Effect of Soil Parameter on the Long Drive Micro-tunelling Process a Case Study of Al Jadaf Area, Dubai, UAE

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Abstract. This paper presents the effect of Soil Parameter on the long drive micro-tunneling process. Terzaghi's Silo Theory and Elastic Stress Relief Formulas are used for calculating the normal stress against the pipes. A detailed study tabulated for Al Jadaf Area across Oud Metha Road in Dubai, United Arab Emirates to check the effect of soil parameter, such as depth of excavation or invert level of micro-tunnelling, depth of ground water table, SPT Value and other soil properties. The study demonstrates that long term surface settlements confirm to the design theory limit. The high ground water table, fractures within the rock and close proximity to existing creek makes it very difficult to reduce the water table level in launching/receiving Pit and have difficulties in breaking the hard ground within the Pit. Determination of the surface settlement spot level difference is done physically at site by using latest surveying instrument, as described in the field exploration programme. By determining the difference between the two spot levels on a same coordinate, the amount of settlement and its effects on surface area can be established, which can be used as a guide line for future project and authentication of the theory.

Keywords: Overcut · Micro-tunnelling · Terzaghi's Silo theory
Ground water table · Jacking · Launch pit · SPT value

1 Introduction

There is a great amount of risk for surface and sub-structure settlement if soil parameters are not considered during the execution of micro-tunnelling. This is due to the fact that overcut is formed to provide space for converging ground and enables evenly distribution of surface lubrication fluid (bentonite) flow on the exterior pipes, as such, the buoyancy effects of fluid lubrication act on the pipe to lessen the drag during jacking.

Poor geological condition, low N value in the standard penetration test (SPT), measured in number of blow, can cause surface settlement, poor and unsuitable ground

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tends to converge string of the pipe line. In hard rock, ground holes hold more stability and are conducive grounds to micro-tunnelling process [1]. The tendency of earth at forefront of micro-tunnelling to move viscously towards steel fitted in front of the pipe to be jacked should be considered. Therefore, sophisticated slurry shield, protection at the fore front of micro-tunnelling machine, are used to overcome this failure. Forces are relevant to face load depending upon the soil condition and its nature [2]. The front seal has the several advantages like safe working place for Men to enter and work; mounting for face stabilized device; a place to observe line and level and adjusting direction of the string.

Seals are control remotely and, in most cases, controlled by Computers. In Jadaf Area, where soil conditions are very poor and SPT values are very low and many services are close to receiving and launching Shaft. Therefore, a proper designing is required for dewatering process and special care is required to remove ground water only, and to ensure that soil particles, and another dissolved particles removal, are minimize to avoid any future surface settlement. Longer the length of micro-tunnelling greater will be frictional force, Resistance due to contact between soil and pipe, and thus can affect Jacking Load [3]. The man factors that can affect Jacking Load are disparity in ground condition; misalignment of pipes; roughness of pipe surface and joint; transient live load; Overcut; Interruption during Jacking; densification of loose sandy soil due to vibration/dynamic loading [4].

2 Field Exploration Programme

After obtaining the require NOC, No Objection Certificate, and other statuary requirements from relevant authority, spot level survey with the help of surveying auto level and co-ordinates by GPS[1] are taken at 2 × 2 m grid from 20 m to the either side from the centre of Micro-tunnelling between launch and receive pit prior to commissioning of the works. Similarly, 3D laser scanning method is used for micro-tunnelling reference no M01 & M04. After a minimum duration of one year from the date of completion similar spot level survey is conducted exactly at the same co-ordinate.

3 SPT Value and Its Effect on Actual Surface Settlement

Figure 1 shows the case study area for Jadaf, Dubai, United Arab Emirates with arrow mark near creek, which is recently connected to main sea via Dubai water canal project. In Fig. 2, complete pipe line network of 1200 mm diameter GRE, Glass Reinforced Epoxy, pipe with micro-tunnelling references highlighted in yellow. Complete network is divided in three stages. Soil parameter varies from M01 to M10 and accordingly the theoretical settlement and its comparisons with actual surface settlement is detailed in the study. The detail of the overall site plan is shown in Fig. 2. Light red colour lines

[1] Global Positing System.

