.0	11.00	1.10	0.733	3.586	3.59E-05
2	1.50	1.25	9.20	2.50	3.545	10.0	19.00	1.90	1.267	3.573	3.57E-05
3	1.50	1.25	9.20	5.00	6.045	10.0	28.00	2.80	1.867	3.088	3.09E-05
4	1.50	1.25	9.20	2.50	3.545	10.0	21.00	2.10	1.400	3.949	3.95E-05
5	1.50	1.25	9.20	1.00	2.045	10.0	13.00	1.30	0.867	4.238	4.24E-05

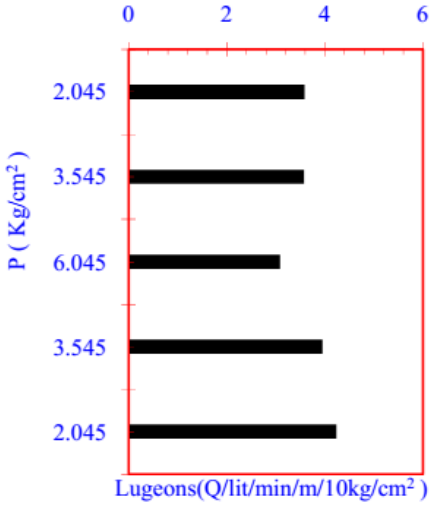
Sample Calculation :-
As per IS - 5529

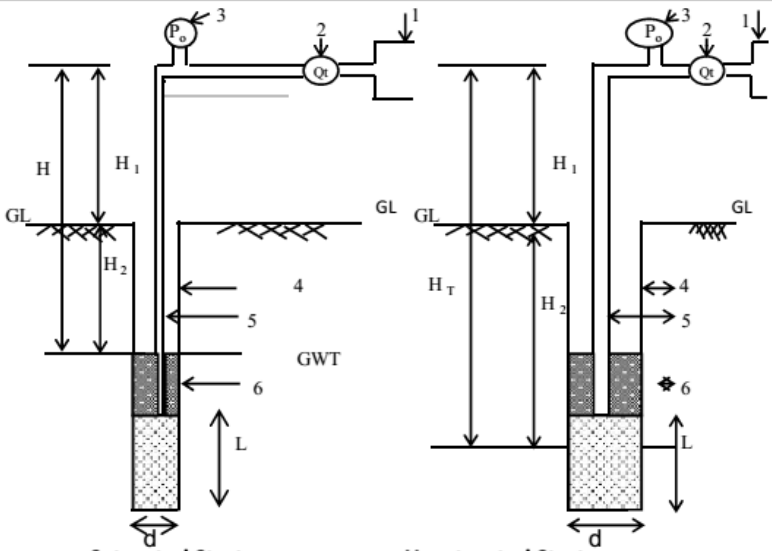
$P : P_0 + (H_1 + H_2)/10$: 2.045 Kg/cm^2
$Q_0 : Q_t / t$ = 1.100 lit / min
$Q : Q_0 / L$ = 0.733 lit/min/m

Lugeon :- $\frac{Q * 1\ Mpa}{\text{Test Pressure i.e. P}}$

= **3.586**

Group : --
Classification : --
Permeability Value : **3.586** Lugeon





Saturated Strata

1 :- Pump
2 :- Flow Meter
3 :- Pressure Gauge
4 :- Drill Hole
5 :- Injection Pipe
6 :- Packer
Lugeon :- Lugeon Value in lit/min/m/10Kg/cm^2
k :- Permeability in cm/sec

Unsaturated Strata

P_o :- Gauge Pressure
H_1 :- Height of Pressure Gauge
H_2 :- Depth of Ground Water or Mid of Test Section to Ground Surface
P :- Effective Pressure
P :- P_0+H/10 or H = H_1 + H_2
t :- Injection Time
Q_t :- Water Volume During time
Q_0 :- Water Volume / min.

4.4.5. Geotechnical Information along Tunnel Alignment:

Due to the restricted drilling locations & access limitations five Borehole were drilled along tunnel alignment. Review of Five borehole logs i.e. BH 02, BH 03, BH 04, BH 05 & BH 06 indicates that the subsurface profile consists of mainly 5 layers were inferred up to final depth of boreholes. Prominently Basalt Rock was present in BH 02 till the depth of drilling, similarly in Borehole BH 04, BH 05 & BH 06 Breccia Rock were Prominent & in BH 03 combination of Basalt & Breccia are Prominent. Following are the subsoil Layers.

Table 4-12: Description of Layers along Tunnel Alignment

Layer Number	Description	Average Thickness (m)
Layer 1	Stiff to Hard Brownish Clayey Sand Mixed with Gravel	0.00 to 2.50
Layer 2 A	Completely Weathered Rock/ Highly Weathered Breccia Rock	2.00 to 2.50
Layer 2 B	Completely Weathered Rock/ Highly Weathered Basalt Rock	Up to 6.00
Layer 3 A	Moderately Weathered Breccia Rock	1.50 to 9.00
Layer 3 B	Moderately Weathered Basalt Rock	Up to 30.00
Layer 4 A	Slightly Weathered Breccia Rock	4.50 to 6.00
Layer 4 B	Slightly Weathered Basalt Rock	1.50 to 12.00
Layer 5 A	Fresh Breccia	> 25.00
Layer 5 B	Fresh Basalt	> 2.00

Layer – 1 Stiff to Hard Brownish Clayey Sand Mixed with Boulders

First layer of subsoil profile is hard Brownish Clayey Sand Mixed with Boulders. This layer consists of sand and clay in varying percentage of boulders or gravels. This layer were present in all boreholes along the tunnel alignment, and has an average thickness layer is 2.00 to 2.50 m. Four Standard penetration tests were conducted in this stratum to check consistency of the stratum. Reported 'N' values are varying from 14 to 23. SPT values indicate stiff to hard consistency of the stratum in BH 04 & 05 Reported 'N' values is Refusal. Due to the limited sample thickness Grain sieve analysis, was not conducted.

Layer – 2 A Completely Weathered Rock/ Highly Weathered Breccia Rock

Second stratum of subsoil profile is Completely Weathered Rock/ Highly Weathered Breccia Rock Stratum mixed with Boulders & clay. This stratum is present in all boreholes except BH 02. Average

thickness of this stratum is varying between 2.00 m to 2.50 m in the boreholes. Examination of sample collected that it was completely/highly weathered rock having yellowish medium-stiff to stiff clay mixed with gravels and boulders/ residual rock structure, which is locally known as murrum or soft rock. Rock core recovery value recorded in boreholes is 16% to 67%. These values of rock recovery show completely/highly weathered condition of rock stratum. Rock quality designation values recorded are NIL in all drill run. These indicate very poor state of fractures in rock mass.

Layer – 2 B Completely Weathered Rock/ Highly Weathered Basalt Rock

Second stratum of subsoil profile is Completely Weathered Rock/ Highly Weathered Basalt Rock Stratum. This stratum is present only in BH 02 borehole. Average thickness of this stratum is up to 6.00 m in the borehole. Examination of sample collected that it was completely/highly weathered rock having yellowish rock mixed with gravels and boulders/ residual rock structure, which is locally known as murrum or soft rock. Rock core recovery value recorded in borehole is 13% to 23%. These values of rock recovery show completely/highly weathered condition of rock stratum. Rock quality designation values recorded are NIL in all drill run. These indicate very poor state of fractures in rock mass.

Layer – 3 A Moderately Weathered Breccia Rock

Third stratum of subsoil profile is Moderately Weathered Breccia Rock. This stratum is presents in all boreholes except BH 02. Average thickness of this stratum is varying between 1.50 to 9.00 m in boreholes. Rock core recovery value recorded is from 51% to 67%, with one higher core recovery value 98% in BH 04 this is due to the presence of boulder & one lower value of 29% in BH 06 indicate presence of soft patch. These values of rock recovery show moderately weathered condition of rock stratum. Rock quality designation values recorded are from NIL to 53 % in drill runs. These indicate poor to moderate state of fractures in rock mass. Examination of sample collected that it was moderately weathered breccia. One rock core was tested in laboratory. Reported Saturated crushing strength value is 527.04 Kg/cm2. This value indicates that rock has medium strength. One Pressure meter field test was conducted in these strata to get the Insitu parameters such as Subgrade Modulus, Field Young Modulus & Shear Modulus etc. One Packer Permeability test was conducted in these strata, Field Test result presented in the Lab & Field Test section.

Sr No	Description of Test	Unit	Test Results
1	Unconfined Compressive Strength	Kg/cm^2	527.04
2	Water absorption	%	0.74
3	Porosity	%	2.02
4	Density	gm/cc	2.75
5	**Pressure Meter Test**		
	Deformation/ Pressure-meter Modulus E_p	MPa	23628.22
	Ground coefficient K	kg/cm^2	4444.44
	Shear Modulus	kg/cm^2	15358.34
6	Packer Permeability Test	Lugeon	7.161

Layer – 3 B Moderately Weathered Basalt

Third stratum of subsoil profile is Moderately Weathered Basalt Stratum mixed with clay. This stratum is present only in BH 02 borehole & Average thickness of this stratum is up to 30 m in the borehole. Examination of sample collected that it was greyish moderately weathered basalt. Rock core recovery value recorded is from 52% to 58%, these values of rock recovery show moderately weathered condition of rock stratum. Rock quality designation values recorded are from NIL to 09 % in all drill runs. These indicate poor state of fractures in rock mass. Two packer permeability tests were conducted in this stratum.

Sr No	Description of Test	Unit	Test Results
1	Packer Permeability Test	Lugeon	11.890 to 16.419

Layer – 4 A Slightly Weathered Breccia Rock

Fourth stratum of subsoil profile is Slightly Weathered Breccia Rock. This stratum is presents only in BH 04 & BH 06 boreholes. Average thickness of this stratum is varying between 4.50 to 6.00 m in boreholes. Rock core recovery value recorded is from 64% to 91%, these values of rock recovery show slightly weathered condition of rock stratum. Rock quality designation values recorded are from 70% to 95% in drill runs. These indicate moderate state of fractures in rock mass. Examination of sample collected that it was slightly weathered breccia. One rock core was tested in laboratory. Reported Saturated crushing strength value is 354.62 Kg/cm2. Thus values indicate that rock has medium strength. Two Packer Permeability test was conducted in this strata, Field Test result presented in the Lab & Field Test section. The available laboratory data such compressive strength,

Tensile Strength, Rock Triaxial, Slake Durability & Young Modulus test results corresponding to intact rock samples are presented here as a function of depth.

Sr No	Description of Test	Unit	Test Results
1	Unconfined Compressive Strength	Kg/cm²	354.62
2	Water absorption	%	0.30
3	Porosity	%	0.81
4	Density	gm/cc	2.74
5	Tensile Strength	MPa	
6	Rock Triaxial Cohesion	MPa	6.11
	Angle of Internal Friction	Degree	51
7	Cerchar Abrasion Index	--	1.58
8	Packer Permeability Test	Lugeon	6.138 to 7.161

Petrographic Analysis:

- BH 04, Core Sample No 43, Depth 15.00 - 16.50 m;
- Method of Analysis: Optical microscopy
- Rock Type: Igneous Rock
- Rock Name: Amygdaloidal Basalt

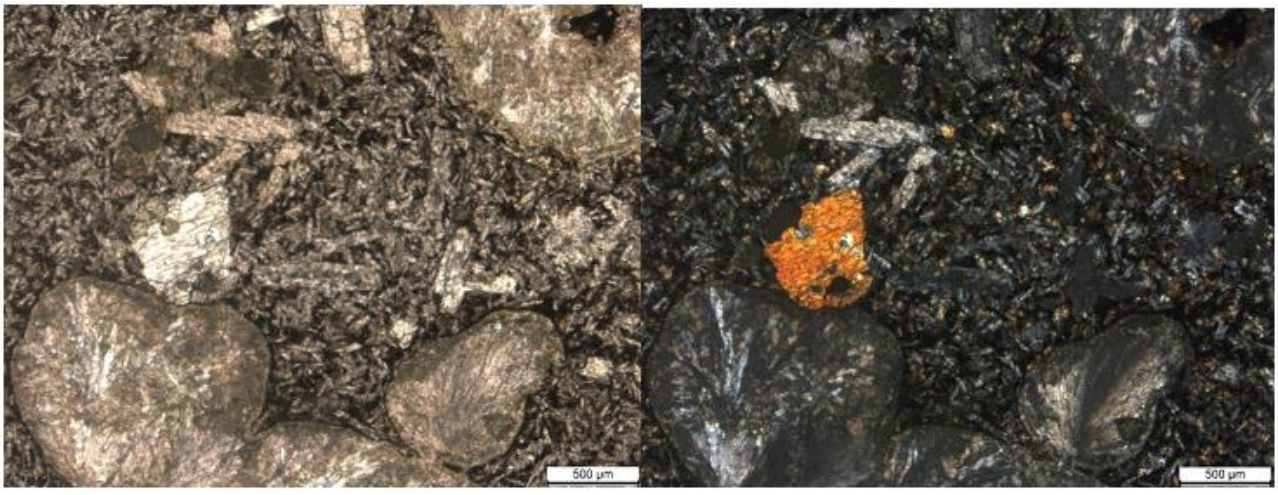


Figure 4-16: Petrographic Analysis of basaltic rock showing uniform distribution of highly altered plagioclase feldspar and augite with altered zeolite minerals (Under cross Nicole)

Thin Section Description: This rock was observed to be slightly weathered rock mass. Zeolite was found which suggest that basalt is of amygdaloidal basalt. Grain boundaries

were found to be open and stained. Intergranular micocracks/hair fractures were also observed in the rock. The compound silica is estimated to be 44-46%.

Minerals in the sample	Modal Analysis (%)	Granulometry		
		Max size (µm)	Min. size (µm)	Avg. size (µm)
Plagioclase	45	230	30	125
Augite	25	-	-	-
Olivine	15	-	-	-
Opaque	10	-	-	-
others	5	-	-	-

Petrographic Analysis:

- BH 06, Core Sample No 104, Depth 16.50 - 18.00 m;
- Method of Analysis: Optical microscopy
- Rock Type: Volcanic Igneous Rock
- Rock Name: Basalt

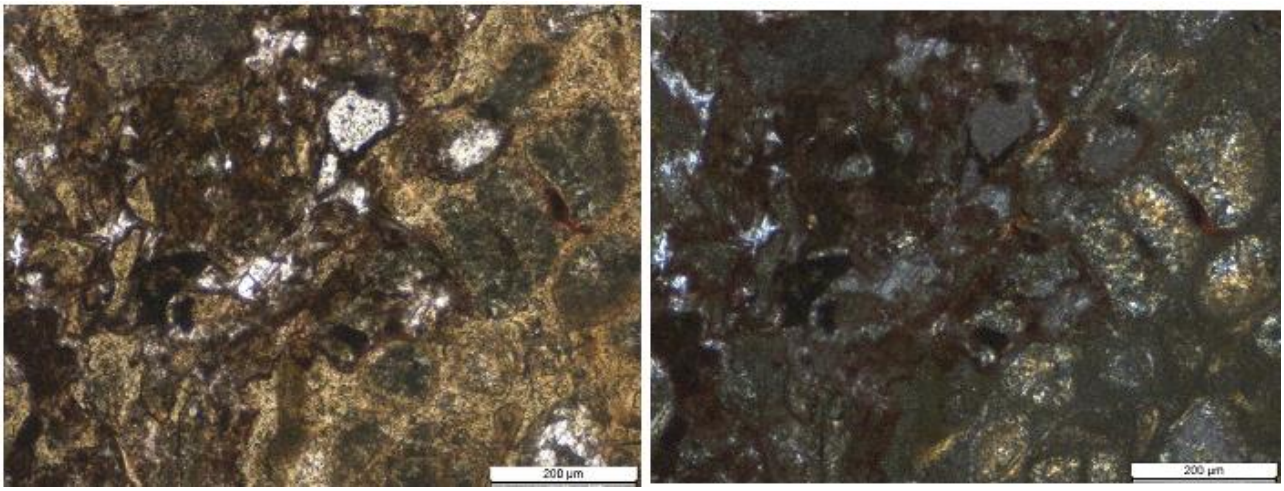


Figure 4-17: Petrographic Analysis of basaltic rock showing fine grained mass. Left: Under PPL and Right: Under cross Nicole.

Thin Section Description: The rock was identified as basalt where leaching of minerals has been occurred. Due to leaching, round features can be observed which suggests that the basalt has undergone extreme weathering in humid conditions.

Minerals in the sample	Modal Analysis (%)	Granulometry		
		Max size (µm)	Min. size (µm)	Avg. size (µm)
Plagioclase	25	600	150	250
Augite	15	-	-	-
Olivine	14	-	-	-
Opaque	6	-	-	-
others	40	-	-	-

Layer – 4 B Slightly Weathered Basalt Rock

Fourth stratum of subsoil profile is Slightly Weathered Basalt Rock Stratum. This stratum is present only in BH 02 & BH 03 borehole. Average thickness of this stratum is varying between 1.50 to 12.00 m in boreholes. Rock core recovery value recorded is from 68% to 88%, these values of rock recovery show slightly weathered condition of rock stratum. Rock quality designation values recorded are from 58% to 78% in drill runs. These indicate moderate state of fractures in rock mass. Examination of sample collected that it was greyish colour slightly weathered basalt. One rock core was tested in laboratory. Reported Saturated crushing strength value is 495.85 Kg/cm^2. These values indicate that rock has Medium strength. The available laboratory data such compressive strength, Tensile Strength, Rock Triaxial, Slake Durability & Young Modulus test results corresponding to intact rock samples are presented here as a function of depth.

Sr No	Description of Test	Unit	Test Results
1	Unconfined Compressive Strength	Kg/cm^2	495.85
2	Water absorption	%	0.42
3	Porosity	%	1.21
4	Density	gm/cc	2.82
5	Tensile Strength	MPa	6.27
6	Rock Triaxial Cohesion	MPa	6.29
	Angle of Internal Friction	Degree	52
7	Young's Modules	Gpa	43.96
8	Poisson's ratio	--	0.24
9	Slake durability index Ist Cycle SDI	%	94.87
	Slake durability index Ist Cycle SDI	%	93.68

Petrographic Analysis:

- BH 02, Core Sample No 200, Depth 48.50 -50.00 m;
- Method of Analysis: Optical microscopy
- Rock Type: Igneous Rock
- Rock Name: Basalt

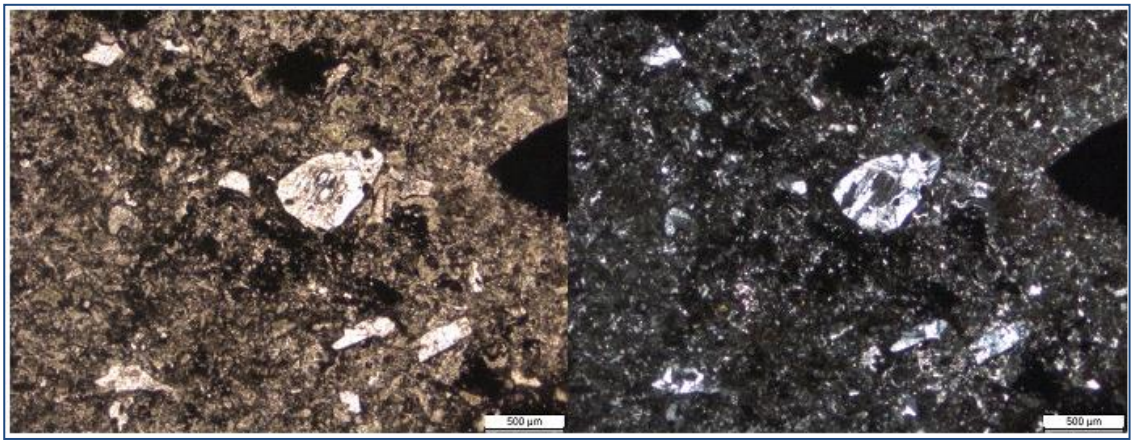


Figure 4-18: Petrographic Analysis of basaltic rock showing completely altered olivine minerals. Left: in PPL and Right: Cross Nicole

Thin section description: Under optical microscope, the rock slide was identified as basaltic rock with predominantly multi-oriented plagioclase laths along with augite minerals. The two major minerals (plagioclase and augite) showed sub-ophitic texture. Most of the grains (plagioclase and augite) were slightly altered. Slightly altered olivine and irregular to sub-rounded shaped opaque minerals were also observed. Grain boundaries were partially altered but demonstrate tight contact. The compound silica is estimated to be 45-47%.

Minerals in the sample	Modal Analysis (%)	Granulometry		
		Max size (µm)	Min. size (µm)	Avg. size (µm)
Plagioclase	61	250	50	240
Augite	22	100	30	70
Olivine	11	-	-	-
Opaque	4	-	-	-
others	2	-	-	-

Layer – 5 A Fresh Breccia

Fifth layer of subsoil profile is Fresh breccia. This stratum is presents in all boreholes except BH 02 & borehole were terminated into these strata. Average thickness of this stratum is more than 5.00 m.

in boreholes. Rock core recovery value recorded is from 86% to 100%, These values of rock recovery show fresh weathered condition of rock stratum, only in borehole BH 01 soft pocket of rock occurred at depth of 35 m. Rock quality designation values recorded are from 30% to 100% in drill runs. These indicate moderate state of fractures in rock mass. Examination of sample collected that it was fresh weathered breccia. Sixteen rock cores were tested in laboratory. Reported Saturated crushing strength value is from 93.11 to 648.22 Kg/cm2. These values indicate that rock has moderate strength. The available laboratory data such compressive strength, Tensile Strength, Rock Triaxial, Slake Durability & Young Modulus test results corresponding to intact rock samples are presented here as a function of depth. Strength test results corresponding to intact rock samples are presented here as a function of depth. The available data derives from 2 sources: a) Directly, measured from the Unconfined Compressive Strength (UCS) device (IS: 9143) and b) indirectly via Point Load Tests (PLT, IS: 8764). The PLT results were correlated with the UCS results in order to obtain indirectly the σci value of the rock samples. Correlation was implemented by comparing the UCS and PLT results from tests performed on the same rock sample. The ratio between UCS and PLT results was determined to vary between 14 and 22. Three Pressure meter field test was conducted in this strata to get the Insitu parameters such as Subgrade Modulus, Field Young Modulus & Shear Modulus etc. Seven Packer Permeability test was conducted in this strata, Field Test result presented in the Lab & Field Test section. The available laboratory data such compressive strength, Tensile Strength, Rock Triaxial, Slake Durability & Young Modulus test results corresponding to intact rock samples are presented here as a function of depth.

Sr No	Description of Test	Unit	Test Results
1	Unconfined Compressive Strength	Kg/cm^2	93.11 to 648.22
2	Water absorption	%	0.30, to 0.92
3	Porosity	%	0.81 to 2.43
4	Density	gm/cc	2.59 to 2.85
5	Tensile Strength	MPa	2.02 to 7.13
6	Rock Triaxial Cohesion	MPa	4.06, to 4.95
	Angle of Internal Friction	Degree	37.5 to 52.75
7	Cerchar Abrasion Index	--	0.92 to 1.44
8	Young's Modules	Gpa	35.07 to 52.28
9	Poisson's ratio	--	0.23 to 0.24
10	Slake durability index Ist Cycle SDI	%	81.72, to 92.16
	Slake durability index IInd Cycle SDI	%	80.43 to 90.49

Sr No	Description of Test	Unit	Test Results
11	**Pressure Meter Test**		
	Deformation/ Pressure-meter Modulus E_p	MPa	17012.66 to 40887.60
	Ground coefficient K	kg/cm²	3333.33 to 8000,
	Shear Modulus	kg/cm²	11058.23 to 26576.94
12	Packer Permeability Test	Lugeon	2.282, 5.216, 10.571, 2.892, 3.765, 4.333

Petrographic Analysis:

- BH 03, Core Sample No 232, Depth 47.00 -48.50 m;
- Method of Analysis: Optical microscopy
- Rock Type: Igneous Rock 5
- Rock Name: Basalt

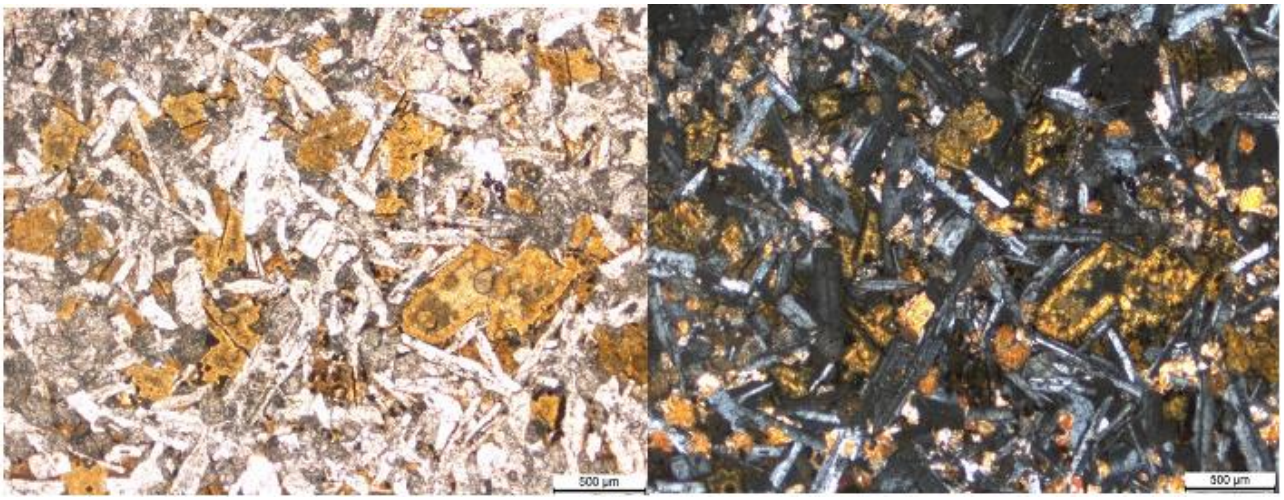


Figure 4-19: Petrographic Analysis of basaltic rock showing completely altered olivine minerals. Left: in PPL and Right: Cross Nicole

Thin Section Description: The rockslide under microscope observation establish mostly plagioclase and augite are altered partially to completely. Grain boundaries were observed to be tight and slightly stained. The compound silica is estimated to be 64-468%.

Minerals in the sample	Modal Analysis (%)	Granulometry		
		Max size (µm)	Min. size (µm)	Avg. size (µm)
Plagioclase	50	210	50	95
Augite	30	-	-	-

Olivine	11	-	-	-
Opaque	5	-	-	-
others	4	-	-	-

Petrographic Analysis:

- BH 04, Core Sample No 77, Depth 21.00 - 22.50 m;
- Method of Analysis: Optical microscopy
- Rock Type: Igneous Rock 10
- Rock Name: Basalt

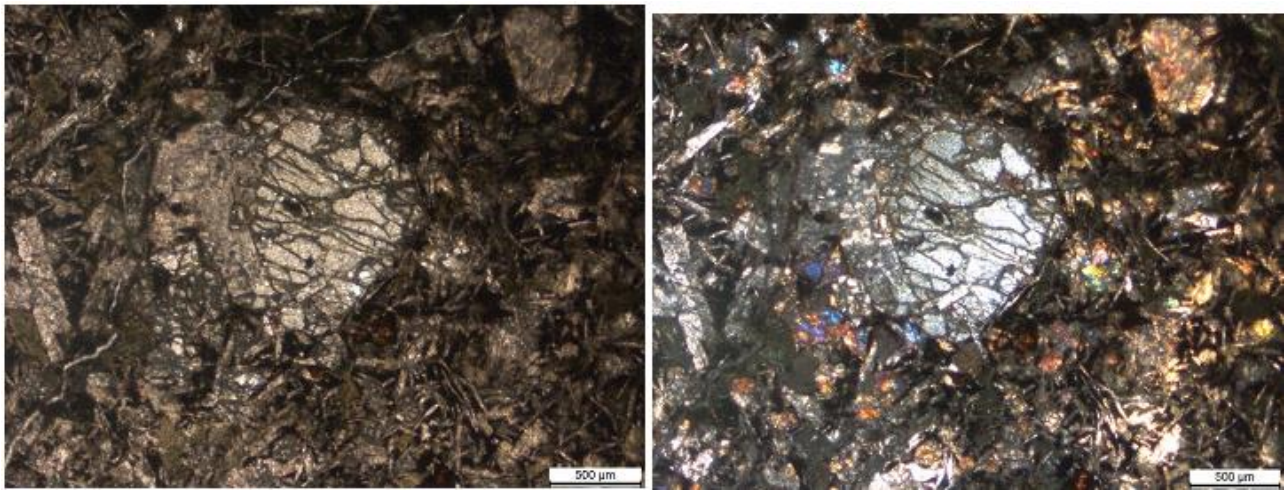


Figure 4-20: Petrographic Analysis of basaltic rock showing fine grained groundmass. Left: Under PPL and Right: Under cross Nicole

Thin Section Description: The basaltic rock displays fine grained groundmass. The rock shows habitually altered minerals as well as altered grain boundaries suffered due to weathering. However, grain boundaries were found to be tight. Altered olivine and opaque minerals were found to be randomly distributed throughout the groundmass of basaltic rock. However, there is no free quartz. The compound silica is estimated to be 44-48%.

Minerals in the sample	Modal Analysis (%)	Granulometry		
		Max size (µm)	Min. size (µm)	Avg. size (µm)
Plagioclase	55	210	40	90
Augite	20	-	-	-
Olivine	15	-	-	-
Opaque	4	-	-	-

others	6	-	-	-

Petrographic Analysis:

- BH 05, Core Sample No 77, Depth 21.50 - 22.50 m;
- Method of Analysis: Optical microscopy
- Rock Type: Volcanic Igneous Rock
- Rock Name: Basalt

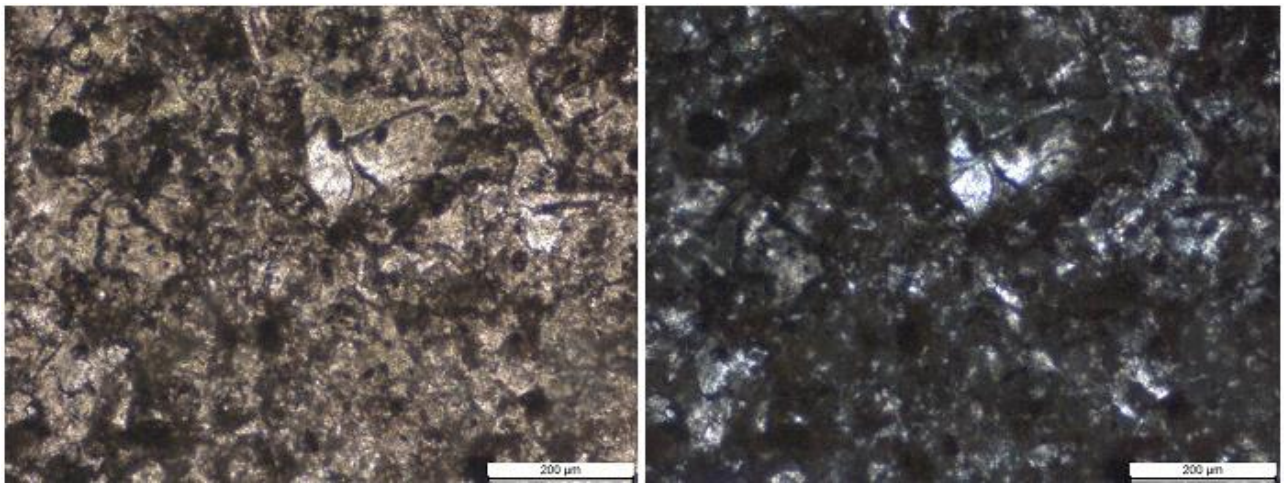


Figure 4-21: Petrographic Analysis of basaltic rock showing fine grained groundmass. Left: Under PPL and Right: Under cross Nicole.

Thin Section Description: The photomicrographs show fine grained groundmass. The minerals are partially transformed with altered gain boundaries. However, majority of grain boundaries were found to be tight. Altered olivine and opaque minerals exhibits to be randomly distributed throughout the groundmass of basaltic rock. The compound silica is estimated to be 47-49%.

Minerals in the sample	Modal Analysis (%)	Granulometry		
		Max size (µm)	Min. size (µm)	Avg. size (µm)
Plagioclase	62	310	20	80
Augite	21	-	-	-
Olivine	11	-	-	-
Opaque	3	-	-	-
others	3	-	-	-

Petrographic Analysis:

- BH 05, Core Sample No 96, Depth 27.00 - 28.50 m;
- Method of Analysis: Optical microscopy
- Rock Type: Igneous Rock
- Rock Name: Basalt

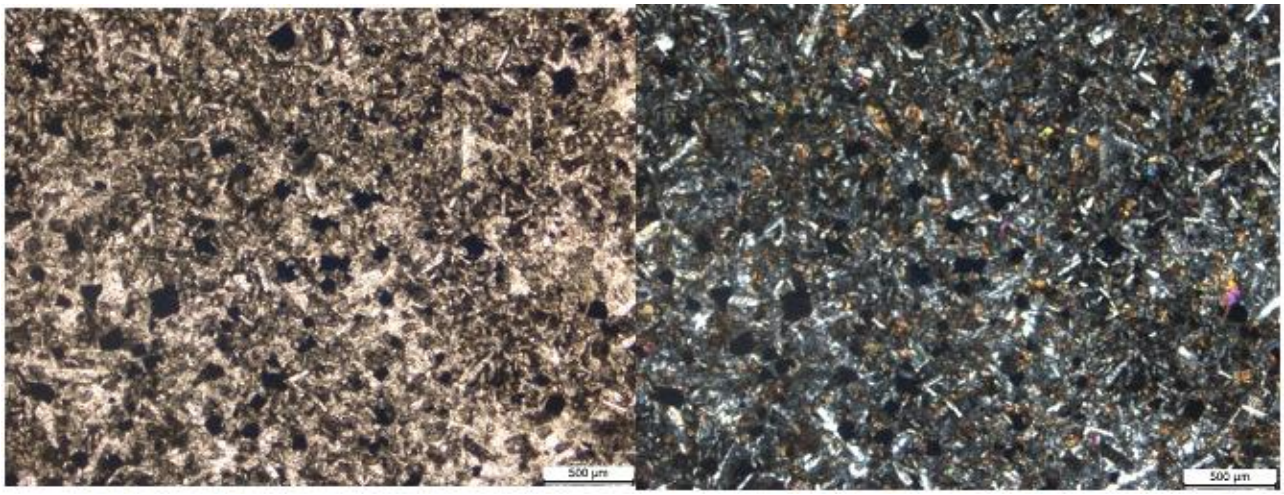


Figure 4-22: Petrographic Analysis of basaltic rock, Left: in PPL and Right: Cross Nicole.

