CHAPTER 12

OTHER ENGINEERING ASPECTS
(LAND, UTILITIES, GEOTECHNICAL DETAILS etc.)

12.0 INTRODUCTION

Besides the details of various aspects e.g. transport demand analysis, route alignment, station locations, system design etc. as brought out in previous chapters, there are a number of other engineering items, which are required to be considered in sufficient detail before really deciding on taking up any infrastructure project of such magnitude. Accordingly, following engineering items have been studied and described in this chapter.

i) Land acquisition necessary for the project both on a permanent basis as well as temporary, including its break up between Government and private ownership.
ii) Utilities and planning for their diversion during construction.
iii) Geo-technical Investigations to enable designer's appreciation of Geo-technical problems that are likely to be encountered during project execution particularly in regard to underground components.

12.1 LAND

Alignment for both the East - West and the North - South corridors traverses major city roads having commercial, institutional and residential complexes including the busy Kempe Gowda Road and Chikpet areas. The Maintenance Depot on the East - West corridor is located in vacant land of NGEF on Old Madras Road while for the North - South corridor it is located adjacent to Yeshwantapur station in the area belonging to Mafatlal and Suryodaya mills both of which are closed down. Since land is a very scarce commodity, especially in metropolitan cities like Bangalore, alignment has been so chosen that land requirement is reduced to the minimum. Acquisition of private property has also been kept at a bare minimum.

12.1.1 Requirement of Land

Land is normally required for the following :

i) Metro structures along the Alignment, Station building, Platforms, Entry and Exit structures, Ventilation shafts, Traffic integration facilities, etc.
ii) Depot/Car shed.
   i) Receiving and Traction Sub stations.
   ii) Temporary Construction Depots and work sites.

12.1.2 Land for Underground and Elevated Stretches

For elevated section, single pier supporting the viaduct will be located on the middle of road so that the existing roads remain in use as usual. Accordingly, necessary permission for using such right-of-way will have to be obtained from the concerned authorities. Elevated stations are generally proposed with

elevated concourse so that land requirement for locating the entry/exit structures is only required. Only at a few stations the concourse is to be provided on ground on both sides of the road. Traffic integration facilities are provided wherever the same are required and necessary land is proposed for acquisition. In stretches, where the elevated alignment has to be located away from road, a strip of 20-m width, is proposed for acquisition.

No land is proposed to be acquired permanently for underground section, except for small areas for entry/exit structures, traffic integration, ramp and ventilation shafts at stations. For construction of underground as well as elevated structures, required land will, however, be temporarily occupied during construction phase.

In addition land is to be acquired for receiving substations at both ends of the corridors. Traction sub stations and auxiliary substations are proposed to be provided at concourse leve7l.

12.1.3 Land for At-Grade Stretch

Land is also required for alignment and stations located in at-grade position. On the East - West corridor land will not be required for "at-grade" alignment, because it is in the Maintenance Depot area. The Depot as well as the Baiyappanahalli Metro station are located between the existing Baiyappanahalli railway station and the Old Madras road, where about 19.90 hectares of open land is available belonging to NGEF, a public sector organization.

Land will be required for "at-grade" alignment at Swastik station which is located just before the switch-over ramp on the Northern side of the underground section. This stretch is proposed to be located inside the abandoned Minerva spinning mill on the Platform Road. Land totaling to about 2-hectares is proposed to be acquired for station and integration area.

12.1.4 Land for Switch-over Ramps

Switch-over ramps are required for transition from the underground to elevated section. The ramp covers a stretch at ground for the whole width of structure for two tracks (about 11 m including the protection works). The length of ramp above ground depends on the existing ground slope and the gradient provided on Metro alignment (normally 3% to 4%). Thus the ramp is to be located in an area where sufficient road width is available or in an open area.

On the East - West corridor two such ramps are provided on both sides of underground section. The Western ramp is provided at the end of the Magadi road near Bapuji College by taking the alignment off the road in open government land belonging to BWSSB and hospital so that the existing road is not affected. An additional 5 to 8 m of land is proposed for acquisition from Bapuji College for road/footpath widening.

The Eastern ramp is proposed in the Cubbon Park which will be merged with the surroundings.

On the North - South corridor the Northern ramp is provided just after the Swastik station in government land belonging to Railways and State Government. The adjacent platform road is unaffected due to the ramp.

The Southern ramp is provided on K R Road, as the right of way is sufficient to provide ramp. The existing road width can be restore by using the footpaths which may in turn be made by acquiring the vacant land on both side belonging to Government.

12.2 PRIVATE LAND

In order to keep acquisition of private land to the barest minimum, alignment has been so chosen that it follows the main arterial roads or within the government land. However, in a few stretches private land is to be acquired for providing curves at sharp bends on existing roads. Besides, to provide concourse at ground level, and also to negotiate some of the mandatory structural/planning requirements, acquisition of some private land is unavoidable. The displaced persons are to be compensated suitably or rehabilitated near by. In certain cases (specially in the underground section) the displacement is temporary lasting for the construction period only as they can be brought back at the same location after construction work is complete.

In order to ease the problem of acquisition of the above mentioned private properties, which may result in delay in execution of the project, it is suggested that owners of these properties may be offered alternative plots of equivalent land area in nearby open land of Bangalore Mahanagar Palike. In this arrangement, the owners of the affected residential structures will be required to be paid only the monetary compensation for their existing structures, provision for which has been made in the cost estimates under the head 'Rehabilitation'. The affected private properties have been proposed for acquisition in full, though at some locations, only a part of the property is affected by the route alignment.

The locations/ chainages of the land to be acquired on East _ West corridor and North - South corridor is given in the **Tables 12.1 and 12.2** respectively.

