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Handling and testing of undisturbed sandy samples by freezing

Maniement et essais sur échantillons sableux non remaniés par congélation

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ABSTRACT: For reasonably accurate measurement of engineering and material properties of sandy soils, specimen preparation and handling of undisturbed samples is as important as the soil sampling process itself. Undisturbed samples of clean sands are disturbed or collapse during the extrusion process in the laboratory. In many situations, the samples cannot be extruded with a simple extruder. Extrusion of undisturbed sandy samples by freezing is an important sample preparation technique that was used in Pakistan for the first time as part of geotechnical investigations for the 184 MW Chashma Hydropower Project located on the right bank of the existing Chashma Barrage on the River Indus. Extensive field testing and laboratory testing was performed during the subsurface exploration program. Undisturbed sandy soil samples were obtained using a Pitcher sampler and air lifted to Central Material Testing Laboratories (CMTL) of Water and Power Development Authority (WAPDA) in Lahore Pakistan. This paper describes various arrangements and techniques involved for sample extrusion and preparation by freezing. The triaxial testing results obtained from frozen undisturbed sandy samples have been compared with the test results obtained from reconstituted specimens. The triaxial testing results have also been compared with the values obtained from field cone penetration tests (CPT) performed at compatible locations. The comparison showed that the freezing technique provided very satisfactory test results and design parameters.

RESUMÉ: Pour mesurer les propriétés d'ingénierie et de matière des sols sableux exactement, la préparation et la manutention des échantillons non remaniés est aussi importantes comme le processus de prelevement de sol lui meme. Les échantillons non remaniés de sables propre sont deteriorés ou detruits pendant le processus de l'extrusion dans la laboratoie. Dans la plus part des cas, les échantillons ne peuvent pas être expulsés avec un extracteur simple. L'extrusion des échantillons sableux non remaniés par congélation est une technique importante pour la préparation d'échantillon, qui a été utilisé dans les investigation géotechnique pour la première fois au Pakistan pour l'aménagement hydroélectrique de Chashma de 184 MW, situe sur la rive droite du barrage Chashma sur le fleuve Indus. L'essai sur terrain et essai en laboratoire ont été faits pendant le programme de la reconnaissance souterraine. Les échantillons de sol sableux ont été obtenus en utilisant le modèle Pitcher et ils sont transportes par avoin aux Laboratoires Central (CMTL) WAPDA a Lahore au Pakistan. Ce document decrit divers arrangements et techniques impliqués pour l'extrusion et la préparation d'échantillon par congélation. Les resultats des essais triaxiaux obtenus des échantillons sableux non remaniés congelés avaient été comparés avec des resultats obtenus avec des échantillons reconstitués. Les resultats d'essai triaxiaux avaient été aussi comaprés avec les valeurs obtenues lors des essais de penetration cone (CPT) faits aux emplacements compatibles. La comparaison montre que la technique de congelation fournit des resultats d'essai et des paramètre de conception très satisfaisants.

INTRODUCTION

The design and construction of foundations and earth related structures require accurate evaluation of the engineering and material properties of foundation soils. This can only be achieved through proper sampling of subsoil strata and appropriate handling/testing of soil samples with the least possible disturbance. Thus sampling, sample handling, and specimen preparation play a vital role in determining the engineering and material properties of a soil. Retrieving high quality undisturbed sandy soil samples is the beginning of the process. Samples should preserve insitu density, soil structure, soil fabric, and grain to grain contact as far as possible.

Many techniques have been developed to recover undisturbed clean or silty sand samples. It has long been recognized that sampling by freezing is an effective means by which to obtain undisturbed sandy samples of saturated sands. Hvorslev (1948) described such a case at Fort Peck Dam in the USA. Similar methods were used by Yoshimi et al (1973,1977). The advantage is that sandy samples obtained by the freezing technique can be prepared using conventional extrusion methods. However, sandy samples obtained without freezing need special extrusion techniques in the laboratory. Thus sample handling and specimen preparation of undisturbed sandy

samples becomes as important as the initial sampling process for clean and silty sands.

Sandy samples with a very small percentage of fines and with no cohesion are invariably disturbed or collapse during the extrusion process in the laboratory. In such cases the specimen cannot be prepared using routine practice. On the other hand, sample preparation by freezing is a successful method of handling for such samples in the laboratory. This method has been applied in the Central Material Testing Laboratories (CMTL) of WAPDA in Lahore Pakistan, for samples collected from the site for the 184 MW Chashma Hydropower Project. The project is located on the right bank of the existing Chashma Barrage over the River Indus in central Pakistan. The subsurface soils consist of fine to medium sands with $5 \pm$ percent of fines. The percentage of fines being negligible or very low, there was no disturbance of the samples on its freezing. A typical grain size distribution curve is shown in Figure 1. Very extensive field and laboratory testing was performed during the subsoil exploration of the project site. Various types of insitu and laboratory tests were performed on the alluvial sands as a part of the project geotechnical investigations. Field tests included, standard penetration, cone penetration, pressuremeter, and dilatometer. The Pitcher sampler was used to retrieve 70 mm tube samples of the alluvial sand from the river bed. These

tube samples were waxed and air lifted to Lahore for triaxial and dynamic testing at Central Material Testing Laboratories, WAPDA, Pakistan.