Thin section description: Under optical microscope, basaltic rock showed fine grained groundmass that was predominantly composed with plagioclase feldspar and augite minerals. Minor olivine grains and opaque minerals were also present in the groundmass. The compound silica is estimated to be 64-68%.

Minerals in the sample	Modal Analysis (%)	Granulometry		
		Max size (µm)	Min. size (µm)	Avg. size (µm)
Plagioclase	68	700	75	270
Augite	21	350	45	80
Olivine	3	-	-	-
Opaque	4	-	-	-
others	4	-	-	-

Petrographic Analysis:

- BH 06, Core Sample No 149, Depth 27.00 - 28.50 m;
- Method of Analysis: Optical microscopy
- Rock Type: Volcanic Igneous Rock
- Rock Name: Basalt

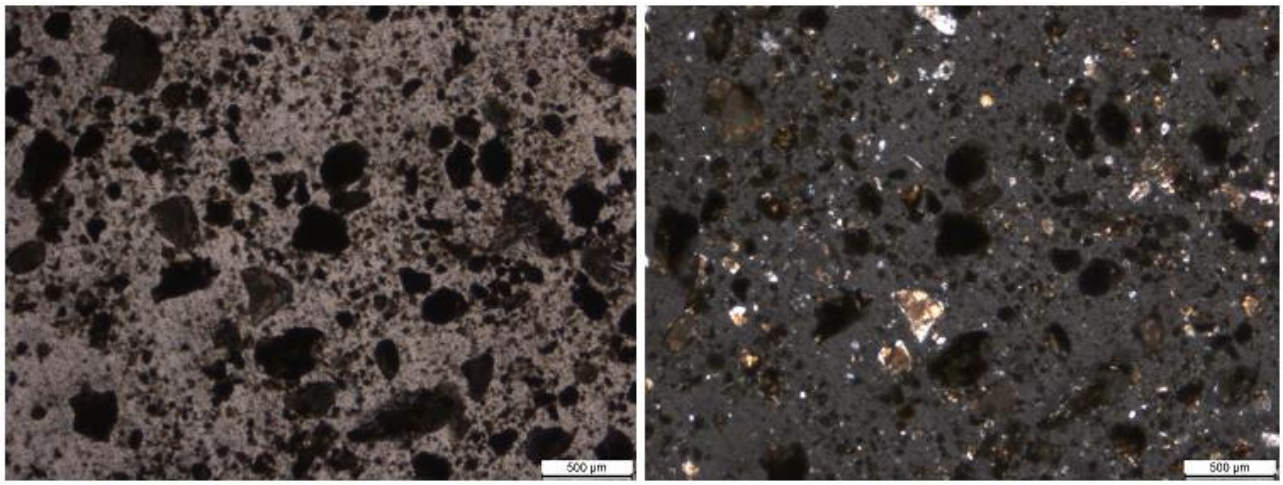


Figure 4-23: Petrographic Analysis of basaltic rock showing uniform distribution of plagioclase feldspar and augite with partially to completely altered olivine minerals. Left: in PPL and Right: Cross Nicole

Thin Section Description: Under optical microscope, the rock was identified as basaltic rock with predominantly multi-oriented fine grained plagioclase laths along with augite minerals. The two major minerals (plagioclase and augite) showed sub-ophitic texture. Most of the grains (plagioclase and augite) were altered. Highly altered olivine and irregular to sub rounded shaped opaque minerals were also observed and may initiate formation of clay mineral. Grain boundaries were partially altered and tight. The compound silica is estimated to be 47-49%.

Minerals in the sample	Modal Analysis (%)	Granulometry		
		Max size (µm)	Min. size (µm)	Avg. size (µm)
Plagioclase	61	100	30	90
Augite	22	-	-	-
Olivine	8	-	-	-
Opaque	5	-	-	-
others	4	-	-	-

Layer – 5 B Fresh Basalt Rock

Fifth stratum of subsoil profile is Fresh Basalt Rock. This stratum is present only in BH 02 & borehole was terminated into these strata assuming that this rock stratum will be the same till the area of interest for tunnel investigation. Average thickness of this stratum is more than 2m in borehole. Rock core recovery value recorded is from 90% to 99%. These values of rock recovery show Fresh weathered condition of rock stratum. Rock quality designation values recorded are from 68% to 75% in drill runs. These indicate moderate to slightly state of fractures in rock mass.

Examination of sample collected that it was Fresh basalt. The basalt is fine-grained and sometimes vesicular, with principal minerals of olivine, augite and plagioclase. The volcanoes make basalt, and have formed long and persistent Deccan trap. Basalt is commonly very fine grained, and it is nearly impossible to see individual minerals without magnification. Basalt found in boring is amygdaloidal basalt with deposition of silica/quartz. Amygdaloidal basalt is formed when minerals are deposited in the almond shaped gas bubbles that were trapped in the basalt as it was cooling. These vesicles or pores were later the site for mineral precipitation. One rock cores was tested in laboratory. Reported Saturated crushing strength value is 610.80 Kg/cm2. This value indicates that rock has moderate to strong strength. The available laboratory data such compressive strength, Tensile Strength, Rock Triaxial, Slake Durability & Young Modulus test results corresponding to intact rock samples are presented here as a function of depth.

Sr No	Description of Test	Unit	Test Results
1	Unconfined Compressive Strength	Kg/cm^2	610.80
2	Water absorption	%	0.58
3	Porosity	%	1.62
4	Density	gm/cc	2.79
5	Tensile Strength	MPa	9.432
6	Cerchar Abrasion Index	--	1.32
7	Young's Modules	Gpa	48.23
8	Poisson's ratio	--	0.24
9	Slake durability index I^{st} Cycle SDI	%	95.78
	Slake durability index II^{nd} Cycle SDI	%	94.64

Soil laboratory testing of the soil/ rock samples collected was carried out in laboratory of M/s OCE Projects Pvt. Ltd. Navi Mumbai & IIT Bombay. Layer wise laboratory tests results were given in the respective tables. Ground water table were encountered in the borehole at a depth of 7.20 m from EGL.

4.4.6. Borehole Log: Tunnel Alignment

CLIENT : **GMLR-PADECO-MCGM**			
PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP			
BORE HOLE NO. : BH-2		SHEET NO. : 1 OF 5	
LOCATION : --		DATE : 23/01/2017 TO 01/03/2017	
CO-ORDINATES : N 19°10'10.6", E72°54'00.1"		METHOD : ROTARY DRILLING	
GROUND R. L. : 117.00m.		CASING : 100mm 2.50m & NX mm Ø UPTO BGL.	
GROUND W. T. : 12.30m Below GL.			

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
1.00	100 mm		Completely weathered, greyish, murum with boulders	0.00	DS1								
				1.50/		15	05	--	--				
				1.70	SPT1	35	53	--	--	R			
2.00													
3.00				3.00/		05	--	--	--				
				3.05	SPT2	55	--	--	--	R			
4.00			Highly weathered, greyish black , BASALT								13	NIL	
				4.50									
5.00	NX												
											23	NIL	
6.00				6.00									
7.00											52	NIL	
				7.50									
8.00			Moderately weathered, greyish black , BASALT										
											56	NIL	
9.00				9.00									
											54	NIL	
10.00													

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-2 | SHEET NO. : 2 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
				10.50							54	NIL	
11.00													
	NX										58	09	
12.00				12.00									
			Moderately weathered, greyish , BASALT								54	NIL	
13.00				13.50									
											52	NIL	
14.00													
15.00				15.00									
			Slightly weathered, greyish , BASALT								79	22	
16.00				16.50									
											57	25	
17.00			Moderately weathered, greyish , BASALT										
18.00				18.00									
			Slightly weathered, greyish , BASALT								76	11	
19.00				19.50									
20.00											79	72	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-2 | SHEET NO. : 3 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
21.00	NX		Moderately weathered, greyish, fractured, BASALT	21.00							79	72	
22.00				22.50							83	51	
23.00													
24.00				24.00							85	53	
25.00				25.50							61	37	
26.00													
27.00				27.00							51	13	
28.00				28.50							62	07	
29.00													
30.00				30.00							56	07	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-2 | SHEET NO. : 4 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
31.00	NX		Moderately weathered, greyish , BASALT	30.00 – 31.50							68	40	
32.00													
33.00				33.00							57	23	
34.00				34.50							71	21	
35.00													
36.00				36.00							57	21	
37.00			Slightly weathered, greyish , BASALT	37.50							85	77	
38.00													
39.00				39.00							81	39	
40.00											88	76	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-2 | SHEET NO. : 5 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
			Slightly weathered, greyish , BASALT	40.50							88	76	
41.00	NX		Moderately weathered, greyish , BASALT	42.00							72	70	
42.00													
43.00				43.50							72	58	
44.00			Slightly weathered, greyish , BASALT	45.00							81	80	
45.00													
46.00				46.50							75	63	
47.00													
48.00				48.00							80	69	
49.00			Fresh, grey, BASALT	49.50							90	75	
50.00				50.00							99	66	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : BORE HOLE IS TERMINATED AT DEPTH 50.00 m. BELOW G. L.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO.	: BH-3	SHEET NO.	: 1 OF 5
LOCATION	: --	DATE	: 03/01/2017 TO 16/02/2017
CO-ORDINATES	: --	METHOD	: ROTARY DRILLING
GROUND R. L.	: 112.00m.	CASING	: 100mm 2.50m & NX mm Ø UPTO BGL.
GROUND W. T.	: 9.20m Below GL.		

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm				SPT N	C R %	RQD %	OTHER TESTS
						15	15	15	15				
1.00	100 mm		Brownish, CLAY with gravel	0.00	DS1								
				1.50/									
2.00			Stiff, brownish, CLAY with gravel	2.10	SPT1	04	05	05	08	13			
				2.50									
3.00			Completely weathered, brownish, ROCK	3.00/		15	05	--	--				
				3.20	SPT2	21	55	--	--	R	67	NIL	
				3.50									
4.00			Highly weathered, reddish grey, BRECCIA								24	NIL	
5.00	NX			5.00									
6.00			Moderately weathered, reddish grey, BRECCIA								52	13	
				6.50									
7.00											67	53	
8.00				8.00									
9.00											60	49	
				9.50									
10.00											58	55	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-3 | SHEET NO. : 2 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
11.00	NX		Moderately weathered, reddish grey, BRECCIA	11.00							58	55	
12.00				12.50							60	50	
13.00			Moderately weathered, greyish, BASALT	14.00							68	58	
14.00													
15.00			Slightly weathered, greyish, BASALT	15.50							79	78	
16.00													
17.00			Fresh, grey, BRECCIA	17.00							97	61	
18.00				18.50							96	81	
19.00													
20.00				20.00							97	97	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-3 | SHEET NO. : 3 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
21.00	NX		Fresh, greyish, BRECCIA	20.00 – 21.50							91	82	
22.00 – 23.00				23.00							96	90	
24.00				24.50							97	87	
25.00 – 26.00				26.00							97	85	
27.00				27.50							93	87	
28.00 – 29.00				29.00							93	84	
30.00			Slightly weathered, greyish, BRECCIA								80	77	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-3 | SHEET NO. : 4 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
			Slightly weathered, greyish, BRECCIA	30.50							80	77	
31.00	NX		Fresh, grey, BRECCIA										
32.00				32.00							90	90	
33.00				33.50							93	63	
34.00													
35.00				35.00							92	63	
36.00													
37.00				36.50							90	64	
38.00				38.00							95	94	
39.00			Slightly weathered, greyish, BRECCIA	39.50							78	49	
40.00											86	51	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-3 | SHEET NO. : 5 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
41.00	NX		Fresh, grey, BRECCIA	41.00							86	57	
42.00				42.50							88	75	
43.00													
44.00				44.00							95	61	
45.00				45.50							91	79	
46.00													
47.00				47.00							87	72	
48.00				48.50							91	70	
49.00													
50.00				50.50							94	90	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : BORE HOLE IS TERMINATED AT DEPTH 50.50 m. BELOW G. L.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO.	: BH-4	SHEET NO.	: 1 OF 5
LOCATION	: --	DATE	: 09/01/2017 TO 01/02/2017
CO-ORDINATES	: N 19°10'24.4", E72°54'35.7"	METHOD	: ROTARY DRILLING
GROUND R. L.	: 89.00m.	CASING	: 100mm 1.50m & NX mm Ø UPTO BGL.
GROUND W. T.	: 8.30m.		

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm				SPT N	C R %	RQD %	OTHER TESTS
						15	15	15	15				
1.00	100 mm		Brownish, CLAY with gravel	0.00	DS1								
				1.50/		15	05	--	--				
2.00			Completely weathered, brownish, ROCK	1.70	SPT1	25	52	--	--	R			
3.00				3.00/		15	15	05	--				
4.00			Highly weathered, brownish, BRECCIA	3.35	SPT2	16	22	52	--	R			
				4.50/		15	05	--	--				
5.00	NX		Moderately weathered, reddish grey, BRECCIA	4.70	SPT2	26	55	--	--	R			
				5.00									
6.00				6.00							66	NIL	
7.00			Fresh, grey, BRECCIA	7.00							95	NIL	
				7.50							98	NIL	
8.00											61	40	
9.00				9.00									
10.00											67	45	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-4 | SHEET NO. : 2 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
11.00	NX		Fresh, grey, BRECCIA	10.50							67	45	
12.00				12.00							95	91	
13.00				13.50							93	65	
14.00													
15.00				15.00							76	55	
16.00				16.50							70	41	
17.00													
18.00				18.00							95	85	
19.00				19.50							88	53	
20.00											87	65	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-4 | SHEET NO. : 3 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
21.00	NX		Fresh, grey, BRECCIA	21.00							87	65	
22.00				22.50							78	41	
23.00				24.00							87	81	
24.00				25.50							90	90	
25.00				27.00							93	92	
26.00				28.50							97	67	
27.00				30.00							84	41	
28.00													
29.00													
30.00													

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-4 | SHEET NO. : 4 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
31.00	NX		Fresh, grey, BRECCIA	30.00 – 31.50							83	61	
32.00 – 33.00				33.00							80	73	
34.00				34.50							79	68	
35.00 – 36.00				36.00							53	07	
37.00				37.50							77	22	
38.00 – 39.00				39.00							73	63	
40.00											77	22	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PADECO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-4 | SHEET NO. : 5 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
41.00	NX		Fresh, grey, BRECCIA	40.50							77	22	
42.00				42.00							85	74	
43.00													
44.00													
45.00													
46.00													
47.00													
48.00													
49.00													
50.00													

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : BORE HOLE IS TERMINATED AT DEPTH 42.00 m. BELOW G. L.

CLIENT : **GMLR-PEDCO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO.	: BH-5	SHEET NO.	: 1 OF 5
LOCATION	: --	DATE	: 20/12/2016 TO 28/12/2016
CO-ORDINATES	: N 19°10'29.4", E72°54'54.7"	METHOD	: ROTARY DRILLING
GROUND R. L.	: 71.00m.	CASING	: 100mm 1.50m & NX mm Ø UPTO BGL.
GROUND W. T.	: --		

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm				SPT N	C R %	RQD %	OTHER TESTS
1.00	100 mm		Brownish, CLAY with gravel	0.00	DS1								
				1.50/		15	05	--	--				
2.00			Completely weathered, brownish, ROCK	1.70	SPT1	10	55	--	--	R			
3.00				3.00/		10	--	--	--				
4.00			Highly weathered, brownish, BRECCIA	3.10	SPT2	55	--	--	--	R	21	NIL	
				4.50									
5.00	NX		Moderately weathered, reddish grey, BRECCIA								51	31	
6.00				6.00									
7.00			Fresh, grey, BRECCIA								80	68	
				7.50									
8.00											95	91	
9.00				9.00									
											99	68	
10.00													

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PEDCO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-5 | SHEET NO. : 2 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
11.00	NX		Fresh, grey, BRECCIA	10.50							99	68	
12.00				12.00							91	91	
13.00				13.50							94	94	
14.00													
15.00				15.00							99	99	
16.00				16.50							93	88	
17.00													
18.00				18.00							98	98	
19.00				19.50							99	73	
20.00											96	96	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PEDCO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-5 | SHEET NO. : 3 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
21.00	NX		Fresh, grey, BRECCIA	21.00							96	96	
22.00				22.50							89	89	
23.00													
24.00				24.00							89	89	
25.00				25.50							89	89	
26.00													
27.00				27.00							93	93	
28.00				28.50							87	79	
29.00													
30.00				30.00							91	91	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PEDCO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-5 | SHEET NO. : 4 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
31.00	NX		Fresh, grey, BRECCIA	30.00 – 31.50							97	97	
32.00													
33.00				33.00							91	85	
34.00				34.50							92	92	
35.00													
36.00				36.00							87	87	
37.00				37.50							91	91	
38.00													
39.00				39.00							87	53	
40.00											87	51	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PEDCO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-5 | SHEET NO. : 5 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
40.50	NX		Fresh, grey, BRECCIA	40.50							87	51	
41.00													
42.00				42.00							93	93	
43.00				43.50							87	71	
44.00													
45.00				45.00							93	77	
46.00				46.50							99	84	
47.00				47.50							99	99	
48.00													
49.00													
50.00													

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : BORE HOLE IS TERMINATED AT DEPTH 47.50 m. BELOW G. L.

CLIENT : **GMLR-PEDCO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO.	: BH-6	SHEET NO.	: 1 OF 5
LOCATION	: --	DATE	: 30/12/2016 TO 17/01/2017
CO-ORDINATES	: N 19°10'21.7", E72°55'54.7"	METHOD	: ROTARY DRILLING
GROUND R. L.	: 89.00m.	CASING	: 100mm 1.50m & NX mm Ø UPTO BGL.
GROUND W. T.	: --		

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
1.00	100 mm		Brownish, CLAY with gravel	0.00	DS1								
				1.50/		--	--	--	--				
2.00			Completely weathered, brownish, ROCK	2.10	SPT1	04	07	07	09	14			
				2.50									
3.00				3.00							56	NIL	
4.00			Highly weathered, brownish, BRECCIA	4.50							16	NIL	
5.00	NX		Moderately weathered, reddish grey, BRECCIA								29	NIL	
6.00				6.00									
7.00			Fresh, grey, BRECCIA								55	15	
				7.50									
8.00											54	07	
9.00				9.00									
10.00											69	65	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PEDCO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-6 | SHEET NO. : 2 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
11.00	NX		Fresh, grey, BRECCIA	10.50							69	65	
12.00				12.00							79	50	
13.00				13.50							37	61	
14.00				15.00							92	51	
15.00				16.50							83	63	
16.00				18.00							73	51	
17.00				19.50							85	48	
18.00													
19.00													
20.00											81	67	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PEDCO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-6 | SHEET NO. : 3 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
21.00	NX		Fresh, grey, BRECCIA	21.00							81	67	
22.00				22.50							82	69	
23.00				24.00							93	91	
24.00				25.50							93	75	
25.00				27.00							86	69	
26.00				28.50							90	82	
27.00				30.00							86	86	
28.00													
29.00													
30.00													

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PEDCO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-6 | SHEET NO. : 4 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
31.00	NX		Fresh, grey, BRECCIA	30.00 – 31.50							77	61	
32.00													
33.00				33.00							81	67	
34.00				34.50							92	40	
35.00													
36.00				36.00							98	86	
37.00				37.50							95	74	
38.00													
39.00				39.00							81	55	
40.00											83	71	

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : CONTINUED ON NEXT PAGE.

CLIENT : **GMLR-PEDCO-MCGM**

PROJECT : Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP

BORE HOLE NO. : BH-6 | SHEET NO. : 5 OF 5

DEPTH (m.)	DIA. OF BORE HOLE	LOG.	STRATA DESCRIPTION	SAMPLE DEPTH (m)	SAMPLE TYPE	BLOWS/15cm 15	15	15	15	SPT N	C R %	RQD %	OTHER TESTS
				40.50							83	71	
41.00	NX		Fresh, grey, BRECCIA										
				42.00							83	61	
42.00													
				43.00							86	47	
43.00													

SPT N =STANDARD PENETRATION TEST VALUE RQD = ROCK QUALITY DESIGNATION UDS = UNDISTURBED SOIL SAMPLE
CR = CORE RECOVERY DS = DISTURBED SOIL SAMPLE

REMARKS : BORE HOLE IS TERMINATED AT DEPTH 43.00 m. BELOW G. L.

4.4.7. Core Box Photo: Tunnel Alignment

Figure 4-24: Borehole No 02 Tunnel Alignment

Figure 4-25: Borehole No 02 Tunnel Alignment

Figure 4-26: Borehole No 03 Tunnel Alignment

Figure 4-27: Borehole No 03 Tunnel Alignment

Figure 4-28: Borehole No 03 Tunnel Alignment

Figure 4-29: Borehole No 04 Tunnel Alignment

Figure 4-30: Borehole No 04 Tunnel Alignment

Figure 4-31: Borehole No 04 Tunnel Alignment

Figure 4-32: Borehole No 05 Tunnel Alignment

Figure 4-33: Borehole No 05 Tunnel Alignment

Figure 4-34: Borehole No 05 Tunnel Alignment

Figure 4-35: Borehole No 05 Tunnel Alignment

Figure 4-36: Borehole No 05 Tunnel Alignment

Figure 4-37: Borehole No 06 Tunnel Alignment

Figure 4-38: Borehole No 06 Tunnel Alignment

Figure 4-39: Borehole No 06 Tunnel Alignment

Figure 4-40: Borehole No 02 Location

Figure 4-41: Borehole No 03 Location

Figure 4-42: Borehole No 04 Location

Figure 4-43: Borehole No 05 Location

Figure 4-44: Borehole 06 Location

4.4.8. Lab Test Results: Tunnel Alignment

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Test Report No: OCEPPL/TPM/33

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock,BH No-2,Piece No-164- Depth 40.00-42.00 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	495.85
2	Water Absorption (%)	0.42
3	Porosity (%)	1.21
4	Density (g/cc)	2.82

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Quality Manager

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Test Report No: OCEPPL/TPM/34

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock,BH No-2,Piece No-198- Depth 48.00-50.00 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	610.80
2	Water Absorption (%)	0.58
3	Porosity (%)	1.62
4	Density (g/cc)	2.79

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Test Report No: OCEPPL/TPM/19

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan Geotechnic
Thane

Sample Description : Rock,BH No-3,Piece No -32- Depth 11.00-12.50 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	527.04
2	Water Absorption (%)	0.74
3	Porosity (%)	2.02
4	Density (g/cc)	2.75

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Test Report No: OCEPPL/TPM/20

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock,BH No-3,Piece No -104A- Depth 26.00-27.50 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	648.22
2	Water Absorption (%)	0.43
3	Porosity (%)	1.21
4	Density (g/cc)	2.81

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Test Report No: OCEPPL/TPM/16

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock,BH No-3,Piece No -160- Depth 38.00-39.50 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	264.19
2	Water Absorption (%)	0.30
3	Porosity (%)	0.81
4	Density (g/cc)	2.72

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Page : 1 of 1

Test Report No: OCEPPL/TPM/17

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock, BH No-3,Piece No -200-Depth 42.50-44.00 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	154.59
2	Water Absorption (%)	0.61
3	Porosity (%)	1.62
4	Density (g/cc)	2.63

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Test Report No: OCEPPL/TPM/18

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock,BH No-3,Piece No -247- Depth 48.50-50.00 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	188.89
2	Water Absorption (%)	0.45
3	Porosity (%)	1.21
4	Density (g/cc)	2.67

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Test Report No: OCEPPL/TPM/21

TEST REPORT

Name of Project / Site : GMLR

Name & Address of Client : M/s Jay Gajanan geotechnic
Thane

Sample Description : Rock,BH No-4,Piece No-28 Depth 13.50-15.00 m

Quantity : 1 Nos

Date of Test Report : 21.03.2017

Sr No.	Description of Tests	Test Results
1	Unconfined Compressive Strength (Kg/cm^2)	354.62
2	Water Absorption (%)	0.30
3	Porosity (%)	0.81
4	Density (g/cc)	2.74

Note : I.These results are valid only for the samples submitted in our laboratory by the above mentioned Client
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Geo-mechanical tests:

Cerchar, slake durability, Rock triaxial, young modulus tests were conducted in IIT Bombay Laboratory, Summary of the tests results are as follows

Table 4-13: Tensile strength of the samples Tunnel Alignment

Bore hole No	Depth (m)	Sample No	Tensile Strength (MPa)
BH 02	40.50-42.00	165	6.27
BH 02	49.50-50.0	205	9.432
BH 03	33.50-35.00	136	2.79
BH 04	22.50-24.0	84	5.763
BH 05	15.00-16.50	65	7.13
BH 05	19.50-21.00	75	2.32
BH 06	27.00-28.50	150	2.02
BH 06	33.00-34.50	172	6.03

Table 4-14: Cerchar Abrasion Index of the samples Tunnel Alignment

Bore hole No	Depth (m)	Specimens	CAI
BH-02	48.00-49.50	R-199	1.32
BH-03	41.00-42.50	R-187	1.44
BH-04	16.50-18.00	R-48	1.58
BH-04	24.00-25.50	R-92	1.08
BH-05	22.50-24.00	R-82	0.92
BH-06	25.50-27.00	R-140	1.29

Table 4-15: Triaxial Compressive Strength (Shear strength parameters) of the samples Tunnel Alignment

Bore hole No	Depth (m)	Sample No	Cohesion strength (MPa)	Angle of internal friction(Phi), degree
BH 02	40.50 - 42.00	166	6.29	52

BH 03	41.00 - 42.50	85	4.95	52.75
BH 04	22.50 - 24.00	84	4.06	37.5
BH 05	15.00 - 16.50	55	4.16	47.75
BH 05	21.00 - 22.50	77		
BH 06	18.00-19.50	115/116	6.11	51
BH 06	27.00 - 28.50	145/146		

Table 4-16: Young's modulus and Poison's ratio of the samples Tunnel Alignment

Bore hole No	Depth (m)	Sample No	Young's Modules (GPa)	Poisson's ratio
BH-02	40.50- 42.00	167	43.96	0.24
BH-02	48.00 - 49.50	195	48.23	0.24
BH-03	45.50- 47.00	224	35.07	0.23
BH-04	21.00 - 22.50	734	44.59	0.24
BH-05	18.00 - 19.50	68	46.78	0.24
BH-06	27.00 - 28.50	148	51.28	0.24

Table 4-17: Slake durability index of the samples Tunnel Alignment

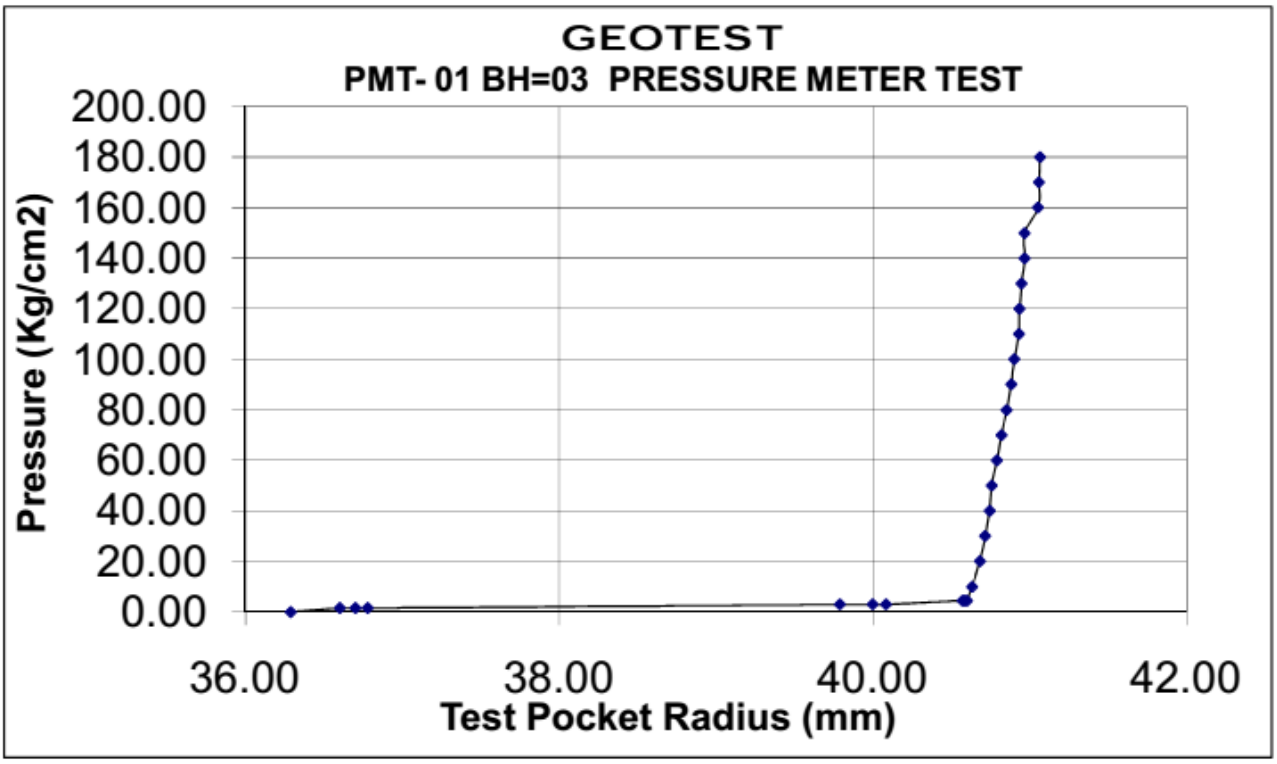
Bore hole No	Depth (m)	Sample No	Ist Cycle SDI (%)	IInd Cycle SDI (%)
BH-02	40.50-42.00	167	94.87	93.68
BH-02	49.50-50.00	203	95.78	94.64
BH-03	44.00-45.50	208	89.79	88.43
BH-04	22.50-24.00	86	81.72	80.43
BH-05	21.00-22.50	78	92.16	90.49
BH-06	27.00-28.00	147	88.64	87.05
BH-06	33.00-34.50	148	90.23	89.36

4.4.9. Field Test Results: Tunnel Alignment

4.4.9.1. Pressure Meter Test Tunnel Alignment

PRESSURE METER TEST

PROJECT			G.M.L.R.					
NAME OF CLIENT			MCGM / PADECO		SIZE OF BOREHOLE (mm)			Nx
BOREHOLE NO.			BH=03		DATE			17.02.2017
LOCATION			N=191017.6 E=725417.2		TEST DEPTH (m)			13.00-14.50
RL (m)			112		FINAL DEPTH (m)			50.00
TYPE OF STRATA			Moderately to Slightly Hard &		CASING (m)			5.00
Sr No.	Time in sec.	Pressure P (MPa)	Pressure P' (Kg/Cm2)	Displacement Display Value Rn	Inner Radius Display Value Ri =Rn+23.5	Thickness Correction Volume PG= P"/K	Reference inner Radius Rs =Ri-PG	Test Pocket Radius R= SQRT (Rs2+S/π)
		(Mpa)	(Kg/Cm2)	(mm)	(mm)		(mm)	(mm)
1	0	0.00	0.00	0.00	23.50	-0.01	23.51	36.29
2	15	0.15	1.50	0.48	23.98	-0.01	23.99	36.60
3	15	0.15	1.50	0.63	24.13	-0.01	24.14	36.70
4	15	0.15	1.50	0.75	24.25	-0.01	24.26	36.78
5	15	0.30	3.00	5.11	28.61	-0.01	28.62	39.79
6	15	0.30	3.00	5.40	28.90	-0.01	28.91	40.00
7	15	0.30	3.00	5.52	29.02	-0.01	29.03	40.08
8	15	0.45	4.50	6.19	29.69	-0.01	29.70	40.57
9	15	0.45	4.50	6.21	29.71	-0.01	29.72	40.59
10	15	0.45	4.50	6.23	29.73	-0.01	29.74	40.60
11		1.00	10.00	6.28	29.78	0.00	29.78	40.63
12		2.00	20.00	6.36	29.86	0.01	29.85	40.68
13		3.00	30.00	6.42	29.92	0.03	29.90	40.72
14		4.00	40.00	6.47	29.97	0.04	29.93	40.74
15		5.00	50.00	6.50	30.00	0.05	29.95	40.76
16		6.00	60.00	6.56	30.06	0.06	30.00	40.79
17		7.00	70.00	6.61	30.11	0.08	30.04	40.82
18		8.00	80.00	6.67	30.17	0.09	30.08	40.85
19		9.00	90.00	6.72	30.22	0.10	30.12	40.88
20		10.00	100.00	6.76	30.26	0.11	30.15	40.90
21		11.00	110.00	6.81	30.31	0.13	30.19	40.93
22		12.00	120.00	6.83	30.33	0.14	30.19	40.94
23		13.00	130.00	6.86	30.36	0.15	30.21	40.95
24		14.00	140.00	6.90	30.40	0.16	30.24	40.97
25		15.00	150.00	6.91	30.41	0.18	30.24	40.97
26		16.00	160.00	7.04	30.54	0.19	30.35	41.05
27		17.00	170.00	7.06	30.56	0.20	30.36	41.06
28		18.00	180.00	7.08	30.58	0.21	30.37	41.06
Calculation Notes:					Type Of Probe	A		
Membrane Calibration Constants					Thickness Correction K :Mn/m2/mm=80			
					Expansion Correction S (mm2)= 2399.35			
GEOTEST						Job No	Prepared by	Cheked By
						2002	Vaibhav	Prasad