TABLE 12.1

Land Requirement on East - West corridor (sq meter)

Sl.No.	Chainage(m)	Total Pvt. Land	Total Govt. Land	Total land
		area (sq.m.)	area (sq.m.)	area (sq.m.)
1	(-).400-500	7494	1586	9080
2	500-900	0	0	0
3	900-985.59	0	506	506
4	1000-1117	1867	0	1867
5	4700-4860	167	679	846
6	4900-5600	4481	0	4481
7	6200-6600	689	2874	3563
8	6600-6900	2924	4172	7096
9	7300-7620	0	3698	3698
10	7503-8697	0	1112	1112
11	8697-9318	0	956	956
12	9318-11380	0	4250	4250
13	11300-12600	1563	1051	2614

14	12800-13100	386	0	386
15	13600-13800	1000	2717	3717
16	13900-14100	817	0	817
17	14530-14700	1882	0	1882
18	15225-15460	1202	0	1202
19	15460-16000	2428	0	2428
20	16100-16800	2691	8700	11391
21	depot		199000	199000
	Sum	**29591**	**231301**	**260892**

TABLE 12.2
Land Requirement on North - South corridor (sq meter)

Sl.No.	Chainage(m)	Total Pvt. Land	Total Govt. Land	Total land
		area (sq.m.)	area (sq.m.)	area (sq.m.)
1	-700 -100	134405	0	134405
2	2000-2100	900	0	900
3	3000-3100	1029	0	1029
4	3200-3300	1377.68	0	1377.68
5	3900-4000	1219	0	1219
6	4600-4800	2535	0	2535
7	4800-5100	1449	376	1825
8	5400-6500	1119	20145	21264
9	8400-8600	1271	833	2104
10	9100-9300	213	446	659
11	10300-10800	4701	150	4851
12	11400-11500	1790	1759	3549
13	12300-12400	1429	930	2359
14	14300-14400	0	2500	2500
	Sum	**153438**	**27139**	**180576.68**

12.3 TEMPORARY CONSTRUCTION DEPOTS

As permanent acquisition of land is kept to bare minimum, additional land will be required during construction period for setting up of construction depots. Two suitable vacant Govt. plots, other than that already proposed for permanent acquisition, are available in the vicinity of proposed alignment. These can be leased/acquired on temporary basis for use as construction depots is proposed. These are shown in the land plans separately.

On the North - South corridor land for construction depot is to be used at the depot area and the Binny mill area.

12.4 Summary of land requirements

Abstract of land requirement for different components of this corridor is given in below

East - West Corridor

A– Government Land

i)	Baiyappanahalli Station	-	19.90 hectares.
ii)	At other locations	-	3.92 "
iii)	**Total Govt. Land**		**23.82 hectares**

B – Private Land

i)	**Total Land**	**-**	**3.23 hectares**

C – Total Land to be acquired {A+ B} **27.05** "

North - South Corridor

A– Government Land

i)	**Total Land**	**-**	**2.57 hectares.**

B – Private Land

i)	For Yeshvantpur Depot.	-	13.43 "
ii)	At other places	-	2.19 "
iii)	**Total Private Land**	**-**	**15.62 "**

C – Total Land to be acquired {A+ B} **18.19 "**

Total Land for both corridors :

Govt.	**26.39 hectares.**
Pvt.	**18.85 hectares.**
Total Land	**45.24 hectares**

12.5 REHABILITATION & RESETTLEMENT

The proposed METRO alignment affects one major residential area at Subhash nagar near Magadi Road and many shops & residences in the Ulsoor areas including the Ulsoor police quarters. Besides, it also affects a few more shops and other structures at isolated locations viz. At Magadi Road, CMH Road, Old Madras etc. The entire affected slum will have to be rehabilitated at suitable locations through Bangalore Mahanagar Palike. All the affected shop and other structures will also have to be rehabilitated in consultation with the concerned authorities.

For rehabilitation of Subhash Nagar residences, a plot of land of about 2 hectares is proposed to be acquired on the left side of Old Mysore Road. On this plot, some old single storey private houses belonging to Minerva mill are located in a scattered manner. Multisoreyed houses can be constructed in a planned manner for rehabilitation of the existing people and the displaced persons from Subhash Nagar.

For rehabilitation of shops, houses, police quarters and other structures at other locations like Ulsoor, an area of government land measuring 15 hectares opposite the BDA complex has been proposed which is already acquired by BMRTL.

On the North - South corridor a few commercial properties are affected at the junction of Chord road and Mahakavi Kuvempu road which can be temporarily shifted during the construction and restored back at same place after construction.

The affected properties at Malleswaram station can be rehabilitated in the same area after construction through multistorey housing complex. However the properties affected by the side of ROB at Malleswaram are to be rehabilitated elsewhere.

The residents of Bhima Nagar can also be rehabilitated in the same area by constructing mulistorey complex.

Two schools namely Govt. Urdu school and C M A school in the Chikpet area are to be shifted temporarily during construction and these can be restored with the new buildings at same place after construction as only a small area is to be acquired permanently for entry/exit to the station and ventilation shaft.

The affected properties at Vani Vilas road are to be relocated for which suitable place is to be located in consultation with state government and the respective owners.

12.6 UTILITIES AND SERVICES

The proposed Metro alignment is passing along major arterial roads of the city road net work, which are serving Institutional, Commercial and residential areas. Large number of sub-surface, surface and over head utility services viz. Sewers, water mains, storm water drains, telephone cables, electrical transmission lines, electric poles, traffic signals etc. are existing along the proposed alignment. These utility services are essential and have to be maintained in working order during different stages of construction by temporary

/ permanent diversions or by supporting in position. As such, these may affect construction and project implementation time schedule / costs, for which necessary planning / action needs to be initiated in advance.

Organisations / Departments responsible for concerned utility services are provided in **Table 12.3**

Table 12.3
ORGANISATION RESPONSIBLE FOR UTILITIES AND SERVICES

S.No.	Organisation / Department	Utility services
1.	Bangalore Water Supply & Sewerage Supply (BWSSB)	i) Sewerage and drainage conduits iii) Water mains, their service lines, including hydrants and fountains etc. water treatment plants, pumping stations etc.
2.	Bangalore Mahanagar Palike (BMP)	Roads, surface water drains, nallahs, etc.
4.	Karnataka Public Works Deptt. (KPWD)	Roads, surface water drains, nallahs etc.
5.	Karnataka Power Transmission Corporation Limited (KPTCL)	iii) Power cables and their appurtenances
6.	Bombay Electricity Services Corporation of Maharastra (BESCOM)	iv) H.T. and L.T. lines, their pylons, electric Light posts, pole mounted transformers etc.
7.	Bharat Sanchar Nigam Limited (BSNL)	Telecommunication cables, junction boxes, telephone posts, O.H. lines etc.
8.	Bangalore Traffic Police	Traffic signal posts, junction boxes and cable connections etc.
9.	Reliance Industries Limited	Telecommunication cables, junction boxes, telephone posts, O.H. lines etc.
10.	Tata Telecommunication Limited	Telecommunication cables, junction boxes, telephone posts, O.H. lines etc.
11.	Bharti Telecommunications.	Telecommunication cables, junction boxes, telephone posts, O.H. lines etc.
12.	Southern Railway, Bangalore Division	Sanitary, water supply, electrical cable, telephone cable in station yard.

