Scientific Journal Impact Factor (SJIF): 1.711
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

Soil-Pile Bond and SPT values relation for SD Micropile Foundation

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Abstract— Self Drilled Micropile (SDM) constructions are used for special foundations. FHWA design guidelines are helpful for design and construction of SDMF, as no dedicated design code is available for SDM foundation. Now a day's SDMF is becomes popular construction solution due its benefits of fast and easy construction work using small drilling and grouting machine. Pile foundation design involves two parts, Structural and Geotechnical pile capacity. The structural capacity and its design parameters are easy to handle due to availability of sufficient proven data for reference but the critical part is to envisage geotechnical capacity due to bond strength relation between soil surface and grout body is complicated due to variable soil strata. FHWA design guideline gives range of bond stress values for different soil types and which are underestimated.
Technology and material cost is high for SDMF and general used required optimum solution. But designer to designer range of assumed soil pile bond strength values may be more for same soil profile and most of the cases overdesign cause uneconomical solutions. This present paper suggested a method to develop refined bond strength data for SDMF design i. e. a relation between the SPT values and soil bond stress for single soil profile by field tests pile load and SPT values.
Keywords— Self Drilled Micropile; FHWA; Micropile; SPT Values, Soil pile interaction and Bond stress relation

I. INTRODUCTION

Concept and practical application of Self Drilled Micropile Foundation (SDMF) has grown-up significantly since 1950s and in particular since 1980s. Basically SDM is part of foundation and its function is to support the structure against static, seismic and wind loads also application as in situ reinforcement in soil provides stability against slops and excavations.

Micropile foundation design guidelines are published by Federal Highway Administration (FHWA). FHWA provide a range of bond stress values for different strata like silt and clay, sand, Gravel, Glacial Till, limestone, Sandstone, Granite and Basalt etc. But it has no any relation with other Geotechnical parameters like SPT and RQD values etc. To select layer wise bond strength value from borehole soil strata and SPT value is becoming a challenging job to the design engineers. For same soil strata, design variation will be more from engineer to engineer and required specific range of values to avoid the high design variation.

So, it can be conclude that, SDM geotechnical capacity is critical part of design. Superior technical knowledge to suitable bond stress values for various types of strata with reasonable factor of safety. Consideration of wrong bond stress values will lead to over or unsafe design. In the present paper a micropile test is conducted for pullout and compression on full scale model to develop the relation between SPT values and bond stress.

II. SOIL PROFILE

Self Drilled Micropile (SDM) concept and use has grown-up significantly since 1950s and in particular since 1980s. Basically SDM is part of foundation and its function is to support static and

Volume 02, Issue 08, [August– 2015] ISSN (Online):2349–9745 ; ISSN (Print):2393-8161

seismic, wind loading condition and as in situ reinforcement to provide stability of slops and excavations.

Micropile foundation design guidelines are published by Federal Highway Administration (FHWA). FHWA gives range of bond stress values for different strata like silt & clay, sand, Gravel, Glacial Till, limestone, Sandstone, Granite and Basalt etc. But it has no any relation with other Geotechnical parameters like SPT, RQD values etc. It is challenging to consider the bond stress values to determine the pile capacity in case same strata in bore hole but varies SPT values with depth also for different layer of soil strata to choose the bond strength value is become challenge to design engineer.

So, it can be conclude that geotechnical micropile capacity is critical part of design and required superior technical knowledge to assume suitable bond stress values for various types of strata with reasonable factor of safety. Consideration of wrong bond stress vales will lead the over or unsafe design. In the present paper micropile is test is conducted for pullout and compression on full scale model to develop relation between SPT value and bond stress