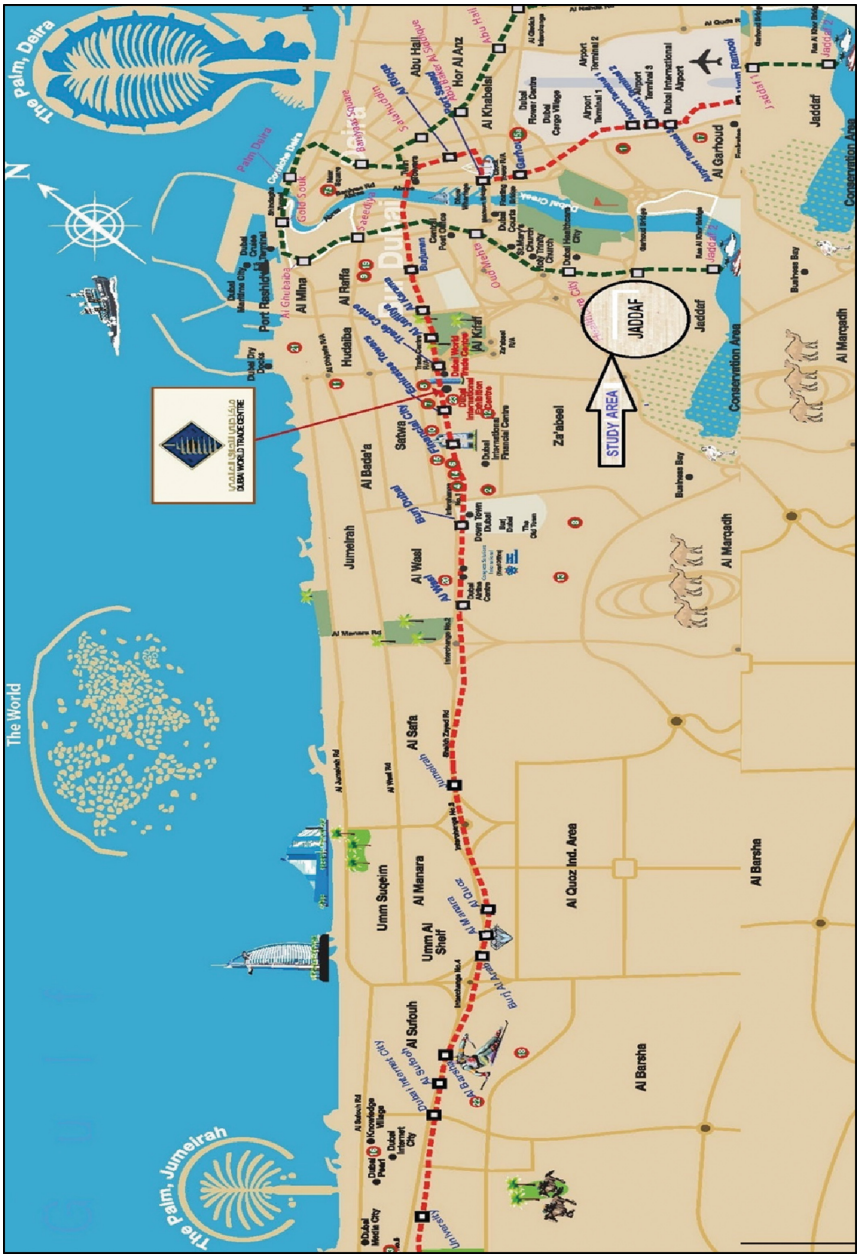

Fig. 1. Case study area of Jadaf, Dubai, UAE

are represented for pipeline and green for micro-tunnel. Source of the supply of the water is from south side after crossing the creek.

It is proved that the higher the N value the lesser the actual surface settlement (Please refer Fig. 7). Also, it is evident from Fig. 3 that greater SPT Value provide