Assessment of the type and location of underground utilities running along and across the proposed route alignment between Mysore Road and Baiyyapanhalli Railway Station has been undertaken with the help of concerned authorities, who generally maintain plans and data of such utility services. Particulars of

main utilities i.e. trunk and main sewers / drainage conduits, water mains etc., wherever possible, were also verified at site by correlating their plan location and on site location with the help of man holes. Locations of these utilities have been marked on alignment plans and checked along with concerned agencies at selected sites. In some cases, the manholes are buried under the road surface, which could not be opened for verification.

12.6.1 Diversion of Underground Utilities

While planning for diversion of underground utility services e.g. sewer lines, water pipe lines, cables etc., during construction of Metro alignment, the following guidelines have been adopted:

i) Utility services have to be kept operational during the entire construction period and after completion of project. All proposals should therefore, ensure their uninterrupted functioning.

ii) Sewer lines and water supply lines are mainly affected in underground cut and cover construction. Where, the services are proposed to be maintained by temporarily replacing them with CI / Steel pipe lines and supporting them during construction, these will be encased in reinforced cement concrete after completion of construction and retained as permanent liner.

iii) The elevated viaduct does not pose any serious difficulty in negotiating the underground utility services, especially those running across the alignment. In such situation, the spanning arrangement of the viaduct may be suitably adjusted to ensure that no foundation need be constructed at the location, where utility is crossing the proposed Metro alignment. In case of utility services running along the alignment either below or at very close distance, the layout of piles in the foundations is to be suitably modified such that the utility service is either encased within the foundation piles or remains clear of them.

12.6.2 Major Utility Diversion

Since most of alignment is elevated, most of the utilities will not be affected. Even in underground portion by adopting tunneling method, the diversion of the surface utilities will also not disturbed. One of the major shifting involved is the substation of 66 KV at km 0.66 on E W Corridor and can be relocated on the opposite side of the road. The list of major electrical wires crossing is given below. These are to be replaced by underground cabling.

S. No.	Chainage	Voltage	Remark
1	66	2x66 KV	E-W Elevated
2	4715	1x66 KV	E-W Elevated
3	5405	1x66 KV	E-W Elevated

The BWSSB pumping station at Toll Gate Junction is likely to be affected as the alignment is passing above the station. The affected structure can be minimised by suitable design at the time of detail designing.

The details of major sewer/water pipe lines affected in both Corridors are given below:

S. No.	Chainage	Affected Length	Dia & Type	Remark
1	(-) 813 - (-) 724	149	600 CI (water)	E-W Elevated
2	965	58.5	450 CI (water)	E-W Elevated
3	1050 – 1140	80	450 CI (water)	E-W Elevated
4	8106	11.40	600 CI (water)	E-W (UG)
5	8474.10	20.24	500/675 CI (water)	E-W (UG)
6	11504 – 11522	29	450 CI (water)	E-W Elevated
7	11522 – 11559	36	400 CI (water)	E-W Elevated
8	12820.3	11.2	700 CI (water)	E-W Elevated
9	15924	18.00	700/600 CI(water)	E-W Elevated
10	8388.74	12.40	600 RCC(sewer)	N-S (UG)
11	8388.74	12	450 SWP(sewer)	N-S (UG)
12	1236.45	13.90	600 CI(water)	N-S (ELEVATED)
13	3225	43.00	600 CI(water)	N-S (ELEVATED)
14	5074 – 5223	152	450 CI(water)	N-S (ELEVATED)
15	5445	11.70	450 CI(water)	N-S (ELEVATED)
16	7091	11	450 CI(water)	N-S (UG)
17	9380	43.00	600 CI(water)	N-S (ELEVATED)
18	11236.25	11	600 CI(water)	N-S (ELEVATED)
19	11236.25	11	450 CI(water)	N-S (ELEVATED)
20	12500	73.10	600 CI(water)	N-S (ELEVATED)
21	12546	66	1750 CI(water)	N-S (ELEVATED)

12.6.3 Underground Section

Of the 33.0 Km long route of both the corridors, the underground alignment including ramps is only 8.16 Km long, located in the busiest portion of the route. The entire underground length would be done by tunneling except the station areas which is required to be constructed with cut and cover method

The underground existing services form Subhash nagar to Cubbon Park for East-West corridor and Platform Road to K R Road for the North-South corridor can be accommodated as there will be a cushion of about 4.5 to 8 m above the finished top of the Metro Tunnel/Box. However, two sewers are running along the left side of the road in the N-S corridor at km 4.191 & km 4.505 while no major sewer line is met in the E-W corridor Besides the sewers, water mains and storm water drains at few locations are also to be diverted. The existing underground services in the E-W & the N-S corridors are given in **Table no 12.4 to 12.7.** The list is for guidance as most of these utilities can be protected while working.

TABLE 12.4

Details of Sewer/Storm Water Pipe Lines on E-W Corridor					
Sl. No.	**Location /Chainage**	**Length in m**	**Avg.depth in m**	**Type & dia in mm**	**Position w.r.t. alignment within 11m stretch**

1	6283	11.5	1.5	S.W.P. 150	Crossing
2	6769	11.50	1.5	S.W.P. 150	Crossing
3	6786	11.50	1.5	S.W.P. 150	Crossing
4	6786	58.00	1.5	S.W.P. 150	2.5m Right of C/L
5	6826	10.50	1.5	S.W.P. 150	Crossing
6	7140	48.00	1.5	S.W.P. 150	Both side
7	7199	18.00	1.5	S.W.P. 150	Crossing
8	7240	11.50	1.5	S.W.P. 150	Crossing
9	7713	11.00	1.5	S.W.P. 225	Crossing @ C/L
10	7831	16.40	1.5	S.W.P. 225	Right @ C/L
11	7846.5	11.00	1.5	S.W.P. 225	Crossing @ C/L
12	7864	13.50	1.5	S.W.P. 225	Crossing
13	7872	9.25	1.5	S.W.P. 225	Crossing @ C/L
14	7986	14.53	1.5	S.W.P. 225	Crossing @ C/L
15	9140	11.10	1.5	S.W.P. 225	Crossing @ C/L