PMT: 01 PRESSURE METER TEST

Observation from Graph

Intial Pressure P1 (Kg/ cm2) =	80.00	
Final Pressure P2 (Kg/ cm2) =	120.00	
Δ P (Kg/cm2) =	40.00	
Intial Radius (mm) =	40.85	
Final Radius (mm) =	40.94	
Δ R(cm) =	**0.009**	
r(cm)=	4.0895	**γ = 0.3**

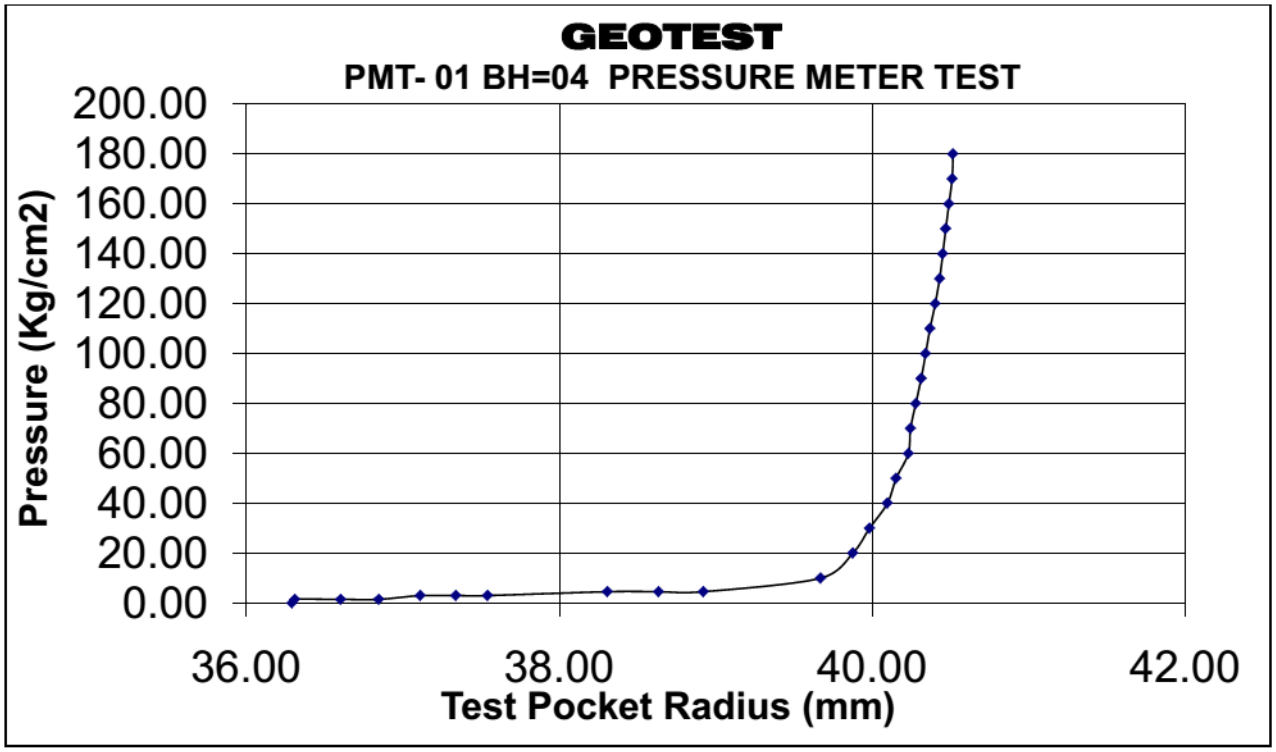
Calculations

K= ΔP/ΔR =	4444.444444	
E=(1+γ)rK=	23628.2222	(kg/cm2)
G= E/2(1+γ)=	15358.3444	(kg/cm2)

GEOTEST

PRESSURE METER TEST

PROJECT			G.M.L.R.					
NAME OF CLIENT			MCGM / PADECO		SIZE OF BOREHOLE (mm)			Nx
BOREHOLE NO.			BH=04		DATE			05.03.2017
LOCATION			N=191024.4 E=725435.1		TEST DEPTH (m)			21.00-22.50
RL (m)			89		FINAL DEPTH (m)			50.00
TYPE OF STRATA			Fresh to Slightly weathered Basalt		CASING (m)			5.00
Sr No.	Time in sec.	Pressure P (MPa)	Pressure P' (Kg/Cm2)	Displacement Display Value Rn	Inner Radius Display Value Ri =Rn+23.5	Thickness Correction Volume PG= P"/K	Reference inner Radius Rs =Ri-PG	Test Pocket Radius R= SQRT (Rs2+S/π)
		(Mpa)	(Kg/Cm2)	(mm)	(mm)		(mm)	(mm)
1	0	0.00	0.00	0.00	23.50	-0.01	23.51	36.29
2	15	0.15	1.50	0.03	23.53	-0.01	23.54	36.31
3	15	0.15	1.50	0.48	23.98	-0.01	23.99	36.60
4	15	0.15	1.50	0.85	24.35	-0.01	24.36	36.85
5	15	0.30	3.00	1.25	24.75	-0.01	24.76	37.11
6	15	0.30	3.00	1.59	25.09	-0.01	25.10	37.34
7	15	0.30	3.00	1.89	25.39	-0.01	25.40	37.54
8	15	0.45	4.50	3.01	26.51	-0.01	26.52	38.30
9	15	0.45	4.50	3.48	26.98	-0.01	26.99	38.63
10	15	0.45	4.50	3.89	27.39	-0.01	27.40	38.92
11		1.00	10.00	4.95	28.45	0.00	28.45	39.67
12		2.00	20.00	5.25	28.75	0.01	28.74	39.87
13		3.00	30.00	5.41	28.91	0.03	28.89	39.98
14		4.00	40.00	5.58	29.08	0.04	29.04	40.09
15		5.00	50.00	5.67	29.17	0.05	29.12	40.15
16		6.00	60.00	5.79	29.29	0.06	29.23	40.23
17		7.00	70.00	5.82	29.32	0.08	29.25	40.24
18		8.00	80.00	5.88	29.38	0.09	29.29	40.28
19		9.00	90.00	5.94	29.44	0.10	29.34	40.31
20		10.00	100.00	5.99	29.49	0.11	29.38	40.34
21		11.00	110.00	6.04	29.54	0.13	29.42	40.37
22		12.00	120.00	6.10	29.60	0.14	29.46	40.40
23		13.00	130.00	6.15	29.65	0.15	29.50	40.43
24		14.00	140.00	6.19	29.69	0.16	29.53	40.45
25		15.00	150.00	6.23	29.73	0.18	29.56	40.47
26		16.00	160.00	6.27	29.77	0.19	29.58	40.49
27		17.00	170.00	6.31	29.81	0.20	29.61	40.51
28		18.00	180.00	6.33	29.83	0.21	29.62	40.51
Calculation Notes:					Type Of Probe	A		
Membrane Calibration Constants					Thickness Correction K :Mn/m2/mm=80			
					Expansion Correction S (mm2)= 2399.35			
GEOTEST						Job No	Prepared by	Cheked By
						2003	Vaibhav	Prasad



PMT: 01 PRESSURE METER TEST

Observation from Graph

Intial Pressure P1 (Kg/ cm2) =	80.00	
Final Pressure P2 (Kg/ cm2) =	120.00	
Δ P (Kg/cm2) =	40.00	
Intial Radius (mm) =	40.28	
Final Radius (mm) =	40.4	
Δ R(cm) =	**0.012**	
r(cm)=	4.034	**γ** = 0.3

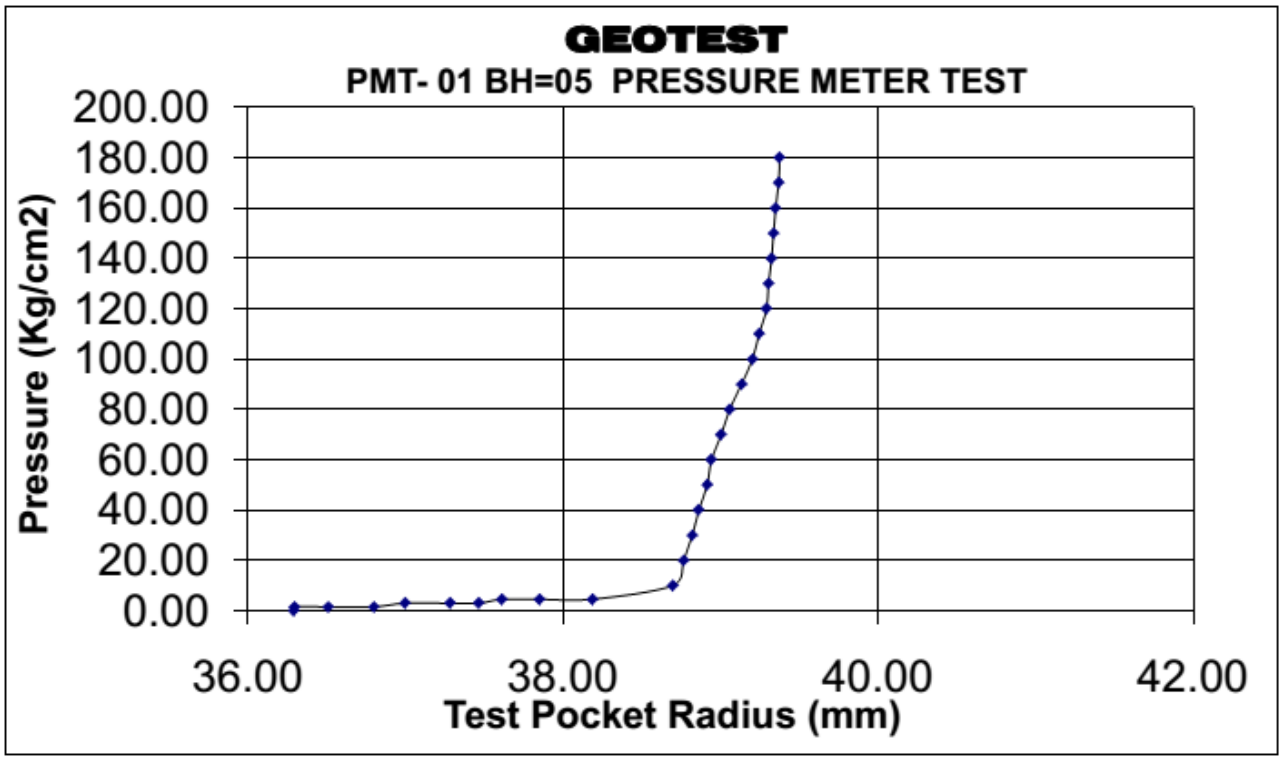
Calculations

K= ΔP/ΔR =	3333.333333	
E=(1+γ)rK=	17480.6667	(kg/cm2)
G= E/2(1+γ)=	11362.4333	(kg/cm2)

GEOTEST

PRESSURE METER TEST

PROJECT			G.M.L.R.					
NAME OF CLIENT			MCGM / PADECO		SIZE OF BOREHOLE (mm)			Nx
BOREHOLE NO.			BH=05		DATE			17.02.2017
LOCATION			N=191029.4 E=725454.7		TEST DEPTH (m)			19.50-21.00
RL (m)			71		FINAL DEPTH (m)			50.00
TYPE OF STRATA			Fresh to Slightly weathered		CASING (m)			5.00
Sr No.	Time in sec.	Pressure P (MPa)	Pressure P' (Kg/Cm2)	Displacement Display Value Rn	Inner Radius Display Value Ri =Rn+23.5	Thickness Correction Volume PG= P"/K	Reference inner Radius Rs =Ri-PG	Test Pocket Radius R= SQRT (Rs2+S/π)
		(Mpa)	(Kg/Cm2)	(mm)	(mm)		(mm)	(mm)
1	0	0.00	0.00	0.00	23.50	-0.01	23.51	36.29
2	15	0.15	1.50	0.01	23.51	-0.01	23.52	36.30
3	15	0.15	1.50	0.34	23.84	-0.01	23.85	36.51
4	15	0.15	1.50	0.78	24.28	-0.01	24.29	36.80
5	15	0.30	3.00	1.08	24.58	-0.01	24.59	37.00
6	15	0.30	3.00	1.51	25.01	-0.01	25.02	37.28
7	15	0.30	3.00	1.78	25.28	-0.01	25.29	37.47
8	15	0.45	4.50	2.00	25.50	-0.01	25.51	37.61
9	15	0.45	4.50	2.35	25.85	-0.01	25.86	37.85
10	15	0.45	4.50	2.84	26.34	-0.01	26.35	38.19
11		1.00	10.00	3.58	27.08	0.00	27.08	38.70
12		2.00	20.00	3.69	27.19	0.01	27.18	38.77
13		3.00	30.00	3.78	27.28	0.03	27.26	38.82
14		4.00	40.00	3.85	27.35	0.04	27.31	38.86
15		5.00	50.00	3.94	27.44	0.05	27.39	38.91
16		6.00	60.00	3.99	27.49	0.06	27.43	38.94
17		7.00	70.00	4.09	27.59	0.08	27.52	39.00
18		8.00	80.00	4.18	27.68	0.09	27.59	39.06
19		9.00	90.00	4.30	27.80	0.10	27.70	39.13
20		10.00	100.00	4.41	27.91	0.11	27.80	39.20
21		11.00	110.00	4.48	27.98	0.13	27.86	39.24
22		12.00	120.00	4.56	28.06	0.14	27.92	39.29
23		13.00	130.00	4.59	28.09	0.15	27.94	39.30
24		14.00	140.00	4.63	28.13	0.16	27.97	39.32
25		15.00	150.00	4.66	28.16	0.18	27.99	39.34
26		16.00	160.00	4.69	28.19	0.19	28.00	39.35
27		17.00	170.00	4.73	28.23	0.20	28.03	39.37
28		18.00	180.00	4.75	28.25	0.21	28.04	39.37
Calculation Notes:					Type Of Probe	A		
Membrane Calibration Constants					Thickness Correction K :Mn/m2/mm=80			
					Expansion Correction S (mm2)= 2399.35			
GEOTEST						Job No	Prepared by	Cheked By
						2003	Vaibhav	Prasad



PMT: 01 PRESSURE METER TEST

Observation from Graph

Intial Pressure P1 (Kg/ cm2) =	100.00	
Final Pressure P2 (Kg/ cm2) =	140.00	
Δ P (Kg/cm2) =	40.00	
Intial Radius (mm) =	39.20	
Final Radius (mm) =	39.32	
Δ R(cm) =	**0.012**	
r(cm)=	3.926	**γ =** 0.3

Calculations

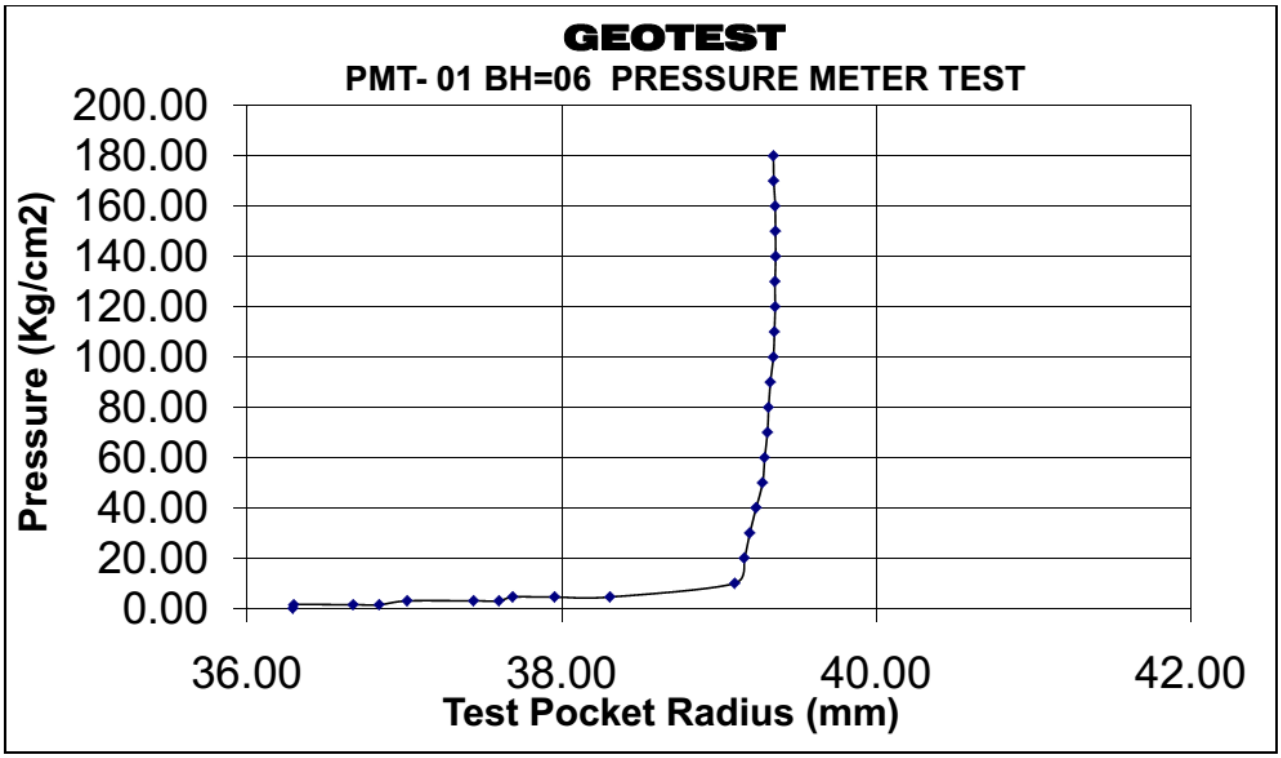
K= ΔP/ΔR =	3333.333333	
E=(1+γ)rK=	17012.6667	(kg/cm2)
G= E/2(1+γ)=	11058.2333	(kg/cm2)

GEOTEST

PRESSURE METER TEST

PROJECT			G.M.L.R.					
NAME OF CLIENT			MCGM / PADECO		SIZE OF BOREHOLE (mm)			Nx
BOREHOLE NO.			BH=06		DATE			17.02.2017
LOCATION			N=191021.7 E=725521.8		TEST DEPTH (m)			30.00-31.50
RL (m)			89		FINAL DEPTH (m)			50.00
TYPE OF STRATA			Fresh to Slightly weathered Basalt		CASING (m)			5.00
Sr No.	Time in sec.	Pressure P (MPa)	Pressure P' (Kg/Cm2)	Displacement Display Value Rn	Inner Radius Display Value Ri =Rn+23.5	Thickness Correction Volume PG= P"/K	Reference inner Radius Rs =Ri-PG	Test Pocket Radius R= SQRT (Rs2+S/π)
		(Mpa)	(Kg/Cm2)	(mm)	(mm)		(mm)	(mm)
1	0	0.00	0.00	0.00	23.50	-0.01	23.51	36.29
2	15	0.15	1.50	0.01	23.51	-0.01	23.52	36.30
3	15	0.15	1.50	0.59	24.09	-0.01	24.10	36.67
4	15	0.15	1.50	0.84	24.34	-0.01	24.35	36.84
5	15	0.30	3.00	1.11	24.61	-0.01	24.62	37.02
6	15	0.30	3.00	1.74	25.24	-0.01	25.25	37.44
7	15	0.30	3.00	1.98	25.48	-0.01	25.49	37.60
8	15	0.45	4.50	2.11	25.61	-0.01	25.62	37.69
9	15	0.45	4.50	2.50	26.00	-0.01	26.01	37.95
10	15	0.45	4.50	3.01	26.51	-0.01	26.52	38.30
11		1.00	10.00	4.15	27.65	0.00	27.65	39.10
12		2.00	20.00	4.25	27.75	0.01	27.74	39.16
13		3.00	30.00	4.31	27.81	0.03	27.79	39.19
14		4.00	40.00	4.38	27.88	0.04	27.84	39.23
15		5.00	50.00	4.45	27.95	0.05	27.90	39.28
16		6.00	60.00	4.48	27.98	0.06	27.92	39.29
17		7.00	70.00	4.52	28.02	0.08	27.95	39.31
18		8.00	80.00	4.54	28.04	0.09	27.95	39.31
19		9.00	90.00	4.57	28.07	0.10	27.97	39.32
20		10.00	100.00	4.61	28.11	0.11	28.00	39.34
21		11.00	110.00	4.63	28.13	0.13	28.01	39.35
22		12.00	120.00	4.65	28.15	0.14	28.01	39.36
23		13.00	130.00	4.66	28.16	0.15	28.01	39.35
24		14.00	140.00	4.68	28.18	0.16	28.02	39.36
25		15.00	150.00	4.69	28.19	0.18	28.02	39.36
26		16.00	160.00	4.70	28.20	0.19	28.01	39.36
27		17.00	170.00	4.70	28.20	0.20	28.00	39.35
28		18.00	180.00	4.71	28.21	0.21	28.00	39.34

Calculation Notes:		Type Of Probe	A	
Membrane Calibration Constants		Thickness Correction K :Mn/m2/mm=80		
		Expansion Correction S (mm2)= 2399.35		
GEOTEST		Job No	Prepared by	Cheked By
		2003	Vaibhav	Prasad



PMT: 01 PRESSURE METER TEST

Observation from Graph

Intial Pressure P1 (Kg/ cm2) =	60.00	
Final Pressure P2 (Kg/ cm2) =	100.00	
Δ P (Kg/cm2) =	40.00	
Intial Radius (mm) =	39.29	
Final Radius (mm) =	39.34	
Δ R(cm) =	**0.005**	
r(cm)=	3.9315	**γ =** 0.3

Calculations

K= ΔP/ΔR =	8000	
E=(1+γ)rK=	40887.6000	(kg/cm2)
G= E/2(1+γ)=	26576.9400	(kg/cm2)

GEOTEST

4.4.9.2. Packer Permeability Test along Tunnel alignment:

PACKER PERMEABILITY TEST

Project : **Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP**

Elevation : 117.00m.
Location : --
Coordinate : N 19°10'10.6", E72°54'00.1"
Inclination : 90 (Deg. With Horizontal)
Test Section : **15.00** To **16.50** m
Length of Test Section : 1.50 m
Type of Test : **Double Packer Test**
Test Locatior : Test Below Water Table

Date : **06/03/2017**
Bore Hole : **BH 2**
Depth of Bore Hole(m) : **50.00**
Diameter (mm) : **NX-76.00**
Water Table (m) : **12.30**
H_1 (m) : **1.25**
H_2 (m) : **12.30**

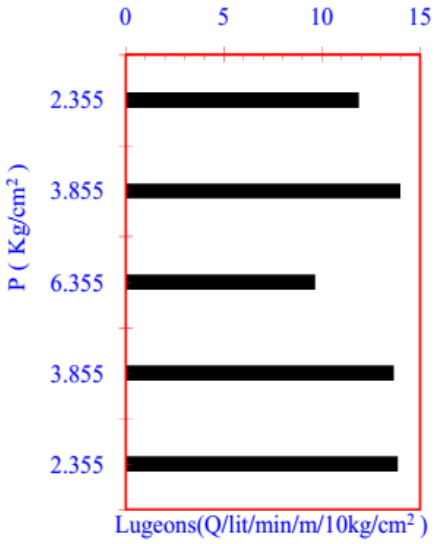
Sr. No.	L (m)	H_1 (m)	H_2 (m)	P_0 Kg / cm²	P Kg / cm²	t (min)	Q_t (lit)	Q_o (lit/min)	Q lit/min/m	Lugeon	k (cm/sec)
1	1.50	1.25	12.30	1.00	2.355	10.0	42.00	4.20	2.800	11.890	1.19E-04
2	1.50	1.25	12.30	2.50	3.855	10.0	81.00	8.10	5.400	14.008	1.40E-04
3	1.50	1.25	12.30	5.00	6.355	10.0	92.00	9.20	6.133	9.651	9.65E-05
4	1.50	1.25	12.30	2.50	3.855	10.0	79.00	7.90	5.267	13.662	1.37E-04
5	1.50	1.25	12.30	1.00	2.355	10.0	49.00	4.90	3.267	13.871	1.39E-04

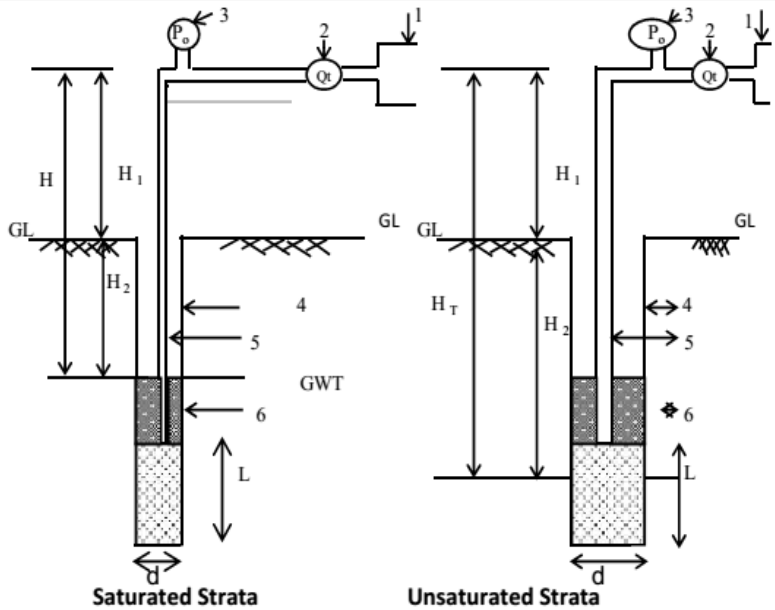
Sample Calculation :-
As per IS - 5529

$P : P_0 + (H_1 + H_2)/10$: 2.355 Kg/cm²
$Q_0 : Q_t / t$ = 4.200 lit / min
$Q : Q_0 / L$ = 2.800 lit/min/m

Lugeon :- $\frac{Q * 1\ Mpa}{\text{Test Pressure i.e. P}}$ = **11.890**

Group : --
Classification : --
Permeability Value : **11.890** Lugeon





Saturated Strata
1 :- Pump
2 :- Flow Meter
3 :- Pressure Gauge
4 :- Drill Hole
5 :- Injection Pipe
6 :- Packer
Lugeon :- Lugeon Value in lit/min/m/10Kg/cm²
k :- Permeability in cm/sec

Unsaturated Strata
P_o :- Gauge Pressure
H_1 :- Height of Pressure Gauge
H_2 :- Depth of Ground Water or Mid of Test Section to Ground Surface
P :- Effective Pressure
P :- P_0+H/10 or H = H_1 + H_2
t :- Injection Time
Q_t :- Water Volume During time
Q_0 :- Water Volume / min.

PACKER PERMEABILITY TEST

Project : **Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP**

Elevation : 117.00m.
Location : --
Coordinate : N 19°10'10.6", E72°54'00.1"
Inclination : 90 (Deg. With Horizontal)
Test Section : **27.00** To **28.50** m
Length of Test Section : 1.50 m
Type of Test : **Double Packer Test**
Test Locatior : Test Below Water Table

Date : **06/03/2017**
Bore Hole : **BH 2**
Depth of Bore Hole(m) : **50.00**
Diameter (mm) : **NX-76.00**
Water Table (m) : **12.30**
H_1 (m) : **1.25**
H_2 (m) : **12.30**

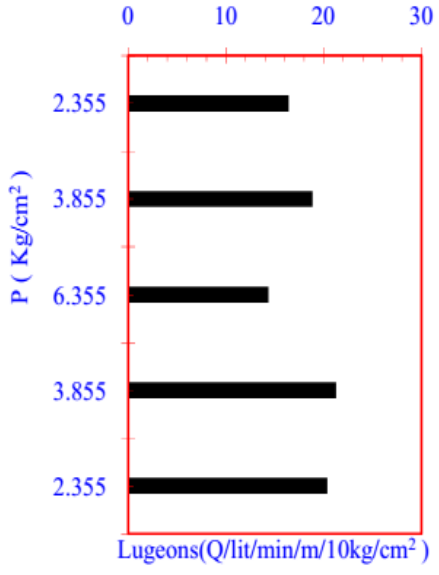
Sr. No.	L (m)	H_1 (m)	H_2 (m)	P_0 Kg / cm^2	P Kg / cm^2	t (min)	Q_t (lit)	Q_o (lit/min)	Q lit/min/m	Lugeon	k (cm/sec)
1	1.50	1.25	12.30	1.00	2.355	10.0	58.00	5.80	3.867	16.419	1.64E-04
2	1.50	1.25	12.30	2.50	3.855	10.0	109.00	10.90	7.267	18.850	1.88E-04
3	1.50	1.25	12.30	5.00	6.355	10.0	137.00	13.70	9.133	14.372	1.44E-04
4	1.50	1.25	12.30	2.50	3.855	10.0	123.00	12.30	8.200	21.271	2.13E-04
5	1.50	1.25	12.30	1.00	2.355	10.0	72.00	7.20	4.800	20.382	2.04E-04

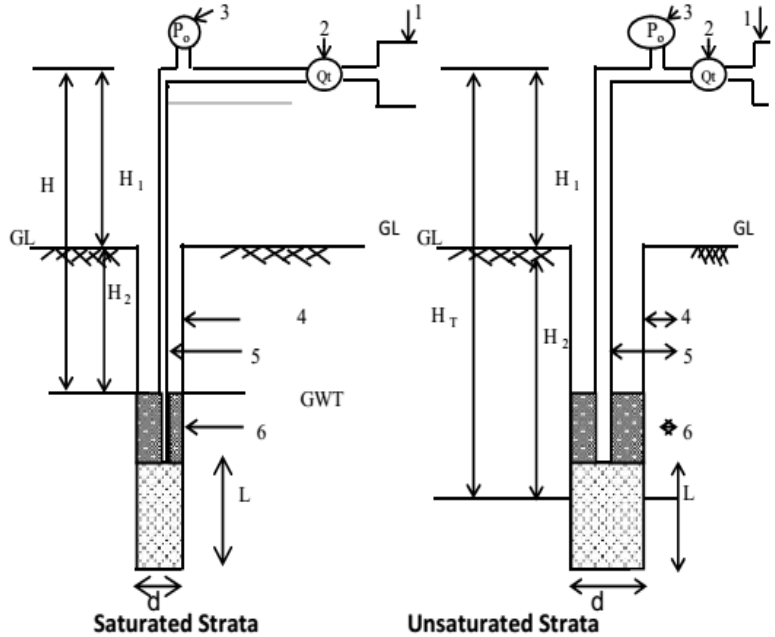
Sample Calculation :-
As per IS - 5529

$P : P_0 + (H_1 + H_2)/10$: 2.355 Kg/cm^2
$Q_0 : Q_t / t$ = 5.800 lit / min
$Q : Q_0 / L$ = 3.867 lit/min/m

Lugeon :- $\frac{Q * 1\ Mpa}{\text{Test Pressure i.e. P}}$ = **16.419**

Group : --
Classification : --
Permeability Value : **16.419** Lugeon





Saturated Strata

1 :- Pump
2 :- Flow Meter
3 :- Pressure Gauge
4 :- Drill Hole
5 :- Injection Pipe
6 :- Packer
Lugeon :- Lugeon Value in lit/min/m/10Kg/cm^2
k :- Permeability in cm/sec

Unsaturated Strata

P_o :- Gauge Pressure
H_1 :- Height of Pressure Gauge
H_2 :- Depth of Ground Water or Mid of Test Section to Ground Surface
P :- Effective Pressure
P :- P_0+H/10 or H = H_1 + H_2
t :- Injection Time
Q_t :- Water Volume During time
Q_0 :- Water Volume / min.