This paper presents the special arrangements which were made to extrude the undisturbed sandy samples and to prepare specimens for triaxial and dynamic testing. The triaxial test results from frozen samples have been compared with the triaxial test results from reconstituted samples. The triaxial test results have also been compared with field CPT test results.

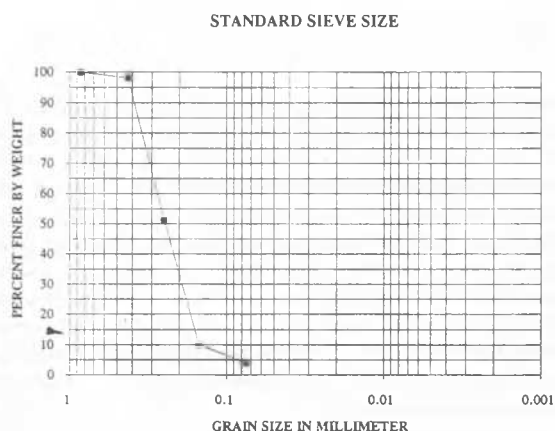


Figure 1: Typical Grain Size Distribution Curve

SAMPLE EXTRUSION AND SPECIMEN PREPARATION

Sometimes drained samples are frozen in the field to further guard against the damage caused by handling and shipping. However, at Chashma, tube samples were only waxed and air lifted to CMTL without freezing. In CMTL, the first samples were prepared by using a simple extruder but in the process the samples were disturbed. Further, those samples which were extruded without any damage did not remain intact and collapsed during trimming and installation in triaxial cell. Later on, small specimens of 50 mm diameter were obtained by pushing sharp edge tubes into the large diameter (70 mm) tubes. This method also failed as the specimens could not stand and collapsed during the extrusion process. In brief, by all means, sample extrusion and specimen preparation was impossible using routine laboratory methods. Samples were damaged either during extrusion, trimming, placing on triaxial pedestal or during placement of the membrane. Therefore, it was decided to prepare the samples by freezing.

Freezing

Freezing has been shown to be a successful tool for extrusion of undisturbed sandy samples. For cohesionless materials, the freezing process facilitates the extrusion of samples and subsequent specimen preparation without significant loss of soil structure (Walberg, 1978). Ishihara and Silver (1977), used freezing techniques to prepare 50 mm diameter tube samples and they demonstrated that by freezing, the samples were least disturbed.

At CMTL the extrusion and sample preparation involved the following steps.

1. It was decided to prepare static and dynamic triaxial

testing specimens to the full size diameter of the sample tubes. For this purpose, sample tubes were first cut to the required specimen height. Samples with excessive water were then drained to give moist conditions before placing them in the freezer. On the other hand specimens with little water were sprinkled with water so that there was sufficient water to make an ice joint between the contact points of particles. Before placing in the freezer the specimens were covered at both ends with steel plates to avoid any disturbance of material at the open ends. The samples were kept in the freezer for about 48 hours.

2. After placing specimens in the freezer, it was initially noticed that water was accumulating at the bottom of the specimen, as the water was draining down from the top of the specimen. To overcome this problem cold water was lightly sprinkled on the top of the specimen. To promote the uniform distribution of moisture, the specimens were rotated top to bottom several times during the freezing process. During freezing, utmost efforts were made to avoid the localized accumulation of water in the specimen.

3. After being kept in freezer for about 48 hours, the samples were extruded using a simple hydraulic extruder. Figure 2 shows an extruded sample after freezing in the freezer. It was observed that during extrusion the exterior surface of the specimen became slightly disturbed due to thawing. To avoid this problem, a special prefrozen clamped jacket was used to help sample extrusion, Figure 3. The jacket was fabricated with a longitudinal slit to close tightly around the specimen.

