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Suitability of Selected Bangladesh Sands for the Determination of In-Situ Soil Density

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Abstract- Usually Ottawa sand is used to find out in-situ density of soil by sand replacement method. Ottawa sand is very expensive and it is always imported from abroad. To avoid these difficulties the quality and suitability of locally available sand in and around Khulna district in Bangladesh in lieu of Ottawa sand were assessed for determining in-situ density using sand replacement method. Five samples of sand named by Sylhet sand, Kushtia sand, Fultala sand, Bogjhuri sand and Mongla sand were collected from nearby business centers. Original sand and some graded sands of each sample were under investigation to ascertain their suitability of use in lieu of Ottawa sand in determining in situ soil density. Five gradations were considered and those were (i) passing #16 and retained in #30, (ii) passing #30 and retained in #40, (iii) passing #40 and retained in #50, (iv) passing #30 and retained in #50 sieve and (v) passing #50 and retained in #100 sieve . Each of the original samples has been characterized by determining its index properties, grain size distribution. Specific gravity and density were determined for each sample of original and graded sands. These properties were compared with those recommended by ASTM (1989) for selecting suitable sand in sand replacement method.

Keywords: in-situ density, ottawa sand, bangladesh sands, grading of sand, sand replacement method.

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From this study it was found that original sands of all selected places in Bangladesh did not satisfy the ASTM (1989) criteria of Ottawa sand. In case of graded sands, Sylhet sand satisfied all the required ASTM criteria for four gradations except the gradation passing from #50 to #100 sieve, while Kushtia and Fultala sands satisfied fully for three gradations except the gradations passing from #16 to #30 sieve and passing from #50 to #100 sieve. Bogjhuri and Mongla sands did not satisfy all criteria. So, the graded sands that satisfy the criteria of Ottawa sand as mentioned in investigation may be used in sand replacement method in lieu of costly Ottawa sand.

Keywords: in-situ density, ottawa sand, bangladesh sands, grading of sand, sand replacement method.

I. Introduction

Without measurement of in-situ density one cannot understand about the bearing capacity and stability of soil. In situ soil density can be measured by various methods. In the present study, only measurement of in-situ density of sandy soil was under consideration. Among all the methods, sand replacement method may be used for all types of soil.

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However to measure in-situ density by sand replacement method, Ottawa sand is used according to ASTM (1989). Ottawa sand consists of pure siliceous materials and is practically all of one size and white in colour. The specification of this test requires that the sand must be uniformly graded and rounded in shape to ascertain its free fall. In Bangladesh, sands are available in abundance and it is expected that some of them might meet the specification requirements for density determination. If so the use of local sand would be less costly and may be used instead of expensive Ottawa sand due to its nominal cost, Furthermore, the local sand can be afforded to left in place after performing the test which will shorten the testing time.

Ottawa sand is collected from abroad and it is very costly. From this point of view, this study was to ascertain the suitability of locally available less costly sands in lieu of costly Ottawa sand.

II. Criteria of Sand to be used

According to ASTM (1989) major required criteria of Sand to be used in sand replacement method are:

a) Sand should be clean, dry, uniform, uncemented, durable and free flowing.

b) Any gradation may be used that has uniformity coefficient ($C_u = D_{60} / D_{10}$) less than 2.0, a maximum particle size less than 2.00 mm (No. 10 sieve) and less than 3 % by weight passing 250 μm (No. 60 sieve).

c) Uniform sand is needed to prevent segregation during handling, storage and use. Sand free of fines and fine sand particles is needed to prevent significant bulk density changes with normal daily changes in atmospheric humidity.

d) Sand comprised of durable, natural surrounded or rounded particles is desirable. Crushed sand or sand having angular particles may not be free flowing.

e) In selecting sand from a potential source, five separate bulk density determinations shall be made on each container or bag of sand. To be acceptable sand, the variation between any determination and average shall not be greater than 1% of the average.

f) Before using sand in density determinations it shall be dried. Then allowed to reach an air dried state in the general location where it is to be used.

g) Sand shall not be reused without removing any contaminating soil, checking the gradation and drying.

h) Bulk density tests shall be made at intervals not exceeding 14 days, always after any significant changes in atmospheric humidity, before reusing and before using a new batch from a previously approved supplier. To determine whether a material is uniformly graded, Hazen (1892) proposed the equation $C_u = D_{60} / D_{10}$. For all Practical purposes the value of Cu < 5 can be considered for uniformly graded granular soils (Murthy, 1996).

III. Selection of Sand and Methodology

For suitability of using locally available sands for determining in-situ soil density, five types of sands were selected, namely, Sylhet sand, Kushtia sand, Fultala sand, Bogjhuri sand and Mongla sand. The sand samples were collected from nearby locations in Bangladesh as mentioned in Table 1.