PACKER PERMEABILITY TEST

Project : **Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP**

Elevation : 112.00m.
Location : --
Coordinate : -
Inclination : 90 (Deg. With Horizontal)
Test Section : **29.00** To **30.50** m
Length of Test Section : 1.50 m
Type of Test : **Double Packer Test**
Test Locatior : Test Below Water Table

Date : **06/03/2017**
Bore Hole : **BH 3**
Depth of Bore Hole(m) : **50.50**
Diameter (mm) : **NX-76.00**
Water Table (m) : **9.20**
H_1 (m) : **1.25**
H_2 (m) : **9.20**

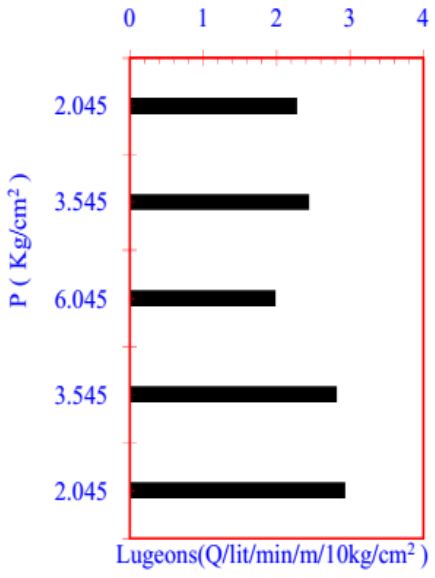
Sr. No.	L (m)	H_1 (m)	H_2 (m)	P_0 Kg / cm^2	P Kg / cm^2	t (min)	Q_t (lit)	Q_o (lit/min)	Q lit/min/m	Lugeon	k (cm/sec)
1	1.50	1.25	9.20	1.00	2.045	10.0	7.00	0.70	0.467	2.282	2.28E-05
2	1.50	1.25	9.20	2.50	3.545	10.0	13.00	1.30	0.867	2.445	2.44E-05
3	1.50	1.25	9.20	5.00	6.045	10.0	18.00	1.80	1.200	1.985	1.99E-05
4	1.50	1.25	9.20	2.50	3.545	10.0	15.00	1.50	1.000	2.821	2.82E-05
5	1.50	1.25	9.20	1.00	2.045	10.0	9.00	0.90	0.600	2.934	2.93E-05

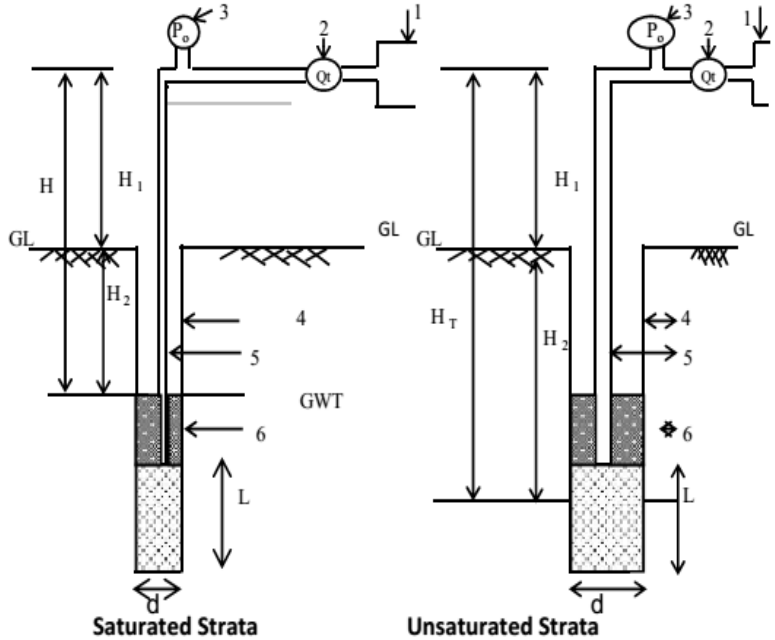
Sample Calculation :-
As per IS - 5529

$P : P_0 + (H_1 + H_2)/10$: 2.045 Kg/cm^2
$Q_0 : Q_t / t$ = 0.700 lit / min
$Q : Q_0 / L$ = 0.467 lit/min/m

Lugeon :- $\frac{Q * 1\ Mpa}{\text{Test Pressure i.e. P}}$ = **2.282**

Group : --
Classification : --
Permeability Value : **2.282** Lugeon





Saturated Strata

1 :- Pump
2 :- Flow Meter
3 :- Pressure Gauge
4 :- Drill Hole
5 :- Injection Pipe
6 :- Packer
Lugeon :- Lugeon Value in lit/min/m/10Kg/cm^2
k :- Permeability in cm/sec

Unsaturated Strata

P_o :- Gauge Pressure
H_1 :- Height of Pressure Gauge
H_2 :- Depth of Ground Water or Mid of Test Section to Ground Surface
P :- Effective Pressure
P :- P_0+H/10 or H = $H_1 + H_2$
t :- Injection Time
Q_t :- Water Volume During time
Q_0 :- Water Volume / min.

PACKER PERMEABILITY TEST

Project : **Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP**

Elevation : 112.00m.
Location : --
Coordinate : -
Inclination : 90 (Deg. With Horizontal)
Test Section : **38.00** To **39.50** m
Length of Test Section : 1.50 m
Type of Test : **Double Packer Test**
Test Locatior : Test Below Water Table

Date : **06/03/2017**
Bore Hole : **BH 3**
Depth of Bore Hole(m) : **50.50**
Diameter (mm) : **NX-76.00**
Water Table (m) : **9.20**
H_1 (m) : **1.25**
H_2 (m) : **9.20**

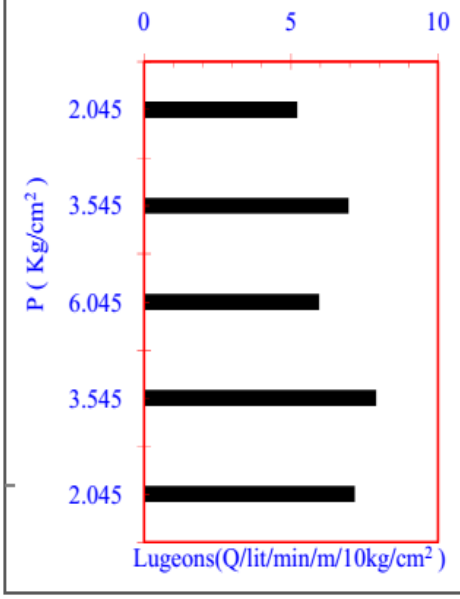
Sr. No.	L (m)	H_1 (m)	H_2 (m)	P_0 Kg / cm^2	P Kg / cm^2	t (min)	Q_t (lit)	Q_o (lit/min)	Q lit/min/m	Lugeon	k (cm/sec)
1	1.50	1.25	9.20	1.00	2.045	10.0	16.00	1.60	1.067	5.216	5.22E-05
2	1.50	1.25	9.20	2.50	3.545	10.0	37.00	3.70	2.467	6.958	6.96E-05
3	1.50	1.25	9.20	5.00	6.045	10.0	54.00	5.40	3.600	5.955	5.96E-05
4	1.50	1.25	9.20	2.50	3.545	10.0	42.00	4.20	2.800	7.898	7.90E-05
5	1.50	1.25	9.20	1.00	2.045	10.0	22.00	2.20	1.467	7.172	7.17E-05

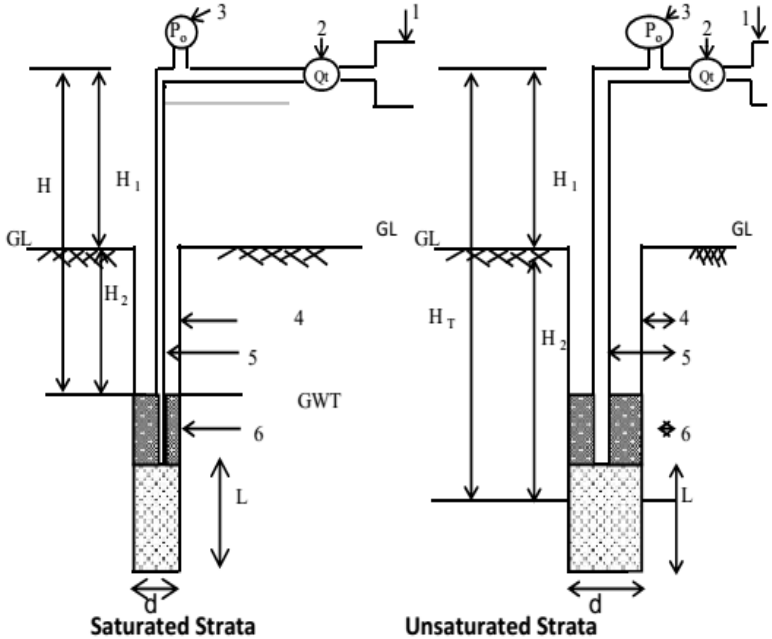
Sample Calculation :-
As per IS - 5529

P : $P_0 + (H_1 + H_2)/10$: 2.045 Kg/cm^2
Q_0 : Q_t / t = 1.600 lit / min
Q : Q_0 / L = 1.067 lit/min/m

Lugeon :- $\frac{Q * 1\ Mpa}{\text{Test Pressure i.e. P}}$ = **5.216**

Group : --
Classification : --
Permeability Value : **5.216** Lugeon





Saturated Strata

1 :- Pump
2 :- Flow Meter
3 :- Pressure Gauge
4 :- Drill Hole
5 :- Injection Pipe
6 :- Packer
Lugeon :- Lugeon Value in lit/min/m/10Kg/cm^2
k :- Permeability in cm/sec

Unsaturated Strata

P_o :- Gauge Pressure
H_1 :- Height of Pressure Gauge
H_2 :- Depth of Ground Water or Mid of Test Section to Ground Surface
P :- Effective Pressure
P :- $P_0+H/10$ or $H = H_1 + H_2$
t :- Injection Time
Q_t :- Water Volume During time
Q_0 :- Water Volume / min.

PACKER PERMEABILITY TEST

Project : **Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP**

Elevation : 89.00m.
Location : --
Coordinate : N 19°10'24.4", E72°54'35.7"
Inclination : 90 (Deg. With Horizontal)
Test Section : **15.00** To **16.50** m
Length of Test Section : 1.50 m
Type of Test : **Double Packer Test**
Test Locatior : Test Below Water Table

Date : **07/03/2017**
Bore Hole : **BH 4**
Depth of Bore Hole(m) : **42.00**
Diameter (mm) : **NX-76.00**
Water Table (m) : **8.30**
H_1 (m) : **1.25**
H_2 (m) : **8.30**

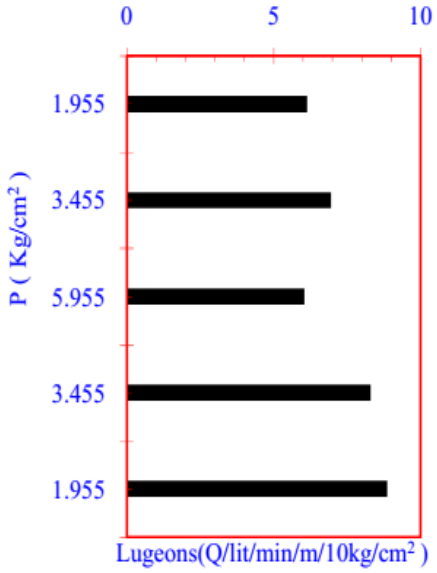
Sr. No.	L (m)	H_1 (m)	H_2 (m)	P_0 Kg / cm^2	P Kg / cm^2	t (min)	Q_t (lit)	Q_o (lit/min)	Q lit/min/m	Lugeon	k (cm/sec)
1	1.50	1.25	8.30	1.00	1.955	10.0	18.00	1.80	1.200	6.138	6.14E-05
2	1.50	1.25	8.30	2.50	3.455	10.0	36.00	3.60	2.400	6.946	6.95E-05
3	1.50	1.25	8.30	5.00	5.955	10.0	54.00	5.40	3.600	6.045	6.05E-05
4	1.50	1.25	8.30	2.50	3.455	10.0	43.00	4.30	2.867	8.297	8.30E-05
5	1.50	1.25	8.30	1.00	1.955	10.0	26.00	2.60	1.733	8.866	8.87E-05

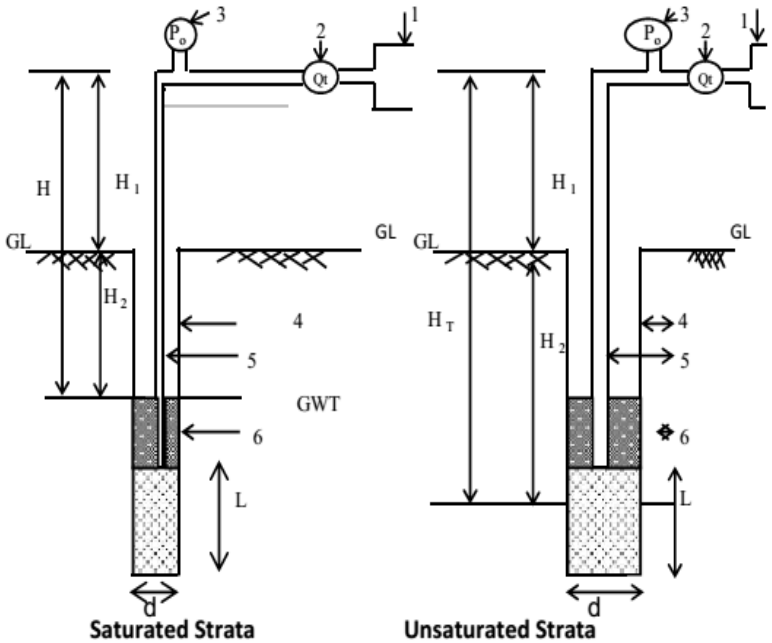
Sample Calculation :-
As per IS - 5529

P : $P_0 + (H_1 + H_2)/10$: 1.955 Kg/cm^2
Q_0 : Q_t / t = 1.800 lit / min
Q : Q_0 / L = 1.200 lit/min/m

Lugeon :- $\frac{Q * 1\ Mpa}{\text{Test Pressure i.e. P}}$ = **6.138**

Group : --
Classification : --
Permeability Value : **6.138** Lugeon





Saturated Strata

1 :- Pump
2 :- Flow Meter
3 :- Pressure Gauge
4 :- Drill Hole
5 :- Injection Pipe
6 :- Packer
Lugeon :- Lugeon Value in lit/min/m/10Kg/cm^2
k :- Permeability in cm/sec

Unsaturated Strata

P_o :- Gauge Pressure
H_1 :- Height of Pressure Gauge
H_2 :- Depth of Ground Water or Mid of Test Section to Ground Surface
P :- Effective Pressure
P :- P_0+H/10 or H = $H_1 + H_2$
t :- Injection Time
Q_t :- Water Volume During time
Q_0 :- Water Volume / min.

PACKER PERMEABILITY TEST

Project : **Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP**

Elevation : 89.00m.
Location : --
Coordinate : N 19°10'24.4", E72°54'35.7"
Inclination : 90 (Deg. With Horizontal)
Test Section : **28.50** To **30.00** m
Length of Test Section : 1.50 m
Type of Test : **Double Packer Test**
Test Locatior : Test Below Water Table

Date : **07/03/2017**
Bore Hole : **BH 4**
Depth of Bore Hole(m) : **42.00**
Diameter (mm) : **NX-76.00**
Water Table (m) : **8.30**
H_1 (m) : **1.25**
H_2 (m) : **8.30**

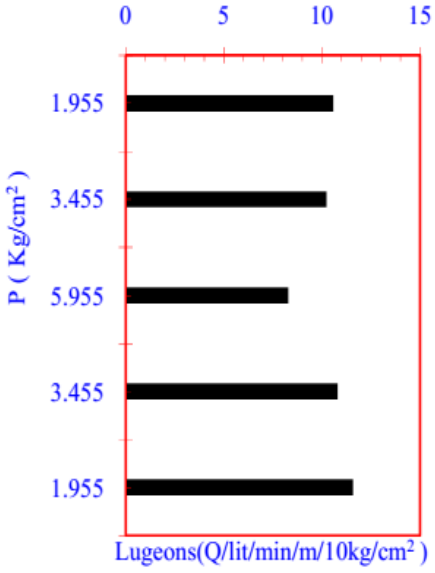
Sr. No.	L (m)	H_1 (m)	H_2 (m)	P_0 Kg / cm^2	P Kg / cm^2	t (min)	Q_t (lit)	Q_o (lit/min)	Q lit/min/m	Lugeon	k (cm/sec)
1	1.50	1.25	8.30	1.00	1.955	10.0	31.00	3.10	2.067	10.571	1.06E-04
2	1.50	1.25	8.30	2.50	3.455	10.0	53.00	5.30	3.533	10.227	1.02E-04
3	1.50	1.25	8.30	5.00	5.955	10.0	74.00	7.40	4.933	8.284	8.28E-05
4	1.50	1.25	8.30	2.50	3.455	10.0	56.00	5.60	3.733	10.806	1.08E-04
5	1.50	1.25	8.30	1.00	1.955	10.0	34.00	3.40	2.267	11.594	1.16E-04

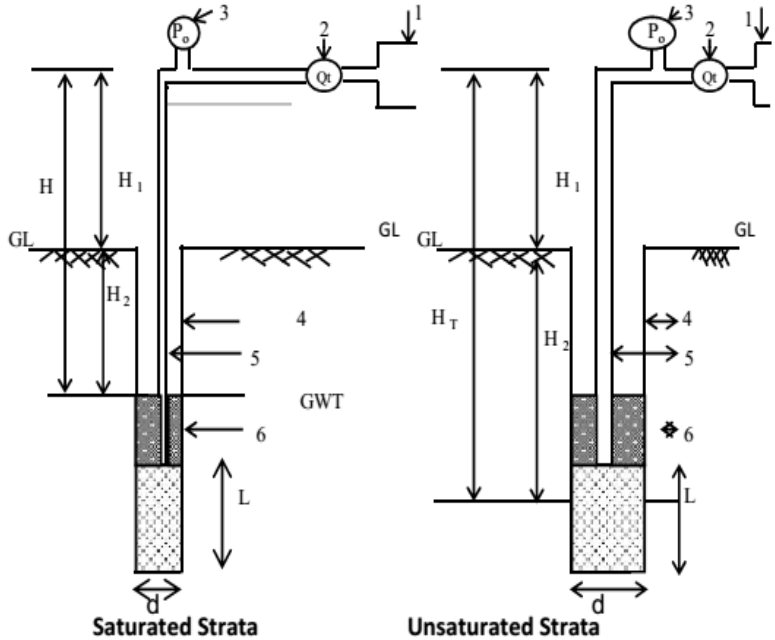
Sample Calculation :-
As per IS - 5529

$P : P_0 + (H_1 + H_2)/10 = 1.955$ Kg/cm^2
$Q_0 : Q_t / t = 3.100$ lit / min
$Q : Q_0 / L = 2.067$ lit/min/m

Lugeon :- $\frac{Q * 1\ Mpa}{\text{Test Pressure i.e. P}}$ = **10.571**

Group : --
Classification : --
Permeability Value : **10.571** Lugeon





Saturated Strata

1 :- Pump
2 :- Flow Meter
3 :- Pressure Gauge
4 :- Drill Hole
5 :- Injection Pipe
6 :- Packer
Lugeon :- Lugeon Value in lit/min/m/10Kg/cm^2
k :- Permeability in cm/sec

Unsaturated Strata

P_o :- Gauge Pressure
H_1 :- Height of Pressure Gauge
H_2 :- Depth of Ground Water or Mid of Test Section to Ground Surface
P :- Effective Pressure
P :- P_0+H/10 or H = H_1 + H_2
t :- Injection Time
Q_t :- Water Volume During time
Q_0 :- Water Volume / min.

PACKER PERMEABILITY TEST

Project : **Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP**

Elevation : 71.00m.
Location : --
Coordinate : N 19°10'29.4", E72°54'54.7"
Inclination : 90 (Deg. With Horizontal)
Test Section : **18.00** To **19.50** m
Length of Test Section : 1.50 m
Type of Test : **Double Packer Test**
Test Locatior : Test Below Water Table

Date : **07/03/2017**
Bore Hole : **BH 5**
Depth of Bore Hole(m) : **47.50**
Diameter (mm) : **NX-76.00**
Water Table (m) : **9.50**
H_1 (m) : **1.25**
H_2 (m) : **9.50**

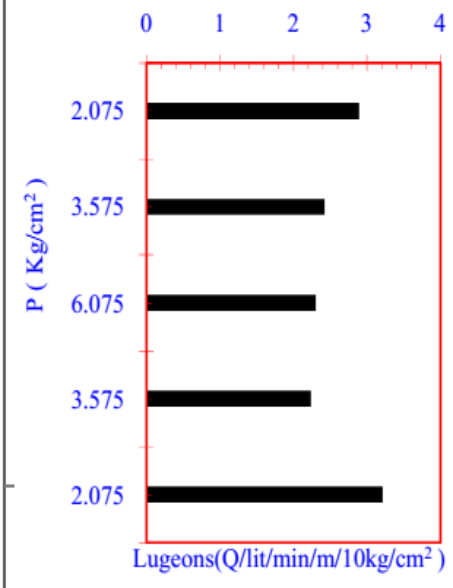
Sr. No.	L (m)	H_1 (m)	H_2 (m)	P_0 Kg / cm^2	P Kg / cm^2	t (min)	Q_t (lit)	Q_o (lit/min)	Q lit/min/m	Lugeon	k (cm/sec)
1	1.50	1.25	9.50	1.00	2.075	10.0	9.00	0.90	0.600	2.892	2.89E-05
2	1.50	1.25	9.50	2.50	3.575	10.0	13.00	1.30	0.867	2.424	2.42E-05
3	1.50	1.25	9.50	5.00	6.075	10.0	21.00	2.10	1.400	2.305	2.30E-05
4	1.50	1.25	9.50	2.50	3.575	10.0	12.00	1.20	0.800	2.238	2.24E-05
5	1.50	1.25	9.50	1.00	2.075	10.0	10.00	1.00	0.667	3.213	3.21E-05

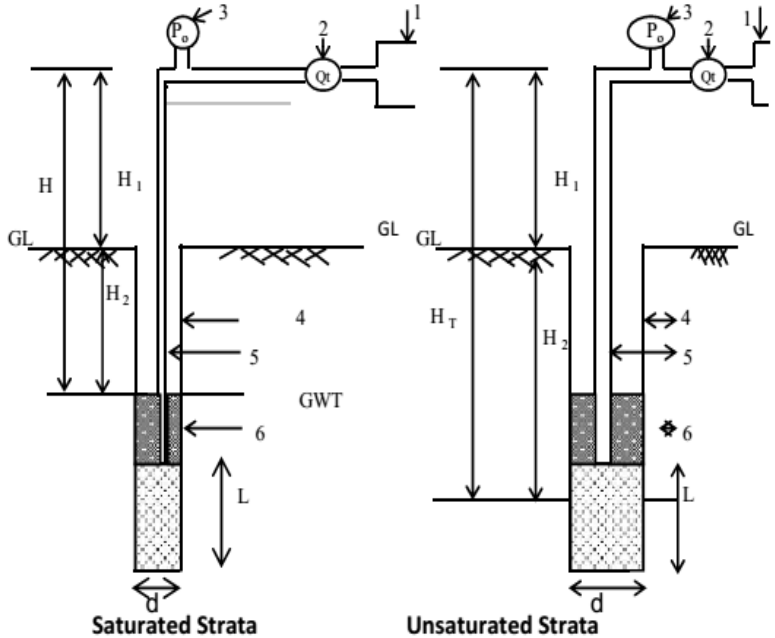
Sample Calculation :-
As per IS - 5529

$P : P_0 + (H_1 + H_2)/10$: 2.075 Kg/cm^2
$Q_0 : Q_t / t$ = 0.900 lit / min
$Q : Q_0 / L$ = 0.600 lit/min/m

Lugeon :- $\frac{Q * 1\ Mpa}{\text{Test Pressure i.e. P}}$ = **2.892**

Group : --
Classification : --
Permeability Value : **2.892** Lugeon





Saturated Strata

1 :- Pump
2 :- Flow Meter
3 :- Pressure Gauge
4 :- Drill Hole
5 :- Injection Pipe
6 :- Packer
Lugeon :- Lugeon Value in lit/min/m/10Kg/cm^2
k :- Permeability in cm/sec

Unsaturated Strata

P_o :- Gauge Pressure
H_1 :- Height of Pressure Gauge
H_2 :- Depth of Ground Water or Mid of Test Section to Ground Surface
P :- Effective Pressure
P :- P_0+H/10 or H = H_1 + H_2
t :- Injection Time
Q_t :- Water Volume During time
Q_0 :- Water Volume / min.

PACKER PERMEABILITY TEST

Project : **Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP**

Elevation : 71.00m.
Location : --
Coordinate : N 19°10'29.4", E72°54'54.7"
Inclination : 90 (Deg. With Horizontal)
Test Section : **27.00** To **28.50** m
Length of Test Section : 1.50 m
Type of Test : **Double Packer Test**
Test Locatior : Test Below Water Table

Date : **07/03/2017**
Bore Hole : **BH 5**
Depth of Bore Hole(m) : **47.50**
Diameter (mm) : **NX-76.00**
Water Table (m) : **10.00**
H_1 (m) : **1.25**
H_2 (m) : **10.00**

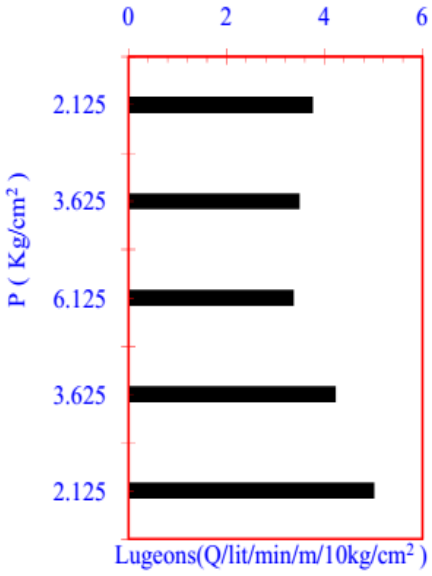
Sr. No.	L (m)	H_1 (m)	H_2 (m)	P_0 Kg / cm^2	P Kg / cm^2	t (min)	Q_t (lit)	Q_o (lit/min)	Q lit/min/m	Lugeon	k (cm/sec)
1	1.50	1.25	10.00	1.00	2.125	10.0	12.00	1.20	0.800	3.765	3.76E-05
2	1.50	1.25	10.00	2.50	3.625	10.0	19.00	1.90	1.267	3.494	3.49E-05
3	1.50	1.25	10.00	5.00	6.125	10.0	31.00	3.10	2.067	3.374	3.37E-05
4	1.50	1.25	10.00	2.50	3.625	10.0	23.00	2.30	1.533	4.230	4.23E-05
5	1.50	1.25	10.00	1.00	2.125	10.0	16.00	1.60	1.067	5.020	5.02E-05

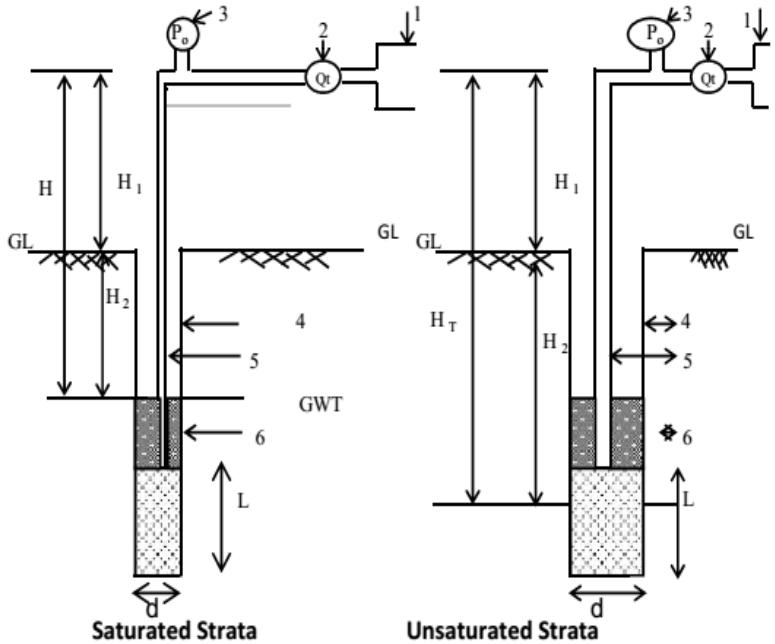
Sample Calculation :-
As per IS - 5529

$P : P_0 + (H_1 + H_2)/10$: 2.125 Kg/cm^2
$Q_0 : Q_t / t$ = 1.200 lit / min
$Q : Q_0 / L$ = 0.800 lit/min/m

Lugeon :- $\frac{Q * 1\ Mpa}{\text{Test Pressure i.e. P}}$ = **3.765**

Group : --
Classification : --
Permeability Value : **3.765** Lugeon





Saturated Strata

1 :- Pump
2 :- Flow Meter
3 :- Pressure Gauge
4 :- Drill Hole
5 :- Injection Pipe
6 :- Packer
Lugeon :- Lugeon Value in lit/min/m/10Kg/cm^2
k :- Permeability in cm/sec

Unsaturated Strata

P_o :- Gauge Pressure
H_1 :- Height of Pressure Gauge
H_2 :- Depth of Ground Water or Mid of Test Section to Ground Surface
P :- Effective Pressure
P :- P_0+H/10 or H = H_1 + H_2
t :- Injection Time
Q_t :- Water Volume During time
Q_0 :- Water Volume / min.

PACKER PERMEABILITY TEST

Project : **Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP**

Elevation : 89.00m.
Location : --
Coordinate : N 19°10'21.7", E72°55'54.7"
Inclination : 90 (Deg. With Horizontal)
Test Section : **12.00** To **13.50** m
Length of Test Section : 1.50 m
Type of Test : **Double Packer Test**
Test Locatior : Test Below Water Table

Date : **07/03/2017**
Bore Hole : **BH 6**
Depth of Bore Hole(m) : **43.00**
Diameter (mm) : **NX-76.00**
Water Table (m) : **8.30**
H_1 (m) : **1.25**
H_2 (m) : **8.30**

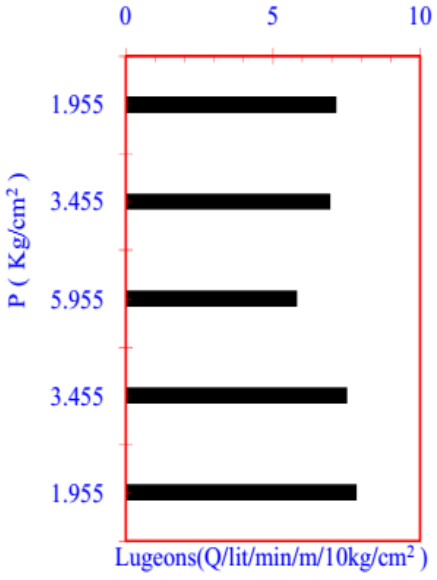
Sr. No.	L (m)	H_1 (m)	H_2 (m)	P_0 Kg / cm^2	P Kg / cm^2	t (min)	Q_t (lit)	Q_o (lit/min)	Q lit/min/m	Lugeon	k (cm/sec)
1	1.50	1.25	8.30	1.00	1.955	10.0	21.00	2.10	1.400	7.161	7.16E-05
2	1.50	1.25	8.30	2.50	3.455	10.0	36.00	3.60	2.400	6.946	6.95E-05
3	1.50	1.25	8.30	5.00	5.955	10.0	52.00	5.20	3.467	5.821	5.82E-05
4	1.50	1.25	8.30	2.50	3.455	10.0	39.00	3.90	2.600	7.525	7.53E-05
5	1.50	1.25	8.30	1.00	1.955	10.0	23.00	2.30	1.533	7.843	7.84E-05

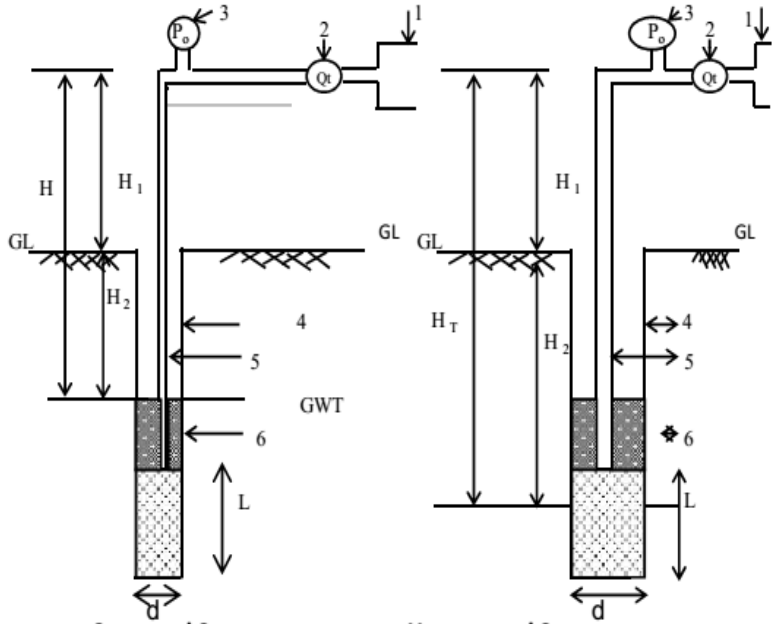
Sample Calculation :-
As per IS - 5529

$P : P_0 + (H_1 + H_2)/10$: 1.955 Kg/cm^2
$Q_0 : Q_t / t$ = 2.100 lit / min
$Q : Q_0 / L$ = 1.400 lit/min/m

Lugeon :- $\frac{Q * 1\ Mpa}{\text{Test Pressure i.e. P}}$ = **7.161**

Group : --
Classification : --
Permeability Value : **7.161** Lugeon





Saturated Strata

1 :- Pump
2 :- Flow Meter
3 :- Pressure Gauge
4 :- Drill Hole
5 :- Injection Pipe
6 :- Packer
Lugeon :- Lugeon Value in lit/min/m/10Kg/cm^2
k :- Permeability in cm/sec

Unsaturated Strata

P_o :- Gauge Pressure
H_1 :- Height of Pressure Gauge
H_2 :- Depth of Ground Water or Mid of Test Section to Ground Surface
P :- Effective Pressure
P :- P_0+H/10 or H = H_1 + H_2
t :- Injection Time
Q_t :- Water Volume During time
Q_0 :- Water Volume / min.