Table 1. Soil Profile Report

Depth below Reference (m)	Nature of Sampling	Depth of Sample below reference level	Level of water table (m)	SPT Test Results		Symbolic Representation	Soil Description with classification	Shear Strength Characteristics	
				Depth (M)	N, Value (Corrected)			Cohesion, C (t/sqm)	Angle of friction (Degrees)
1	DS	1.0	5.50 m	0.00 to 1.00			Field up Soil		
2	SPT	1.5		1.50 to 1.95	17				
3	UDS	2.5		2.50 to 2.80			Grayish Fine Sand (SP-SM)	0	29
4	SPT	3.0		3.00 to 3.45	23				
5	SPT	4.5		4.50 to 4.95	22				
6	UDS	5.5		5.50 to 5.80				0	30
7	SPT	6.0		6.00 to 6.45	19				
8	SPT	7.5		7.50 to 7.95	21				
9	UDS	8.5		8.50 to 8.80				0	31
10	SPT	9.0		9.00 to 9.45	22				
11	SPT	10.5		10.50 to 10.95	25				
12	UDS	11.5		11.50 to 11.80				0	32
13	SPT	12.0		12.00 to 12.45	26				
14	SPT	13.5		13.50 to 13.95	26				
15	UDS / DS	14.5		14.50 to 14.80				0	33
16	SPT	15.0		15.00 to 15.45	27				
17	SPT	16.5		16.50 to 16.95	28				
18	UDS / DS	17.5		17.50 to 17.80				0	34
19	SPT	18.0		18.00 to 18.45	28				
20	SPT	20.0		20.00 to 20.45	29				

Abbreviations: DS = Disturbed Sample, UDS = Undisturbed Sample

III. PILE TESTING

The dimensional and construction details for full scale single pile are as follows. Pile length is 14.5m, pile grout body diameter is 125mm and grout compressive strength is 30Mpa. The service load for pile design is 25T and ultimate load 62.5 T with 2.5 factor of safety. The 52/26 ISCHEBECK TITAN anchor rods (i.e. 56 mm-OD & 26 mm-ID) yield stress is 585 N/mm^2. The Sacrificial Drill bit of TITAN 52/26 make cross cut type and 115mm diameter. Piles are tested for 63.9 T pullout (or tension) cyclic load test and load v/s deflection curve is obtained.

IV. FIELD PILE TESTING

The test is carried out as per IS 2911 (Part-4) and the test is carried out up to ultimate design load 63.9T and the noted deflection is 7.28mm. After the ultimate load the load reduction is started as cyclic test and load and deflection is tabulated below.

Table 2 Tension Ultimate Load Test

Load (P) (T)	Deflection (mm)
0	0
15.0	0.57
17.2	0.65
24.7	1.28
33.7	2.28
42.0	3.23
52.2	4.92
60.6	6.5
63.9	7.28
59.0	6.87
51.0	6.26
42.0	5.42
34.0	4.53
25.0	3.43
17.0	2.53
11.0	1.89
0.0	0.76

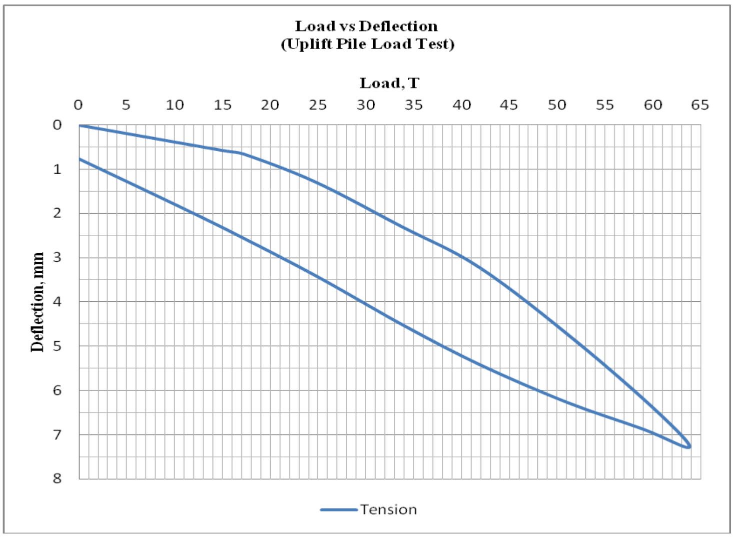

Fig 1. Load v/s Deflection Curve

V. BOND STRENGTH VALUES BETWEEN SOIL AND PILE GROUT BODY

The above graph is used to develop reverse relation between Deflection and Load.

$$P_{(ultimate)} = \text{End Bearing Capacity} + \text{Skin Friction Capacity} \quad (1)$$
$$P_{(ultimate)} = \sigma_t \times N_q \times A + K \times \sigma_v \times \tan\delta \times A_p$$

Where, $P_{(ultimate)}$ is ultimate pile load capacity, σ_t is effective stress at the tip of the pile, N_q is bearing factor coefficient, A_p is cross-sectional area of the pile at the tip, K is lateral earth pressure coefficient, σ_v *is* effective stress at the perimeter of the pile, $\tan\delta$ is friction angle between pile and soil and A_p is perimeter area of the pile.