Each of the collected samples was characterized by determining their index properties. In the laboratory grain size analysis and specific gravity test for each of the samples were performed according to standard procedure (Josheph, 1992; Lambe, 1993). In addition to original sands, some graded sands of these locations were also selected to ascertain the suitability of using in sand replacement method. Each sample was air dried and then graded with ASTM standard set of sieves containing #16, #30, #40, #50. In case of all the graded sands in addition to Ottawa sand, density was also measured in the laboratory. The following gradations of sands are selected in this study.

a) Sample passing sieve #16 and retained in sieve #30

b) Sample passing sieve #30 and retained in sieve #40

c) Sample passing sieve #40 and retained in sieve #50

d) Sample passing sieve #30 and retained in sieve #50

e) Sample passing sieve #50 and retained in sieve #100

Table 1 : Types of sands and designations

Sl. No.	Types of sand	Sample designation	Place of collection
1.	Sylhet	S-1	*Nowapara, Jessore*
2.	Sylhet	S-2	Patkelghata, Satkhira
3.	Sylhet	S-3	Rupshaghat, Khulna
4.	Kushtia	K-1	Nowapara, Jessore
5.	Kushtia	K-2	Nogorghat Railigate, Khulna
6.	Kushtia	K-3	Daulatpur, Khulna
7.	Fultala	F-1	Damodar, Fultala, Khulna
8.	Bagjhuri	B-1	Cable-ghat, Shiramoni, Khulna
9.	Mongla	M-1	Mongla, Bagerhat

IV. Laboratory Investigation

From grain size distribution analysis, D_{10} (particle size against 10% finer of the sample), D_{60} (particle size against 60% finer of the sample), FM (fineness modulus) and Cu (uniformity coefficient) were determined. Specific gravity of each collected sand sample was also determined. The index properties of original sands are shown in Table 2 and index properties of graded sands are shown in Tables 3 and 4.

Table 2 : Index properties of original sands

Sl. no.	Sample Designation	D_{10}	D_{60}	C_u	F.M.	G_S	Max. Particle Size (mm)	% Passing through 250 µm
1.	S-1	0.22	0.64	2.91	2.39	2.69	2.36	10.00
2.	S-2	0.23	0.72	3.13	2.56	2.71	2.31	8.00
3.	S-3	0.23	0.78	3.39	2.61	2.66	2.36	4.00
4.	K-1	0.12	0.32	2.67	1.32	2.72	1.52	13.00
5.	K-2	0.14	0.36	2.57	1.52	2.70	1.24	14.00
6.	K-3	0.16	0.47	2.56	1.74	2.72	1.50	9.00
7.	F-1	0.14	0.37	2.64	1.55	2.86	0.84	23.00
8.	B-1	0.13	0.29	2.23	1.27	2.72	0.76	82.00
9.	M-1	0.16	0.27	1.69	1.08	2.71	0.70	55.00

Table 3 : Index properties of graded Sylhet sands (S-1)

Sl. No.	*Gradation*	D_{10}	D_{60}	C_u	Max. Particle (mm)	% Passing through 250 μm
1.	(-) No. 16 & (+) No.30	0.65	0.86	1.323	1.20	0.00
2.	(-) No. 30 & (+) No.40	0.45	0.56	1.244	0.62	0.00
3.	(-) No. 40 & (+) No.50	0.30	0.40	1.330	0.40	0.00
4.	(-) No. 50 & (+) No.100	0.18	0.25	1.390	0.32	66.00

N.B.: (-) means passing through sieve and (+) means retaining on sieve

Table 4 : Index properties of all sands of grade (-) No. 30 & (+) No. 50

Sl. No.	Sample Designation	D_{10}	D_{60}	C_u	Max. Particle Size (mm)	% Passing through 250 μm
1.	S-1	0.31	0.45	1.45	0.40	0.00
2.	S-2	0.32	0.45	1.41	0.40	0.00
3.	S-3	0.34	0.46	1.35	0.40	0.00
4.	K-1	0.32	0.46	1.44	0.40	0.00
5.	K-2	0.30	0.42	1.40	0.40	0.00
6.	K-3	0.33	0.45	1.36	0.40	0.00
7.	F-1	0.32	0.42	1.31	0.40	0.00
8.	B-1	0.31	0.40	1.29	0.40	0.00
9.	M-1	0.30	0.35	1.17	0.40	0.00

Bulk density test on graded Ottawa sand (O-1) was performed in the laboratory by sand replacement method and the results are shown in Table 5. Bulk densities of all graded sands were also measured in the laboratory by using same method. The results are also shown in Table 5. Five separate density tests were performed on each graded sand. From the results it can be observed that the first four grades of Sylhet sand in Table 5 fulfill the criteria mentioned by ASTM (1989).