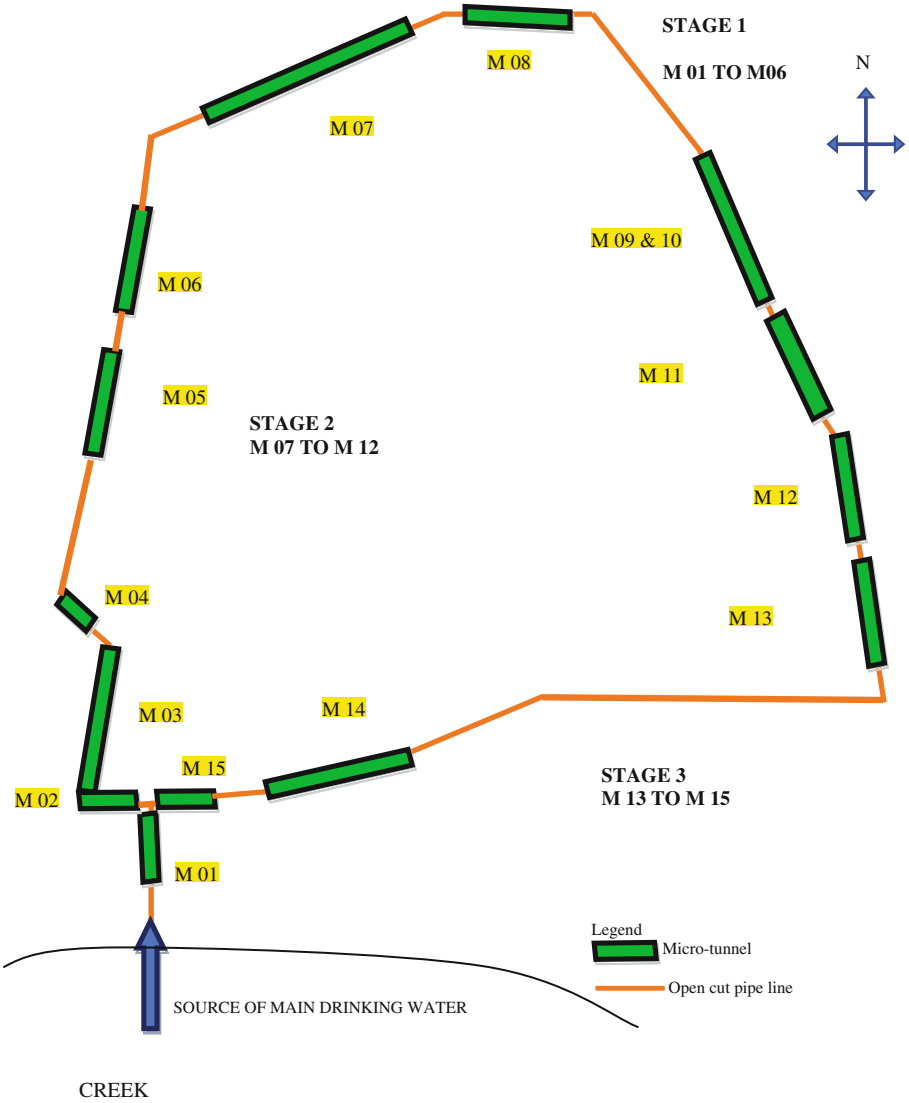

Fig. 2. Bird eye view of pipeline network with micro-tunnelling Jadaf, Dubai, UAE

more stability to the ground in all the cases, except for micro-tunnelling M01 and M04 where actual surface settlements are extremely un-expected are required to further scrutinize the method statement for spot level difference. Similarly, Table 1 gives the clear idea that higher the SPT value gives lower surface settlement. Higher the N Value means soil is dense and there is less chance for surface settlement [5, 6] (Table 2).