PACKER PERMEABILITY TEST

Project : **Geotechnical Investigation for Construction of Goregaon Mulund Link Road Tunnel Underneath SGNP**

Elevation : 89.00m.
Location : --
Coordinate : N 19°10'21.7", E72°55'54.7"
Inclination : 90 (Deg. With Horizontal)
Test Section : **25.50** To **27.00** m
Length of Test Section : 1.50 m
Type of Test : **Double Packer Test**
Test Locatior : Test Below Water Table

Date : 07/03/2017
Bore Hole : **BH 6**
Depth of Bore Hole(m) : **43.00**
Diameter (mm) : **NX-76.00**
Water Table (m) : **8.30**
H_1 (m) : **1.25**
H_2 (m) : **8.30**

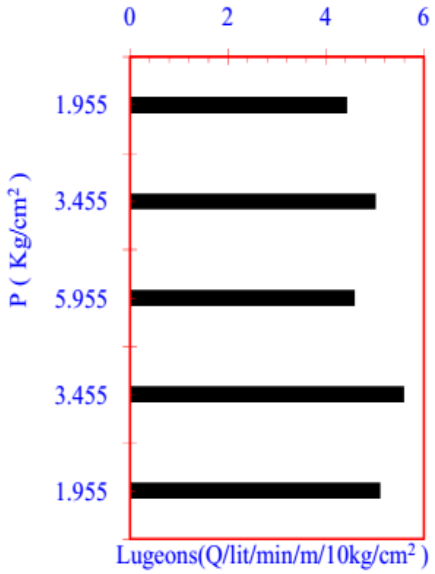
Sr. No.	L (m)	H_1 (m)	H_2 (m)	P_0 Kg / cm^2	P Kg / cm^2	t (min)	Q_t (lit)	Q_o (lit/min)	Q lit/min/m	Lugeon	k (cm/sec)
1	1.50	1.25	8.30	1.00	1.955	10.0	13.00	1.30	0.867	4.433	4.43E-05
2	1.50	1.25	8.30	2.50	3.455	10.0	26.00	2.60	1.733	5.017	5.02E-05
3	1.50	1.25	8.30	5.00	5.955	10.0	41.00	4.10	2.733	4.590	4.59E-05
4	1.50	1.25	8.30	2.50	3.455	10.0	29.00	2.90	1.933	5.596	5.60E-05
5	1.50	1.25	8.30	1.00	1.955	10.0	15.00	1.50	1.000	5.115	5.12E-05

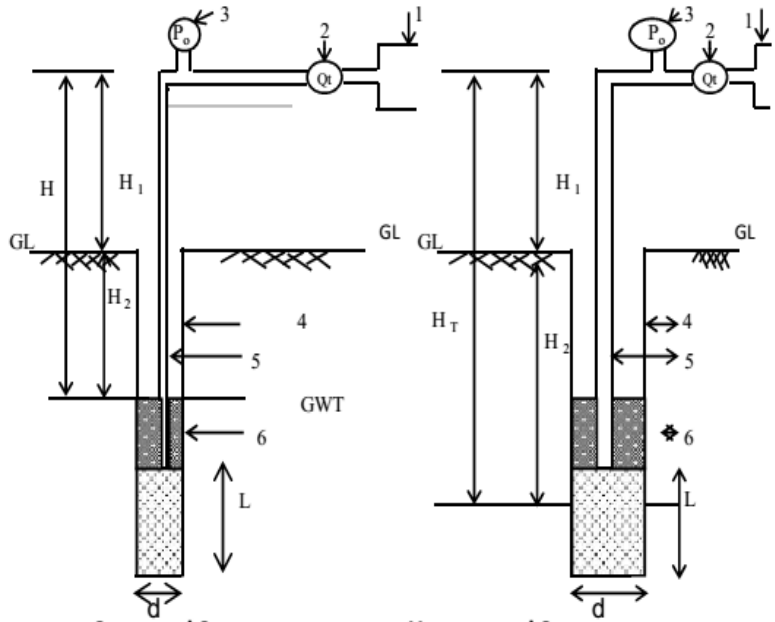
Sample Calculation :-
As per IS - 5529

P : $P_0 + (H_1 + H_2)/10$: 1.955 Kg/cm^2
Q_0 : Q_t / t = 1.300 lit / min
Q : Q_0 / L = 0.867 lit/min/m

Lugeon :- $\frac{Q * 1\ Mpa}{\text{Test Pressure i.e. P}}$ = **4.433**

Group : --
Classification : --
Permeability Value : **4.433** Lugeon





Saturated Strata

1 :- Pump
2 :- Flow Meter
3 :- Pressure Gauge
4 :- Drill Hole
5 :- Injection Pipe
6 :- Packer
Lugeon :- Lugeon Value in lit/min/m/10Kg/cm^2
k :- Permeability in cm/sec

Unsaturated Strata

P_o :- Gauge Pressure
H_1 :- Height of Pressure Gauge
H_2 :- Depth of Ground Water or Mid of Test Section to Ground Surface
P :- Effective Pressure
P :- P_0+H/10 or H = $H_1 + H_2$
t :- Injection Time
Q_t :- Water Volume During time
Q_0 :- Water Volume / min.

4.5. Geotechnical Evaluation and Opinion

This section contains the interpretation of field results, derivations and justification for the values of parameters adopted for the purposes of design of GMLR Portal & tunnel section. These geotechnical parameters described in the sections below are derived based on borehole information. Parameters for different layers are arrived based on the field tests and Laboratory tests by using different empirical correlations. Derivations of these parameters are discussed in this section. Geological profiles have been developed on the basis of the borehole data. The general geological profile developed for GMLR project, the site can be broadly categorized into 3 Units (strata). The geological profile drawings are attached in this section.

Total Seven boreholes were drilled for GMLR Tunnel in present investigation. Out of Seven boreholes two boreholes were drilled at Portal Locations & Five boreholes along the tunnel alignment. Boreholes were drilled up to maximum 50.0 m depth from the existing ground level. Following are the level of GMLR tunnel

Table 4-18: GMLR Reduce Level

	Film City Area	Khindipada Area
Tunnel Top Level	63.00	42.00
Tunnel Road Level	54.00	33.00
Tunnel Bottom Level	48.70	28.70

4.5.1. Portal Location: Foundation System Recommendation

Based on the subsoil stratums for Portal Location, first stratum of subsoil profile is hard Brownish Clayey Sand Mixed with Boulders. This layer consists of sand and clay in varying percentage of boulders or gravels & has an average thickness layer is 2.00 to 3.00 m in BH 01 & BH 07. Examination of sample collected that it was completely weathered rock having yellowish medium-stiff to stiff clay mixed with gravels and boulders/ residual rock structure, which is locally known as murrum. Rock core recovery value recorded in boreholes is NIL & Rock quality designation values recorded are zero percentage in all drill run. These indicate very poor state of fractures in rock mass. Three Standard penetration tests were conducted in this stratum & Reported 'N' values are varying from 10 to 21. SPT values indicate Stiff to hard consistency of the stratum. This soil has high to Very high infiltration and permeability and moderately high capacity for holding available moisture. It creates problems for structures built on them due to their high settlement characteristics. Bearing capacity will be very low for proposed structure due to the compressibility nature and therefore this stratum is not suitable for placing foundation.

Second stratum is Moderately Weathered Basalt Stratum mixed with Boulders & clay. Average thickness of this stratum is varying between 3.00 to 7.50 m in boreholes. Examination of sample collected that it was greyish moderately weathered basalt. Rock core recovery value recorded is from 57% to 77%, & Rock quality designation values recorded are from 29% to 68%. One rock core was tested in laboratory. Reported Saturated crushing strength value is 299.38 Kg/cm2. This value indicates that rock has Medium strength.

This stratum is followed by slightly Weathered Basalt below which Fresh Weathered Basalt stratum is present. After detail studying two bore logs, up to 2 m depth of investigation moderately weathered Basalt is present & these stratums are most suitable for placing foundations.

4.5.2. Open Foundation for Portal Location

Review of subsoil profile shows that upper strata cannot support Portal Foundation. Therefore, shallow foundation is recommended for this structure. Due to extensive research in the topic of bearing capacity, numerous methods of analysis have been developed. The research started by Terzaghi (1943) and was followed by Skempton (1951), Meyerhof (1951), Hansen (1961), De Beer and Ladanyi (1961), Meyerhof (1963), Hansen (1970), Vesic (1973, 1975), and others. The most popular and widely used bearing capacity equations in practice today are the Terzaghi and AASHTO equations. When physical characteristics such as cohesion, angle of internal friction, density etc. are available, the bearing capacity shall be calculated from stability considerations. Established bearing capacity equations shall be used for calculating bearing capacity. A factor of safety of between 2.0 to 3.0 (depending on the extent of soil exploration, quality control and monitoring of construction) shall be adopted to obtain allowable bearing pressure when dead load and normal live load is used.

Following are the two methods used to calculate bearing capacity of the soil strata

4.5.2.1. Presumptive Bearing Capacities from IS 1904 - 1978

For different types of soils, IS 1904 (1978) has recommends the following bearing capacity values. The presumptive bearing values (allowable) as given in the following Table may be assumed for uniform soil in the absence of test results. The minimum depth of foundation shall be 1.5 m for exterior footing of permanent structures in cohesive soils and 2 m in cohesion less soils.

Table 4-19: Presumptive Bearing Capacities from IS 1904 - 1978

Type of Rock	Safe /Allowable Bearing Capacity kN/m²	Safe /Allowable Bearing Capacity in T/m²
	3240	324.0
Soft Rock	**440**	**44.0**
Coarse Sand	440	44.0
Medium Sand	254	25.4
Fine Sand	100	10.0
Soft Shale/ Stiff clay	440	44.0
Soft Clay	100	10
Very Soft Clay	50	0.50

Considering the soft Rock i.e. Moderately weathered Basalt and has an average thickness layer is more than 3.00 to 12.00 m, the presumptive Safe Bearing Capacity for Moderately weathered rock will be 440 kN/m² i.e. 44 T/m² as this presumptive bearing capacity.

Table 4-20: Presumptive Safe Bearing Capacity in T/m²

Minimum RL of footing in Basalt	Safe /Allowable Bearing Capacity T/m²
7-9 m	**44**

4.5.2.2. RMR Method (Rock Mass Rating) IS 12070 & IS 13365:

Second stratum in the boreholes log is highly/Moderately Weathered Basalt rock stratum, which is low to medium rock strength. Bearing Capacity of this stratum will be sufficient for proposed portal structure. To evaluate safe bearing capacity of founding stratum, rock mass rating values were determined for average rock quality properties. RMR value is workout as per IS: 13365 (part I). Using this value and referring to table 3 of IS 12070-1987, net safe bearing capacity works out. Considering variation over project area net safe bearing capacity of 60 T/m² is recommended 7-9 m depth, from excavated ground level.

Table 4-21: Rock Mass Rating Calculation for Portal Location Film City BH 01

Depth (M)			Point Load Index /UCS Mpa	Rating for Comp. Strength	RQD (%)			Rating Drilling Quality	Spacing of Discon tinuity m	Rating for Spacing	Oreintation of Discon tinuity	Rating for Oreintation	Condition of Discon tinuity	Rating for Condition	Ground water Condition	Rating for Ground water	Sum of Rating increments	Rock Class No. & Description
	To					To												
0.0	-	2.0										soil						
2.0	-	3.0		12	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	50	III - Fair
3.0	-	4.5		12	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	50	III - Fair
4.5	-	6.0		12	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	38	IV.Poor
6.0	-	7.5		12	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	62	II - Good
7.5	-	9.0		12	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	62	II - Good
9.0	-	10.5		12	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	50	III - Fair
10.5	-	12.0		12	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	50	III - Fair
12.0	-	13.5		12	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	38	IV.Poor
13.5	-	15.0		12	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	38	IV.Poor
15.0	-	16.5		12	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	50	III - Fair
16.5	-	18.0	100-250	12	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	50	III - Fair
18.0	-	19.5		12	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	50	III - Fair
19.5	-	21.0	100-250	12	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	50	III - Fair
21.0	-	22.5		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
22.5	-	24.0		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
24.0	-	25.5	25-50	2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
25.5	-	27.0		7	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	33	IV.Poor
27.0	-	28.5		7	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	33	IV.Poor
28.5	-	30.0	50-100	7	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	33	IV.Poor

Table 4-22: Rock Mass Rating Calculation for Portal Location Khindipada BH 07

Depth (M)			Point Load Index /UCS Mpa	Rating for Comp. Strength	RQD (%)			Rating Drilling Quality	Spacing of Discon tinuity m	Rating for Spacing	Oreintation of Discon tinuity	Rating for Oreintation	Condition of Discon tinuity	Rating for Condition	Ground water Condition	Rating for Ground water	Sum of Rating increments	Rock Class No. & Description
	To					To												
0.0	-	3.1										soil						
3.1	-	4.5		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
4.5	-	6.0		4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
6.0	-	7.5		4	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	54	III - Fair
7.5	-	9.0		4	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	30	IV.Poor
9.0	-	10.5		4	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	30	IV.Poor
10.5	-	12.0	25-50	4	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	30	IV.Poor
12.0	-	13.5		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
13.5	-	15.0		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
15.0	-	16.5	25-50	4	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	30	IV.Poor
16.5	-	18.0		4	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	54	III - Fair
18.0	-	19.5	25-50	4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
19.5	-	21.0		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
21.0	-	22.5		4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
22.5	-	24.0		4	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	54	III - Fair
24.0	-	25.5		4	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	54	III - Fair
25.5	-	27.0		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
27.0	-	28.5		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
28.5	-	30.0		4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good

Design Parameters :

Sr. No	Description		Value	Unit	Classification
1	Strength of Intact rock Material	.=	280	kg/cm^2	Average
2	Rock Quality Designation (RQD)	.=	54	%	Fair
3	Spacing of Discontinuities	.=	0.02	cm	Very Close
4	Condition of Discontinuities	.=	4		0
5	Ground Water Condition	.=	4		Dripping

Sr. No	Description	RM Rating
1	Strength of Intact rock Material	4
2	Rock Quality Designation (RQD)	13
3	Spacing of Discontinuities	5
4	Condition of Discontinuities	10
5	Ground Water Condition	4

RMR	SBC (ton/m^2)	Rock Description
0-20	40-55	Very Poor
20-40	58-145	Poor
40-60	151-280	Fair
60-80	288-440	Good
80-100	448-600	Very Good

Total RMR =	36	127.6	Fair

Ultimate Net Bearing Capacity, (q_{net})	127.60	ton / m^2
Recommended Safe Bearing Capacity, ($q_{recommended}$)	63.80	ton / m^2

Figure 4-45: Safe Bearing Capacity by RMR Method for Portal Location

4.5.2.3. Recommendation & Design Parameters for Portal Location:

From the above calculations & results; recommended bearing capacity for foundation is as follows

Table 4-23: Recommended SBC for Portal

RL of Foundation from EGL in m	Recommended Safe Bearing Capacity in T/m^2
Film City Side --	**60**
Khindipada side--	

It will be desirable that structural engineer inspects the founding stratum to confirm that there are no soft pockets in the footing plan area before placing PCC. Rubble soling should not be provided below footing foundation on reaching this founding stratum. It is suggested that excavation from ground level to 3.00 m depth should be carried out as general area excavation. At this level,

foundation plan sizes are to be plotted in the large pit. Local excavation by manual method is then carried out to reach the founding stratum. It is possible that there may be some variation in rock quality. Therefore, we should keep a typically approved sample of founding stratum at site and excavate to reach same quality of rock at each location. Area around the foundation shall be backfilled and compacted as advised by the structural consultant in the layers of 300 mm compacted to 250 mm.

4.5.3. Geotechnical Evaluation and Opinion for Tunnel Section

In order to assist interpretation of the geotechnical properties of the different geological formations as mentioned in previous chapter, a combination of laboratory and in situ testing results have been used to derive design parameters. The geotechnical properties are provided as a summary of the available data from site exploration and should be read in conjunction with the relevant exploratory borehole records. For determination of design parameters, a combination of laboratory test results, in-situ test results, published information and engineering judgment have been used.

4.5.3.1. Ground Conditions along the Alignment (Geological Profile)

Geological profiles have been developed for the underground section on the basis of the borehole & field data. The general geological profile developed for the site can be broadly categorized into 3 Units (strata), which are further subcategory as summarized in Table 4-24.

Table 4-24: Geological Units for Tunnel design

Geological Units		Descriptions	Layer extents from GL
Unit 1 (Soil & Residual Soil)	Soil (Hard Brownish Clayey Sand Mixed with Gravel)	Silty sand, sandy silty, sandy clay, clayey sand, gravelly clay, gravelly sand, etc. with SPT N < 100	From 0 to 2.50 m
Unit 2 (Basalt)	Unit 2a: Basalt WG V (Completely Weathered Basalt Rock)	Weak completely to highly weathered grey to yellowish brown highly fractured basalt with very closely spaced fractures and well cemented sand	2.50 to 6.00

	Unit 2b: Basalt WG IV (Highly Weathered Basalt Rock)	Strong highly to moderately weathered brownish grey non-intact Basalt with very closely to moderately spaced horizontal to vertical fractures.	
	Unit 2c: Basalt WG III (Moderately Weathered Basalt Rock)	Slightly Strong to moderately weathered very dark grey Basalt with very closely to moderately spaced sub-horizontal to inclined fractures and well cemented sand.	6.00 to 36.00
	Unit 2d : Basalt WG I & II (Slightly Weathered & Fresh Basalt Rock)	Strong slightly weathered grey fine grained Basalt / light grey Amygdaloidal Basalt with very closely spaced horizontal fractures.	36.00 to 50.00
Unit 3 (Tuff & Breccia)	Unit 3a: Tuff/ Breccia - WG - V & IV (Completely to Highly Weathered Breccia Rock)	Weak highly to moderately weathered grey Tuff/Breccia closely spaced horizontal fractures.	2.50 to 5.00
	Unit 3b: Tuff/ Breccia - WG - III (Moderately Weathered Breccia Rock)	Weak moderately weathered grey Tuff/ Breccia & very closely spaced horizontal fractures.	5.00 to 14.00
	Unit 3c: Tuff/ Breccia - WG- II & I (Slightly Weathered & Fresh Breccia Rock)	Weak slightly weathered greenish grey to greyish black Tuff/ Breccia & with very closely to moderately space horizontal fractures.	14.00 to 50.00

4.5.3.2. Geotechnical Design Parameters:

Summary of laboratory test results of intact rock like Dry Unit Weight, Saturated Unit Weight, Moisture Content under Saturated Condition, Specific Gravity, Water Absorption and Porosity with respect to different Weathering Grade (WG) are presented in Table 4-24. Unit Weight is calculated by multiplication the density with 10 for all calculation purpose. In this laboratory test results of intact rock were determined by IS 13030. The rock layers effective strength parameters have been derived from the Hoek-Brown parameters using the computer program “RocLab”. The “RocLab” program allows the mass strength and stiffness of the rock to be estimated based on a number of parameters that have been determined or that are assessed from the available data. These parameters are:

- Intact axial compression strength (UCS, MPa).
- Degree of disturbance due to excavation: assumed D=0.0
- Material constant, mi:
- Geological strength Index, GSI
- Tunnel construction at average depth

Table 4-25: GSI designation for the identified rock units

Strata	Geological Unit	GSI	Legend
Weathered rock (Grades V and IV)	2a, 2b & 3a	25	
Competent rock (Grade III)	2c & 3b	40	
Competent rock (Grades II and I)	2d & 3c	50	

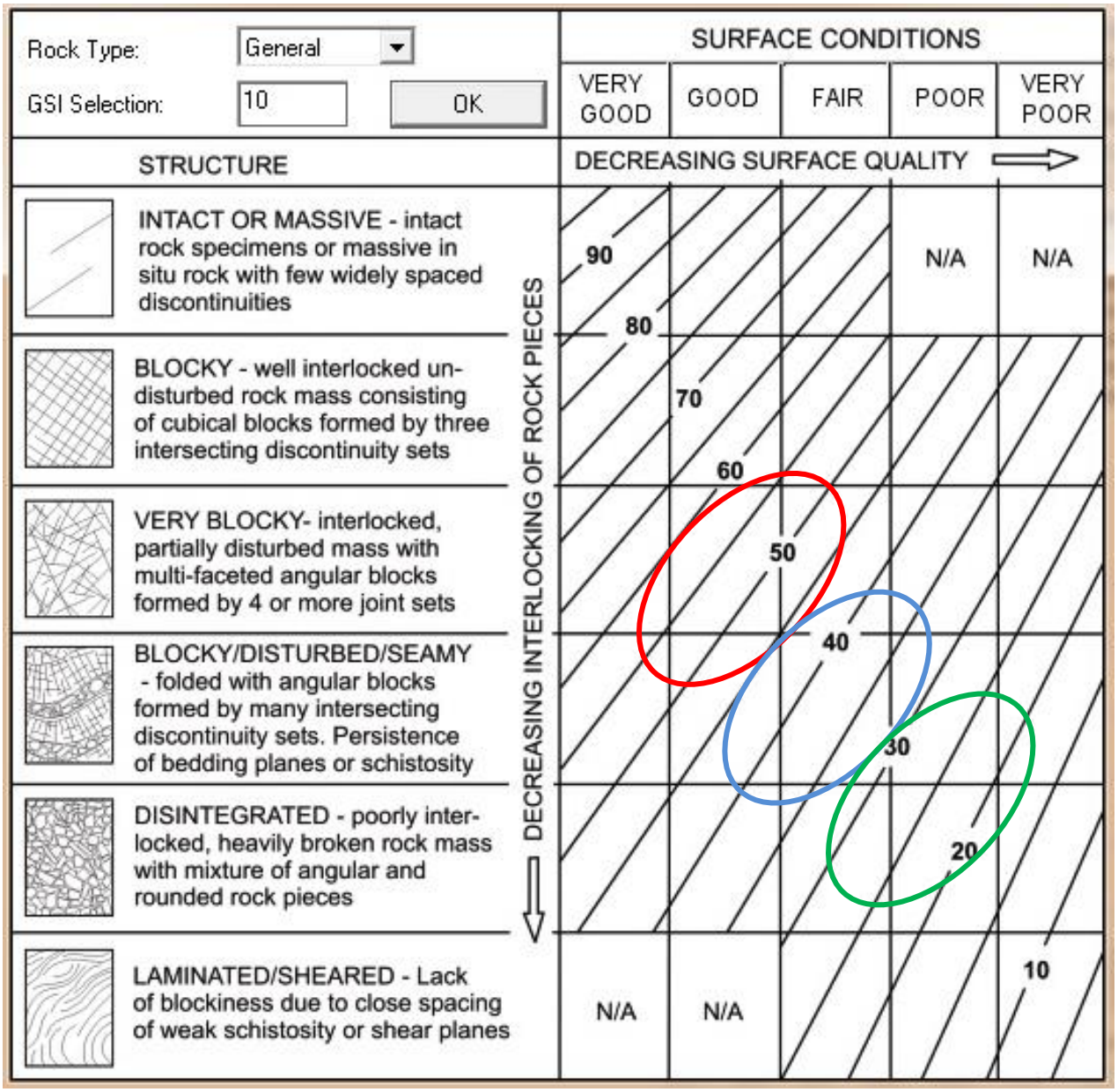


Figure 4-46: Geological Strength Index Classification after Hoek et al.

A. Determination of RMR and GSI Values

Rock Strata	Geological Unit	Weathering Grade	RQD in %	UCS in MPa	RMR	GSI	MI
Completely to Highly Weathered Basalt Rock	Unit 2a & 2b	V & IV	NIL	05*	20	15	12

Rock Strata	Geological Unit	Weathering Grade	RQD in %	UCS in MPa	RMR	GSI	MI
Moderately Weathered Basalt	Unit 2c	III	09	15*	42	37	17
Slightly Weathered & Fresh Basalt	Unit 2d	I & II	66	45	57	52	17
Completely to Highly Weathered Breccia Rock	Unit 3a	V & IV	NIL	03*	23	18	12
Moderately Weathered Breccia	Unit 3b	III	40	15**	33	28	15
Slightly Weathered & Fresh Breccia	Unit 3c	II & I	67	45	54	49	15

Note: * assumed value

** Value is slightly higher so higher value ignore & 15 MPa assumed

Table 4-26: Rock Mass Rating Calculation for Portal Location Film City BH 03

Depth (M)			Point Load Index /UCS Mpa	Rating for Comp. Strength	RQD (%)			Rating Drilling Quality	Spacing of Discon tinuity m	Rating for Spacing	Oreintation of Discon tinuity	Rating for Oreintation	Condition of Discon tinuity	Rating for Condition	Ground water Condition	Rating for Ground water	Sum of Rating increments	Rock Class No. & Description
	To					To												
0.0	-	3.2										soil						
3.2	-	3.5		7	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	23	IV.Poor
3.5	-	5.0		7	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	23	IV.Poor
5.0	-	6.5		7	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	23	IV.Poor
6.5	-	8.0		7	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	45	III - Fair
8.0	-	9.5		7	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	33	IV.Poor
9.5	-	11.0		7	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	45	III - Fair
11.0	-	12.5	50-100	7	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	45	III - Fair
12.5	-	14.0		7	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	45	III - Fair
14.0	-	15.5		7	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	57	III - Fair
15.5	-	17.0		7	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	45	III - Fair
17.0	-	18.5		7	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	57	III - Fair
18.5	-	20.0		7	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	67	II - Good
20.0	-	21.5		7	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	57	III - Fair
21.5	-	23.0		7	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	67	II - Good
23.0	-	24.5		7	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	57	III - Fair
24.5	-	26.0		7	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	57	III - Fair
26.0	-	27.5	50-100	7	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	57	III - Fair
27.5	-	29.0		4	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	54	III - Fair
29.0	-	30.5		4	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	54	III - Fair
30.5	-	32.0		4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
32.0	-	33.5		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
33.5	-	35.0		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
35.0	-	36.5		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
36.5	-	38.0		4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
38.0	-	39.5	25-50	4	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	30	IV.Poor
39.5	-	41.0		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
41.0	-	42.5		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
42.5	-	44.0	10-25	2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
44.0	-	45.5		2	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	52	III - Fair
45.5	-	47.0		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
47.0	-	48.5		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
48.5	-	50.5	10-25	2	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	62	II - Good

Table 4-27: Rock Mass Rating Calculation for Portal Location Film City BH 04

Depth (M)			Point Load Index /UCS Mpa	Rating for Comp. Strength	RQD (%)			Rating Drilling Quality	Spacing of Discon tinuity m	Rating for Spacing	Oreintation of Discon tinuity	Rating for Oreintation	Condition of Discon tinuity	Rating for Condition	Ground water Condition	Rating for Ground water	Sum of Rating increments	Rock Class No. & Description
	To					To												
0.0	-	5.0										soil						
5.0	-	6.0		4	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	20	V.V. Poor
6.0	-	7.5		4	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	20	V.V. Poor
7.5	-	9.0		4	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	20	V.V. Poor
9.0	-	10.5		4	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	30	IV.Poor
10.5	-	12.0		4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
12.0	-	13.5		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
13.5	-	15.0	25-50	4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
15.0	-	16.5		2	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	28	IV.Poor
16.5	-	18.0		2	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	52	III - Fair
18.0	-	19.5	10-25	2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
19.5	-	21.0		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
21.0	-	22.5	10-25	2	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	28	IV.Poor
22.5	-	24.0		4	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	54	III - Fair
24.0	-	25.5		4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
25.5	-	27.0	25-50	4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
27.0	-	28.5		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
28.5	-	30.0	10-25	2	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	28	IV.Poor
30.0	-	31.5		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
31.5	-	33.0		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
33.0	-	34.5		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
34.5	-	36.0		2	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	18	V.V. Poor
36.0	-	37.5		2	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	18	V.V. Poor
37.5	-	39.0		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
39.0	-	40.5		2	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	18	V.V. Poor
40.5	-	42.0		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor

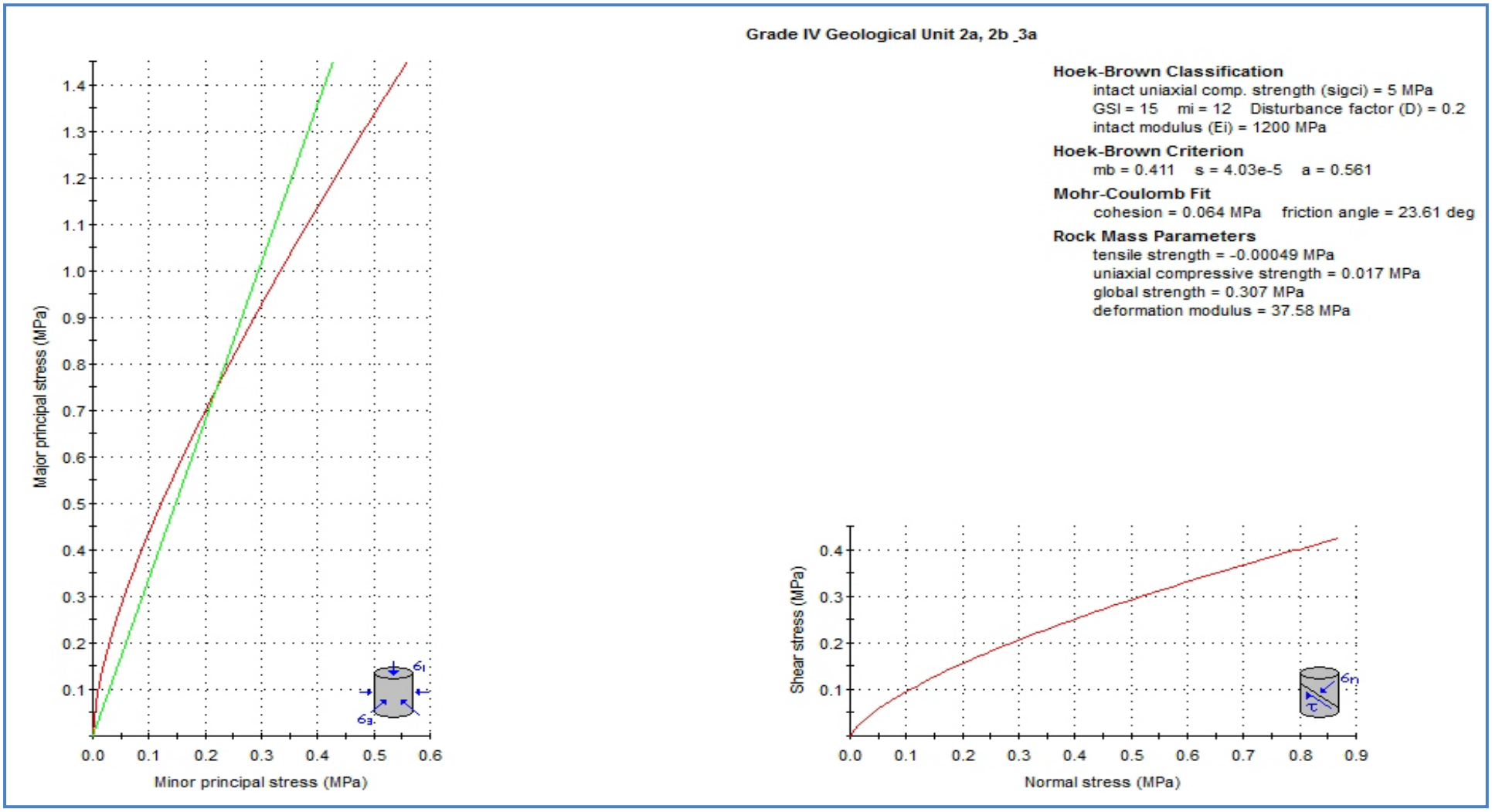
Table 4-28: Rock Mass Rating Calculation for Portal Location Film City BH 05

Depth (M)			Point Load Index /UCS Mpa	Rating for Comp. Strength	RQD (%)			Rating Drilling Quality	Spacing of Discon tinuity m	Rating for Spacing	Oreintation of Discon tinuity	Rating for Oreintation	Condition of Discon tinuity	Rating for Condition	Ground water Condition	Rating for Ground water	Sum of Rating increments	Rock Class No. & Description
	To					To												
0.0	-	3.1										soil						
3.1	-	4.5		4	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	20	V.V. Poor
4.5	-	6.0		4	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	30	IV.Poor
6.0	-	7.5		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
7.5	-	9.0		4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
9.0	-	10.5		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
10.5	-	12.0		4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
12.0	-	13.5	25-50	4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
13.5	-	15.0		4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
15.0	-	16.5		4	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	54	III - Fair
16.5	-	18.0		4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
18.0	-	19.5	25-50	4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
19.5	-	21.0		4	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	64	II - Good
21.0	-	22.5	25-50	4	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	54	III - Fair
22.5	-	24.0		2	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	52	III - Fair
24.0	-	25.5		2	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	52	III - Fair
25.5	-	27.0		2	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	62	II - Good
27.0	-	28.5	10-25	2	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	52	III - Fair
28.5	-	30.0		2	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	62	II - Good
30.0	-	31.5		2	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	62	II - Good
31.5	-	33.0		2	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	52	III - Fair
33.0	-	34.5		2	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	62	II - Good
34.5	-	36.0		2	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	52	III - Fair
36.0	-	37.5		2	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	62	II - Good
37.5	-	39.0		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
39.0	-	40.5		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
40.5	-	42.0		2	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	62	II - Good
42.0	-	43.5		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
43.5	-	45.0		2	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	52	III - Fair
45.0	-	46.5		2	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	52	III - Fair
46.5	-	47.5		2	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	62	II - Good

