Combination of SDMT and CPT Results for Effective Analysis of Soil Parameters at a Site near Piacenza, Italy.

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ABSTRACT: Seismic dilatometer test(SDMT) was conducted in Piacenza, Italy using Marchetti's SDMT equipment. Using the usual correlations, oedometer modulus, undrained shear strength, friction angle and shear wave velocity profile were obtained. A clear subsoil profile was determined and it was revealed that subsoil consisted of mostly silty sand to sand. In the same location, cone penetration test was also carried out using PAGANI Geotechnical equipment. Subsequently cone penetration resistance or tip resistance (q_t), Sleeve frictional resistance (f_s) and piezocone resistance (q_c) were obtained. Pore pressure distribution (u_c) was also determined. Based on this, subsoil profile of the site was drawn. In the present investigation, an attempt has been made to portray the results of combination of these two methods, viz..SDMT and cone penetration test (CPT).Finally a broad discussion is brought forward delineating the various pros and cons of these two methods.

1 INTRODUCTION

Seismic dilatometer test(SDMT) and cone penetration tests(CPT) were carried out at a location consisting of alluvial lacustrine deposits in Paganico(Piacenza).The upper layer of variable thickness was mainly on alluvial deposit comprising silty sands or sandy silts and overlying the lacustrine deposit(clay and silty clay).The DMT/SDMT tests were carried out upto a depth of 6m and that of CPT upto 3m.

Seismic dilatometer is the combination of the DMT blade with a seismic module for measuring the shear wave velocity. The flat dilatometer consisted of a steel blade with dimension 95x200x15mm having one face with an expandable steel membrane. Cone penetration test was also performed using PAGANI Geotechnical equipment(TG63/150).The mechanical cone penetration test consisted of pushing a cone penetrometer by using a series of push rods at constant rate of penetration(20mm/sec).The hydraulic pushing system consisted of a CPT hydraulic system mounted on crawler and its full capacity was 200 kN.

Based on DMT/SDMT tests, oedometer modulus, undrained shear strength, friction angle and shear wave velocity were determined. From CPT tests, cone penetration resistance or tip resistance, sleeve frictional resistance, piezocone resistance and pore pressure distribution were obtained.

After compilation of results from both the tests, subsoil profile of the site along with various design parameters were determined. Finally, results obtained from these two methods were compared and interpretations were made portraying the various pros and cons of the two methods.

2 LOCATION OF TEST SITE

Seismic Dilatometer test (SDMT) and cone penetration test were carried out at Piacenza (PC), Italy by Jadavpur University, India. Tests were conducted at a location (N 45.079270° E 9.579690°) in Piacenza, Italy using Marchetti's SDMT equipments and PAGANI Geotechnical equipment (TG63/150). Water table was at 1.5m below GL.

3 DESCRIPTIONS OF EQUIPMENT AND TEST PROCEDURE

3.1 Seismic dilatometer (SDMT)

Seismic dilatometer is the combination of the DMT blade with a seismic module for measuring the shear wave velocity. The flat dilatometer (DMT) is a steel blade having dimensions 95 x 200 x15 mm, ending with a sharp lower edge. One face carries a circular steel membrane that is expanded during the test. The blade is advanced into the soil by pushing vertically on a series of rods. At fixed depth intervals (generally 0.20m) the penetration is stopped and the membrane is pressurized by gas traveling in the pneumatic tubing and the readings are taken. The seismic module is an instrumented tube, located above the blade housing two receivers at a distance of 0.5m. A clear sub-soil profile was obtained upto a termination depth of 6.0 m. Shear wave velocity was determined at 0.5m interval. Test procedures were followed as per recommendations contained in ASTM D6635, Eurocode7, and ISSMGE TC 16.

3.2 Cone Penetration Test (CPT)

In the same location, cone penetration test was also carried out using PAGANI Geotechnical equipment (TG63/150). The mechanical cone penetration test consisted of pushing a cone penetrometer by means of a series of push rods, into the soil at a constant rate of penetration (20mm/sec) as per ASTM D5778. During penetration, discontinuous measurement (every 0.20m of penetration) of cone penetration resistance or tip resistance (q_t) and sleeve frictional resistance (f_s) were recorded. The front end of the cone consisted of a 60^o apex conical tip which was approximately 5mm long at the upper portion. The hydraulic pushing system consisted of a CPT hydraulic system mounted on a crawler and its full capacity was around 200kN.Tests were conducted upto a depth of 3m as in case of SDMT test was done.