The test results are for uplift tension test so the end bearing capacity of pile is neglected i.e. End Bearing Capacity $\sigma_t \; x \; N_q \; x \; A = 0$, based on soil investigation report assuming the Coefficient (K) is 1.0, soil density (□□□is□1.0 (T/m^3), average angle of friction (□) is 31 degree for 14.5m pile depth.

$P_{(ultimate)} = K \; x \; \sigma_v \; x \; tan\delta \; x \; A_p = \quad K \; x \; \sigma_v \; x \; tan\delta \; x$ *pile perimeter x pile depth (z)*

Pile depth (z) =($P_{(ultimate)}$*) / (*$K \; x \; \sigma_v \; x \; tan\delta$ *x pile perimeter)*

Table 3 Geotechnical Parameters

Deflection (mm)	Load (T)	Earth Pressure Coefficient (K)	Soil Density (γ) T/m^3	Angle of friction (□)	tan (□)	K γ tan(□)
0.5	12	1.0	1.0	29	0.60	0.60
1.0	21	1.0	1.0	29	0.60	0.60
1.5	27	1.0	1.0	29	0.60	0.60
2.0	31	1.0	1.1	30	0.60	0.60
2.5	35	1.0	1.1	30	0.60	0.60
3.0	40	1.0	1.1	30	0.60	0.60
3.5	44	1.0	1.2	31	0.60	0.60
4.0	47	1.0	1.2	31	0.60	0.60
4.5	50	1.0	1.2	31.5	0.60	0.60
5.0	52	1.0	1.3	31.5	0.60	0.60
5.5	55	1.0	1.3	31.5	0.60	0.60
6.0	58	1.0	1.3	32	0.60	0.60
6.5	61	1.0	1.3	32	0.60	0.60
7.0	63	1.0	1.4	32	0.60	0.60

Table 4 Bond Strength and SPT Values

Load (T)	Pile Dia (m)	Perimeter (m)	Pile length (m)	Surface Area (m^2)	Depth (m)	α_s (T/m^2)	SPT (N)
12	0.175	0.55	14.5	7.97	2.5	1.5	18
21	0.175	0.55	14.5	7.97	4.4	2.6	20
27	0.175	0.55	14.5	7.97	5.6	3.4	21
31	0.175	0.55	14.5	7.97	6.5	3.9	21
35	0.175	0.55	14.5	7.97	7.3	4.4	21
40	0.175	0.55	14.5	7.97	8.4	5.0	21
44	0.175	0.55	14.5	7.97	9.2	5.5	22
47	0.175	0.55	14.5	7.97	9.8	5.9	23
50	0.175	0.55	14.5	7.97	10.4	6.3	25
52	0.175	0.55	14.5	7.97	10.9	6.5	25
55	0.175	0.55	14.5	7.97	11.5	6.9	25
58	0.175	0.55	14.5	7.97	12.1	7.3	26
61	0.175	0.55	14.5	7.97	12.7	7.7	26
63	0.175	0.55	14.5	7.97	13.2	7.9	26

Volume 02, Issue 08, [August– 2015] ISSN (Online):2349–9745 ; ISSN (Print):2393-8161