TABLE 12.5

Details of Sewer/Storm Water Pipe Lines on N-S Corridor					
Sl. No.	**Location /Chainage**	**Length in m**	**Avg.depth in m**	**Type & dia in mm**	**Position w.r.t. alignment within 11m stretch**
1	7037	78.05	2.5	270 SWP	cross
2	7703	6.38	3	360 SWP	cross
3	7750.56	18.2	3	360 SWP	cross
4	7788	14.37	3	360 SWP	cross
5	7876	25.38	2.5	240SWP	cross
6	8174	14.18	2.5	240SWP	cross
7	8224.2	19.77	2.5	240SWP	cross
8	8257.77	11.7	2.5	240SWP	cross
9	8287	21.38	2.5	240SWP	cross
10	8320	13.15	2.5	240SWP	cross

11	8388.74	12.4	3.5	600 RCC	cross
12	8388.74	12.4	3	450SWP	cross
13	8533	12.4	2.5	240SWP	cross
14	8673.34	11.73	3	360SWP	cross

TABLE 12.6

Details of affected Water pipe Lines on E-W Corridor				
Sl. No.	**Location@km.**	**Affected length in m.**	**Description & dia in mm**	**Position w.r.t. alignment within 11 m stretch**
1	6424 - 6582.20	163.12	150 mm dia CI	Right of C/L & Crossing at 6582.20
2	6595.06	11.00	150 mm dia CI	Crossing @ C/L
3	6761	11.50	80 mm dia CI	Crossing @ C/L
4	6844	11.50	80 mm dia CI	Crossing @ C/L
5	6853	11.50	80 mm dia CI	Crossing @ C/L
6	6876	11.50	80 mm dia CI	Crossing @ C/L
7	6880	11.50	80 mm dia CI	Crossing @ C/L
8	6882	11.50	80 mm dia CI	Crossing @ C/L
9	6996	11.50	80 mm dia CI	Crossing @ C/L
10	7001	11.50	80 mm dia CI	Crossing @ C/L
11	7006	11.50	80 mm dia CI	Crossing @ C/L
12	7011	11.50	80 mm dia CI	Crossing @ C/L
13	7155	11.50	80 mm dia CI	Crossing @ C/L
14	7235	11.00	80 mm dia CI	Crossing @ C/L
15	7714.5	11.00	100 mm dia CI	Crossing @ C/L
16	7850 - 7882	40.70	375 mm dia CI	Crossing @ C/L
17	8106	11.40	600 mm dia CI	Crossing @ C/L
18	8445.76	11.60	225 mm dia CI	Crossing @ C/L
19	8474.10	20.24	500/675 mm dia CI	Crossing @ C/L

20	8511.11	17.43	100 mm dia CI	Crossing @ C/L
21	8562	12.50	300 mm dia CI	Crossing @ C/L
22	9200	12.00	375 mm dia CI	Crossing @ C/L
23	10184	13	100 mm dia CI	Crossing @ C/L

TABLE 12.7

Details of affected Telephone cables on E-W Corridor				
Sl. No.	**Location@ km.**	**Affected length**	**Description & Size**	**Position w.r.t. alignment within 11 m wide stretch**
1	6254 - 6572	317.7	200 JF(1), 400 PJ(1) & 800 JF(1)	Crossing at ch 6304&6551
2	7716.5	11.5	100/6.5(1),50/6.5(1)	
3	7792-7807	15.00	100/6.5(1),50/6.5(1),copper cable	
4	7900 - 7972	72	OFC for Reliance	Left of C/L
5	8115.7	11	OFC for Tata	Crossing @ C/L
6	8117.4	11	OFC for Tata	Crossing @ C/L
7	8423	11	OFC for Tata	Crossing @ C/L
8	8473	13.8	OFC for Reliance	Crossing @ C/L
9	8506 - 8537	31.4	400/6.5(1)	Left of C/L
10	9153	11	200/6.5JF(1),50/6.5JF(1)	
11	9228 - 9272	62	100/6.5(1), 50/6.5(2)	Crossing at Ch. 9224.30
12	10127-10192	65	20/6.5JF(2), 10/6.5 JF(2)	

12.6.4 Elevated Section

In the elevated stretch, the alignment is running mostly along the central verge of the road except at few locations while negotiating existing/proposed flyovers, curves and other obligatory points etc. The sewer / drainage lines generally exist in the service lanes i.e. away from main carriageway. However, in certain stretches, these have come near the central verge or under main carriage way, as a result of subsequent road widening.

The sewer / drainage lines and water mains running across the alignment and getting affected by the normal location of column foundations are proposed to be taken care of by relocating column supports of viaduct by change in span length or by suitably adjusting the layout of pile foundation. Where, this is not feasible, lines will be suitably diverted. Provision has been made in the project cost estimate towards diversion of utility service lines. Details of sewer lines, water pipe lines and storm water drains affected in elevated stretch are indicated in **Table 12.8 and 12.9.** Only some of these are to be diverted which can be identified at detailed design stage.

TABLE 12.8

Details of affected Sewer/Storm Water Pipe Lines on E-W Corridor

Sl. No.	Location/ Chainage	Length in m	Avg.depth in m	Type & dia in mm	Position w.r.t. alignment within 11m stretch
1	(-) 383 - (-) 366	17	1.15	S.W.P. 225	At 5.0 m right of C/L
2	(-) 286.64 - (-)272.64	14	1.5	S.W.P. 225	At 4.8 m right of C/L
3	500 - 512	13.34	1.5	S.W.P. 225	Right of C/L
4	512 - 558	44.80	1.5	S.W.P. 225	Left of C/L
5	700 - 780	82.00	1.5	S.W.P. 225	Left of C/L
6	900 - 917	14.60	1.9	S.W.P. 225	Right of C/L
7	917 - 927.76	12.00	1.25	S.W.P. 225	Right of C/L
8	947.76 - 953.38	8.30	1.25	S.W.P. 225	Left of C/L
9	953.38 - 974.76	21.65	1.25	S.W.P. 225	Crossing (diag) @ C/L
10	1537.70	11.50	1.25	S.W.P. 225	Crossing @ C/L
11	1733 - 1834.70	100.5	1.15	S.W.P. 225	Left of C/L
12	4762.395	12.00	1.7	R.C.C. 1200	Crossing @ C/L
13	4970.20 - 5021.9	49.19	1.5	S.W.P. 225	Left of C/L
14	5391.36	11.5	1.5	S.W.P. 225	Crossing @ C/L
15	12844	34.70	1.5	S.W.P. 150	Crossing
16	13388.50 - 13621.02	221.72	1.5	S.W.P. 150	Left of C/L & Crossing at Ch. 13621.02