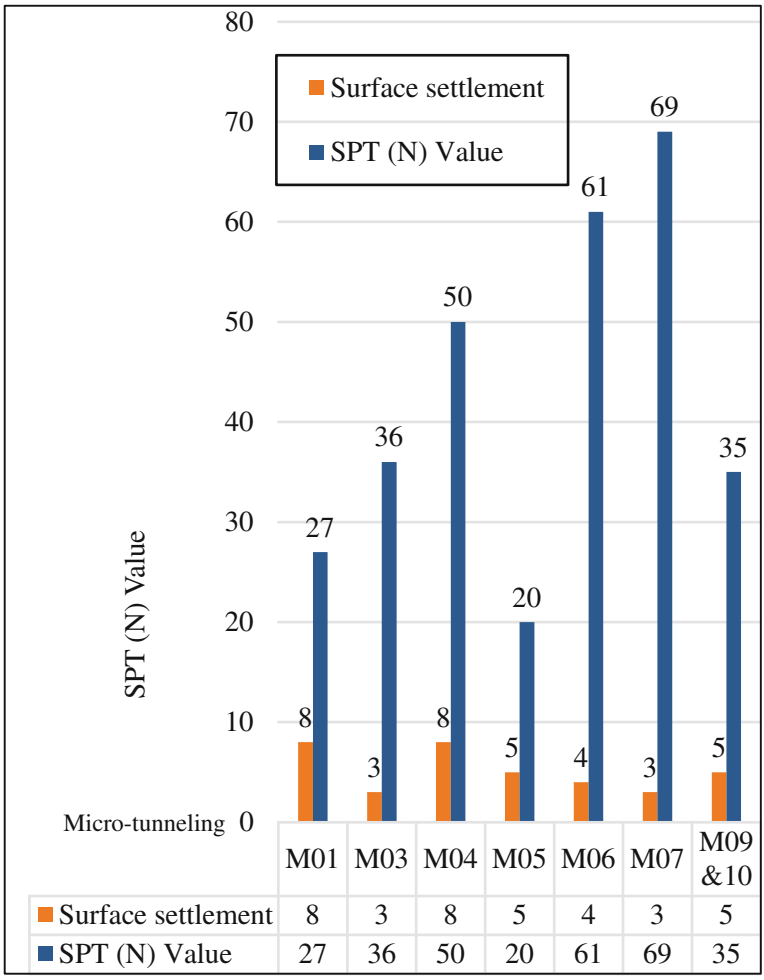

Fig. 3. SPT value (N) Vs actual surface settlement

4 Effect of Ground Water Table on Actual Surface Settlement

Under the design theory, if water table is shallow then surface settlement is likely to be more and it is also reflected in the case study except for M01 and M04, where settlement is quite high (8 mm) with respect to their water level table. Reasons for this discrepancy might be the way spot level has been taken. Table 3 shows the maximum actual settlement and effect of ground water table and confirms to design theory [7, 8]. From Fig. 4, for micro-tunnelling M03 & 07, ground water table is 4 m and actual settlement observed at site by spot level method was found as 3 mm, whereas for others, if we calculate percentage between ground water table and surface settlement,

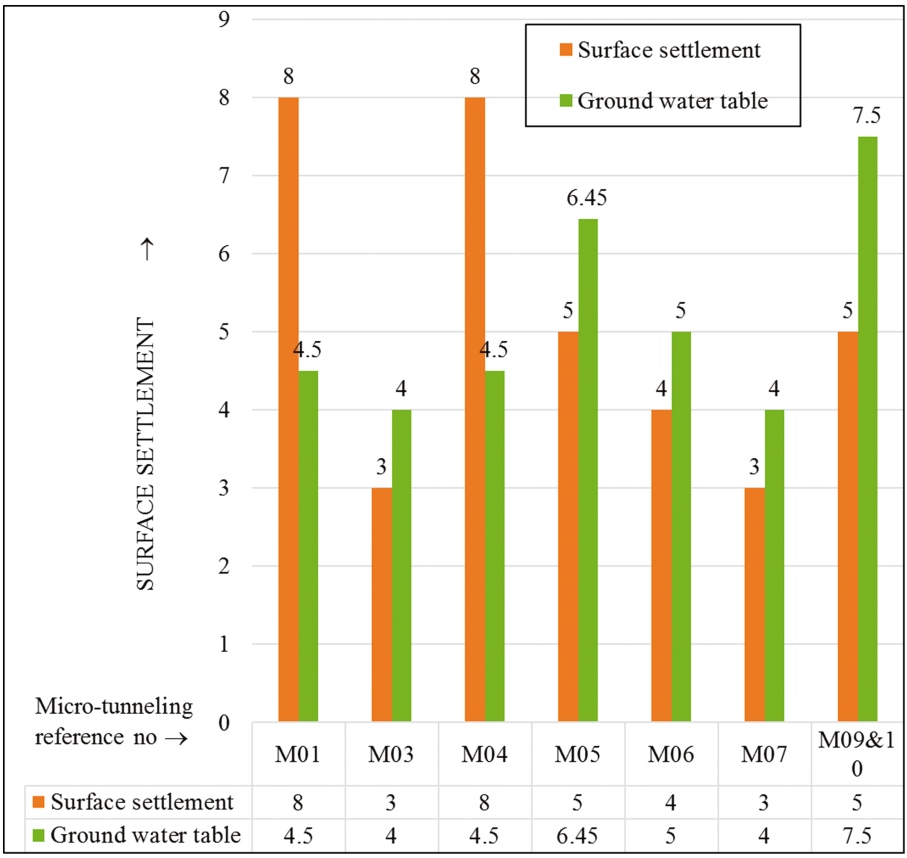

Fig. 4. Ground water table vs actual surface settlement

will find slight increase in the percentage as the water table depth increases. Though percentage difference very marginal such as for M03 it is 0.75, for M05 it is 0.78 and for M06 it is 0.80. Therefore, Ground water table has an impact on the micro-tunnelling process (Refer Fig. 8). It is also important to consider the dewatering process shall be in such a way so that silt/soil content remains within soil structure and does not pass through de-watering system. Also, slotted pipe or vertical screen pipe, generally PVC, and in special cases slotted steel, deep well must be of good quality and as per the design [9].