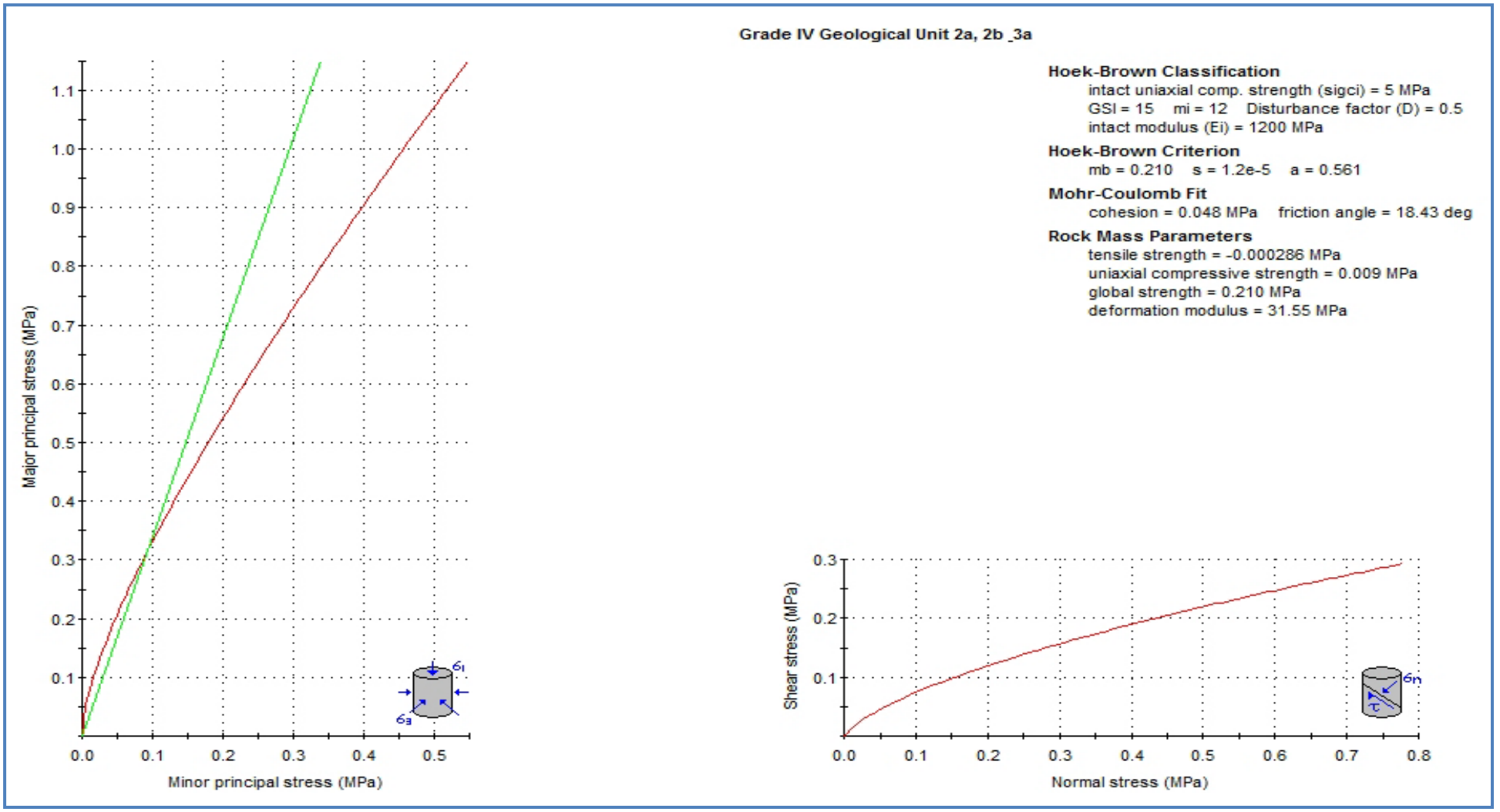
Table 4-29: Rock Mass Rating Calculation for Portal Location Film City BH 06

Depth (M)			Point Load Index /UCS Mpa	Rating for Comp. Strength	RQD (%)			Rating Drilling Quality	Spacing of Discon tinuity m	Rating for Spacing	Oreintation of Discon tinuity	Rating for Oreintation	Condition of Discon tinuity	Rating for Condition	Ground water Condition	Rating for Ground water	Sum of Rating increments	Rock Class No. & Description
	To					To												
0.0	-	2.5										soil						
2.5	-	3.0		2	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	18	V.V. Poor
3.0	-	4.5		2	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	18	V.V. Poor
4.5	-	6.0		2	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	18	V.V. Poor
6.0	-	7.5		2	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	18	V.V. Poor
7.5	-	9.0		2	0	-	25	3	<0.005	5	V.unfavourable	-12	slickened	10	damp	10	18	V.V. Poor
9.0	-	10.5		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
10.5	-	12.0		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
12.0	-	13.5		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
13.5	-	15.0		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
15.0	-	16.5		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
16.5	-	18.0		2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
18.0	-	19.5		2	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	28	IV.Poor
19.5	-	21.0	10-25	2	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	40	IV.Poor
21.0	-	22.5		1	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	39	IV.Poor
22.5	-	24.0		1	90	-	100	20	> 2	20	Very unfavourable	0	Slickensided	10	damp	10	61	II - Good
24.0	-	25.5	2-10	1	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	51	III - Fair
25.5	-	27.0	25-50	4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
27.0	-	28.5		4	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	54	III - Fair
28.5	-	30.0		4	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	54	III - Fair
30.0	-	31.5		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
31.5	-	33.0		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
33.0	-	34.5	25-50	4	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	30	IV.Poor
34.5	-	36.0		4	75	-	90	17	1.0 - 3.0	15	Favourable	-2	slickened	10	damp	10	54	III - Fair
36.0	-	37.5		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
37.5	-	39.0		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
39.0	-	40.5		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
40.5	-	42.0		4	50	-	75	13	0.3 - 0.6	10	Fair	-5	slickened	10	damp	10	42	III - Fair
42.0	-	43.0		4	25	-	50	8	0.005 - 0.3	8	Unfavourable	-10	slickened	10	damp	10	30	IV.Poor

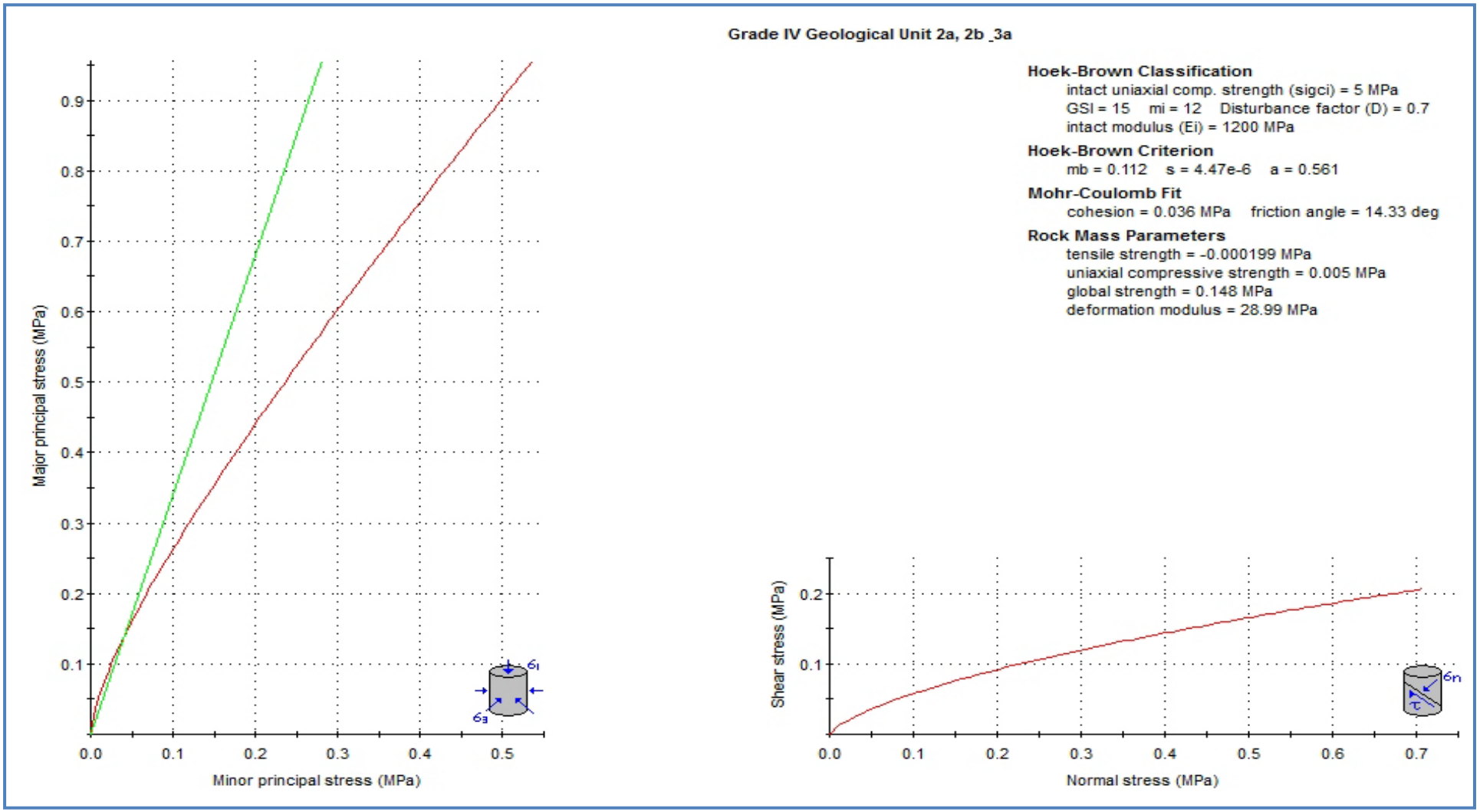
1. Rock Mass Parameters For Weathering Grade IV Basalt with Disturbance Factor D = 0.2



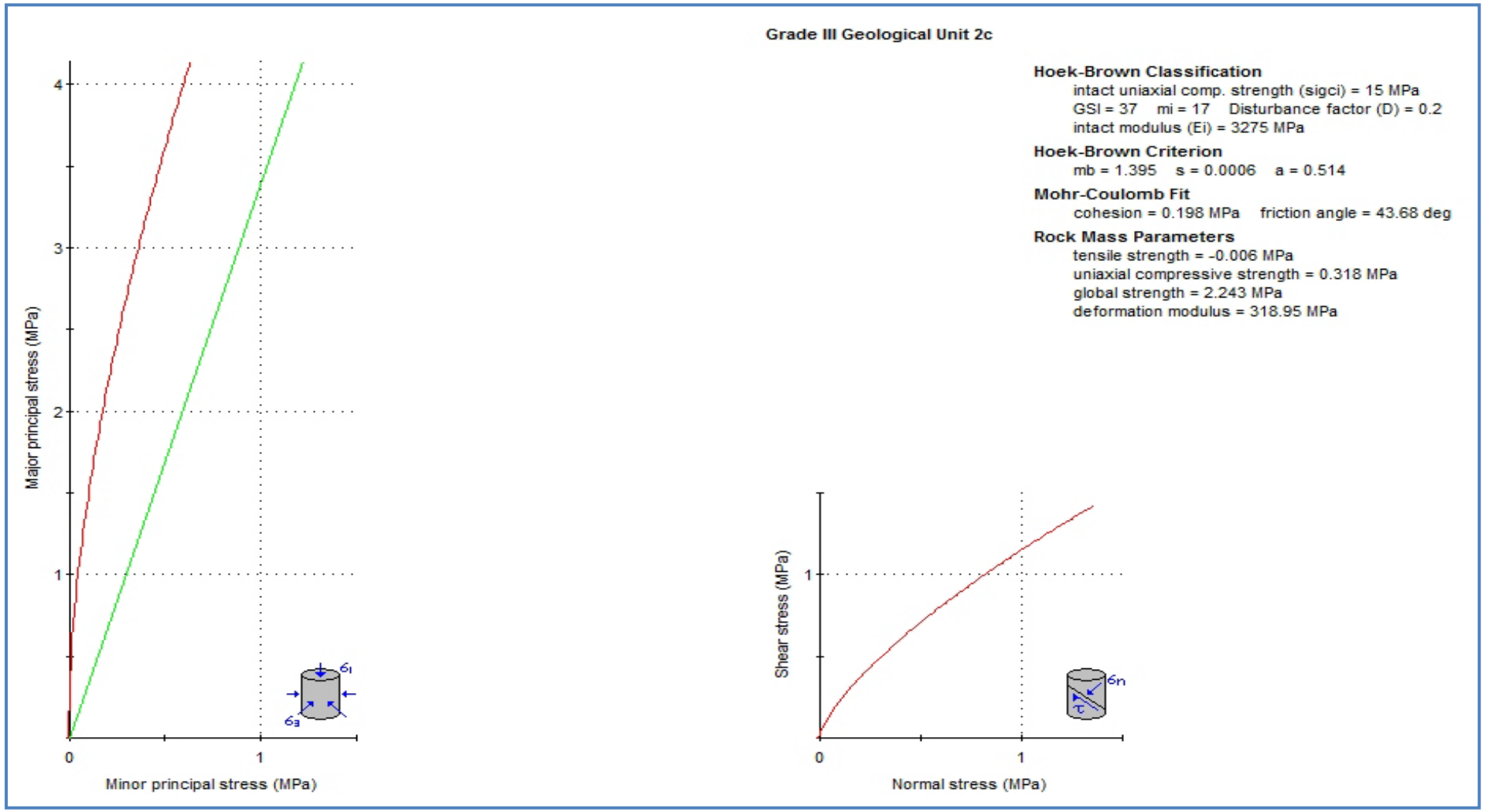
2. Rock Mass Parameters For Weathering Grade IV Basalt with Disturbance Factor D = 0.5



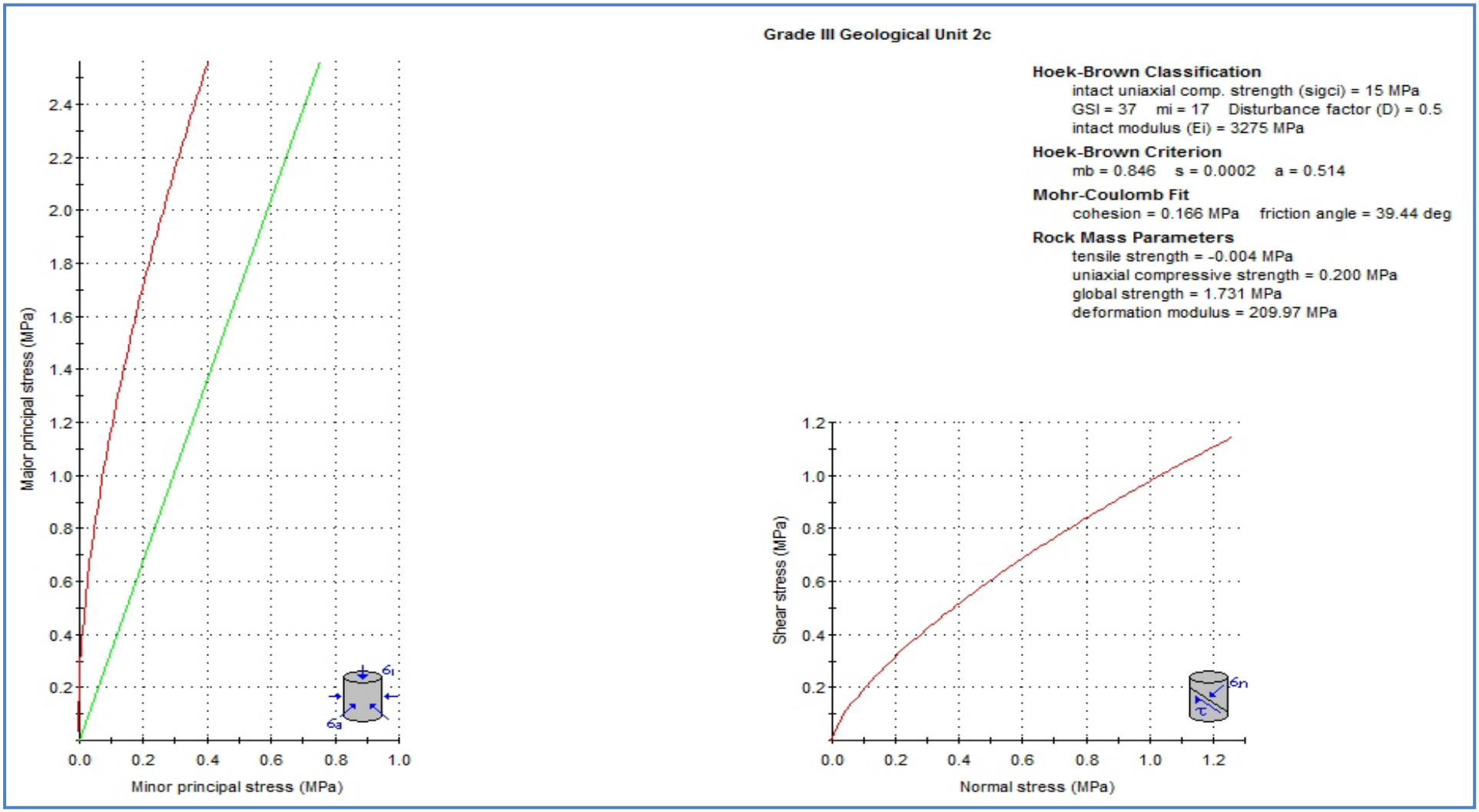
3. Rock Mass Parameters For Weathering Grade IV Basalt with Disturbance Factor D = 0.7



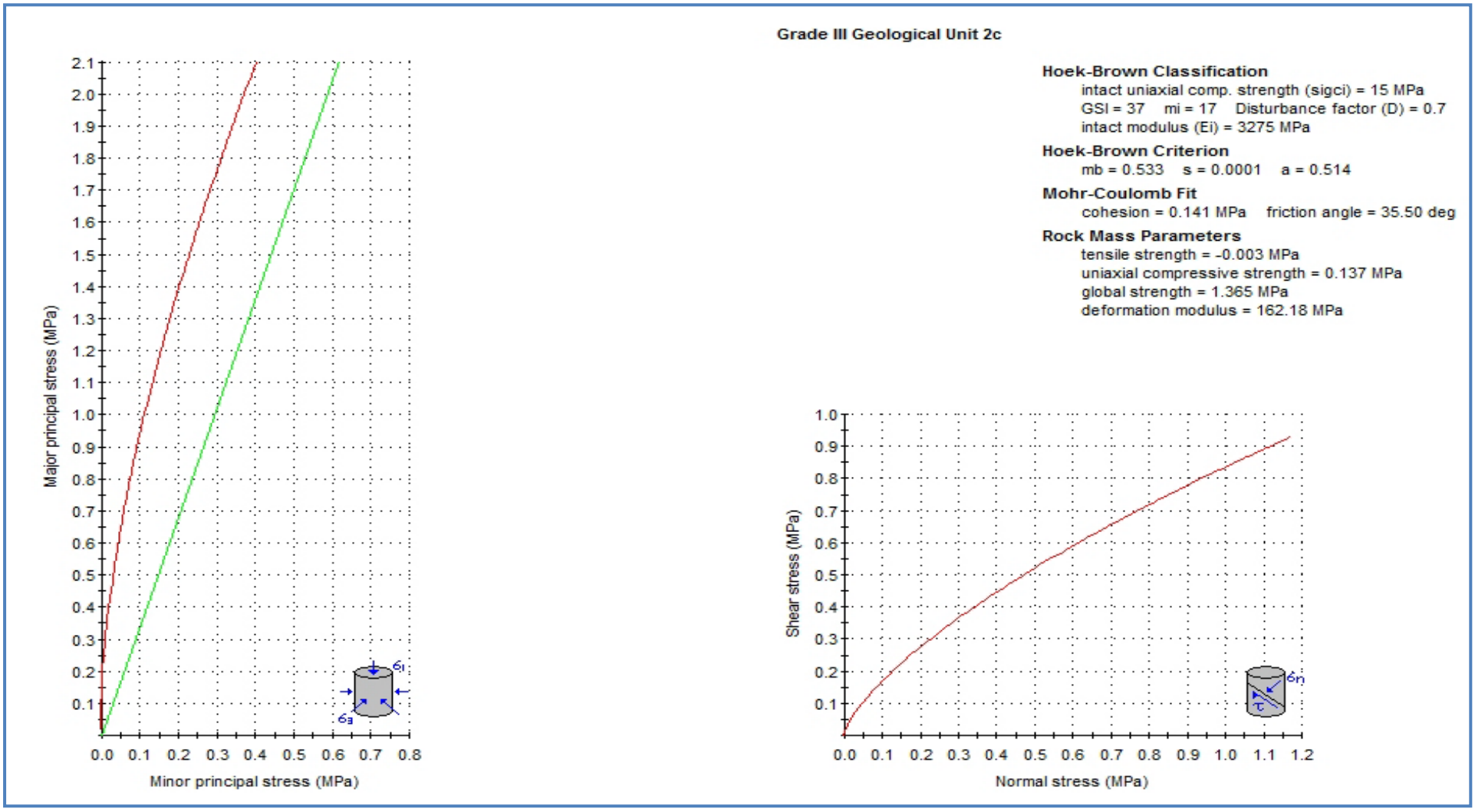
4. Rock Mass Parameters For Weathering Grade III Basalt with Disturbance Factor D = 0.2



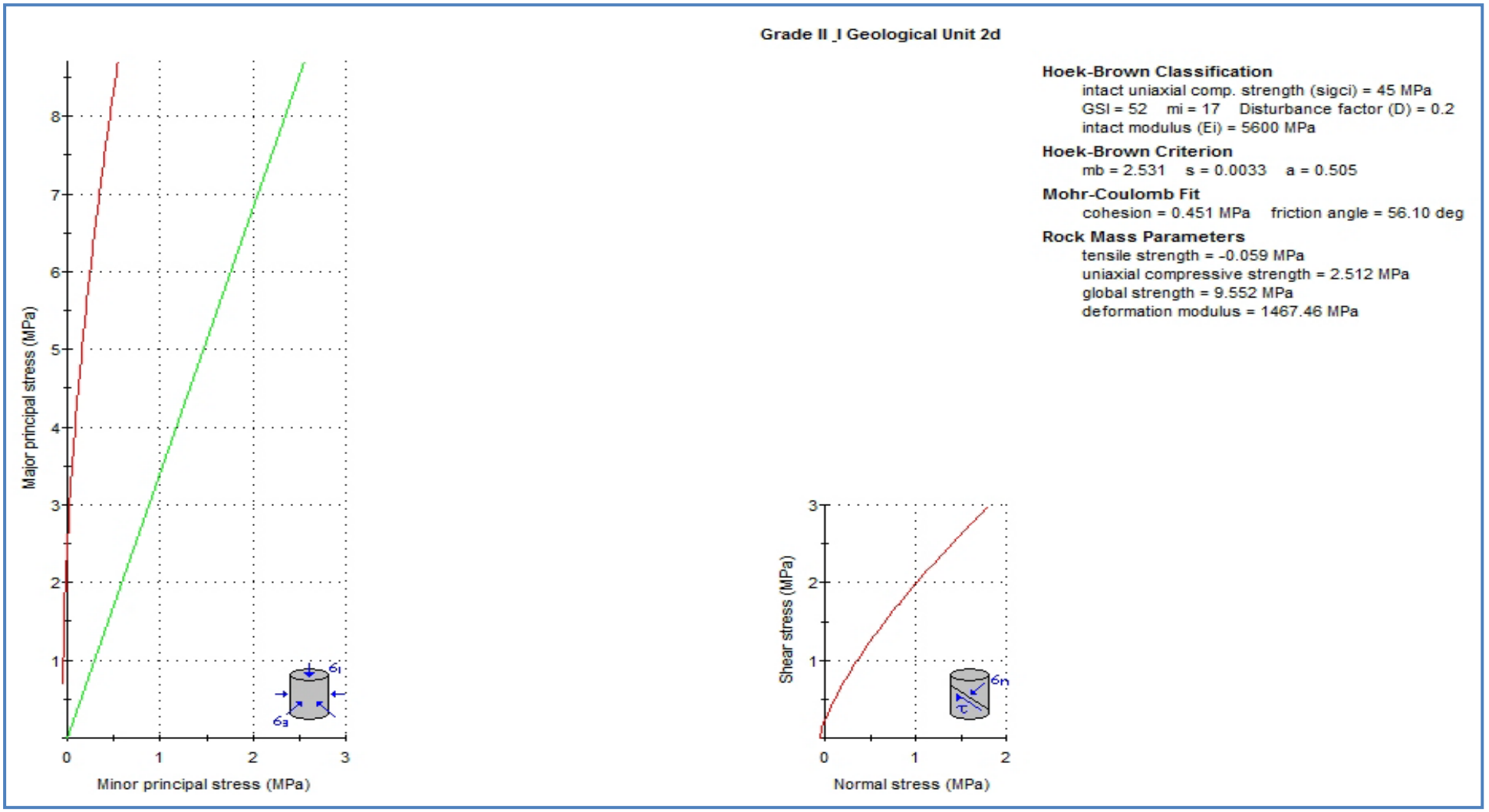
5. Rock Mass Parameters For Weathering Grade III Basalt with Disturbance Factor D = 0.5



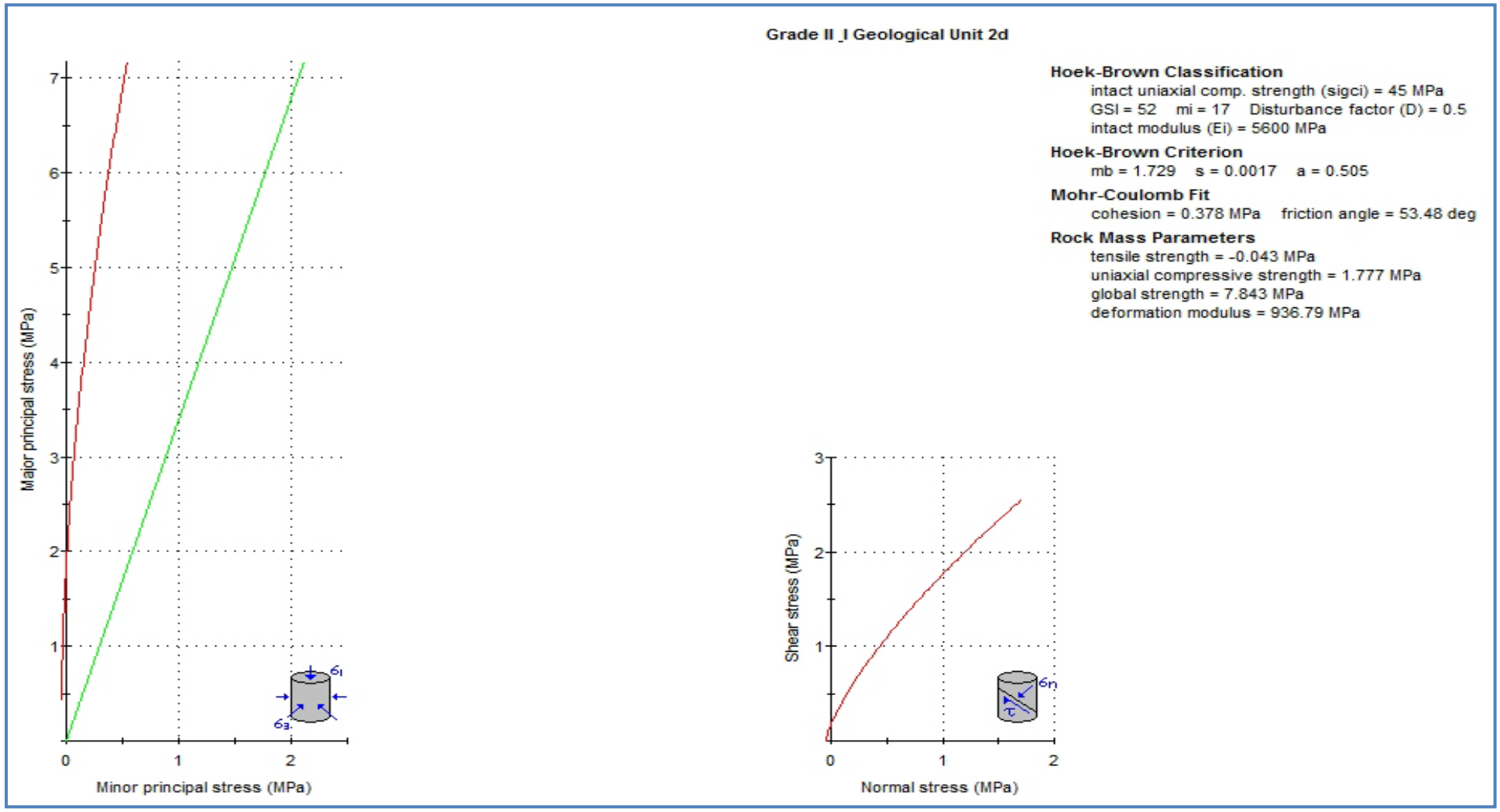
6. Rock Mass Parameters For Weathering Grade III Basalt with Disturbance Factor D = 0.7



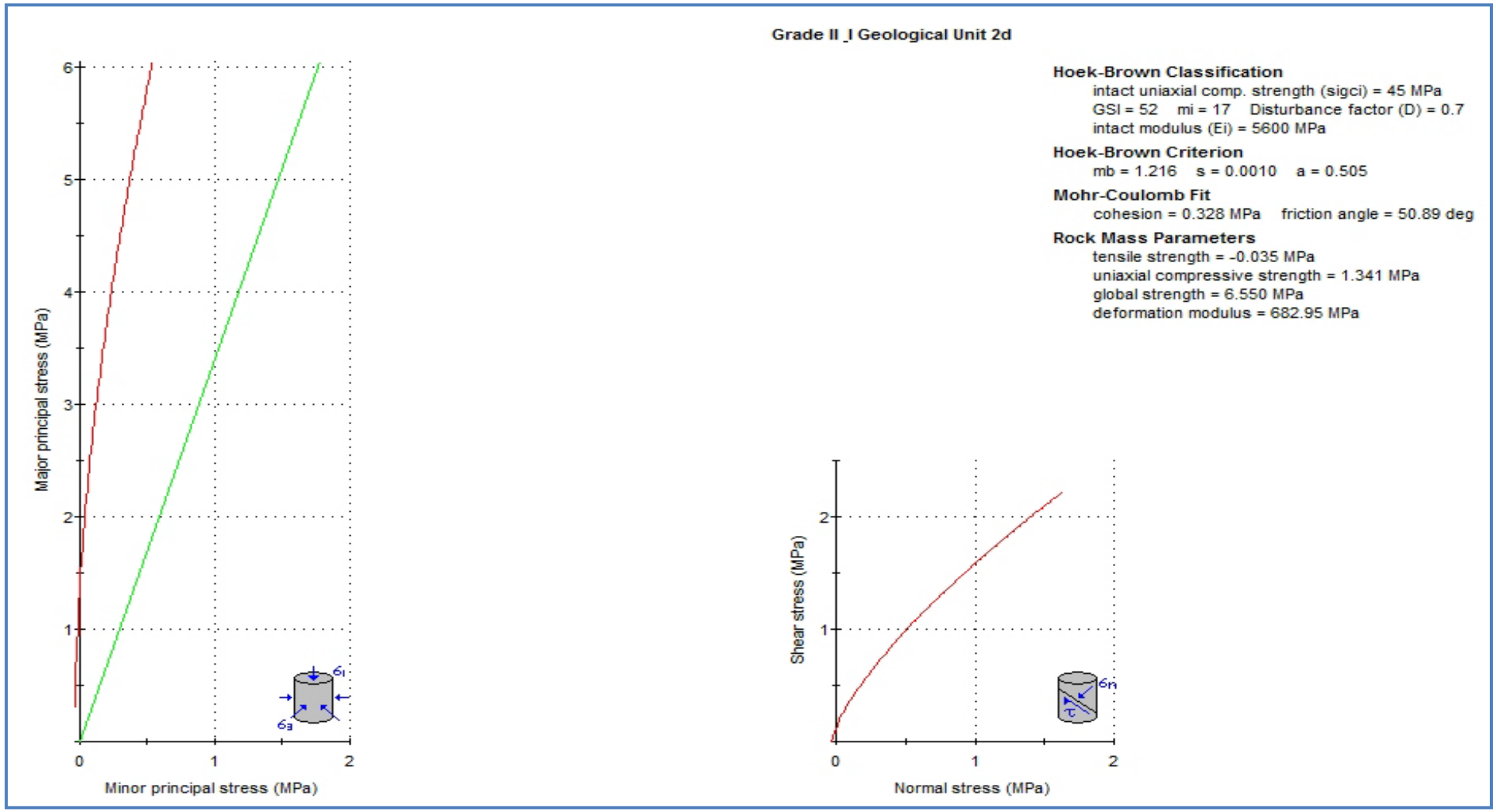
7. Rock Mass Parameters For Weathering Grade II & I Basalt with Disturbance Factor D = 0.2



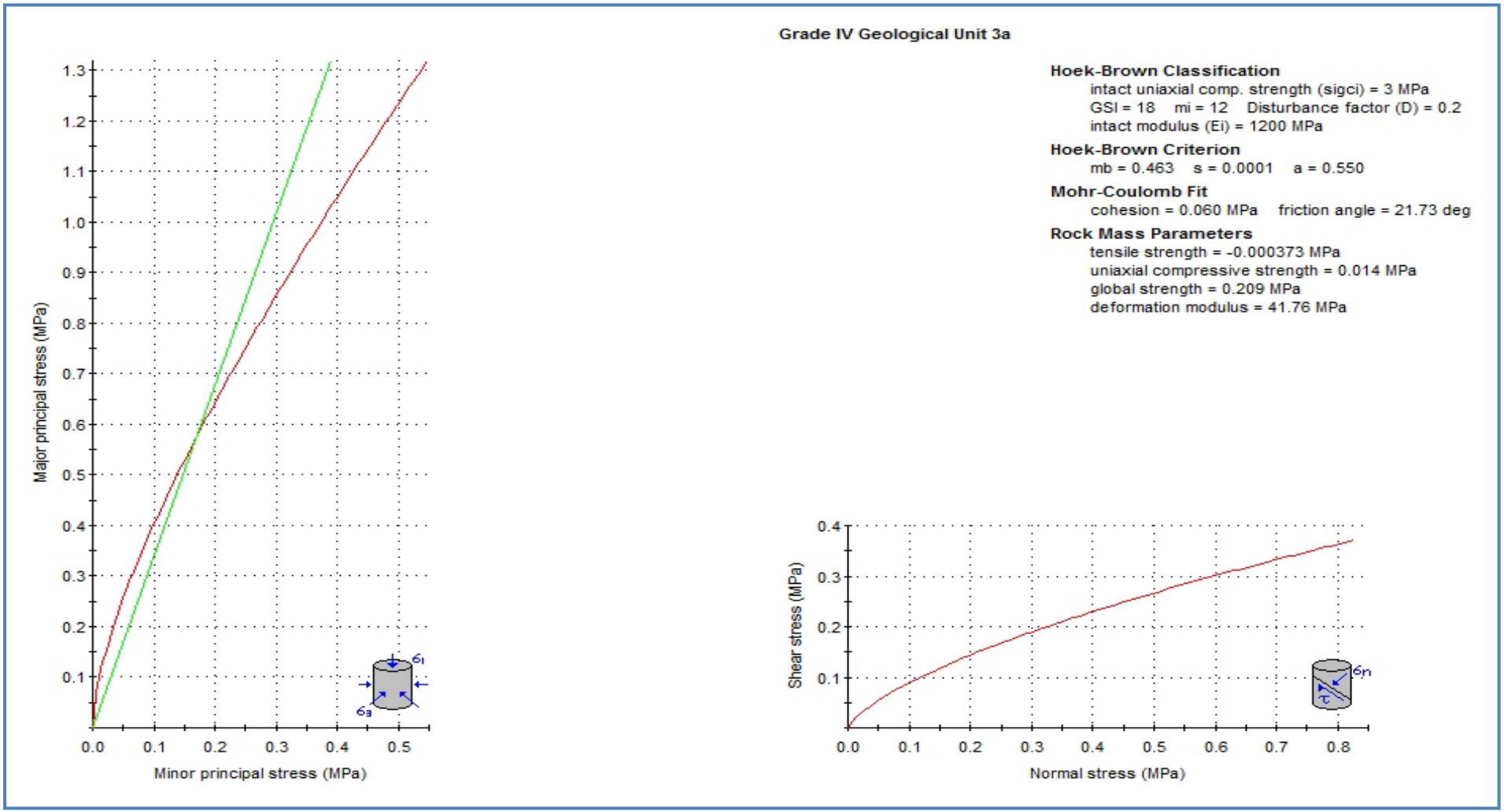
8. Rock Mass Parameters For Weathering Grade II & I Basalt with Disturbance Factor D = 0.5