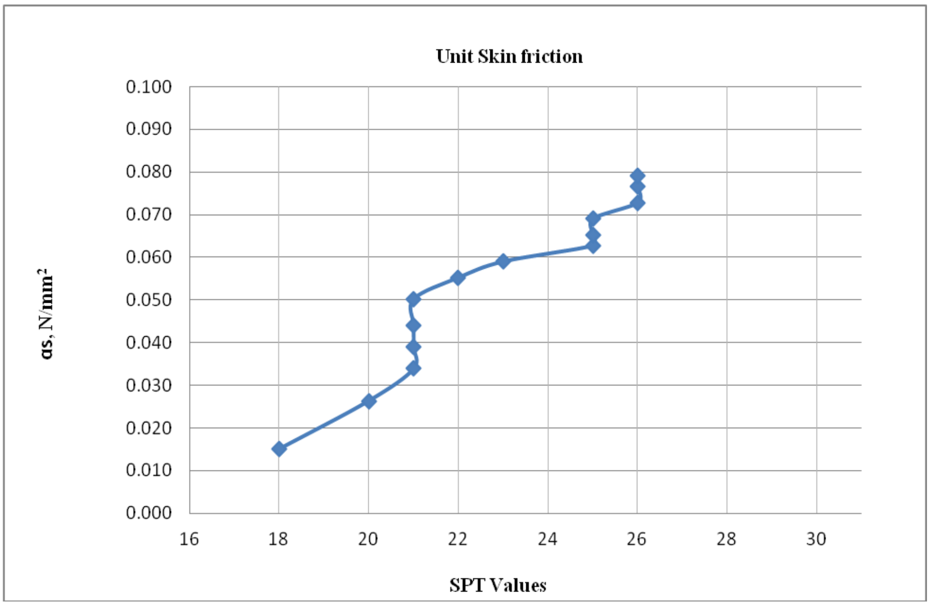

Fig 2 (a) Relation between Bond strength and SPT values

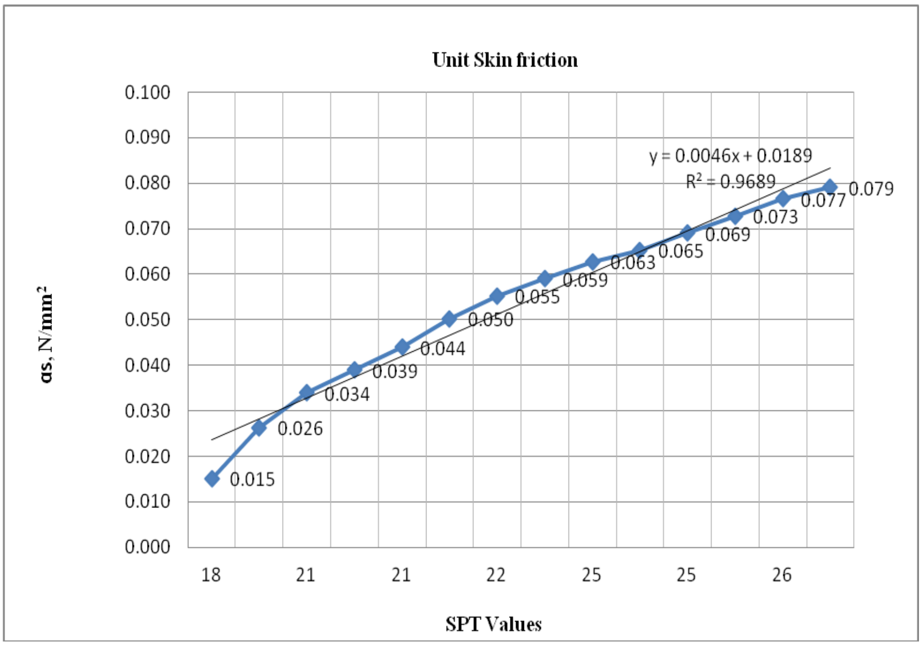

Fig 2 (b) Relation between Bond strength and SPT values

VI. RESULTS AND DISCUSSION

The pullout test is carried out for one cycle and up to the ultimate design load to verify the pile load carrying capacity as per design load and assumption. But the intension of this paper to obtain the relation between soil pile surface bond strength and SPT values by using testing data. From the above graphs the liner relation between SPT values and Bond strength is obtained.

$$\text{Bond Stress} = 0.0046\,(\text{SPT Value}) + 0.0189 \quad (2)$$

The same type of relations can be obtained for different soil profiles and SPT values which will help to design engineer to produces safe and economical design. In this study the test was carries out only for one cycle due to some project limitation but to obtain the refined results at least three cycles are required to be carried out. The field results can be simulated in FEM based software for the validation of results.

VII. CONCLUSION

A linear relation between bond strength and SPT values is obtained for the Grayish Fine Sand soil profile. The relation between soil pile bond strength and SPT values can obtained, which is need and required extensive experiential, testing, simulation and analysis to obtain the refined relations for different soil profiles. These relations will be very useful to design safe and economical design Micropile foundation.

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