5 Local Conditions of Micro-Tunnelling in Jadaf Area

As the site area is in the city, the movement of heavy vehicles and noise is to be controlled accordingly. A special care is required for the summer time where cooling effect is necessary for the people working in the launching Pit. It is also necessary to control the temperature of air inside the tunnel; otherwise it can deflect laser control

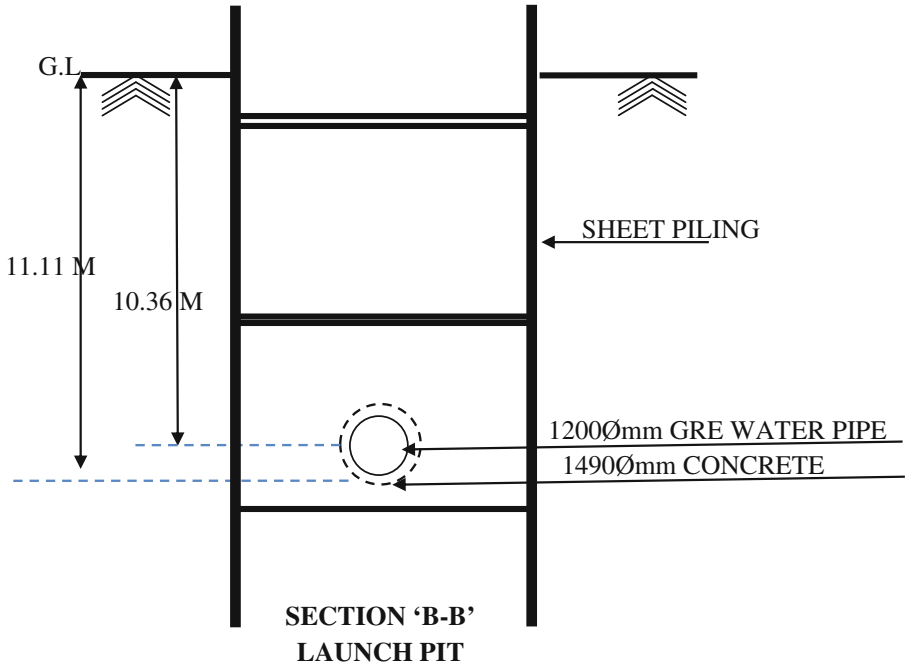

Fig. 5. Section of launch pit for micro-tunneling M09 & M10

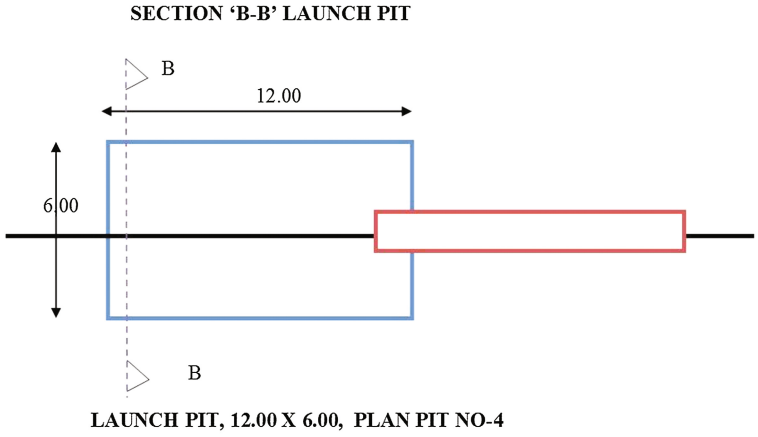

Fig. 6. Plan of launch pit for micro-tunneling M09 & M10

system and ultimately alignment of the tunnel. In Fig. 2 detail alignment of the pipeline and micro-tunnelling has been shown, to control overall movement of the traffic and other obstruction it is divided into three stages, all these are described in Table 3.