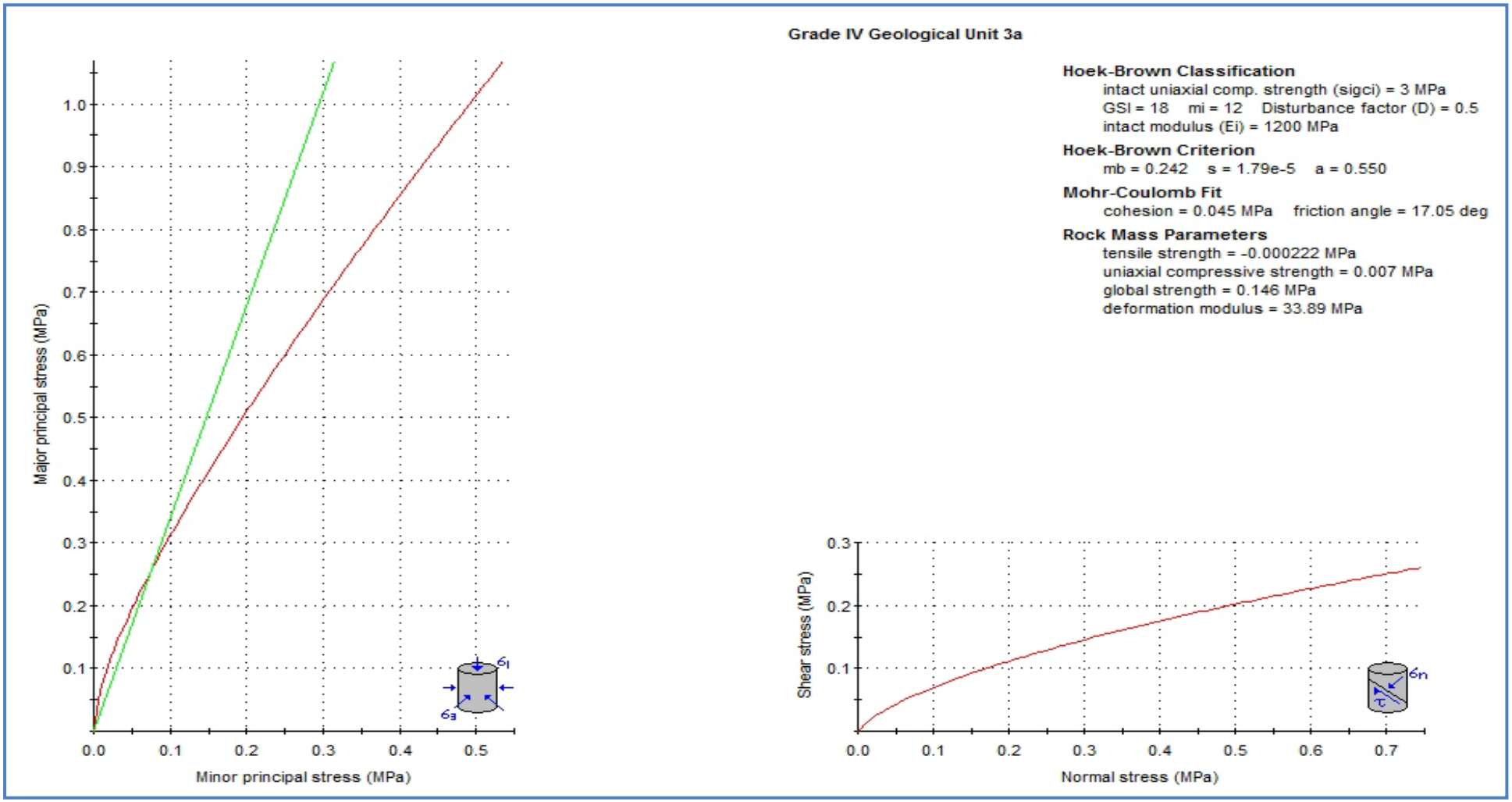
9. Rock Mass Parameters For Weathering Grade II & I Basalt with Disturbance Factor D = 0.7



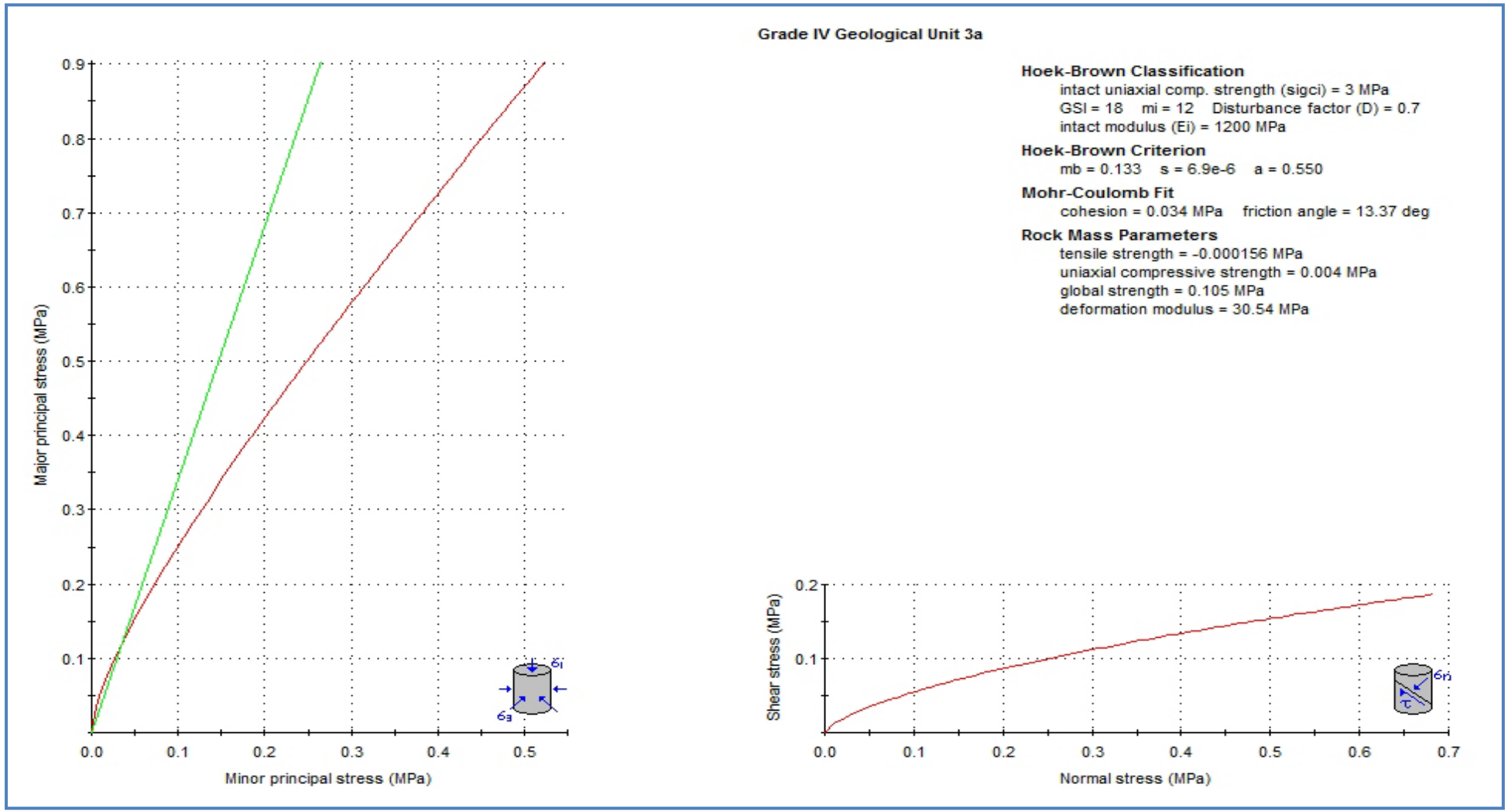
10. Rock Mass Parameters For Weathering Grade IV Breccia with Disturbance Factor D = 0.2



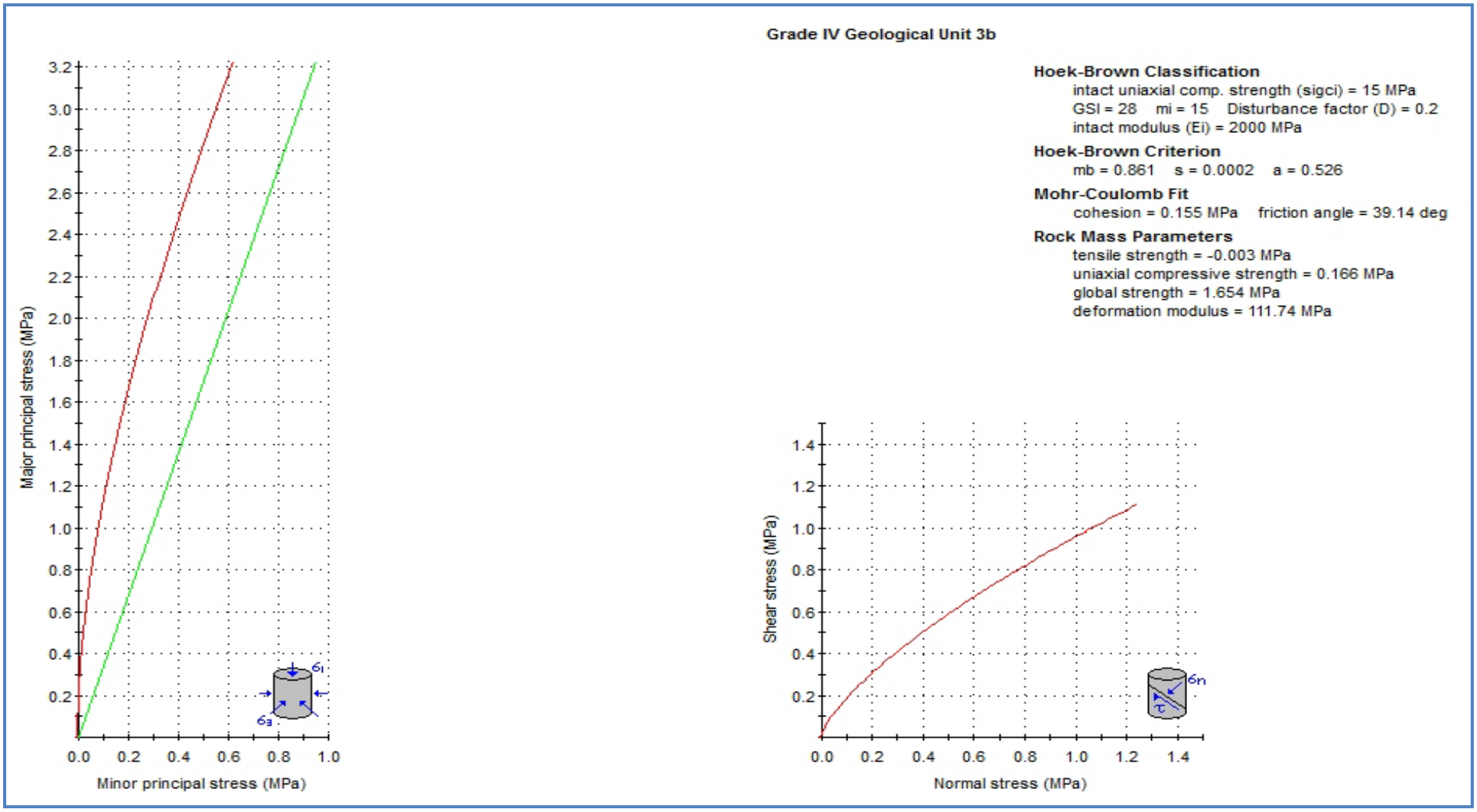
11. Rock Mass Parameters For Weathering Grade IV Breccia with Disturbance Factor D = 0.5



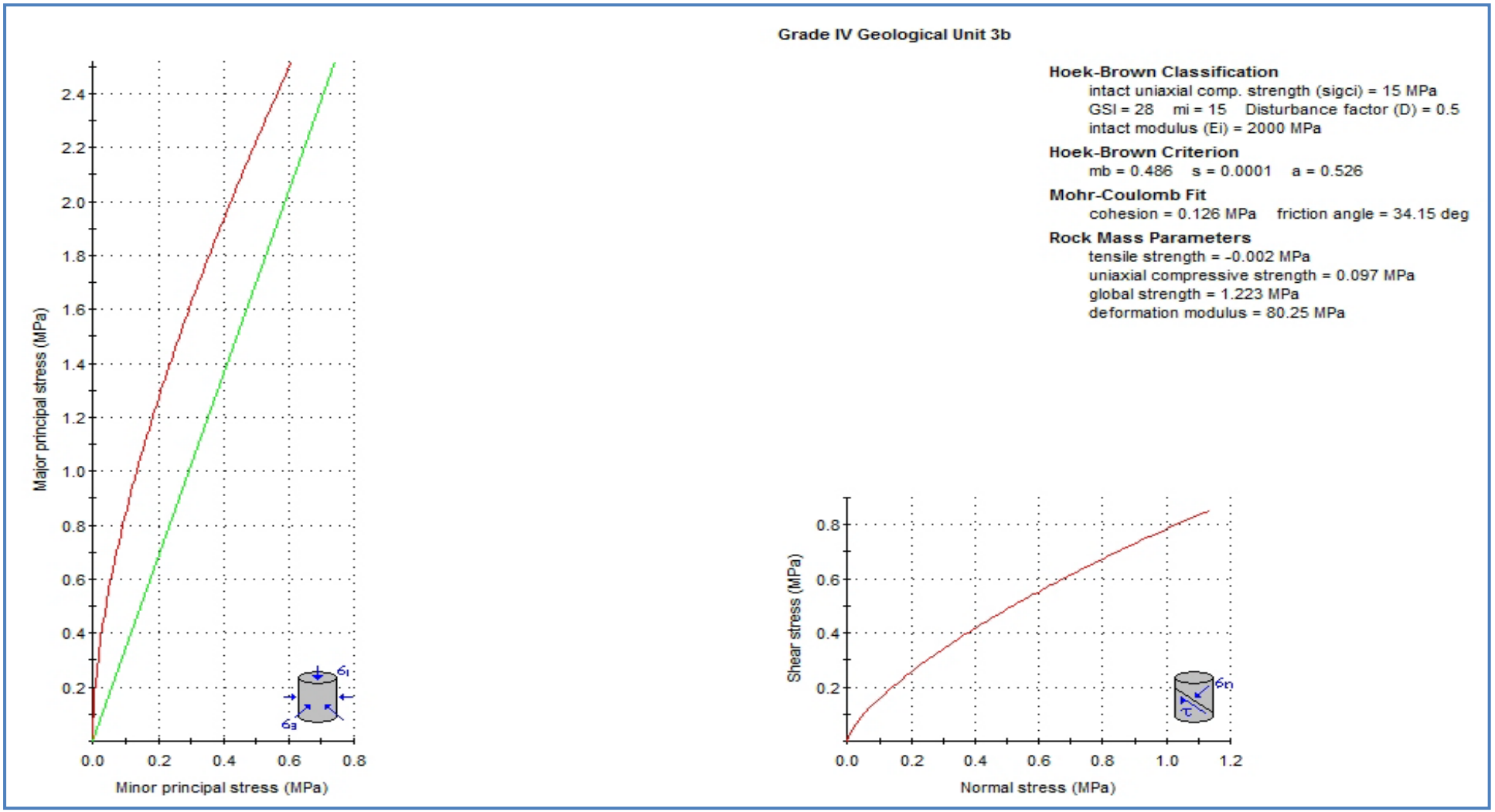
12. Rock Mass Parameters For Weathering Grade IV Breccia with Disturbance Factor D = 0.7



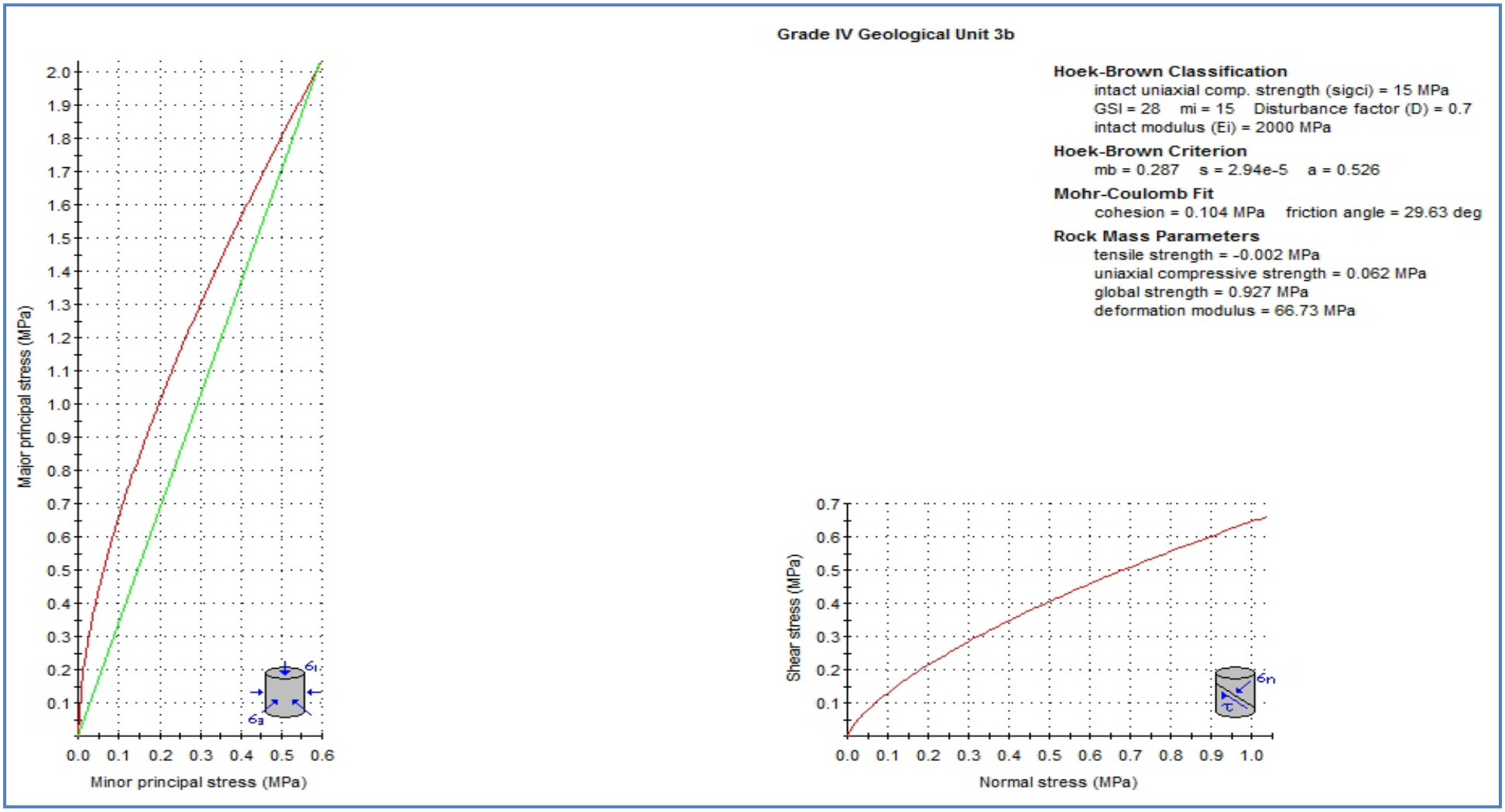
13. Rock Mass Parameters For Weathering Grade III Breccia with Disturbance Factor D = 0.2



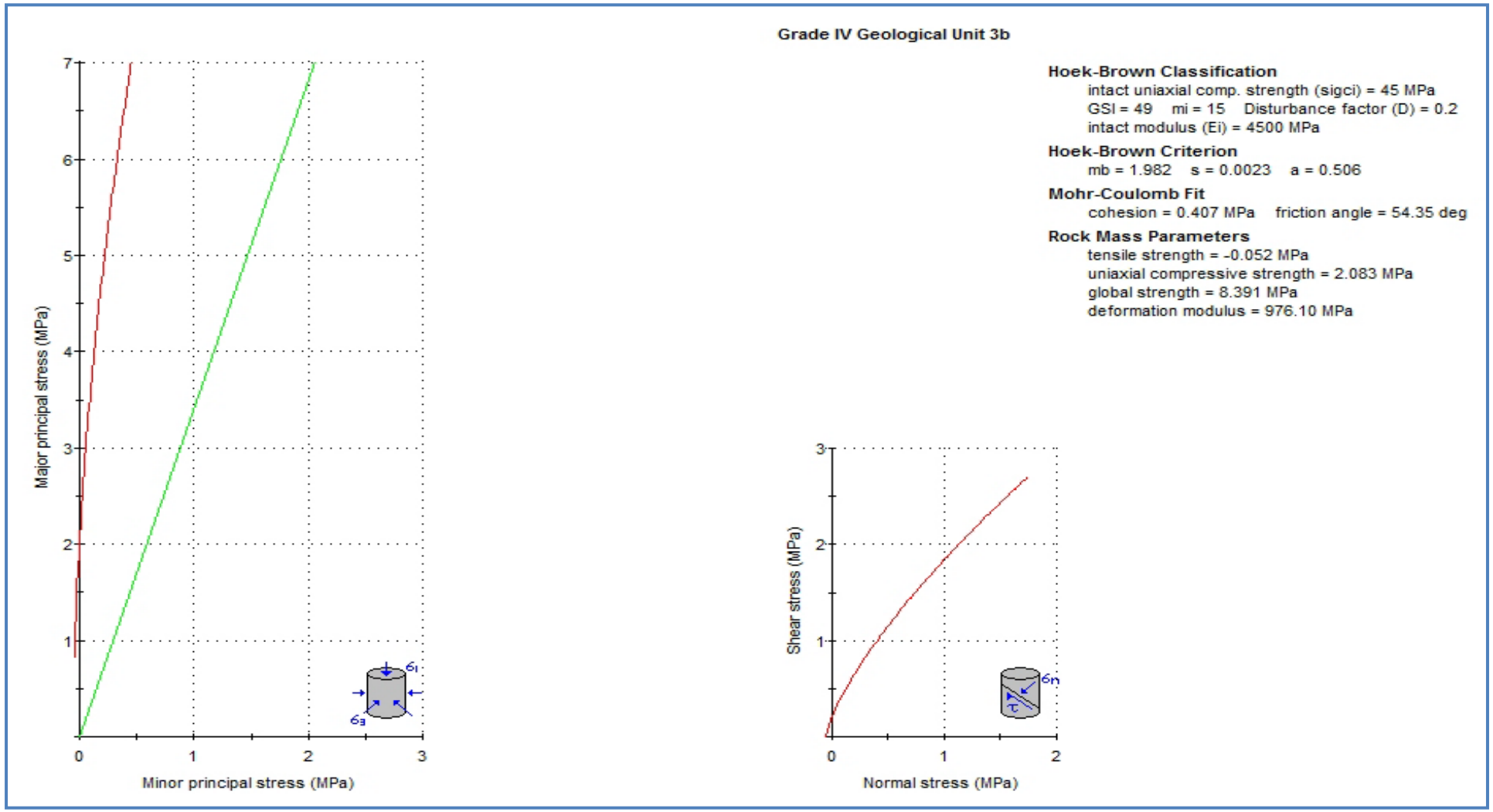
14. Rock Mass Parameters For Weathering Grade III Breccia with Disturbance Factor D = 0.5



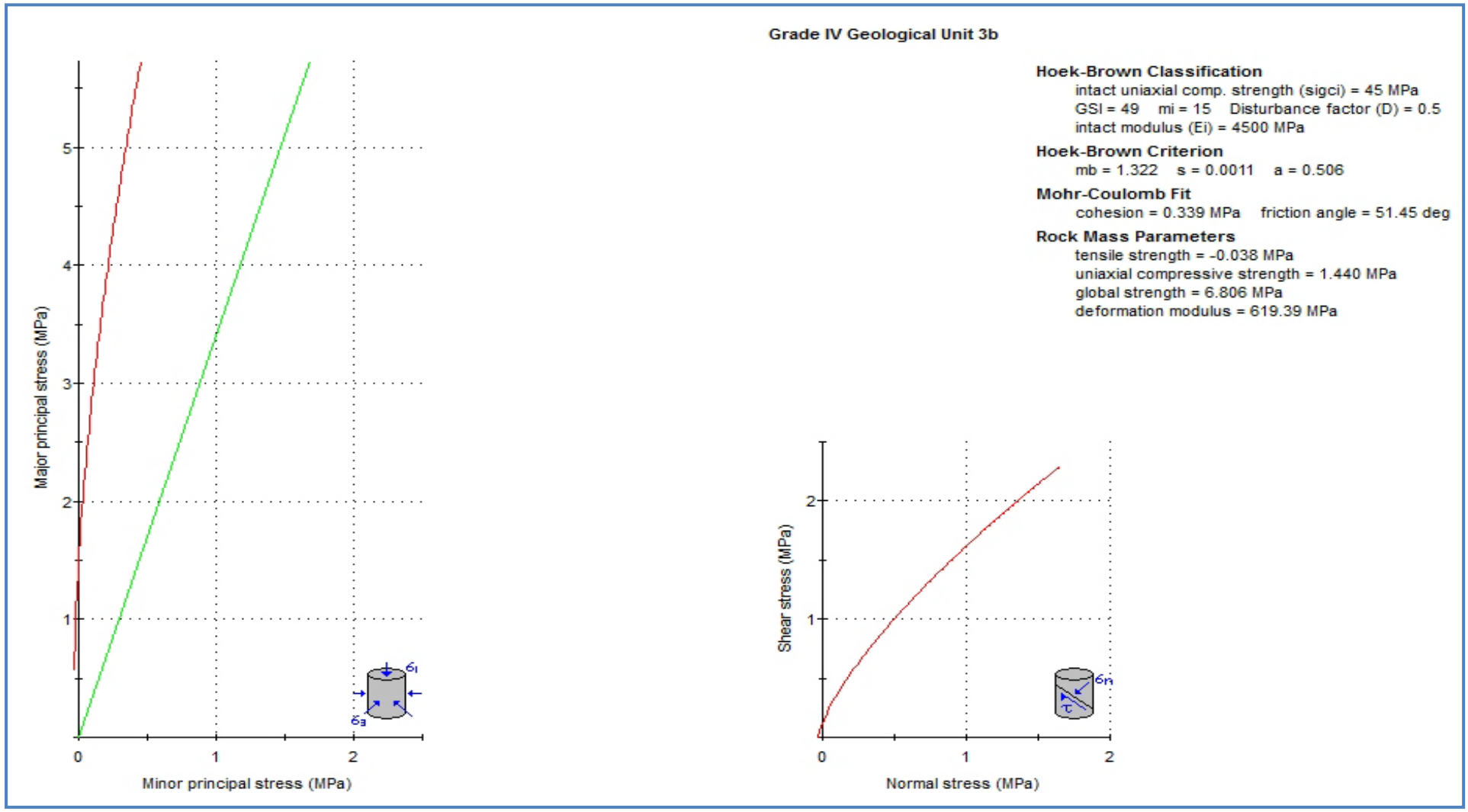
15. Rock Mass Parameters For Weathering Grade III Breccia with Disturbance Factor D = 0.7



16. Rock Mass Parameters For Weathering Grade II & I Breccia with Disturbance Factor D = 0.2



17. Rock Mass Parameters For Weathering Grade II & I Breccia with Disturbance Factor D = 0.5



18. Rock Mass Parameters For Weathering Grade II & I Breccia with Disturbance Factor D = 0.7

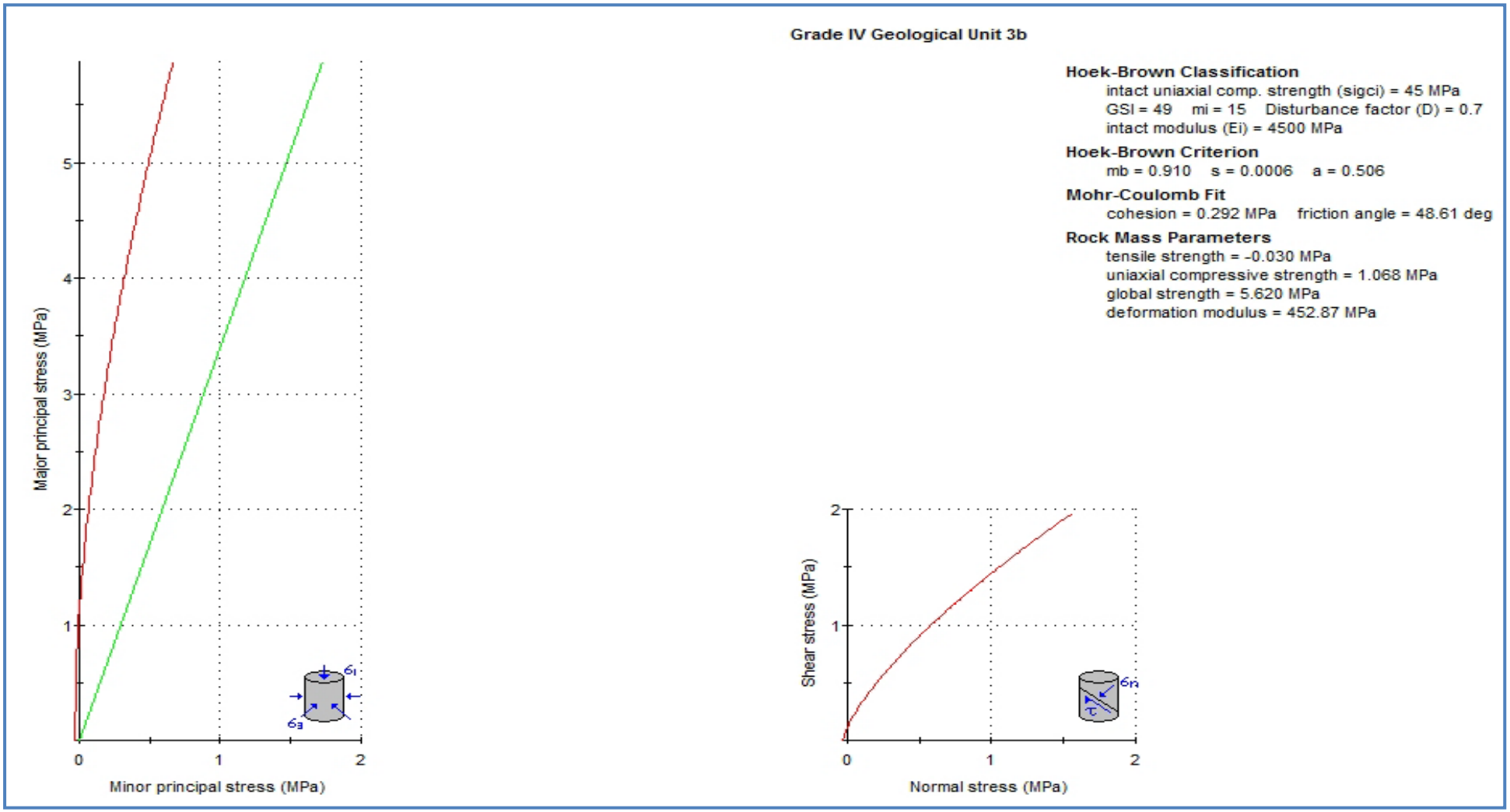


Table 4-30: Recommended Geotechnical Design Parameters - Failure Envelope by General Application

Geological Unit	σci, UCS for intact rock, Mpa	Intact rock parameter, mi	Intact Modulus, Ei, Mpa	GSI (Geological Strength Index)	Disturbance Factor, D = 0.2			Disturbance Factor, D = 0.5			Disturbance Factor, D = 0.7			Unit weight under soaked condition, kN/m³	Tunnel Depth, m	Permeability, Lugeon
					Cohesion, Mpa	Angle of internal friction	Rock Mass Deformation Modulus, Erm Mpa	Cohesion, Mpa	Angle of internal friction	Rock Mass Deformation Modulus, Erm Mpa	Cohesion, Mpa	Angle of internal friction	Rock Mass Deformation Modulus, Erm Mpa			
Unit 2a & 2b	5	12	1200	15	0.064	23.61	37.58	0.048	18.43	31.55	0.036	14.33	28.99	26	50	--
Unit 2c	15	17	3275	37	0.198	43.68	318.95	0.166	39.44	209.97	0.141	35.50	162.18	27		16.149
Unit 2d	45	17	5600	52	0.451	56.10	1467.4	0.378	53.48	936.7	0.328	50.89	682.9	28.2		4.336
Unit 3a	5	12	1200	18	0.060	21.73	41.76	0.045	17.05	33.89	0.034	13.37	30.54	26*		--
Unit 3b	15	15	2000	28	0.155	39.14	111.74	0.126	34.15	80.25	0.104	29.63	66.73	27.5		7.161
Unit 3c	45	15	4500	49	0.407	54.35	976.1	0.339	51.45	619.3	0.292	48.61	452.8	28		10.517

Note: * assumed value Poisson`s ratio can be considered as 0.25 for the all type of rock strata.