17	13621.02 - 13648.2	28.17	1.5	S.W.P. 150	Left of C/L
18	13783.5 - 13806.9	25.8	1.5	S.W.P. 150	Crossing at Ch. 13795.00
19	13805.28 - 13888	84.48	1.5	S.W.P. 150	Crossing at Ch. 13828.25
20	13894.50 - 14004.6	112.74	1.5	S.W.P. 150	Crossing at Ch. 13919.20
21	14038.96	16.20	1.5	S.W.P. 150	Crossing (Diag)
22	14147	11.00	1.5	S.W.P. 150	Crossing
23	14177	11.00	1.5	S.W.P. 150	Crossing
24	14204	11.00	1.5	S.W.P. 150	Crossing
25	14238	11.00	1.5	S.W.P. 150	Crossing @ C/L
26	14251.8 - 14275	33.00	1.5	S.W.P. 150	Crossing at Ch. 14251.8 & left of C/L
27	14347	11.20	1.5	S.W.P. 150	Crossing @ C/L
28	14502	11.80	1.5	S.W.P. 150	Crossing @ C/L
29	14500 - 14553	55.60	1.5	S.W.P. 150	Right of C/L
30	14818	11.00	1.5	S.W.P. 150	Crossing @ C/L
31	14892	11.50	1.5	S.W.P. 150	Crossing @ C/L
32	14907	11.50	1.5	S.W.P. 150	Crossing @ C/L
33	15363 - 15396	30.00	1.5	S.W.P. 150	Crossing (Diag) at Ch. 15378
34	15726.7	11.10	1.5	S.W.P. 150	Crossing @ C/L
35	15920	17.90	1.5	S.W.P. 150	Crossing @ C/L
36	16811.7	13.50	1.5	S.W.P. 150	Crossing @ C/L
37	17331.1	11.20	1.5	S.W.P. 150	Crossing @ C/L

TABLE 12.9

Details of affected Water pipe Lines on E-W Corridor

Sl. No.	Location@km.	Affected length in m.	Description & dia in mm	Position w.r.t. alignment within 11 m stretch
1	(-) 873 - (-) 724	149	600 mm dia CI main	At 4.56 m right of C/L
2	965	58.5	450 mm dia CI feeder main	Crossing @ Ch. 965
3	1049.49 - 1140.061	81.13	450 mm dia CI feeder main	At Left from 4.20 m of C/L
4	1217.701	11.37	150 mm dia CI	Crossing @ C/L
5	1520 - 1634.25	114.3	150 mm dia CI	Right of C/L
6	1709.80	11.50	300 mm dia CI	Crossing @ C/L
7	1745.50 - 1805.15	59.56	100 mm dia CI	Left of C/L
8	1830.90	11.00	150 mm dia CI	Crossing @ C/L
9	2822.8	11.20	150 mm dia CI	Crossing @ C/L
10	3155	11.00	150 mm dia CI	Crossing @ C/L
11	4086.3	11.00	200 mm dia CI	Crossing @ C/L
12	4559.3	11.10	120 mm dia CI	Crossing @ C/L
13	4750.615	12.00	300 mm dia CI	Crossing @ C/L
14	4756.955	12.00	300 mm dia CI	Crossing @ C/L
15	4810.37 - 4911	102.00	300 mm dia CI	Crossing at Ch. 4842.59
16	5018.64	16.20	300 mm dia CI	Crossing @ C/L
17	5220.63 - 5266.93	46.00	150 mm dia CI	Right of C/L
18	5243	2.50	150 mm dia CI	Right of C/L
19	5342.66 - 6234.73	89.5	300 mm dia CI	Left of C/L
20	5478.74 - 6322.96	843.49	150 mm dia CI	Right of C/L
21	5484-5973	489	150 mm dia CI	Right of C/L
22	6233-6340	107	150 mm dia CI	Right of C/L
23	6374-6580	206.00	150 mm dia CI	Right of C/L & Crossing at 6579.80

47	11504.14 - 11522.73	29.73	450 mm dia w/s line	18 m left of C/L & Crossing at 11522.73
48	11522.73 - 11559.86	36.87	400 mm dia w/s line	Left of C/L
49	11600	11.10	100 mm dia w/s line	Crossing @ C/L
50	11673.32	11.20	100 mm dia w/s line	Crossing @ C/L
51	11677.1	11.20	150 mm dia w/s line	Crossing @ C/L
52	11869	11.20	150 mm dia w/s line	Crossing @ C/L
53	12077.1	11.10	80 mm dia w/s line	Crossing @ C/L
54	12204	11.10	100 mm dia w/s line	Crossing @ C/L
55	12633 - 12700	65.37	80 mm dia w/s line	Right of C/L
56	12820.3	11.20	700 mm dia w/s line	Crossing @ C/L
57	12817.70 - 12835.89	24.35	400 mm dia w/s line	Crossing at Ch. 12817.70
58	12832.66 - 12864.95	33.90	150 mm UGD line	Crossing at Ch. 12844.45
59	12919.90 - 12995	74.40	400 mm dia w/s line	Left of C/L
60	12975 - 12995	30.34	400 mm dia w/s line	Left of C/L & Crossing at Ch. 12995
61	13015.40 - 13126.38	111.8	300 mm dia w/s line	Right of C/L
62	13390 - 13611	221	100 mm dia w/s line	Right of C/L
63	13805-13888	83	151 mm dia w/s line	Right of C/L
64	14040	16.20	150 mm dia w/s line	Crossing @ C/L

65	14042	15.50	200 mm dia w/s line	Crossing @ C/L
66	14147.5	11.00	100 mm dia w/s line	Crossing @ C/L
67	14177.5	11.00	100 mm dia w/s line	Crossing @ C/L
68	14204	11.00	75 mm dia w/s line	Crossing @ C/L
69	14123.5 - 14568	444.80	75 mm dia w/s line	Left of C/L
70	14888	10.30	75 mm dia w/s line	Crossing @ C/L
71	14692 - 14838.3	147.00	100/75 mm dia w/s line	Left of C/L
72	14893	11.20	100/75 mm dia w/s line	Crossing @ C/L
73	14906.9	11.20	100/75 mm dia w/s line	Crossing @ C/L
74	14903.7	11.20	75 mm dia w/s line	Crossing @ C/L
75	15034	11.20	75 mm dia w/s line	Crossing @ C/L
76	15085	11.10	75 mm dia w/s line	Crossing @ C/L
77	15134.5	11.10	75 mm dia w/s line	Crossing @ C/L
78	15184	11.10	75 mm dia w/s line	Crossing @ C/L
79	15194 - 15254	62.50	100 mm dia w/s line	Left of C/L & Crossing at Ch. 15237
80	15233	11.10	75 mm dia w/s line	Crossing @ C/L
81	15460	12.00	100 mm dia CI	Crossing @ C/L
82	15758	11.00	300 mm dia CI	Crossing @ C/L
83	15761	11.00	300 mm dia CI	Crossing @ C/L