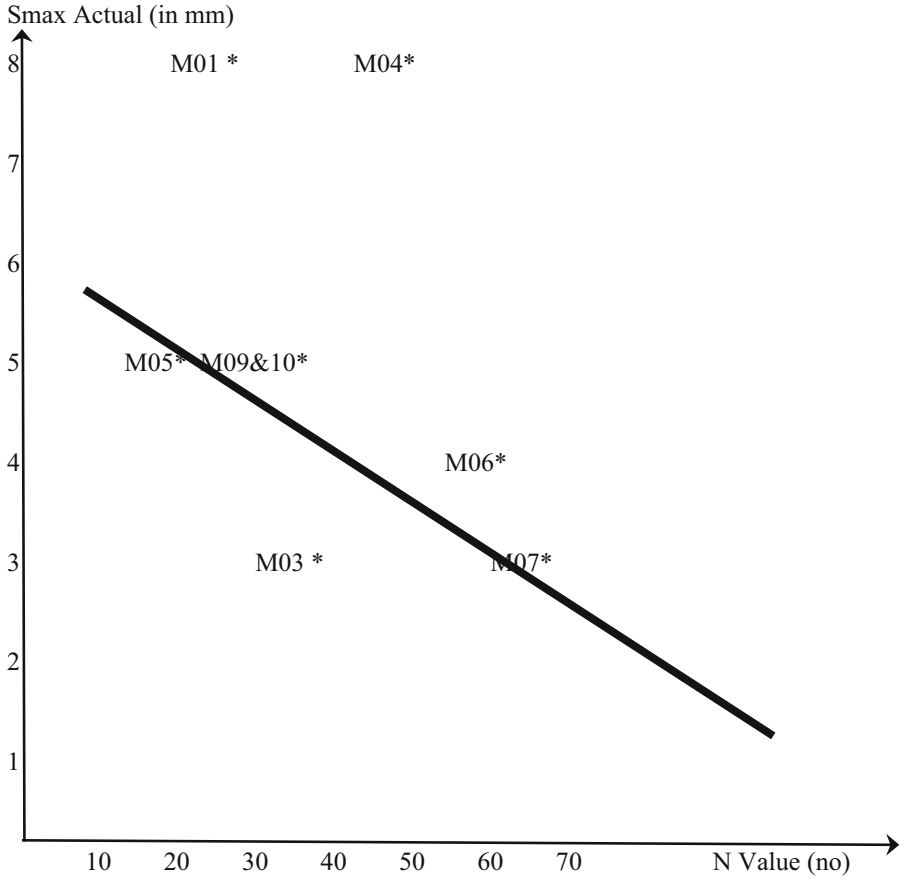

Fig. 7. Combined graph between N value (X-Axis) and Actual surface settlement (Y-Axis)

Table 1. Comparison of settlement between SPT (N), ground water table and actual surface settlement

Serial Number	Micro-tunneling reference number	Maximum Settlement mm	SPT value	Water table below ground level
1	M01	8	27	4.5
2	M03	3	36	4
3	M04	8	50	4.5
4	M05	5	20	6.45
5	M06	4	61	5
6	M07	3	69	4
7	M09&10	5	35	7.5

Table 2. Micro-tunnelling details for 1200 diameter GRE water transmission Pipe

S. n	Ref	Chainage		Length in meter	Stage	Line Ref No.	Location	Road reference
		From (L.P)	To (R.P)					
1	M-01	(-) 0 + 025.215	0 + 091.785	117	**Stage: 1 (796 M)**	18	Al Khail road crossing	E44
2	M-02	0 + 097.065	0 + 187.065	90		18	Existing services crossing (electric trough & 800 mm irrigation pipe)	Unmade area
3	M-03	0 + 493.865	0 + 192.865	301		18	Near Merriot hotel	Partially unmade area & one side service road crossing
4	M-04	0 + 499.510	0 + 637.510	138		18	Oud Metha road	E66
5	M-05	1 + 450.584	1 + 528.584	78		18	Service road crossing	Before EPCO petrol pump going towards Bur- Dubai
6	M-06	2 + 013.688	1 + 941.688	72		18	Service road crossing	After EPCO petrol pump going towards Bur -Dubai
7	M-07	(-) 0 + 009.943	0 + 304.734	309	**Stage: 2 (1,146 M)**	18A	Oud Metha road, WFI interchange	E66
8	M-08	0 + 397.734	0 + 304.734	93		18A	Service road crossing	Unmade area inside Latifa hospital
9	M-09	0 + 761.238	0 + 947.238	186		18A	Service road crossing	D79
10	M-10	1 + 137.313	0 + 951.813	186		18A		
11	M-11	1 + 146.205	1 + 404.205	258		18A	Existing services crossing	D79
12	M-12	1 + 524.468	1 + 410.468	114		18A	Existing services crossing (electric trough)	D79
13	M-13	0 + 458.688	0 + 686.688	228	**Stage - 3 (477 M)**	16A	Service road crossing	Near Jadaf Metro station
14	M-14	2 + 308.887	2 + 476.887	168		16	Service road crossing	Near Meriot hotel along Al Khail road towards Abu Dhabi
15	M-15	2 + 615.195	2 + 534.195	81		16	Service road crossing	Unmade area
Total Microtunneling Cummulative				**2419**				