Table 5 : Density of Ottawa and graded sands

Sample Designation	Density (gm/cm^3)				
	(-) No. 16 & (+) No. 30	(-) No. 30 & (+) No. 40	(-) No. 40 & (+) No. 50	(-) No. 30 & (+) No. 50	(-) No. 50 & (+) No. 100
O-1	1.545	1.528	1.510	1.498	1.520
S-1	1.323	1.228	1.226	1.248	1.246
S-2	1.324	1.226	1.225	1.256	1.244
S-3	1.321	1.235	1.226	1.264	1.251
K-1	1.323	1.336	1.335	1.333	1.332
K-2	1.270	1.309	1.284	1.320	1.276
K-3	1.305	1.266	1.264	1.266	1.260
F-1	1.321	1.235	1.226	1.263	1.251
B-1	--	1.215	1.203	1.091	1.244
M-1	--	--	1.164	1.237	1.230

N.B.: (-) means passing through sieve and (+) means retaining on sieve

V. Results and Discussions

a) Analysis on Grain Size Distribution and Specific Gravity

In Table 2 average F.M. values of Sylhet, Kushtia and Fultala sands are exhibited as 2.52, 1.53 and 1.55 respectively. In case of Bogjhuri and Mongla sands, F.M. values are exhibited as 1.27 and 1.08 respectively which can be considered as fine sand in comparison with Sylhet, Kushtia and Fultala sands. From Table 2 it can also be observed that except Mongla sand the uniformity coefficient, Cu of all other original sands were greater than 2.0, while it can be observed from Tables 3 to 4, the values of Cu are less than 2.0 for all the graded sands. The ASTM (1989) recommended that the value of Cu for the sand used in sand replacement method should be less than 2.0.

From Tables 2 to 4 it can be observed that except the original Sylhet sand, maximum particle size for all types of collected sands as well as the graded sands were less than 2.00 mm which satisfy the recommended value of ASTM (1989). In case of original Sylhet sand maximum particle size varies from 2.31 mm to 2.36 mm which does not satisfy the criteria.

ASTM (1989) recommends that less than 3% by weight of sand should pass through 250μm. From Table

2 it can be observed that in case of original sands this value varies form 4% to 82%. Table 3 shows that 66% by weight passes through 250μm in case of graded sands of passing No. 50 sieve and retained on No. 100 sieve, while 0% by weight passes through 250μm in case of all other graded sands. So all the graded sands of passing No. 50 sieve and retained on No. 100 sieve including all original samples fail to satisfy the ASTM (1989) criteria. Table 4 shows that all the graded sands passing through No. 30 sieve and retained on No. 50 sieve recommend the criteria.

In first four selected grades of Sylhet sand in Table 5, the maximum variation of measured density was less than 1% from mean which is not desirable. In case of original Sylhet sand it was observed that this sand is not free flowing and uniform but in case of graded Sylhet sand, this quality improved significantly.

b) Density Analysis of Sand

From Table 5 it is observed that for any particular grade of Ottawa sand, the bulk density is almost same in each determination. Bulk density of graded Sylhet, Kushtia, Fultala, Bogjhuri and Mongla sands are also shown in Table 5. From Table 5 it is observed that the bulk density differs with the different locations for each grade.

In case of Bogjhuri and Mongla sands it is observed that the bulk density of any grade differs significantly from that of Ottawa. Moreover, it is found that these two types of sand are fine for which sufficient coarse grade sample could not be found easily.

From Table 5 it is observed that the bulk densities of Sylhet Sand and Kushtia Sand differ significantly in compared with that of Ottawa sand. In case of graded Sylhet sand it is observed that the bulk density differs significantly from grade passing No. 16 sieve and retained on No. 30 sieve with other grades. However in case of graded Kushtia sand it is observed that the variations of bulk densities of various grades and mixed grades do not differ substantially.

In first four selected grades of Sylhet sand in Table 5, the maximum variation of measured density was less than 1% from mean for three Sylhet sands (S-1, S-2, S-3), while Kushtia sand of 2nd, 3rd and 4th grades in Table 5 showed the maximum variation in measured density was less than 1% from mean for three sands. In case of Fultala sand, 2nd, 3rd and 4th grades in Table 5, this variation was less than 1%.

VI. Conclusions

Based on this study, the main findings have been outlined into following sections:

a) In the determination of in-situ density the following four types of graded Sylhet sands are found to be suitable:

- Sand passing #16 sieve and retained in #30 sieve.
- Sand passing #30 sieve and retained in #40 sieve.
- Sand passing #40 sieve and retained in #50 sieve.
- Sand passing #30 sieve and retained in #50 sieve.

b) The following three types of graded Kushtia Sands are also found to be suitable for determining the in-situ soil density by sand replacement method:

- Sand passing #30 sieve and retained in #40 sieve.
- Sand passing #40 sieve and retained in #50 sieve.
- Sand passing #30 sieve and retained in #50 sieve.

c) The following three types of Graded Fultala Sands are also found to be suitable for determining the in-situ soil density by sand replacement method:

- Sand passing #30 sieve and retained in #40 sieve.
- Sand passing #40 sieve and retained in #50 sieve.
- Sand passing #30 sieve and retained in #50 sieve.

The types of sand mentioned in above three sections [(a), (b) and (c)] fulfill all the criteria recommended by the ASTM (1989) for determination of in-situ soil density.

d) Other sands including original Sylhet and Kushtia sands did not satisfy the required criteria of ASTM (1989).

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