Effect of Gradation and Particle Size on Correlations between DCP Index (ASTM D6951 – 03) and Relative Density for Sand

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Abstract

This research study was mainly focus on performing dynamic cone penetration tests according to ASTM D691 - 03 with various relative density on different gradation (poorly graded and well graded) of sand. Sand samples were collected from different region of Gujarat viz. Khanpur, Sevaliya, Ahmedabad. Well graded sand samples were prepared by mixing in different proportions of sand samples collected from above locations. Dynamic cone penetration tests were carried out in Plexiglas tank (60 cm × 60 cm × 75 cm) on three different poorly graded and three different well graded sand at different relative density of 30, 50, 65, 75 %. Relative density of sand samples were determined according to IS : 2720 (Part 14) – 1983. Dry sand has been filled in tank up to 70 cm height of tank. Tamping was done with rammer (30 cm × 30 cm × 1 cm) of 9.5 kg weight to achieve desired density. Desired depth of penetration is 60 cm. Dynamic cone penetration tests were performed according to ASTM D6951-03.

1 Introduction

Sand is required for many purposes, for example, backfill of earth retaining structures, backfill in foundation trenches, reclamation of low lands and construction of road embankments etc. In all these situations good compaction of fill should be ensured to avoid future subsidence, failure of foundation and moreover liquefaction. Relative density is the most appropriate index to control the compaction of Sand. The term used to indicate the strength characteristics in a qualitative manner is relative density (Dr) which describes the state condition of cohesion-less soils. So, relative density is a very important index for a sandy soil. The density of granular soil varies with the shape and size of grains, the gradation and the manner in which the mass is compacted. Relative density is 0% for loosest condition of sand and 100% for densest condition of sand. Relative density of cohesion-less soil can be determined from IS: 2720 (Part – 14) – 1983.On the other hand, extensive information on the behavior of sandy soils has been obtained from laboratory tests on reconstituted and undisturbed samples. In these laboratory studies, the relative density (Dr) is commonly identified as a principal

factor influencing the deformation and strength characteristics of sands. No any available soil compaction measuring devices provide direct readout of soil density values which is main parameter to control soil compaction performance. Most of these devices are strength or stiffness measuring devices which monitor the change of in-place engineering properties due to the application of impact or vibrating force on the soil. Their output, however, provide a measure of soil densification and they can be used satisfactorily in compaction control when they are calibrated to soil relative compaction and moisture content. In order to establish the relationship between the readings of these devices and soil relative compaction, there is a need to evaluate the sensitivity of the measured strength or stiffness parameters to the changes of soil types, and compaction efforts. Dynamic Cone Penetrometer (DCP) is one of those devices and is performed on sand of known relative densities in calibration chamber.

The Dynamic Cone Penetration Test (DCPT) is a simple ground investigation technique in which a solid penetrometer is driven into the ground and the number of blows required to drive it to a given depth is recorded.

During the past decade, the DCP test has been correlated to many engineering properties such as the CBR, shear strength of granular materials, and most recently, the subgrade Resilient modulus (MR) Elastic Modulus (Es) and soil classification.

2 Experimental Investigation

It includes laboratory investigations for dynamic cone penetration resistance as well as relative density.

Dynamic cone penetration tests were carried out in Plexiglas tank (60 cm × 60 cm × 75 cm) on three different poorly graded and three different well graded sand at different relative density of 30, 50, 65, 75 %. Dry sand has been filled in tank up to 70 cm height of tank. Whole 70 cm of height is divided into 14 different layers of 5 cm height. Uniformly distributed compactive efforts are applied at each layer of sand with tamping rammer (30 cm × 30 cm × 1 cm) of 9.5 kg weight to achieve required density. Desired depth of penetration is 60 cm. Dynamic cone penetration tests were performed according to ASTM D6951-03.
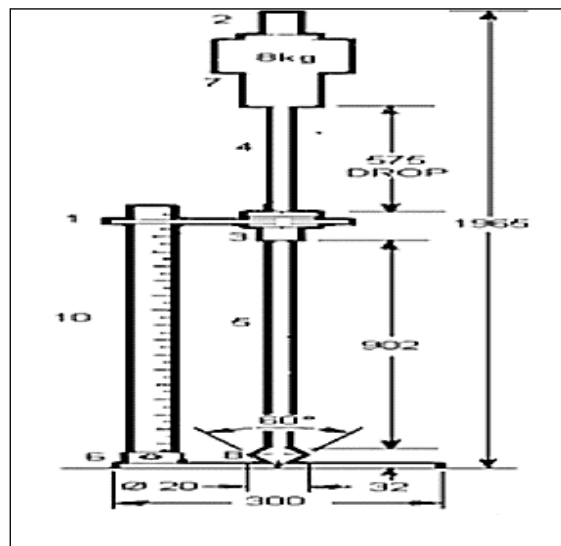

Figure 1: Dynamic Cone Penetrometer

Where,
1 : Reading Edge
2 : Handle
3 : Top edge of lower shaft
4 : Upper shaft (d = 16 mm)
5 : Lower shaft (d = 16 mm)
6 : Bottom of measuring scale
7 : Hammer (8 kg. weight)
8 : Cone (d= 20 mm)
10 : Measuring scale
All dimensions are in mm.