6 Comparation on Different Soil Parameter, Theoretical and Actual Surface Settlement

Table 3 summarizes, soil parameter being used in this case study and overall summary of the result obtain from spot level difference with other details such as difference in the theoretical & actual surface settlement. It can be concluded that depth of micro-tunneling of the soil, ground water table, nature of soil, particle size distribution, diameter of the bore hole, has major effect on the surface settlement. For example, Fig. 5 is a typical cross-section at launching pit, where depth of invert level of the micro-tunnelling pipe is 11.10 m and depth of the axis of the pipe is 10.36 m, these are also reflected in Table 3, these data are required to work out surface settlement, which is 5.1 mm in this case. One of the bore log details is attracted herewith in Fig. 9. Figure 6 is the plan of the launching pit of M09 & 10, in which blue line represents sheet piling and red line is the centre of the micro-tunnelling longitudinally. Section B-B is shown in Fig. 5.

Table 3. Comparison of surface settlement between theoretical and actual with respect to soil parameter

S. nr	Micro-tunneling reference number	Maximum settlement (theoretical) mm	Maximum settlement (actual measure) mm	Length (m)	Depth of invert (m)	Depth of axis of pipe m	Water table below ground level (m)	SPT value (N)	Friction angle of soil (°)	Duration between spot level on same coordinate (day)
1	M01	4.4	8	117	12.67	11.93	4.5	27	40	338
2	M03	4.2	3	301	13.04	12.3	4	36	40	404
3	M04	4.4	8	138	12.64	11.9	4.5	50	40	400
4	M05	5.7	5	78	9.91	9.17	6.45	20	40	863
5	M06	6.4	4	72	9.01	8.27	5	61	40	639
6	M07	5.4	3	309	10.51	9.76	4	69	40	211
7	M09 & 10	5.1	5	372	11.1	10.36	7.5	35	40	515

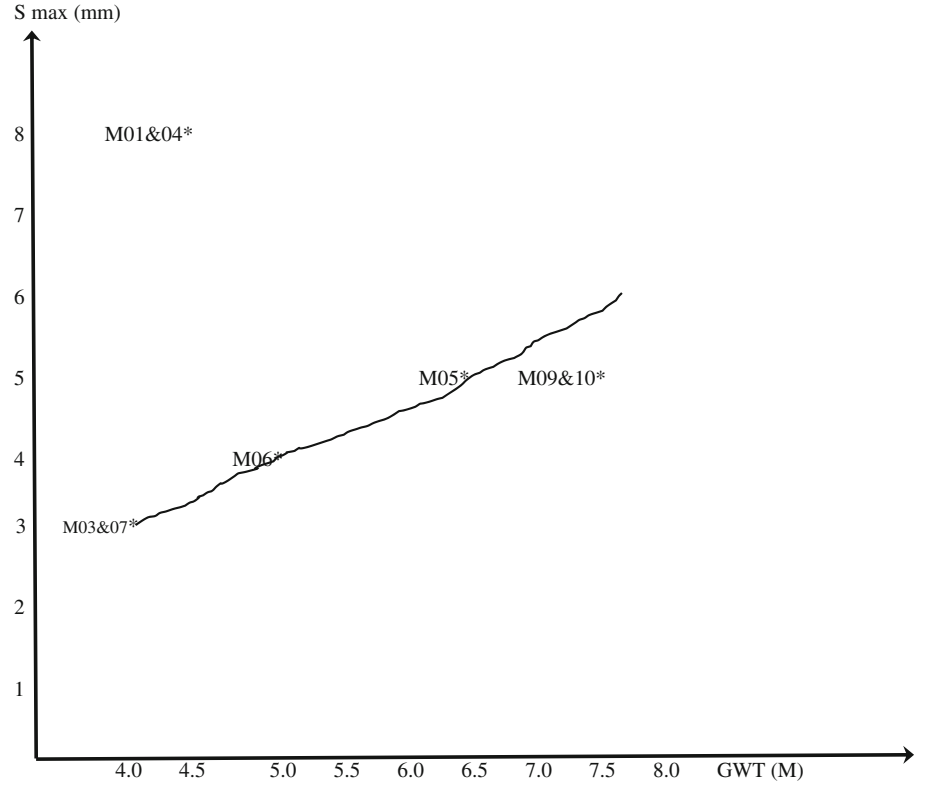

Fig. 8. Combined graph between Ground water Table (10-Axis) and Actual surface settlement (Y-Axis)