84	15863 - 15900	28.45	300 mm dia CI	Crossing (Diag) at Ch. 15869
85	15910.7	11.50	100 mm dia CI	Crossing @ C/L
86	15924	18.00	700/600 mm dia CI	Crossing @ C/L
87	15952.8 - 16052	100.20	100 mm dia CI	Crossing (Diag) at Ch. 15975
88	15956 - 16070	117.00	100 mm dia CI	Crossing at Ch. 15980
89	15958	131.00	300 mm dia CI	Crossing at Ch. 15986
90	16767	14.60	300 mm dia CI	Crossing @ C/L

The details of Telephone cables along/across the alignment is given in **Table 12.10** for East - West corridor. As most of the cables are across the alignment, their diversion can be avoided by shifting the pile/open foundation location.

TABLE 12.10

Details of affected Telephone cables on E-W Corridor				
Sl. No.	**Location@km.**	**Affected length**	**Description & Size**	**Position w.r.t. alignment within 11 m wide stretch**
1	(-)429.73 - (-)105	324.66	Copper cable 400/6.5 & 100/6.5	Crossing @ C/L at ch. (-) 375m
2	455 - 510	53	Copper cable 400/6.5 & 100/6.5	Crossing @ C/L at Ch. 482 m
3	890 - 985	95.8	Copper cable 100/6.5 (1) & 50/5.6 (1)	Crossing at Ch. 917
4	1480 - 1536	60	OFC for Reliance	Crossing at Ch. 1506
5	1636.2 - 1689	53	OFC for Reliance	Crossing at Ch. 1667
6	2132 - 2169	41.00	OFC for Tata	Crossing at Ch. 2154
7	2850	11.00	800 JF(2) & 400 JF	Crossing @ C/L
8	4362	11.30	2000JF(1),1200JF(5),400PJ (2)	Crossing @ C/L
9	4561	11.50	200 PJ (2)	Crossing @ C/L
10	4643 - 4655	20.10	OFC for Reliance	Crossing at Ch. 4655
11	4658 - 4688	32.00	OFC for Tata	Crossing at Ch. 4667

12	4658 - 4692	36.20	OFC for Reliance	Left of C/L
13	4702	17.30	OFC for Touchtel	
14	4801 - 4869.35	70.53	100 JF(1), 50JF(1)	Crossing at Ch. 4820
15	4801.5 - 4878.35	76.50	100 JF(1), 50JF(1)	Crossing at Ch. 4820.5
16	4808	2.50	100 JF(1), 50JF(1)	Offset on Left side
17	4892 - 5045	156.23	OFC (1)	Right side of alignment
18	4894 - 5079	189.00	100 JF(1), 50JF(1)	Right side of alignment
19	5034 - 5585	50.00	OFC for Reliance	4.5 m Left from C/L
20	5348-5378	30.00	OFC for Reliance	
21	5533-5685	152.00	OFC for Reliance	
22	5857 - 6216	362.40	OFC for Reliance	4.5 m Left from C/L
23	10522	11.5	20/6.5JF(2), 10/6.5 JF(2)	Crossing @ C/L
24	10845 - 11100	255.48	Copper cable	Left of C/L
25	11502	11.5	OFC for Tata	Crossing @ C/L
26	11527	11.5	OFC for Reliance	Crossing @ C/L
27	11535	11.5	OFC for Reliance	Crossing @ C/L
28	11996	13.3	OFC for Tata	Crossing @ C/L
29	12174	12.7	OFC for Reliance	Crossing @ C/L
30	12185	11	0.5 Copper cable	Crossing @ C/L
31	12169	11.5	OFC for Touchtel	Crossing @ C/L
32	12679	12	OFC for Touchtel	Crossing @ C/L
33	12822	15.38	OFC for Reliance	Crossing @ C/L
34	12830	151.64	1200/16.5(3) 180	Crossing at Ch. 12846.76
35	12834	135.60	1200/16.5(3) 180	Right side of alignment
36	12895 - 13040	130.00	OFC for Reliance	Crossing at Ch. 12941.2
37	13025 - 13071	45.00	OFC for Tata	Crossing at Ch. 13050.2
38	13005 - 13071	59.60	Copper cable	Left of C/L

39	13160 - 13485	324.40	Copper cable	Left of C/L
40	13237 - 13480	248.70	600/4, 400 m	Right side of alignment
41	13315 - 13545	26.80	1200/6.5, 20 m	Left of C/L
42	13600 - 13612	12.60	200/6.5, 250 m	Right side of alignment
43	13626.5 - 13665.9	39.46	200/6.5, 250 m	Right side of alignment
44	13777 - 13806	30.90	200/6.5, 250 m	Crossing at Ch. 13792
45	13778 - 13805.5	30.00	OFC for Touchtel	Crossing at Ch.13790
46	13807	30.30	OFC for Tata	Crossing at Ch. 13780
47	13817 - 13868	85.00	400/6.5, 350 m	Right side of alignment
48	13817.5 - 13867.5	83.00	400/6.5, 350 m	Right side of alignment
49	13891 - 14007	120.27	OFC	Crossing at Ch. 13914
50	13907 - 13973.9	89.00	OFC for Tata	Crossing at Ch. 13930
51	13908.5 - 13986	83.90	200/6.5, 250 m	Crossing at Ch. 13970.4 & at 13930
52	14065 - 14100	38.00	100/6.5, 420 m	Right side of alignment
53	14064 - 14100	37.00	Copper cable	Right side of alignment
54	14143.2	11.00	Copper cable	Crossing @ C/L
55	14208-14530	322.00	Copper cable	Along
56	14300	11.00	Copper cable	
57	14500	20.00	Copper cable	Crossing (Diag.)
58	14870	23.60	Copper cable	Crossing (Diag.)
59	15210 - 15256	47.60	OFC for Touchtel	Crossing at Ch. 15240
60	15210.5 - 15256.5	47.00	OFC for Tata	Crossing at Ch. 15240.5
61	15226.60 - 15247.50	35.78	100/6.5, 450 m	Crossing at Ch. 15242
62	15362 - 15388	36.20	100/6.5, 300 m	Crossing at Ch. 15373
63	15362 - 15389	36.20	OFC for Touchtel	Crossing at Ch. 15379
64	15367 - 15396	36.20	OFC for Tata	Crossing at Ch. 15386
65	15870 - 15895	27.00	OFC for Reliance	Crossing at Ch. 15887