After assembling DCP, dynamic cone penetrometer is held vertically at center of the tank with one hand placed at the top of the handle. Set the instrument is such that the wildest part of the cone is flushing with the surface of the sand. In data sheet, record the current shaft reading as the starting point for blow number zero. With one hand placed on the top handle, use other hand to seat the cone by dropping the hammer from a partial height until the widest part of the cone is below the reference surface. Do not record penetration during the seating operation. Establish a reference for reading the penetration of the shaft after each blow. The reading edge is a reference level that must remain constant for accurate depth readings. On the data sheet as shown in figure 1, record the current shaft reading as the starting point for blow number zero. Raise the hammer and let it fall freely on the anvil with height of fall 575 mm. Note down the shaft reading after each number of blow to the nearest of millimeter. Record the reading and blow count by reading the shaft to the nearest millimeter if using a metric scale. Record this as penetration for blow number 1. Operation is continued until the total penetration is less than 3 mm/blow for ten consecutive drops or 60 cm depth is reached.

Table 1: Sample sheet for DCPT

Record Sheet		
Cumulative No. of Blows	Penetration Depth (mm)	DCP Index (mm/blow)
0	110	0
1	251	141
2	317	66
3	364	47
4	407	43
5	443	36
6	472	29
7	512	40
8	543	31
9	572	29
10	603	31
11	635	32
12	666	31

Relative density of sand samples were determined according to IS : 2720 (Part 14) – 1983.

3 Analysis and Results

A graph of cumulative number of blow vs. depth is prepared. Some unreliable data up to top 30 cm depth is neglected due to lower confinement pressure at the top of sand deposit. Such kind of graph is shown in figure 2 below.
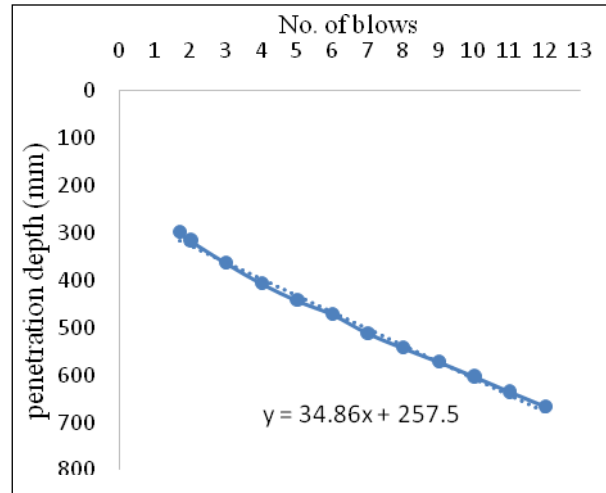

Figure 2: Depth of penetration vs. No. of Blow

It is observed that cumulative number of blows increases linearly with depth. DCPIndex was calculated from the average slope of the cumulative number of blow vs. depth plot. DCP Index for the graph shown in figure is 34.863 mm/blow.

Dynamic cone penetration test has been performed on three different sand samples collected from different region of Gujarat e.g. Khanpur, Sevaliya, Ahmedabadat different relative density of 30%, 50%, 65% and75%. Three well graded sand samples were preparedby mixing different proportions of sand samplescollected from above locations.Properties of sand samples collected (Poorly GradedSand) and well graded sand is shown in table below.

Table 2: Properties of poorly graded sand

	Khanpur Sand	Sevaliya Sand	Ahmedabad Sand
% G	6.28	4.2	-
% C S	35.04	1.9	0.47
% M S	58.0	75.0	6.5
% F S	0.68	15.92	88.4
% S & C	-	2.98	4.63
D_{60}(mm)	2.5	0.9	0.33
D_{30} (mm)	1.5	0.5	0.23
D_{10} (mm)	0.75	0.35	0.15
Cu	3.3	2.6	2.2
Cc	1.2	0.8	1.1
Sp.Gty, G	2.7	2.6	2.59

γ_{max} (g/cc)	1.94	1.81	1.66
e_{min}	0.39	0.38	0.56
γ_{min} (g/cc)	1.69	1.53	1.47
e_{max}	0.6	0.63	0.71

Table 3: Properties of well graded sand

	Comb 1	Comb 2	Comb 3
% G	1.38	8.93	10.6
% C S	20.28	14.65	16.76
% M S	50.2	51.08	52.53
% F S	17.35	22.36	18.15
% S & C	-	2.98	1.96
D_{60}(mm)	1.9	1.6	1.7
D_{30} (mm)	0.75	0.51	0.65
D_{10} (mm)	0.31	0.17	0.26
Cu	6.1	9.4	6.5
Cc	1.0	1.0	1.0
Sp.Gty, G	2.63	2.60	2.60
γ_{max} (g/cc)	2.16	2.16	2.23
e_{min}	0.22	0.2	0.17
γ_{min} (g/cc)	1.72	1.72	1.77
e_{max}	0.48	0.51	0.47

Composition of three well graded sample is given below.