Location	Various Location in Dubai(Al Wasl Hospital)													
			Strata	Sample				Standard Penetration Test						
Depth	Reduced	Layer	Symbol	No	Test Depth		TCR	Number of blows				UCS		
(m)	Level (m)	Thick	W.L	&	(m)		[SCR]	Seating	Test Drive			N/mm2	Description of Strata	
	[DMD]	(m)	Casing	Core			(RQD)	150	150	150	N Value			
			Depth	Run	From	To		mm	mm	mm				
0.5		0.5		1 B	0.00	0.50		0	0 /	0			Brown, mottled grey slightly silty fine SAND with few gravel and shell fragments	
1				2 D	0.50	0.95		3	5 /	6	11		0.5m	
1.5		1.5		3 D	1.00	1.45		3	6 /	8	14		Medium dense, brown slighlty silty to silty medium to fine SAND with few cemented band and shell fragments	
2				4 D	1.50	1.95		4	7 /	10	17		2.0m	
2.5		0.5		5 D	2.00	2.45		2	4 /	6	10		Medium dense, brown, fine SAND with few cemented band and shell fragments	
3				6 D	2.50	2.95		7	10 /	15	25		2.5m	
3.5				7 D	3.00	3.45		6	11 /	13	24			
4														
4.5				8 D	4.00	4.45		4	9	12	21			
5														
5.5				9 D	5.00	5.45		6	14	19	33		Medium dense to dense, brown to light grey slighlty silty to silty medium to fine/fine SAND with locally few cemented band and shell fragments	
6		6.5												
6.5				10 D	6.00	6.45		5	11	16	27			
7														
7.5				11 D	7.00	7.45		8	13	17	30			
8														
8.5				12 D	8.00	8.45		6	14	15	29			
9													9.0m	
9.5				13 D	9.00	9.45		8	14	18	32		Dense brown silty medium to fine SAND with few cemented bands and little gypsum	
10		1.5												
10.5				14 D	10.00	10.45		10	17	18	35		10.5m E.O.B. 27.03.2011	
11														
11.5														
12														
12.5														
13														
13.5														
14														
14.5														
15														

Coordinates:	N : 2791062	E : 498768	Ground Level:		Ground Water Level:	7.5m	Date of Drilling: 27.03.2011
Drilling Method:	Cable tool percussion		Bore hole dia:	150mm	Casing Depth:	10.0m	Logged By:
Core Barrel:	N.A		Core diameter:	N.A	Bit type:	N.A	Scale: 1:85
Remarks: Refer Plate No:	7	for Sample/ Test keys					

Fig. 9. Soil profile (Bore log for M09 & 10)

7 Overcut and Geological Condition

The case study has been conducted in a soil profile and geological condition (Please refer Fig. 9, soil profile), however other soil profile of other areas may represent different result. Similarly overcut, which is required to achieve workability and provide space for converging ground and evenly distribution of bentonite to be as per manufacturers recommendation, cutting wheel diameter of 1505 mm and a shield with

external diameter of 1490 mm in front of shield that induce overcut equal to 7.50 mm each side of shield (difference between the external diameter and diameter of the outer surface of pipe string).

8 Conclusions

The present study has focused exclusively on the Jadaf area, Dubai, The United Arab Emirates, in a particular pattern of the soil with specific parameter for a given (1490 mm outer diameter composite pipe with concrete encashment, 1200 mm internal diameter, Glass Reinforce Epoxy pipe) pipe for main water transmission pipe line for DEWA. The bore and accordingly the micro-tunnelling machine has been selected for typical soil parameter, surrounded by existing underground services and various future proposal of infrastructure. Similar case study is required for other parameter of the soil structure and sub-soil geological condition such as detailed particle size distribution, rock strength, sulphite and chloride content etc. to ascertain challenges faced during construction and the amount of surface settlement within the range predicted in theory and after effect of the micro-tunneling. Therefore, we can conclude from this study that depth of micro-tunneling, ground water depth, nature of soil, particle size distribution and Diameter of Borehole has a major effect for surface settlement.

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