4 RESULTS AND DISCUSSION

Table-1, Figs.1, 2, 3 and 4 shows the variation of I_D(Material index), K_D(Lateral stress index), M(Constrained modulus) and angle of shearing resistance(ϕ) with depth. I_D values were consistently higher than 1.8 at depth 3.2m it rises drastically high. According to Marchetti(1980),if $1.8<I_D<10$,the soil type can be identified as sand which had been matched to actual observed specimens at different strata. Angle of shearing resistance varied from 26^o to 43^o.Cohesion was zero for all the strata. Lateral stress index (K_D) followed higher values above water table. From K_D profile overconsolidation ratio (OCR) profile can be assessed. Hence it is helpful for understanding the soil deposit and its stress history (Marcetti1980, Jamiolkowski et al.1988).Constrained modulus(M) is the vertical drained confined(one-dimensional) tangent modulus at σ'_{vo} and is the same modulus which, is obtained by oedometer. It is directly proportional to lateral stress index (K_D).Shear wave velocity (Vs) and shear modulus (G_o) were found from SDMT test which are presented in Table-2. Graphical representations of shear wave velocity and shear modulus with depth at 0.5 m intervals are shown in Figs.5 and 6**.** Both the curves follow similar trend. Shear wave velocity and shear modulus increases with depth. From Table-3 and Fig.7, it is observed that cone tip resistances (q_t) are higher above the water table and gradually decreases below it. Similarly Fig.8 reveals that frictional resistance (f_s) gives higher value just below the water table. Piezocone resistance (q_c) and measured pore pressure distribution (u_2) from cone penetration test are shown in Figs.9and10 respectively. Effective friction angle from CPT is found to lie in between 30.28 to 39.84 degree whereas from DMT test it varies from 26 to 43 degree (Fig.4). This shows that DMT results are quite well at par with those of CPT. Higher values of the upper strata as obtained from DMT test may be due to some initial disturbance and probably also due to local soil heterogeneities (Presti and Meisina,2014) in those regions. Similarly constrained modulus from CPT was ranged between 13 to 17 MPa and to whereas from DMT it varies from 9.1 to 39.5 MPa (Fig.3). Here also it is observed at upper strata the results of CPT and DMT varies to some extent whereas at the lower region they complied. The reason may be similar that at the upper strata the disturbances were higher relative to those below the water table as well as the local lithological heterogeneities. In case of CPT relative density (D_r) varies from 0.31 to 0.53 but for DMT it lies in between 42% to 67% (from Table.1 &3). Relative density is overpredicted in case of DMT compared to CPT test. The amount of the overprediction is difficult to evaluate at the moment (TC16). It is possibly due to some overconsolidation and cementation effect of strata (Cestari, 2012).

Table 1. Test Results from Seismic Dilatometer Test (SDMT) Test

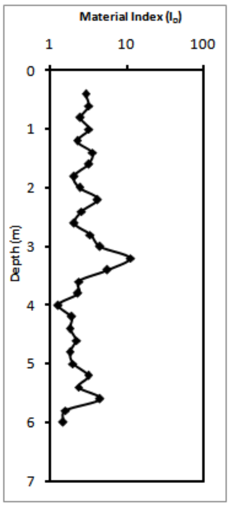
Depth (z) (m)	Material Index I_D	Horizontal Stress Index K_D	Constrained Modulus M (MPa)	Friction Angle Φ (Degree)	Relative Density (D_r)
0.4	2.94	16.5	34.0	43	-
0.6	3.22	8.3	22.4	40	-
0.8	2.52	14.8	31.6	42	-
1.0	3.22	7.5	32.2	39	-
1.2	2.28	9.9	30.3	40	-
1.4	3.58	6.3	39.5	38	-
1.6	3.2	6.2	38.9	38	-
1.8	2.07	8	37.5	39	-
2.0	2.45	5.8	29.6	38	-
2.2	4.2	2.7	17.1	34	0.46
2.4	2.59	3.6	16.6	35	0.54
2.6	2.08	4.4	19.2	37	0.62
2.8	3.34	3	18.6	35	0.51
3.0	4.51	1.9	11.6	32	0.47
3.2	11.23	0.7	9.1	26	0.49
3.4	5.62	1.5	10.4	31	0.46
3.6	2.39	3	15.1	35	0.54
3.8	2.35	3	15.0	35	0.56
4.0	1.3	5.1	18.7	37	0.67
4.2	1.91	3.8	18.8	36	0.53
4.4	1.83	3.9	16.5	36	0.56
4.6	2.22	3.1	17.8	35	0.63
4.8	1.82	3.6	14.5	35	0.65
5.0	2.0	2.8	13.7	34	0.61
5.2	3.16	1.7	9.5	31	0.46
5.4	2.37	2.2	11.2	33	0.51
5.6	4.52	1.5	11.6	31	0.42
5.8	1.6	2.4	9.2	33	0.48
6.0	1.5	3.2	13.8	35	0.64