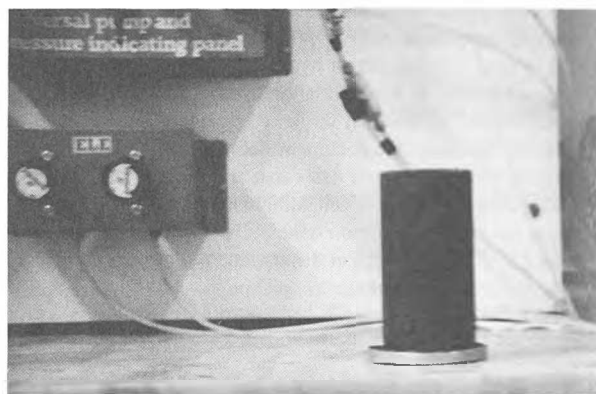


Figure 2: A Typical Frozen Sample

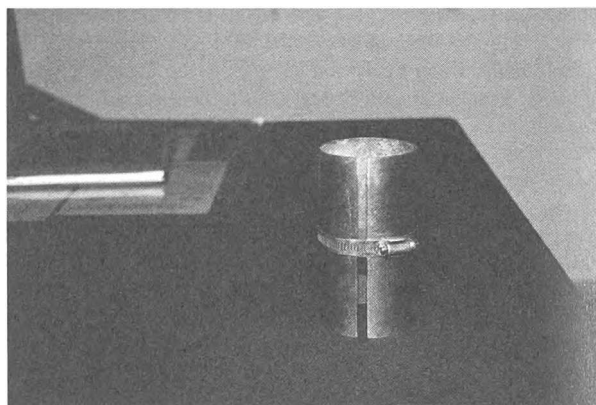


Figure 3: A Locally Fabricated Clamped Jacket

4. After extruding the frozen specimens, they were fit in the clamped jacket and were again placed in the freezer for about 4 hours to harden them. Hand gloves were used to take the specimens out of freezer to minimize sample warming.

5. The frozen samples, within their clamped jacket, were then placed on the triaxial pedestal; the jacket was removed by unscrewing the clamps; and specimen dimensions were measured rapidly. The rubber membrane was installed, the cell was assembled, and a small vacuum pressure was applied to the specimen while it was allowed to thaw. During thawing the height of the specimen was monitored to allow for the calculation of the thawed specimen density. The resulting triaxial specimen was found to have effectively the same density as the sample in the thin walled sampler.

6. Since the percentage of fines was negligible and that too was cohesionless, there was no disturbance of sample due to expansion during freezing. The triaxial test was performed with a normal procedure.

COMPARISON BETWEEN UNDISTURBED AND REMOULDED SPECIMENS

As mentioned earlier that during geotechnical investigations for Chashma Hydropower Project very extensive field and laboratory testing was performed. The Laboratory testing program also included static and dynamic triaxial testing on reconstituted sandy samples. For variety of geotechnical studies reconstituted sandy samples of selected grading, relative density and moisture content were tested in CMTL. The minimum and maximum densities were determined in accordance with ASTM (D 2049-69). These densities were used to calculate the dry density at a given relative density. The soil samples of desired dry density were prepared in a cylindrical mould of 70 mm diameter and 140 mm height. To achieve a uniform density along the sample height, the soil was compacted in 10 layers using the under compaction technique as suggested by Ladd (1978).

After the samples were extruded, they collapsed and disturbed as happened during the extrusion process of undisturbed sandy samples. So it was decided to use the freezing technique for extrusion of reconstituted sandy samples also. Since the reconstituted specimens were prepared under proper controlled conditions, the triaxial test results of these samples were assumed to be very reliable. It provided a good opportunity to compare the triaxial test results of undisturbed and reconstituted sandy samples and to make sure the validity of triaxial test results of undisturbed frozen sandy samples.

Mostly the static triaxial tests were performed "Consolidated Undrained" with pore pressure measurement. The effective shear strength parameters obtained for Chashma sands were generally in the expected range of such type of soils. The angle of internal friction varied between 32 and 39 degrees and cohesion generally ranged from 0 to 50 Kpa. For comparison of triaxial test results between undisturbed and reconstituted sandy samples, the respective samples having very close dry densities and gradings were selected. The comparison did not reveal any significant variation in the shear strength parameters of both types of samples. However, some of the undisturbed samples had slightly higher angle of internal friction about 2 to 3 degrees than that of reconstituted samples. This comparison showed that the freezing technique provides very satisfactory test results for clean sands.

COMPARISON BETWEEN LABORATORY TRIAXIAL AND FIELD CPT RESULTS

During in-situ field testing, various penetration tests were performed at many locations of the project site. In addition to that four types of penetration tests which included Standard Penetration (SPT), Cone Penetration (CPT), Dilatometer and Pressuremeter were performed at the proposed location of power house building. Since these tests were performed very close to each other it was a good opportunity to develop various correlations among these test results for local sands. Hussain et al (1995) developed various correlations among the field penetration test results for Chashma sands. Since this paper is basically dealing with triaxial laboratory testing by freezing, therefore it will limit to the theme of the paper. As in the preceding section a comparison was made between the triaxial test results of undisturbed and reconstituted frozen samples, in this section a comparison will be made between the triaxial test results of undisturbed sandy samples and field CPT test results and will be discussed very briefly. The comparison will give a feeling of the validity of triaxial test results using freezing technique.

