TECHNICAL NOTES※

SPT PRACTICE SURVEY AND COMPARATIVE TESTS

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ABSTRACT

A questionnaire survey was conducted to ascertain the current practice of standard penetration test (SPT) in Japan. All 53 respondents perform the test according to the Japan Industrial Standard using drilling mud to stabilize boreholes in sand below groundwater table. The cathead and rope method is more popular than the trip monkey method, although about 75 percent of the respondents have used either method. The cathead and rope method is typically performed by turning a 15 mm manila rope twice around a 120 mm cathead.

A level site in Niigata where the soil profile consisted of horizontal sand strata enabled a direct comparison of the N -values determined by the cathead and rope method and those by the trip monkey method. The test results show that the cathead and rope method yielded significantly higher N -values than the trip monkey method where N exceeded about 24, whereas either method produced about the same N -values where they were below 12.

Key words : drilling, penetration test, sand, site investigation, sounding, test equipment, test procedure (IGC : C3/C9)

INTRODUCTION

For the last two decades, the standard penetration test (SPT) in Japan has been performed according to the Japan Industrial Standard (JIS) A 1219-1961, "Method of Penetration Test for Soils," that was based on the American Society for Testing and Materials (ASTM) D-1586-58 T. Some essential features of the JIS method are described below although the method has previously been introduced in English (Muro-machi et al, 1974).

"*Sampler*: Steel split barrel sampler as

shown in Fig.1(a).

Sampler rods: Hollow steel rods of either 40.5 mm OD and 31 mm ID, or 42 mm OD and 32 mm ID.

Anvil: Steel anvil typically as shown in Fig. 1(b).

Hammer: Steel hammer weighing 63.5 kgf (623 N) without the chain, constructed essentially as shown in Fig.1(c).

Boring: Borehole diameter shall be from 65 to 150 mm as a rule. The hole shall be cleaned after reaching a desired depth. Care shall be taken not to disturb the soil below the borehole during the drilling and cleaning

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Fig. 1. Apparatus for JIS A 1219-1961 "Method of penetration test for soils": (a) sampler assembly with specified dimensions, (b) anvil shown as an example, and (c) hammer shown as an example (all dimensions in mm)

operations.

Penetration test: the sampler-rod assembly shall be lowered gently in the borehole. Sampler penetration shall consist of a 15 cm seating drive, a 30 cm test drive, and an approximately 5 cm additional drive which is optional. During the test drive, the hammer shall be dropped freely from a height of 75 cm. the number of blows during the 30 cm test drive is recorded as an N -value. The test drive may be terminated at 50 blows unless more blows are necessary, and the penetration distance during 50 blows is recorded."

It may be noted that except for the sampler dimensions (Fig. 1(a)), the hammer weight and the fall height, the specifications are either qualitative, e.g., "the hammer shall be dropped freely," or only a range of quantities are indicated, e.g., with respect to the borehole diameter.

In view of recent studies (e.g., Kovacs et al, 1977; Schmertmann, 1978) indicating that such factors as a borehole diameter, an anvil size, and a method of dropping the hammer have a significant influence on N -values, it is relevant to obtain information on details of the apparatus and procedure

being used in the field. The object of this study is to obtain such information by sending out a questionnaire to engineering firms who practice subsurface investigations, and to apply a representative method based on the survey to a site in Niigata, Japan, to study the effects of hammer dropping methods which have been known to cause considerable variation in N -values.

SPT PRACTICE SURVEY

On January 28, 1981, the senior author mailed a questionnaire to 80 offices of 23 firms in various parts of Japan who practiced subsurface investigations for geotechnical engineering purposes. In order to effect nationwide coverage, separate forms were sent to branch offices as well as main offices. Of the 80 sent out 53 replies were received. The recovery ratio of 66 percent may be judged satisfactory considering the detailed nature of the questionnaire. In terms of the sample size, however, the survey was not as extensive as a similar one conducted by the ASTM that received 116 replies (Kovacs, 1981).

The results of the survey are summarized in Table 1. The survey may be considered to show a nationwide trend although Shikoku and Okinawa were not included (Item 1).

All the respondents use samplers whose outside and inside diameters are as specified by the JIS (Items 2(a) and 2(b)). But only eight respondents (15 percent) seem to provide four vents as shown in Fig. 1(a) (Item 2(c)) while a majority (75 percent) provide two holes. All the respondents use sampler rods of the specified sizes (40.5 or 42 mm), although one respondent uses heavier rods occasionally (Item 3). About one half of the respondents seem to use anvils and hammers of the dimensions as shown in Figs. 1(b) and 1(c) (Items 4 and 5).