Combination 1 (250, 100, 50): This combination is having 250 kg. ofKhanpur Sand, 100 kg. ofSevaliya Sand and 50 kg. of Ahmedabad sand for 400 kg. mass of Sample.

Combination 2 (137, 168, 95): This combination is having 137 kg. ofKhanpur Sand, 168 kg. ofSevaliya Sand and 95 kg. of Ahmedabad sand for 400 kg. mass of Sample.

Combination 3 (180, 143, 77): This combination is having 180 kg. ofKhanpur Sand, 143 kg. ofSevaliya Sand and 77 kg. of Ahmedabad sand for 400 kg. mass of Sample.

Results of DCP Index for each poorly graded sample are given in table 4 and figure 3 below.

Table 4: Values of DCP Index at Different Relative density for poorly graded sand

D_R (%)	DCP Index (mm/blow)		
	Khanpur Sand	Sevaliya Sand	Ahmedabad Sand
30	107.02	118.85	144.41
50	51.306	85.543	105.82

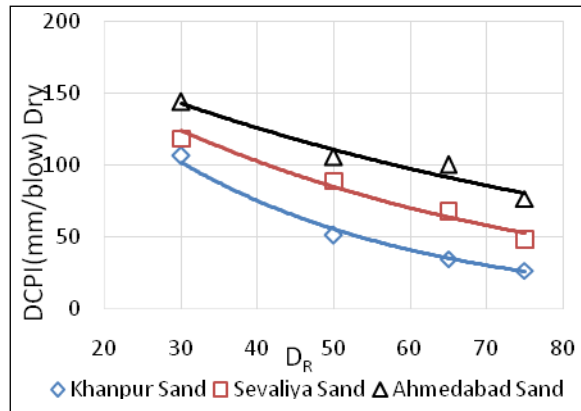| 65 | 34.863 | 68.368 | 100.7 |
| 75 | 27.023 | 48.648 | 76.077 |

Figure 3: DCP Index vs. D_R for poorly graded sand

DCP Index decreases exponentially with increase in value of D_R. Correlation follows the equations.

ForKhanpur sand
$DCPI = 255.14e^{-0.03DR}(R^2=0.9905)$,
ForSevaliya sand
$DCPI = 215.8e^{-0.019DR}(R^2=0.97)$,
For Ahmedabad sand.
$DCPI = 211.81e^{-0.013DR}(R^2=0.9294)$.
Results of DCP Index for each well graded sand are given in table 5 and figure 4 below.

Table 5: Values of DCP Index at Different Relative Density for well graded sand

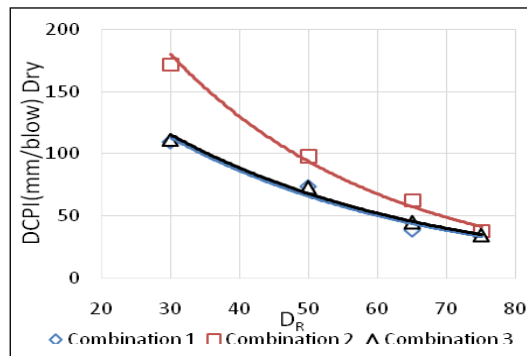| D_R (%)	DCP Index (mm/blow)		
	Comb 1	Comb 2	Comb 3
30	109.32	171.77	111.3
50	73.136	98.128	72.365
65	38.229	62.36	44.45
75	35.1	37.9	34.258

Figure 4: DCP Index vs D_R for well graded sand

DCP Index decreases exponentially with increase in value of D_R. Correlation follows the equations.

For Combination 1
$DCPI = 254.72e^{-0.027DR}(R^2=0.9622)$,
For Combination 2
$DCPI = 478.8e^{-0.033DR}(R^2=0.9847)$,
For Combination 3
$DCPI = 255.61e^{-0.027DR}(R^2=0.9922)$.

4 Conclusions

DCP Index decrease exponentially with increase in value of relative density for each poorly graded sand as well as well graded sand.

Decrement in values of DCP Index with respect to increase in values of relative density is almost similar regardless to particle size for poorly graded sand. Whereas, decrement in values of DCP Index with respect to relative density is depend upon particle size for well graded sand.

Increase in values of DCP Index with decrease in particle size is uniform at any relative density for poorly graded sand, whereas increase in values of DCP Index with decrease in particle size, decrease with increase in relative density for well graded sand.

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