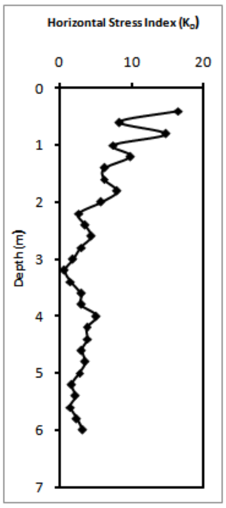
Table 2. Shear Wave Velocity Determination from Seismic Dilatometer Test (SDMT)

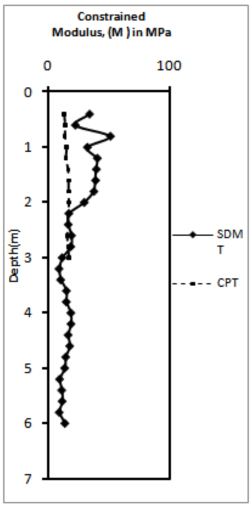
Depth (z) (m)	Shear wave Velocity (V_s) (m/sec)	Initial Shear Modulus (G_0) = ρV_s^2 (MPa)	Constrained Modulus M (MPa)	Working Strain Shear Modulus (G) (MPa)	Decay Factor G/G_0
1.0	132	31.4	32.2	12.06	0.384
1.5	152	41.6	39.2	14.68	0.353
2.0	156	43.8	29.6	11.09	0.253
2.5	160	46.1	17.9	6.70	0.145
3.0	168	48.0	11.6	4.34	0.091
3.5	172	51.8	12.8	4.79	0.093
4.0	172	50.3	18.7	7.00	0.139
4.5	179	57.7	17.2	6.44	0.112
5.0	178	57.0	13.7	5.13	0.090
5.5	187	62.9	11.4	4.27	0.068

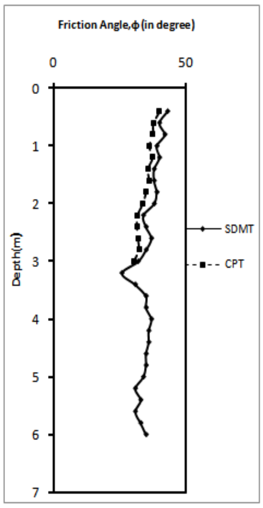
Table 3. Test Results from Cone Penetration Test(CPT)

Depth z (m)	Corrected Cone Resistance q_t (kPa)	Corrected Frictional Resistance f_s (kPa)	Piezo cone Resis tance q_c (MPa)	Measured Pore Pressure u_2 (MPa)	σ'_{vo} (kPa)	Effective Friction Angle Φ (Degree)	Drained Connstrained Modulus M_o (MPa)	Relative Density D_r
0.20	4356	64	2.2	0.0				
0.40	2756	183	2.5	0.0	7	39.84	13.02	0.51
0.60	2056	155	2.5	0.0	10	37.59	13.98	0.48
0.80	2156	183	1.9	0.0	12	37.38	13.79	0.43
1.00	1956	190	2.0	0.0	17	36.08	15.27	0.41
1.20	2756	176	1.5	0.0	21	37.22	14.63	0.32
1.40	2056	162	2.3	0.0	24	35.49	16.51	0.39
1.60	2356	204	2.5	0.6	26	35.96	16.92	0.40
1.80	1956	274	2.0	0.2	28	34.89	16.87	0.37
2.00	1556	190	2.3	3.0	30	33.63	17.26	0.34
2.20	1056	190	1.9	3.4	31	31.70	16.67	0.39
2.40	1056	92	1.8	3.0	33	31.55	16.73	0.45
2.60	1156	85	1.2	0.2	34	31.92	15.63	0.53
2.80	1256	92	1.6	1.4	36	32.17	16.62	0.42
3.00	856	85	1.9	4.2	37	30.28	17.27	0.31