Most respondents (96 percent) mainly use a 66 mm borehole which is near the lower limit of the range specified by the JIS (Item 6(a)). All the respondents use drilling mud to stabilize the borehole when drilling in

Table 1. Results of the SPT practice survey

Item No.	Reply	No. of Replies	Remarks	Item No.	Reply	No. of Replies	Remarks
1	Geographical distribution Sapporo Sendai Tokyo and vicinity Niigata Nagoya Osaka and vicinity Hiroshima and vicinity Fukuoka and vicinity	6 5 13 2 6 12 4 5		7	Standard penetration test (a) Usual crew size, persons: 2 3 No reply	49 2 2	
2	Sampler (a) Outside dia. in mm: 51* (b) Inside dia. in mm: 35* (c) Vents: Dia. in mm No. 5 7-8 9-10 11-12 13-14 20 var. Total 6 1 1 3 3 4 2 1 1 4* 1 1 3 3 4 2 1 8 2 2 3 20 7 4 2 1 39 1 1 2 2 1 1 1 3 Others 2 2 2 1 2	53 53	*JIS Fig.1(a)		(b) Positive replies for each method for driving hammer: Cathead & rope Trip monkey Automatic	40 39 14	
3	Dia. of sampler rod in mm 40.5* 40.5-42* (mostly 40.5) 40.5-50 (mostly 40.5)	50 2 1	*JIS		(c) Percentage use reported by 50 respondents: Percentage use 0 25 50 75 100 Cathead & rope Trip monkey Automatic	1 3 7 26 11 7 0 12 6 2 0 2	
4	Anvil (a) Diameter in mm: 70 75* 80-90 100 No reply (b) Height in mm: 50 60* 61-70 71-80 81-90 91-100 No reply	1 26 18 5 3 1 25 13 5 2 6 1	*JIS Fig.1(b)	8	Details of cathead and rope method (a) Rope type: Manila Others (b) Rope dia. in mm: 9-11 12-14 15-17 18-20 21-30 No reply (c) Cathead dia. in mm: 100-109 110-119 120-129 130-139 140-159 160-210 No reply (d) No. of turns of rope around cathead: 1 1-2 2 2-3 3 (e) Method to release rope for dropping hammer: Rope completely thrown off cathead Rope partially thrown off cathead No reply (f) Operating rpm of cathead: 20-30 40-50 60-70 80-100 150-250 Others (g) Crown sheave dia. in mm: 50-85 100 120-125 130-135 150 200	35 5 7 11 14 3 4 1 6 6 14 6 4 2 2 6 4 25 3 2 19 7 14 6 5 11 6 3 9 5 11 12 3 8 1	Median =15 mm Median =120 mm Median =60 rpm Median =120 mm
5	Hammer (a) Steel cylinder with center hole: (b) Outside dia. in mm: 150-170 180 190 200* 210-220 Others (c) Center hole dia. in mm: 42 44* 45 46-49 50-53 Others (d) Height in mm: 240-270 280* 300-330 340-370 380-410 Others	53 4 9 4 30 2 4 5 18 15 3 9 3 7 19 7 10 5 5	*JIS Fig.1(c)				
6	Boring (a) Borehole dia. mainly used in mm: 66 86 (b) Smallest borehole dia. in mm: 56 60 66 (c) Largest borehole dia. in mm: 66 86 96 101 111 116 150 (d) Method to stabilize borehole for sand below groundwater table: Casing and mud Mud only	51 2 6 1 46 6 19 1 4 2 20 1 40 13	JIS: 65-150				

sand below groundwater table either with or without casing (Item 6(d)). Although not included in the questionnaire, it is customary to use a rotary drilling equipment, the hole being advanced with a hand lever (Muro-machi et al, 1974).

As shown in Item 7(a), most respondents report that their standard penetration tests are usually carried out by two-man crews. The respondents were asked to check three boxes concerning the method of dropping the hammer: the cathead (pulley) and rope method, the trip monkey (*tonbi* in Japanese) method, and other methods, and indicate percentage of use if more than one method were used. As shown in Item 7(b), about 75 percent of the respondents use the cathead and rope method or the trip monkey method, whereas 26 percent use some form of automatic methods. The replies from 50 respondents who reported the percentage of use are summarized as histograms in Item 7(c), which show that the number of respondents who use a certain method more than 75 percent of the time is as follows:

The cathead and rope method.....26

The trip monkey method.....12

Automatic methods2

Thus, the cathead and rope method is by far the most popular method among the respondents, except in Sapporo where all six respondents use the trip monkey method only.

Fig. 2. A popular type of cathead for the SPT

It appears that the cathead and rope method is typically performed by turning a 15 mm manila rope twice around a 120 mm cathead which spins at a speed of 60 rpm (Item 8). A typical cathead with a free end as shown in Fig. 2 enables the operator to throw the rope completely off cathead when he lets the hammer drop. Nineteen respondents report that they use such a procedure, and additional seven respondents throw part of the rope, e.g., one turn out of two, off the cathead (Item 8(e)). Thus, 26 respondents report that they remove the rope from the cathead one way or the other in an attempt to reduce rope friction when the hammer falls.