66	15878 - 15925	49.40	100/6.5, 300 m	Crossing at Ch.15891 & at 15851
67	15912 - 15927	19.00	100/6.5, 300 m	Crossing at Ch. 15919
68	15950 - 16043	93.30	OFC for Reliance	Crossing at Ch. 15970
69	15951 - 16042	93.00	Copper Cable	Crossing at Ch. 15971
70	15953.5 - 16046	97.00	Copper Cable	Crossing at Ch. 15973.5
71	17336	11.50	Copper Cable	Crossing @ C/L

12.7 GEOTECHNICAL INVESTIGATIONS

The main purpose of the Geo-Technical Investigations under taken by DMRC is to have an insight into the Geological conditions along the proposed corridors – the East-West and the North-South, so as to arrive at the type of foundations to be adopted for the Elevated corridors and to design the tunnelling for the underground routes with appropriate technology particularly in the busy areas of the Central Business District, Market, Railway Station, Central Bus-Stand, Government Offices etc.

The Geo-Technical Investigations were carried out by M/s. TORSTEEL RESEARCH FOUNDATION IN INDIA, Bangalore, one of the leading organizations in the field of Geo-Technology, having accredition to their laboratories under ISO (International Standard Organization).

12.7.1 General Description of the Area and Geology:

Bangalore is situated at an altitude of about 900m above the sea level and is existing on a gneissic terrain of peninsular origin. The mean temperature varies from 17^0C to 36^0C. The area has the benefit of North-East and South-West monsoons. The annual rainfall is about 760mm. The atmosphere is neither humid nor dry. The soil formation is due to physical weathering of parent rock caused by temperature changes accompanied by chemical transformations. Climate has played an important role in the weathering of rock. Except for the material met with in the tank beds in the nearby localities, the soil is residual in nature with increase in strength with depth.

The Geology here dates back to the Archean formations. These include the oldest rocks of the earth crust found at the bottom of stratified deposits. They are crystalline in nature and exhibit high compressive strengths. They generally have a well defined foliated structure. The Archean gneiss generally consists of orthoclase, oligoclase or microcline, quartz, muscovite, biotite and hornblende with a variety of other accessory minerals. The type of rock encountered in this region are generally hard granites with low permeability and good strength characteristics forming an ideal founding strata.

12.7.2 FIELD INVESTIGATION:

Field Investigation consisted of borehole exploration to a maximum depth of 30m and in exceptional cases up to 36m. If rock was encountered within 30m, drilling was carried to a depth of 3m in intact hard rock for the elevated corridor and to a depth of 6m for underground portions of the corridor. Boreholes were generally located at about 500m interval in elevated portion and 250m in underground portions along the alignment.
Borehole exploration was carried out by wash boring method without bentonite, using heavy duty hydraulic drilling rigs. The hydraulic rigs mobilized are, TRD-80 (Rock Drill make) – 1 No., Joy-12 (Voltas) – 1 No., Voltas-60 – 2 Nos., Acker – 1 No. Drilling in soil was carried out by core barrels having suitable cutting edges. In soft rock where the strata is very dense, advancement of bore holes was done by TC Bits of Nx size. In weathered rock and hard rock, core drilling was progressed using Nx size diamond bits with double tube core barrel.

Standard Penetration tests (SPT) were carried out as per IS:2131-1981 at regular intervals of generally 1.5 m. Undisturbed soil samples were collected using thin walled steel tubes of 100mm diameter, 450mm long as per IS:2132-1986 wherever required. Both SPT and undisturbed soil samples were sealed and labelled properly and brought to laboratory for further testing. Rock cores were collected from core barrel after the completion of each drill run and marked with bore hole numbers and sequential core piece numbers. Rock recovery and RQD (Rock Quality Designation) have been recorded. The rock cores were stored in core boxes and brought to laboratory for further testing.

For determining field permeability in rock, pumping in tests were carried out as per IS:5529(PART-2)-1985 in selected bore holes in the tunnel portion. Single packers were used to seal the top of the test section. Generally it was seen that the coefficient of permeability was nil or negligible in both the corridors.

The depth of ground water table was monitored daily after 24 hours of drilling operation in the bore holes and depth of water level was recorded after it stabilised.

The ground temperature with respect to depth at intervals of 5m depth was measured in the tunnel region in 3 bore holes and found that the temperature increased nominally about 0.5^0C in East-West corridor to 0.8^0 C in North-South Corridor.

The details of stratification, SPT Values, Ground Water Table etc. are indicated in the Stratigraphy enclosed (**6 sheets**).

12.7.3 LABORATORY TESTING:

The following laboratory tests were conducted on soil, water and rock samples collected from bore holes.

Tests on soil samples:

(i) Insitu density and moisture content.
(ii) Grain size analysis.
(iii) Liquid Limit and Plastic Limit
(iv) Triaxial Shear

(v) Direct Shear
(vi) Consolidation
(vii) Permeability
(viii) Chemical analysis to determine pH, Chlorides and sulphates

Tests on Rock samples:

(i) Density
(ii) Water absorption
(iii) Specific gravity
(iv) Hardness
(v) Abrasion
(vi) Unconfined Compressive strength
(vii) Point load index
(viii) Determination of modulus of elasticity

Tests on Water Samples for Chemical analysis to determine pH, Chlorides and Sulphates.

The above tests were carried out as per the relevant Indian and International standards and indicated in borelogs.

12.7.4 GENERAL STRATIFICATION:

General stratification as obtained from the field and laboratory investigation shows typical residual formation, which is characteristic feature in this region. The top layer generally consists of reddish silty sand with clay or yellowish / greyish clayey sand / sandy clay. This layer is medium dense and is underlain by medium dense to dense greyish / whitish / yellowish silty sand / sandy silt layer. This is followed by soft rock made up of very dense silty sand / sandy silt layer. Weathered rock with degree of weathering varying from slight to high followed the soft rock layer and under lain by more compact hard rock.
The Rock strata was encountered in all the bore holes except in BH1, BH10 and BH15 E in the East to West Corridor and BHNS 7,9,14,25 & 26 in North-South corridors where soft rock in the form of dense silty sand was encountered, up to the investigated depth.