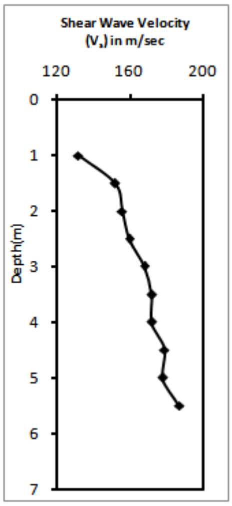


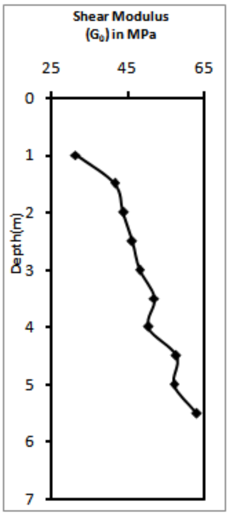
Fig.1.Depth vs Material Index(I_D)

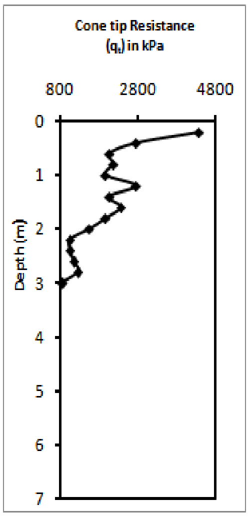
Fig.2. Depth vs Horizontal Stress Index(K_D)

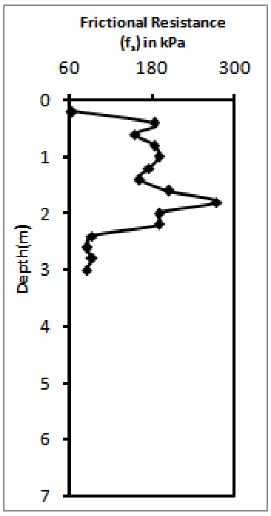
Fig.3.Depth vs Constrained Modulus(M)

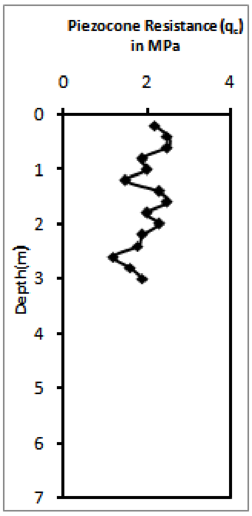
Fig.4.Depth vs Friction angle(ϕ)

Fig.5. Depth vs Shear Wave velocity(Vs)









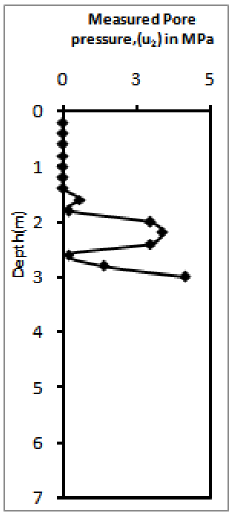


Fig.6.Depth vs Shear Modulus(G_o)

Fig.7. Depth vs Cone tip Resistance(q_t)

Fig.8. Depth vs Frictional Resistance(f_s)

Fig.9.Depth vs Piezocone Resistance(q_c)

Fig.10.Depth vs Measured Pore Pressure(u_2)

5 CONCLUSIONS

CPT method of determination of subsoil profile and various engineering properties of soil is much older and well established. DMT method is relatively a recent one and using it the same parameters may be obtained.

In the present investigation a comparison had been made between these two methods to evaluate the suitability of DMT method with regard to CPT method. It is observed that information obtained from DMT test correlate very well with that of CPT.

In addition to this with the use of SDMT shear wave velocity profile can also be determined.

Subsequently, shear modulus can be calculated from this.

Consequently the relationship between shear modulus (Go) versus shear strain(γ) may be carried out for study related to liquefaction.

Finally it may be concluded that the DMT/SDMT method is well suited for the detailed soil exploration work.

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