B. Interpretation of Field Tests & Lab test Values

1. Pressure-Meter Test

Oyo Pressure-meter Test, also known as the High-Pressure Dilatometer Test, is a direct displacement measuring method used to obtain the elastic properties of a rock mass. The test was performed using an OYO Elastmeter-2, with a rated pressure range of 0 to 200 Bar, for the type of membrane. The probe (or Sonde) is lowered down to the depth of test section and inflated, exerting pressure against the wall of the borehole and consequent radial deformation is measured. Based on pressure-meter test results to derive the elastic modulus (E_m) and the shear modulus (G_m) of the rock mass. Total five pressure meter tests were conducted. Results of Pressure-Meter Test are presented in previous chapter. The summary of Pressure-Meter Test results for different weathering grade of rock mass are as given in Table 4-31

Table 4-31: Summary of Pressure-Meter Test results for different weathering grade of rock mass

Description	Geological Unit	Rock Type	Weathering Grade	Value
E_m Modulus of Elasticity of Rock Mass Modulus of Elasticity of Rock Mass in MPa	Unit 3b	MWR Breccia	III	23628.22
	Unit 3c	Fresh Breccia	I & II	17012.66 to 40887.60
	Unit 2c & 2d	SWR Basalt*	I & II	27306.50
G_m Shear Modulus of Rock Mass in kg/cm²	Unit 3b	MWR Breccia	III	15358.34
	Unit 3c	Fresh Breccia	I & II	11058.23 to 26576.94
	Unit 2c & 2d	SWR Basalt*	I & II	17749.22
Ground coefficient K kg/cm²	Unit 3b	MWR Breccia	III	4444.44
	Unit 3c	Fresh Breccia	I & II	3333.33 to 8000
	Unit 2c & 2d	SWR Basalt*	I & II	5000

Note: * from Portal location

2. Packer Permeability Tests

Permeability for the rock mass has been obtained from 2 sources: falling head field permeability tests (IS: 5529-1) and Lugeon (packer) tests (IS: 5529-2). The former tests are applicable for soil and highly/completely weathered rock formations whereas the latter are more applicable on competent rock strata. The Lugeon test is a good aid in deducing the rock mass weathering profile as it correlates well with the density of discontinuities and joint opening. The Lugeon Packer permeability test measure the permeability of a test section in bedrock by packing the test section by mechanical expanding a membrane above and below the test section, and pumping in water into the test section under pressure. The pressure applied and the corresponding amount of flow of water into the test section is measured and permeability of the bedrock is calculated. Total 13 Packer permeability test were carried out in various stratum. Based on the test results, average Packer permeability values for different rock types are summarized in the Table 4-32

Table 4-32: Summary of average Packer permeability values for different rock

Geological Unit	Rock Type	Weathering Grade	Packer head Permeability test in Lugeon	k (m/s)	Condition of Rock mass discontinuities
Unit 3b	MWR Breccia	III	7.161	7.58E-07	Few partly open
Unit 2c	MWR Basalt	III	11.890 to 16.419	1.26E-06 to 1.74E-06	Some open joints due to high permeability value
Unit 3c	SWR Breccia	II	6.138 to 7.161	6.50E-07 to 7.59E-07	Few partly open
Unit 2c	SWR Basalt*	II	4.336	4.59E-07	
Unit 3c	Fresh Breccia	I	2.282 to 5.216 with one higher value of 10.571	2.42E-07 to 5.52E-07 higher value 1.12E-06	Few partly open to Some open joints due to high permeability value
Unit 2c	Fresh Basalt*	I	3.586	3.80E-07	Few partly open

Table 4-33: Representative Lugeon values and deduced Rock mass permeability

Geological Unit	Lugeon value	Permeability (m/s)
Unit 2c: Moderately Weathered Basalt	16.419	1.74E-06
Unit 2d: Slightly Weathered & Fresh Basalt	4.336	4.59E-07
Unit 3b: Moderately Weathered Breccia	7.161	7.59E-07
Unit 3c: Slightly Weathered & Fresh Breccia	5.216	5.52E-07

3. Abrasiveness

Rock abrasivity plays an important role in characterizing a rock material for excavation purposes. Abrasion can be defined as the wearing or tearing away of particles from the surface, i.e. it is a process causing removal or displacement of material at a solid surface, which will lead to wear, especially on tools that are used in mining, drilling, and tunnelling applications. The CERCHAR Abrasivity Test is a method to determine an index called CERCHAR Abrasivity Index (CAI) for the rock's abrasivity.

The CERCHAR Abrasivity Test is intended as an index test for classifying the abrasivity of a rock material. The test measures the wear on the tip of a steel stylus having a Rockwell Hardness of HRC 55. A rock specimen, disc-shaped or irregular, is firmly held in the test apparatus. The stylus is lowered carefully onto the rock surface. While under a normal force of 70 N, the stylus is moved a total distance of 10.0 mm across the rock.

Table 4-34: Summary CAI result

Geological Unit	Bore hole No	Depth (m)	Specimens	CAI
Unit 2d: Slightly Weathered & Fresh Basalt	BH-02	48.00-49.50	R-199	1.32
Unit 3c: Slightly Weathered & Fresh Breccia	BH-03	41.00-42.50	R-187	1.44
	BH-04	16.50-18.00	R-48	1.58
	BH-04	24.00-25.50	R-92	1.08
	BH-05	22.50-24.00	R-82	0.92
	BH-06	25.50-27.00	R-140	1.29

The obtained CAI value for Basalt i.e. **Unit 2d:** Slightly Weathered & Fresh Basalt is 1.32 which is Medium abrasiveness to abrasive & for **Unit 3c:** Slightly Weathered & Fresh Breccia it is varies from 0.92 to 1.58, corresponding to a slightly abrasive to abrasive condition according to CERCHAR classification:

Table 4-35: Classification of Rock Abrasivenes

CAI Value	Cerchar, 1986 (pin hardness 54)	Michalakopoulas et al (pin hardness 55)	NTNU classification (pin hardness 43)	CSM classification (pin hardness 56)
0.3 – 0.5	Not very abrasive	Very low abrasiveness	Not very abrasive	Not very abrasive
0.5 – 1.0	Slightly abrasive	Low abrasiveness	Slightly abrasive	
1.0 – 2.0	Medium abrasiveness to abrasive	Medium abrasiveness	Medium abrasiveness to abrasive	Slightly abrasive
2.0 – 4.0	Very abrasive	High abrasiveness	Very abrasive	Medium abrasiveness to abrasive
4.0 – 5.0	Extremely abrasive	Extreme abrasiveness	Extremely abrasive	Very Abrasive
5.0 -6.0				Quartzitic
6.0 – 7.0	Quartzitic	-	Quartzitic	-

4.5.3.3. Seismicity

Mumbai is located in Seismic Zone III as per IS: 1893-2002 (BIS, 2002) signifying that the city may be subjected to intensity VII damage as per MSK64 Intensity Scale. A review of the historical as well as the recent earthquake activity in peninsular India indicates that different parts of the region are characterized by low to moderate level of seismic activity (Jaiswal and Sinha, 2007). Occasionally some large and damaging earthquakes, such as the Koyna (1967), Killari (1993), Jabalpur (1997), and Kachchh (2001) earthquakes have occurred in the region. Unlike the earthquakes occurring on plate boundaries, demarcated by mid-oceanic ridges, transform faults and island arcs, these are intraplate earthquakes and are thus more rare. Mumbai is located near the Panvel seismic source zone, which is known to be seismically active (Nandy, 1995 and Dessai, 1995) Seismic hazard quantifies ground motions generated due to an earthquake in terms of peak ground acceleration (PGA) or other similar parameters associated with a scenario earthquake (Kramer, 1996). In this paper, a deterministic seismic hazard assessment has been carried out, where hazard in terms of the peak ground acceleration is evaluated at the centre of each grid after dividing the city into a number of small grids. The seismic hazard map of India was updated in 2000 by the Bureau of Indian Standards (BIS). The new map includes the central districts of Beed (Bir), Dharashiv (Osmanabad) and Latur, along with eastern sections of Ahmednagar, Pune, Satara and Sangli districts in Zone III. All of these areas lay in Zone I or II in the BIS 1984 map. Refer Figure 4-37.

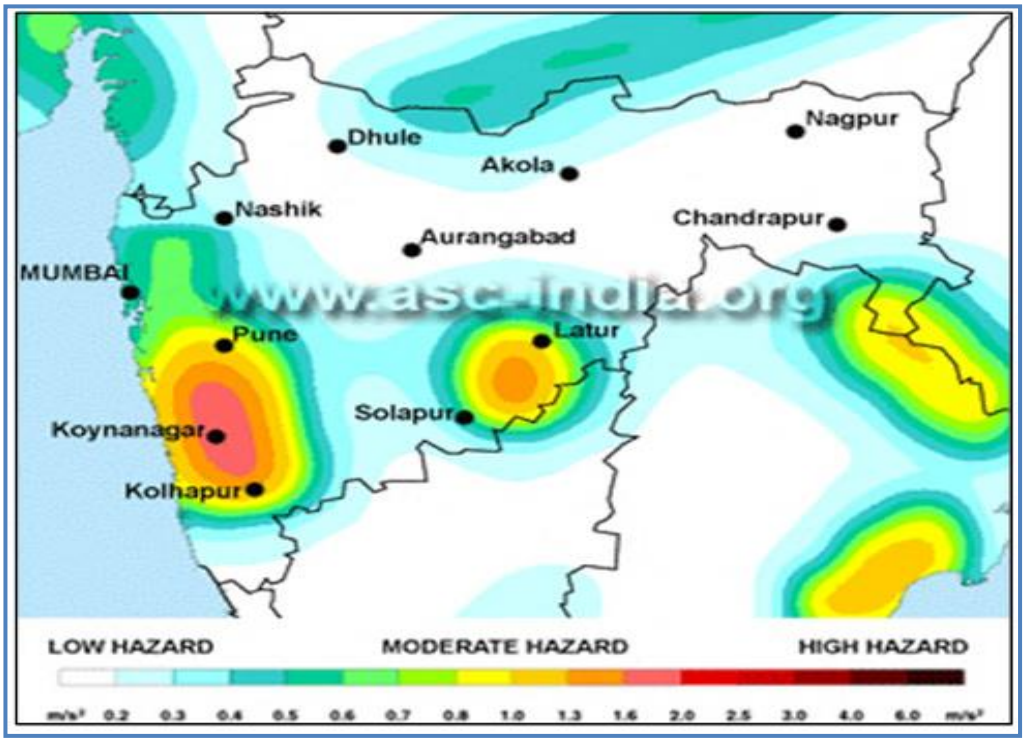


Figure 4-47: Seismic Hazard Map of Mumbai

5. Project Hindrances

The proposed Alignment of GMLR Tunnel is been classified into 3 parts i.e. Approach Road on Goregaon side, approach Road on Mulund Side and the Tunnel Portion. Approach road on Goregaon Side commence from whistling wood gate in Film City up to Tunnel Portal before SGNP Boundary, Approach Road on the Mulund side commence from Tansa pipeline up to Tunnel portal outside SGNP in Amar Nagar Slums at Khindipada Junction. Project will be having many hindrances as classified below:-

5.1. Affected Structures

Along the Mulund Side Approach approximately 300 Structures in Amar Nagar, area of land required is approximately 14340.594 m^2. Figure 5-1 indicates the detail drawing showing structure and Trees affected along Mulund side approach Road.

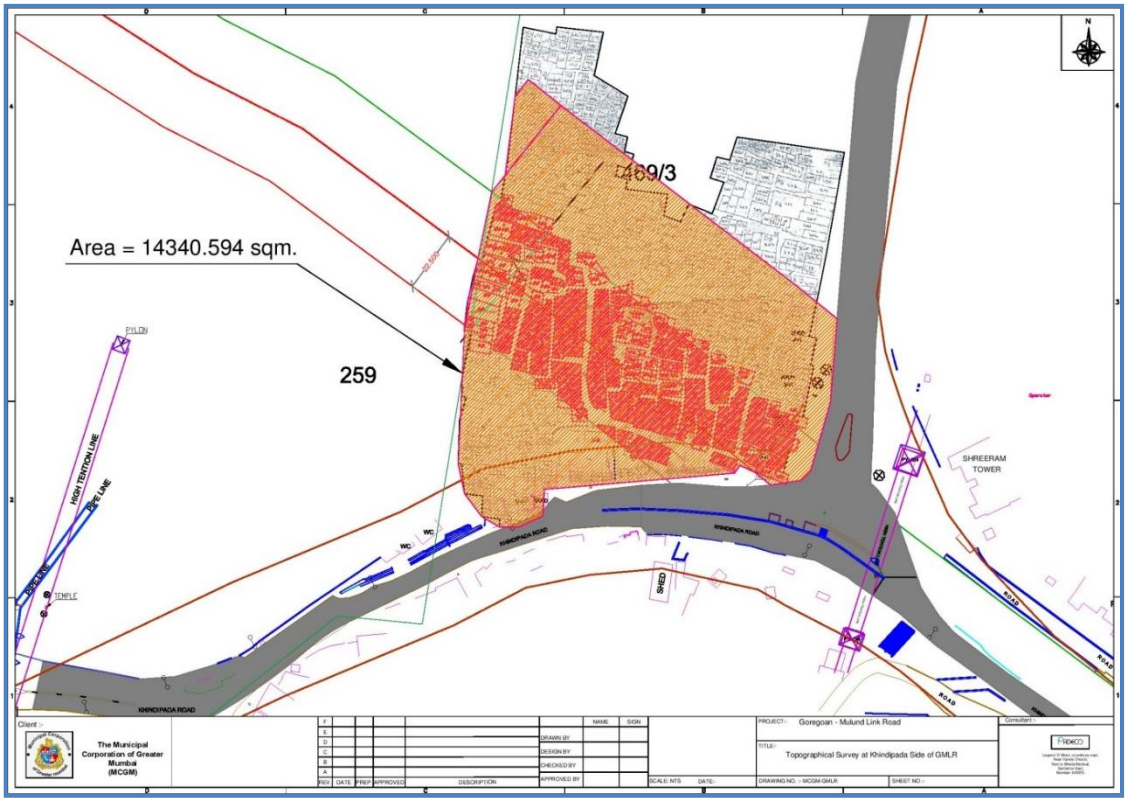


Figure 5-1 Structure affected on Khindipada side Amar Nagar Slums Tunnel East side approach Road

Along Goregaon side approximately 20 structures in film City has to be relocated for tunnel portal and Approach road. Figure 5-2 is the pictures of affected areas along Mulund Side approach

Few Hutments is also observed within Sanjay Gandhi National Park near to Mulund side portal, approximately 7nos of Hutment will be required to shift temporary during construction

5.2. Affected Trees

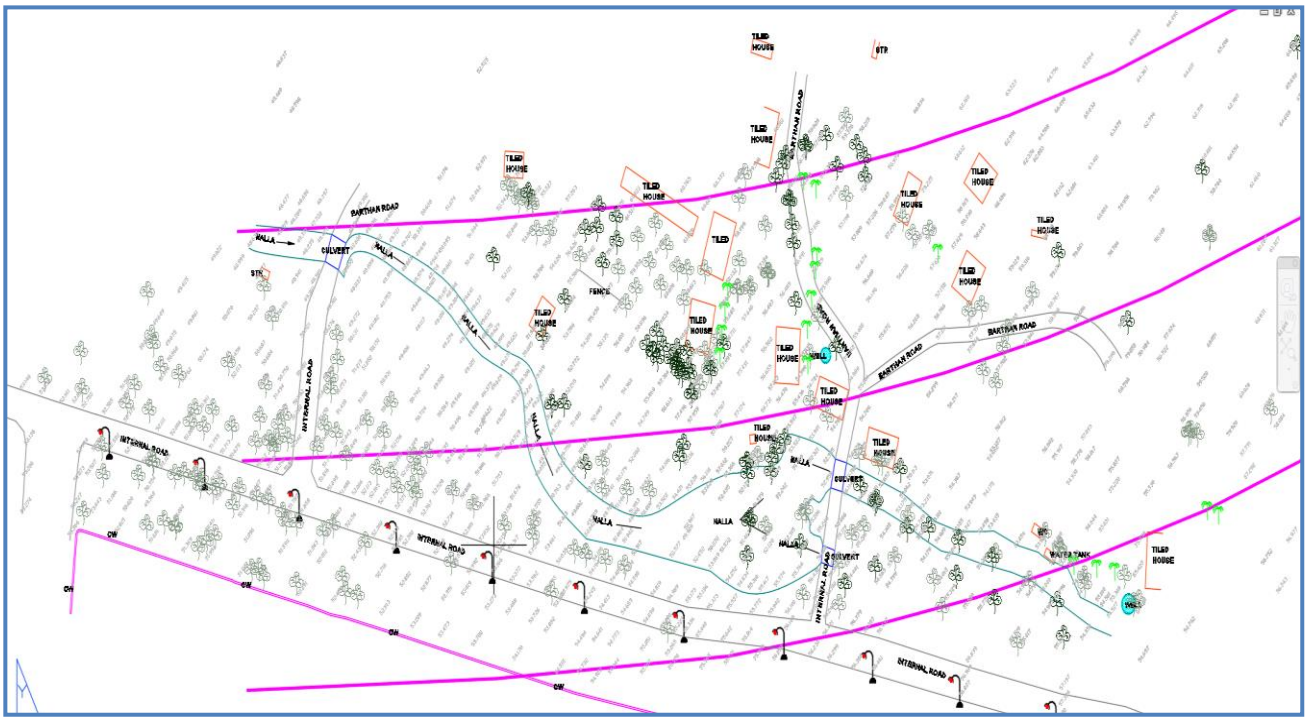


Figure 5-2 shows the detail drawing showing structure and Trees affected along Goregaon side approach Road.

Along the Mulund Side Approach Road total nos. of affected tree is approximately 10 Nos. side approach Road and along the Goregaon Side Approach Road Total nos. of affected trees are approximately 600 nos.

Figure 5-3 Hutment infringing Mulund side Tunnel approach road

Existing Drains and Culverts

- Water course is observed plying from Sanjay Gandhi National Park towards Film city west side with in approach road area. The drain is not having permanent lining, it is natural formed drain with the width range from 2m to 6m and depth varies from 2.00m to 3.00m. The Drain need to be diverted.
- Two Adjoining road perpendicular to existing Film city road towards North side is observed with width of 3m for the access to Film City shooting locations. Three culverts are constructed on the adjoining road which need to be diverted.

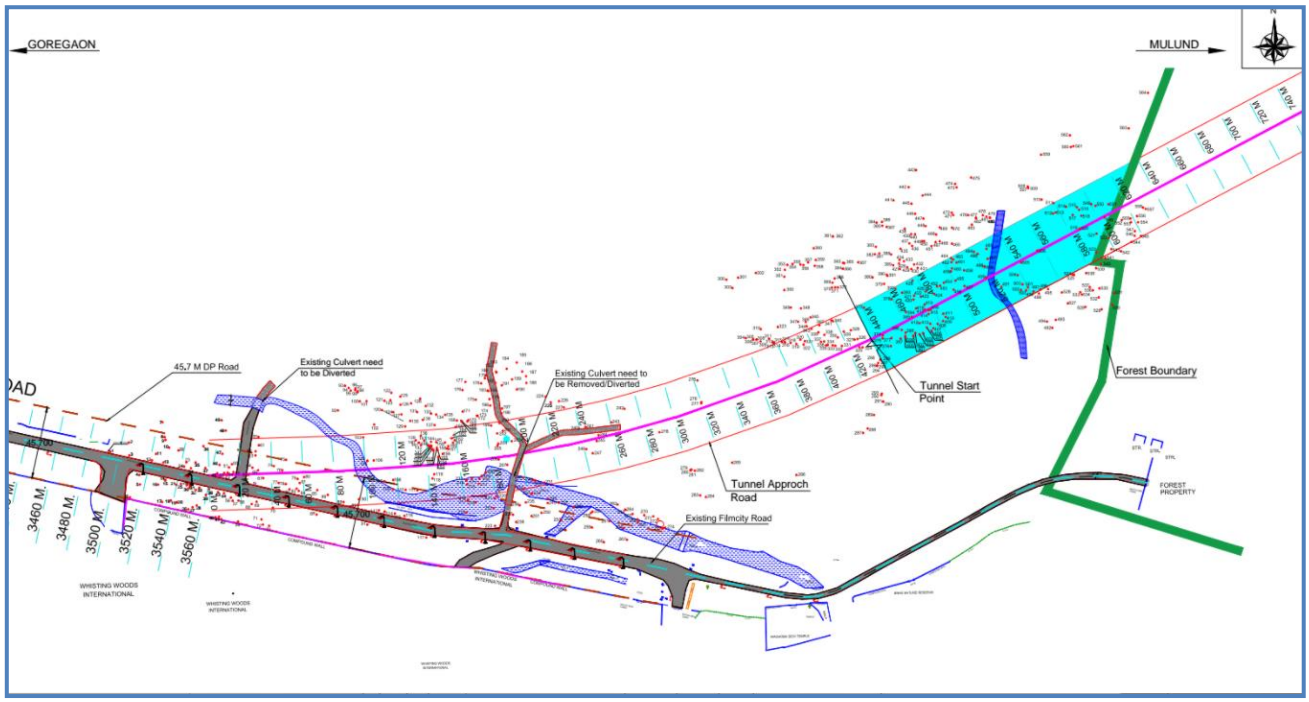


Figure 5-4 Drain and Culvert on Film city side Tunnel west side approach road

6. Utility Survey

Utility surveys are undertaken to locate existing surface utilities and underground Tunnel available data for consideration in engineering design, purposes of utility relocation, and right-of-way acquisition. Survey limits and types of utilities to be located should be shown on the Survey Request. The following are lists of facilities and critical points to be located for various utilities.

6.1. Water Pipelines

Water Supply tunnel passing underground and Surface from Bhandup Complex Pumping Station within Sanjay Gandhi National Park.

Bhandup Complex to Charkop

It is Underground Water Tunnel from Bhandup Complex Pumping Station to Charkop with One Vent Shaft within Sanjay Gandhi National Park. The alignment of Water Tunnel is crossing the Road Tunnel approximately at 19°10'12.60"N 72°54'2.70"E and Vent Shaft located at 19°10'13.64"N 72°54'0.07"E. The invert level of Water Tunnel Shaft at Bhandup Complex is 32.15m RL from GL and invert level at Charkop Shaft is 32.00m RL. The water tunnel is 4000 m with single tube RCC Segment with inner dia of 3.0 m. Tunnel passes beneath 10m of proposed GMLR Alignment at chainage 1+780 m

Shastri Nagar to Dhamu Nagar

It is surface Tunnel water MS Line passing from Shastri Nagar on East side of Mumbai – Mulund and passing through SGNP to Dhamu Nagar in West Mumbai (Kandivali). It is pressure line. Minimum Distance is 150m from proposed GMLR Tunnel underground Alignment.

Gundavali to Bhandup Complex

It is another Underground Tunnel from Gundavali to Bhandup Complex with 3m dia Single Tube RCC Segment lining. It crosses the GMLR on exit of eastern side of Tunnel below approach road.

Figure 6-2 Underground Water Supply Tunnel crossing GMLR Alignment Google Map

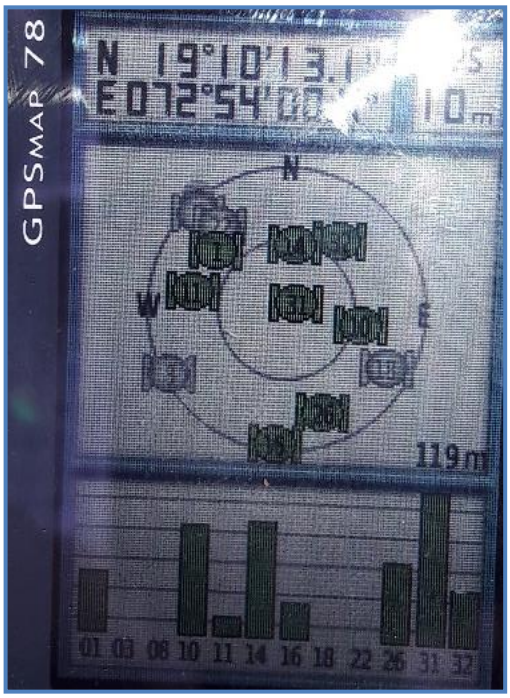


Figure 6-1 Bhandup- Charkop Water Tunnel Vent Shaft Location with co-ordinate

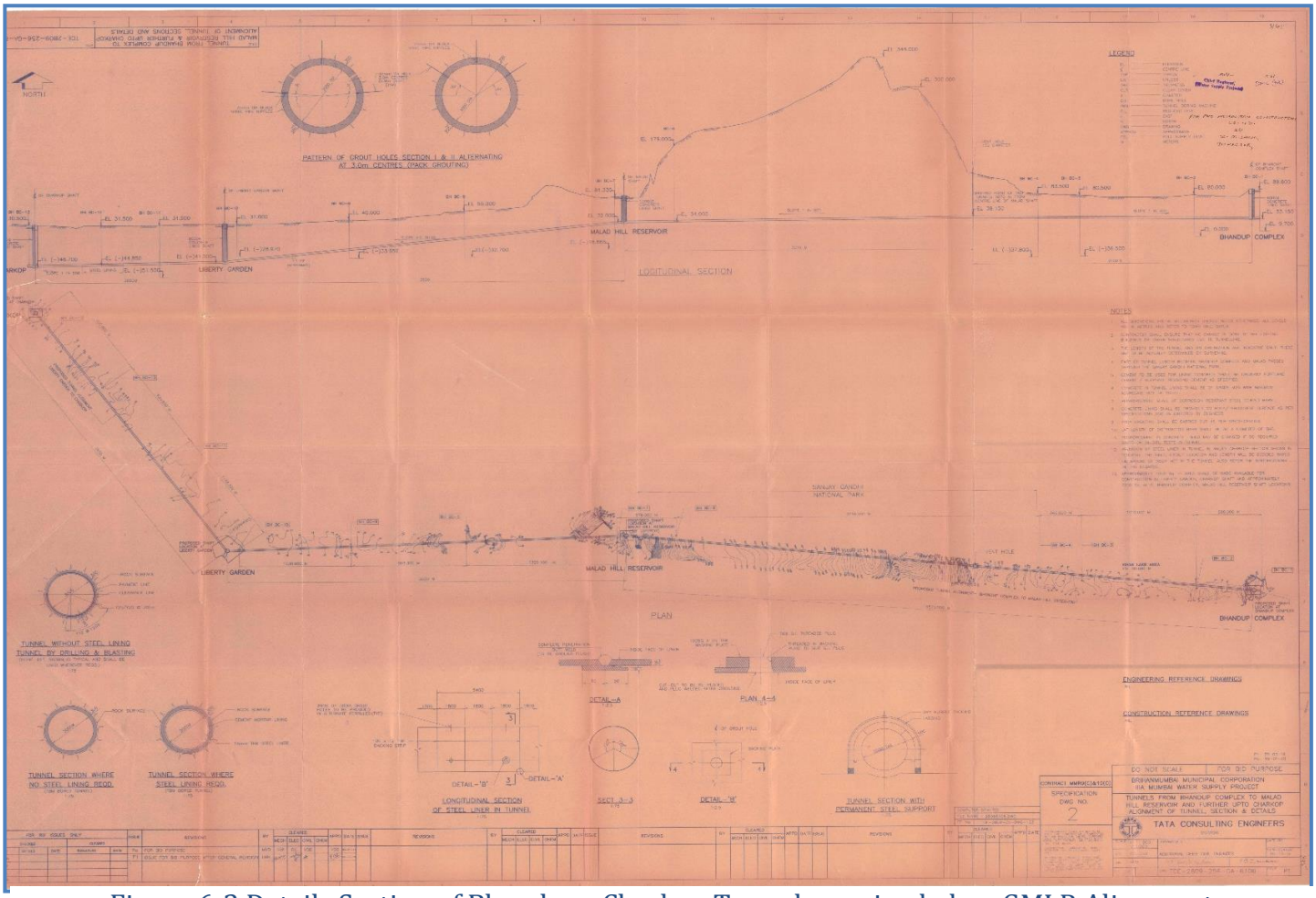


Figure 6-3 Details Section of Bhandup –Charkop Tunnel crossing below GMLR Alignment

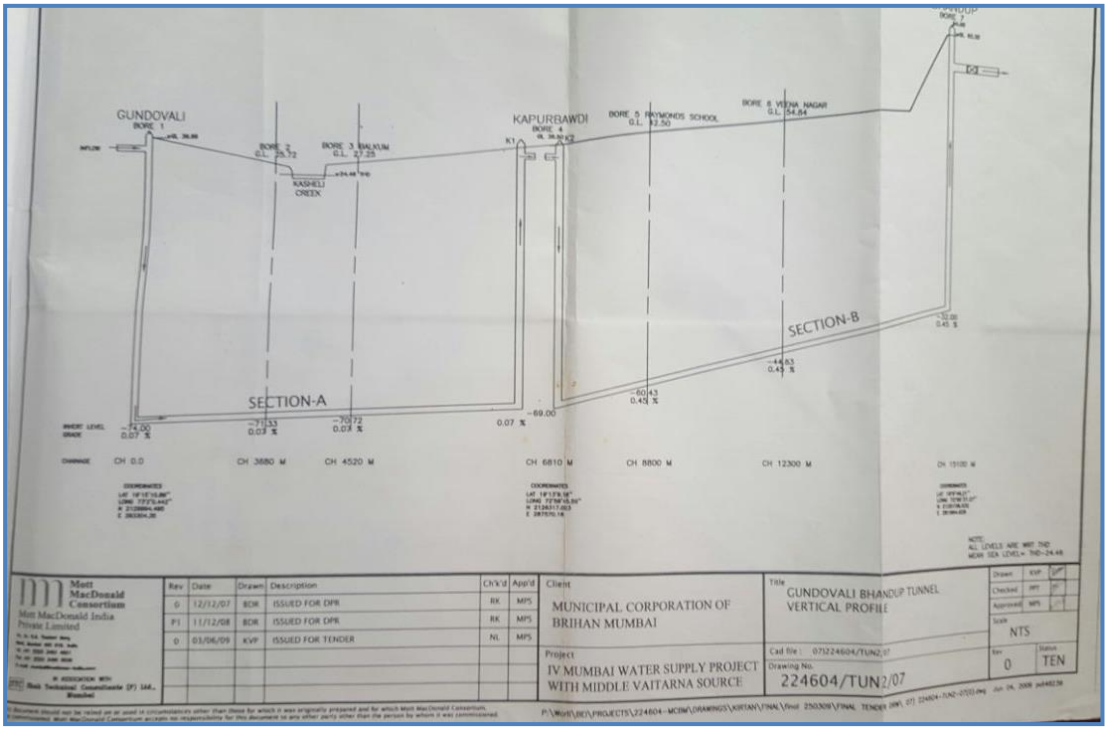


Figure 6-4 Vertical Profile of Gundavali to Bhandup Complex

6.2. Lakes and pumping station

- Underground Road Alignment is passing in between two Lakes and One Pumping Station.
- Vihar Lake is approximately situated on South end of Alignment and GL is approximately 57.00m RL with depth of Lakes is approximately 35.00m RL. The distance from Alignment to Vihar Lakes is approximately 750m away
- Bhandup Complex area is approximately 300m away from the proposed Tunnel Alignment. Since Tunnel is passing through rocky strata so, there would be no impact on the existing structures.
- Tulsi Lake is situated approximately on North end of Alignment and GL is approximately 121.00m RL and bed level of Lake is approximately 90.00m RL. The distance from Alignment to Tulsi Lake is approximately 1275m
- Reference for Distance and co-ordinate is taken from Google Earth.
- 19° 9'56.24"N 72°55'14.41"E coordinate of Bhandup Complex.
- 19° 9'49.76"N 72°54'43.46"E tentative coordinate of Vihar Lake.
- 19°11'25.29"N 72°55'0.79"E tentative coordinate of Tulsi Lake.

Figure 6-5 GMLR Alignment Underground Tunnel Alignment along Bhandup Complex

6.3. High Tension Line

- Existing 220KVA TPC and 110KVA TPC High Tension Overhead Electric Lines are laid on surface within Sanjay Gandhi National Park from Bhandup Complex – parallel to SGNP Tulsi Gate- Tulsi Lake – RSS at Borivali and crossing Tunnel Alignment. Tentative Three Towers at following co-ordinate are above Tunnel Alignment. Due to unavailability of actual data, co-ordinate is considered from Google Earth which is only for reference.

- 19°10'28.63"N 72°54'57.23"E 68.00m RL Approx.

- 19°10'24.96"N 72°55'12.82"E 105.00m RL Approx.
- 19°10'29.49"N 72°55'9.13"E 118.00m RL Approx.

Figure 6-6 High Tension Tower crossing within Sanjay Gandhi National Park from Khindipada to Borivali Stretch

7. Way Forward

Sr. No.	Deliverables	Remarks
1	Finalization of Suitable Alignment	Preliminary Alignment finalised by MCGM on February 20, 2016. Final submission expected by 30th April, 2017.
2	Finalization of GAD	Expected by 10th May 2017 subject to finalisation of approval of final Alignment.
3	Preliminary Design and Design Based Report	expected by 10th May 2017 subject to approval of GAD
4	EIA report & Regulatory Approvals	Target to submit till 30th April 2017
5	Preparation of Tender Document & Assisting in Bid Process Management	PADECO had a discussion with Chief Engineer for formalising the criteria for Tender document. Some Points to be finalize after discussing with AMC