12.7.5 ANALYSIS OF RESULTS

The stratification encountered along the proposed route mostly consists of medium dense to dense silty sand with clay or sandy clay / clayey sand at shallow depths. This layer is followed by medium dense to dense silty sand or sandy silt, which is non-plastic to moderately plastic. Density of this layer is increasing with depth. This layer is followed by soft rock consisting of very dense silty sand / sandy silt. Weathered rock and hard rock layers underlain this soft rock layer.

The formation of successive layers is varying along the route. The yellowish silty sand layer is encountered from ground level itself at a few locations. In general, the stratification follows regular pattern as described above.

Standard penetration tests (SPT) in the soft rock indicate very high 'N' values of 100 and more with virtually no penetration of SPT tube in this layer. The colour and structure of soil samples collected in the split spoon closely resembles the underlying minerological constituents of weathered rock / hard rock.

Index properties such as grain size distribution and liquid limit and plastic limit values indicate that, plasticity characteristics of the soil is low to moderate. Hydrometer tests conducted on selected soil samples show that finer fraction predominantly consists of silt and is non-expansive in nature.

Consolidated undrained shear test and direct shear test results indicate that in general, the average values of cohesive strength of soil is ranging from 0.104 to 0.61 kg/sq.cm and angle of internal friction is ranging from 12 to 35 degrees.

Chemical analysis of soil and water samples show that pH, chlorides and sulphates are well within permissible limits and do not call for any special treatment.

Rock cores extracted from the bore holes show the presence of gray granite with pockets of amphibolites, granodiorite and mylorite rock. The rock is intruded with pegmatite veins at some places. The granite rock shows gneissic texture due to metamorphic activity.

In general, core recovery obtained in the weathered rock is ranging from 0 to 56 % with rock quality designation (RQD) values of 0 to 38%. In the hard rock, the core recovery is ranging from 48 to 100% and RQD is varying from 41 to 100%.

It is seen from the index properties that density value of rock specimen is ranging from 2.21 g/cc to 3.06 g/cc and porosity is ranging from 0.32 % to 10.85 %. Water absorption of the tested specimen show a range of 0.11 to 2.26%.

Uniaxial compressive strength results indicate that strength of hard rock is ranging from 311 Kg/cm to 1958 Kg/sq.cm. Point load strength index values is in the range of 17.7 kg/sq.cm to 110.9 kg/sq.cm.

Modulus of Elasticity (E) values obtained from 5 locations in tunnel portion shows a variation of 0.93×10^5 to 5.91×10^5 kg/sq.cm.

12.7.6 RECOMMENDATIONS

The type of foundation depends on stratification, type of structure, loading, allowable settlement, etc. In the present case, the structure is Metro railway system, which is a combination of elevated, surface and underground corridors. The various structures envisaged in the system includes Elevated tracks supported on piers, Elevated stations, underground stations and underground tunnels. The loads coming on to the foundation system will be considerable, from the structures.

Shallow Foundations

Shallow Foundations are recommended wherever the hard strata (soft rock / weathered rock / hard rock) is encountered within 4m depth below ground level. Based on field and laboratory test results, an allowable bearing pressure of 45

T/sq.m is recommended. The hard strata is usually overlain by a medium dense soil layer. Hence, adequate shoring and strutting will be necessary while carrying out foundation excavation. Necessary dewatering arrangements will also be required where water table is encountered at shallow depths.

Open foundations are also recommended for underground stations, which involve open excavation. The foundation in this case shall rest on soft rock / weathered rock / hard rock. The founding level depends on the depth of excavation. Since the soil layers become dense with increase in depth, the Open foundations are feasible. However, in open excavation, due considerations are to be given to shoring, strutting, dewatering and its possible effects on the nearby structures.

However, moderately loaded structures on-ground stations can be supported on shallow foundations at depths varying from 1.5 to 3.0m. the net allowable bearing pressure for such footings at various bore holes locations have been indicated.

12.7.7 Deep Foundations

Deep foundations, in the form of bored cast in-situ piles are recommended where the hard strata is encountered at considerable depths. The columns supporting the elevated rail track and elevated station are recommended to be supported on pile foundations. In particular, bored cast in-situ piles are recommended keeping in view the site locations, which are within the city and vicinity to the structures around them.
The piles are essentially end bearing piles, socketed into the hard strata. In this case, the hard strata encountered consists of soft rock, weathered rock and hard rock. Past experience indicate that the piles socketed in soft rock have performed satisfactorily. In view of this, it is recommended to anchor the pile in soft rock layer itself, wherever the thickness of soft rock is considerable. The soft rock layer encountered in the pile bore can be verified through SPT tests in the pile bore. Further, while chiselling for socketing the uniformity of strata can be ensured by measuring the number of drops Vs penetration.

Depending on the hard strata encountered at pile termination, the following depth of socketing is recommended:

Type of strata	**Depth of socketing (D = Dia of pile)**
Soft Rock	3 to 4 D
Weathered Rock	2 to 3 D
Hard Rock	1 D

The length of piles considering the strata at pile termination at various bore hole locations have been indicated.

The safe load carrying capacity of end bearing pile depends on the characteristics of strata at pile termination, anchoring depth and structural capacity of pile section. The piles of diameter 900 mm, 1000 mm, 1250 mm and

1500 mm are considered for evaluation. The safe load carrying capacity of piles in this case is generally governed by structural capacity of pile.

The recommended safe load on piles considering piles with M25 concrete are as follows:

Pile dia (mm)	Recommended Safe Load (Tonnes)
900	380
1000	470
1250	730
1500	1060

The increase in grade of concrete increases the structural capacity. However, it is recommended to limit the safe loads as above, in view of the uncertainties involved in quality of in-situ concrete in pile bore. Further, in soft rock, the capacities are also governed by the properties of soft rock at termination. Hence, it is preferable to limit the safe loads as recommended above.

The uplift capacity of piles can be taken as 10 % of safe vertical load and the safe horizontal load can be taken as 5 % of safe vertical load.

The safe load in piles shall be confirmed through pile load tests as per relevant Indian Standards.

The pile bore, after achieving the required depth shall be washed thoroughly to remove all the slush to ensure good bearing strata.

12.7.8 Underground Corridor

This has been dealt with in Chapter No 5 “Civil Structures & Construction Methodology”.

****