Undisturbed sandy samples were obtained from the bore holes at regular interval prior to Standard Penetration Testing. Triaxial laboratory testing on these samples using freezing technique provided shear strength parameters of sandy soil at relative depths along the bore hole. These shear strength parameters have been compared with the shear strength parameters obtained at the same depth through insitu Cone Penetration Test (CPT). But, for comparison of these results the data obtained through triaxial tests on undisturbed frozen samples is very limited. Some of the samples retrieved from the bore holes were not enough to perform complete set of triaxial testing. Similarly some of the samples were not of good quality. Therefore laboratory testing was limited to the selective samples. As some of the samples were short, only one or two specimens were tested for triaxial testing. For comparison with CPT test results at respective depths, only those triaxial test results were considered where 2 or 3 specimens were tested. However, test results of single specimens were also given due consideration while comparing with CPT results where triaxial data was missing for larger depth interval.

The comparison between these two tests at respective depths is only an approximation. Undisturbed triaxial test specimens are prepared from about one meter long tube and CPT results are generally for localized soil column representing a few centimeters along the penetration depth. Therefore, in case of larger variation in soil profile, both the results may be totally different from each other. This comparison is only feasible if soil type and soil consistency does not vary considerably along the penetration depth. In case of Chashma soils the strata are generally uniform for larger depths and from place to place. Similarly the consistency does not vary significantly along the penetration depth. Hence the comparison between these two tests at respective depths is very reasonable and valid.

A direct correlation between cone resistance and friction angle ϕ was developed by Durgunoghi and Mitchell (1975). Their correlation has been used to estimate the friction angle along the CPT depth. The following table shows a comparison of friction angles obtained through laboratory triaxial tests and CPT procedure at the same depths.

TRIAXIAL VERSES CPT TEST RESULTS

DEPTH (m)	PEAK FRICTION ANGLE (DEGREES)	
	TRIAXIAL	CPT
9.5	35	39
14.0	35	36
17.0	32	37
18.5	35	35
21.5	38	35
23.0	36	36
24.5	35	37
26.0	34	37
27.5	35	38

From the above table it may be seen that the friction angles obtained through in-situ CPT test are, in general, slightly higher than those obtained through laboratory testing procedure. Apart from the fact that CPT results show slightly higher ϕ values than the triaxial tests, the consistency of the results confirms the validity of freezing technique for laboratory testing on sandy samples.

CONCLUSIONS

1. Extrusion of undisturbed sandy samples from tubes and preparation and setting up of sandy soil specimens was not possible in spite of all the precautions.
2. Freezing of tube samples was a successful technique in preparation and setting up of samples in triaxial testing machine.
3. Comparison of undisturbed sandy samples and reconstituted samples of about same densities prepared by freezing provided approximately similar results.
4. Comparison between insitu cone penetration tests and laboratory triaxial tests revealed very consistent results.

REFERENCES

Ishihara, K. and Silver, M. L. 1977; "Large Diameter Sand sampling to Provide Specimens for Liquefaction Testing". 9th International Conference on Soil Mechanics and Foundation Engineering, Tokyo, Japan.

Hussain S., Kibria S, and Haq I.U. (1995), "Insitu Penetration Tests in Clean Sands, Chashma, Pakistan." 10th Asian regional Conference on Soil Mechanics and Foundation Engineering, Aug-29 - Sept. 2, 1995, Beijing, China. ISSMFE.

Hvorslev, M. J. (1948), Subsurface Exploration and Sampling of Soils for Civil Engineering Purpose, Report of Committee on Sampling and Testing, Soil Mechanics and Foundation Division, ASCE, 521 PP.

Ladd, R. S., Preparing Test Specimens using under compaction; GTJ, ASTM, Vol-1, No. 1, 1978, P.P. 16-23.

Yoshimi, Y. and Hatanaka, M. 1973), "In-Situ Density Measurement of a loose Sand Deposit". Proc. 10th Symposium on Disaster Science, PP-341-342.

Yoshimi, Y and et. al. (1977) "A Simple Method for Undisturbed Sand Sampling by Freezing." 9th International Conference on Soil Mechanics and Foundation Engineering, Tokyo, Japan.

Walberg, F. C. (1978), "Freezing and Cyclic Triaxial Behaviour of Sands." Technical Note, Journal of the Geotechnical Engineering Division, ASCE, Vol 104, No. GT5, PP. 667-671