COMPARISON BETWEEN THE TRIP MONKEY METHOD AND THE CATHEAD AND ROPE METHOD IN A SAND DEPOSIT

It was reported that the cathead and rope method tended to yield significantly higher *N*-values than a free-fall method (Schmertmann, 1978). A previous attempt in Japan to compare the trip monkey method and the cathead and rope method in the field (Kanto

Fig. 3. Location of test site and boreholes

Table 2. Apparatus and procedure for the SPT in Niigata

Items	Dimensions and procedure	Remarks
Sampler	Standard dimensions with two 11.3-mm vents	Fig. 1(a)
Sampler rods	40.5 mm OD	JIS
Anvil	88 mm dia., 64 mm high	
Hammer	180 mm OD, 48 mm ID, 340 mm high	
Borehole	66 mm dia., stabilized with drilling mud	
Cathead	130 mm dia., 100 rpm	Fig. 2
Rope	Used manila rope, 15 mm dia., 2 turns around cathead. Not thrown off when released.	7/4 turns
Crown sheave	125 mm dia.	
Trip monkey
Crew	2 men	

Soil Investigators Association, 1976) produced widely scattered results as reported by Tokimatsu and Yoshimi (1981). It is conceivable that the scatter included systematic errors due to variations in the apparatus and the procedure in addition to random variations in the soils. The results of the current survey were expected to enable the authors

to select representative methods by specifying conditions close to the median values for the variable quantities as shown in Table 1, thus minimizing the systematic errors. Furthermore, the availability of a level site in Niigata city as shown in Fig. 3(a) consisting of nearly horizontal sand strata prompted the authors to have standard penetration tests performed there in an attempt to make a meaningful comparison between the trip monkey method and the cathead and rope method.

As shown in Fig. 3(b), the standard penetration tests were performed at six equally spaced boreholes arranged in a circle 4 m in diameter. The standard penetration tests were performed at 75 cm interval to a depth of 11 m using the trip monkey method in Boreholes 1, 2 and 3, and the cathead and rope method in Boreholes 4, 5 and 6. The apparatus and procedure for the standard penetration tests are summarized in Table 2, most of which represent the median values of Table 1. Thus, the standard penetration tests for the present study may be considered to represent average conditions of the current SPT practice in Japan, except for the 75 cm interval that differs from a commonly used

Fig. 4. Results of SPT in Niigata

Fig. 5. Comparison of trip monkey method and cathead and rope method

1 m interval. The unorthodox 75 cm interval was expected to yield more test data with a minimum of interference.

A two-man crew performed the standard penetration tests, with one operator handling the rope for all tests, and the other operator attending the trip monkey for all tests in Boreholes 1, 2 and 3. The operators were told to perform the tests as they would normally do on routine jobs. It is conceivable, however, that the test setup that did not appear routine could have influenced the operators to be more careful than usual.

Fig. 4 shows the soil profile, grain size data for Boreholes 1, 2 and 3, and N -values in all six holes. Except for the cohesive soil

layer at shallow depths, the soil profile consists of very clean, uniform, fine sands whose N -values range from 3 to 43. Figs. 4(c) and 4(d) show that the variation in the N -values is rather small among the three boreholes for each driving method, and that the N -values determined by the cathead and rope method are higher than those by the trip monkey method at depths below 6 m. The general shapes of the curves in Fig. 4 are quite similar, confirming the assumption that the soil strata are uniform in the horizontal direction.

The standard penetration tests were performed in the order of the borehole number starting with Borehole 1. It was expected that the 2 m interval between the boreholes was sufficient to minimize possible effects of the test sequence. Although there was no positive proof that such sequence effects were absent, Fig. 4 does not appear to show that they were present either.

Fig. 5 is shown to facilitate comparison of the trip monkey method and the cathead and rope method at each depth. The data of Fig. 4 are replotted in Fig. 5(a) in which the mean value and the range of the N -values are shown separately for the two driving methods. For depths below 7 m, Fig. 5(a) shows clearly that a significant difference exists between the N -values determined by the two methods, in that the ranges do not overlap each other at all.

The mean N -values of Fig. 5(a) are replotted in Fig. 5(b), which shows that the driving methods do not seem to affect the SPT results when the N -values are below 12 or so, whereas the effect of the driving methods becomes significant when the N -values exceed about 24, with the cathead and rope method producing greater N -values than the trip monkey method. Fig. 5(b) shows much less scatter than a similar plot reported previously (Tokimatsu and Yoshimi, 1981) because mean N -values are used and a single crew produced all the data in soil strata that are uniform in the horizontal direction.

SUMMARY AND CONCLUSIONS

The results of the practice survey of the standard penetration test in Japan may be summarized as follows:

1. All the 53 respondents perform the standard penetration test according to the JIS A 1219-1961 except for the number of vents in the sampler.

2. All the respondents use drilling mud to stabilize the borehole in sand below groundwater table either with or without casing.

3. Twenty-six respondents use the cathead and rope method more than 75 percent, whereas 12 use the trip monkey method more than 75 percent.

4. The cathead and rope method is typically performed by turning a 15 mm manila rope twice around a 120 mm cathead which spins at 60 rpm.

The standard penetration tests in a deposit of clean sand in Niigata showed that the cathead and rope method produced significantly higher N -values than those determined by the trip monkey method where N exceeded about 24, but that either method produced about the same N -values where they were below 12.

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