Reference test procedure for field vane tests

Danish Geotechnical Society - Field Committee
Revision 3
August 1999 (English translation September 2009 - In case of disagreement the Danish version applies)

1. INTRODUCTION

This reference test procedure provides a guideline for execution of field vane tests in cohesive soils. A shear vane test determines the vane strength of the soil. Normally this indicates the undrained shear strength of the soil.

2. EQUIPMENT

2.1 General

The vane probe consists of two blades mounted perpendicular to each other at the end of a cylindrical rod. The blades have rounded corners and sharpened edges. Just above the blades a ring is inserted to reduce the friction between the rod and the penetrated soil.

Traditionally the torque on the rod is measured by a spring scale or a dial indicator spring connecting a fixed arm with the handle. It is this type of equipment that is described below.

Alternatively, the measurement can be performed by a torque wrench. If a torque wrench is applied, it shall be verified that the level of accuracy and quality assurance complies with the description for the traditional equipment.

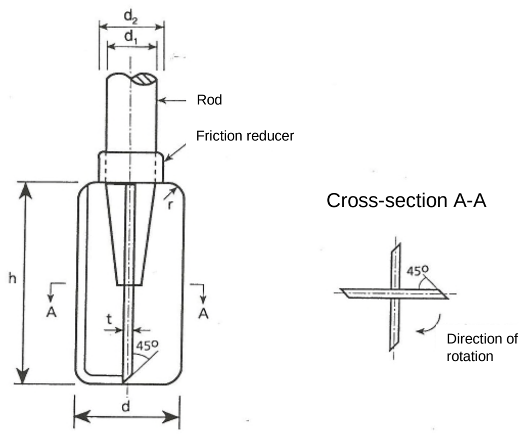

Fig. 1. The vane probe. The figure shows a hand vane A

A “deep vane” equipment is applied in the bottom of a borehole in connection with the execution of a geotechnical investigation boring. The “hand vane” equipment has a low weight and is designed for shallow tests.

Different dimensions of the blades are used for measurements in cohesive soils with different strengths. The connection of the blades to the rod is shown in Figure 1. The blades are welded to the conical tip of the rod.

The height of the vane is two times the diameter (however, for V9.2 four times the diameter), all corners are rounded, but the edges are sharpened. The traditionally applied vane blade dimensions are shown in Table 1, where V signifies deep vanes and HV hand vanes. Generally, deviations of *h* and *d* up to ±2 % are accepted.

Table 1. Geometry of the vanes

Vane No	***H* (mm)**	***d* (mm)**	***r* (mm)**	***t* (mm)**	**d_1 (mm)**	**d_2 (mm)**
V4	80	40	10.0	3.0	20	26
V5	100	50	12.5	3.0	20	26
V7.5	150	75	18.8	3.0	20	26
V9.2	350	92	23.0	3.0	20	26
HVA	66	33	7.0	2.5	15	18
HVB	96	48	10.0	2.5	15	18

2.2 Deep vane

Four vane sizes are applied: V4, V5, V7.5 and V9.5.The number denotes the vane diameter in cm.

The torque is measured by a 50 kg dial indicator spring (dynamometer) with a moment arm (*a*) of 300 mm (measured at ¾ excitation of the dynamometer). The equipment rod is shown in Figure 2.

The equipment shall be suspended by a clutch with low friction to prevent penetration into the soil during the test. For greater depths a ball bearing is applied to reduce the friction.

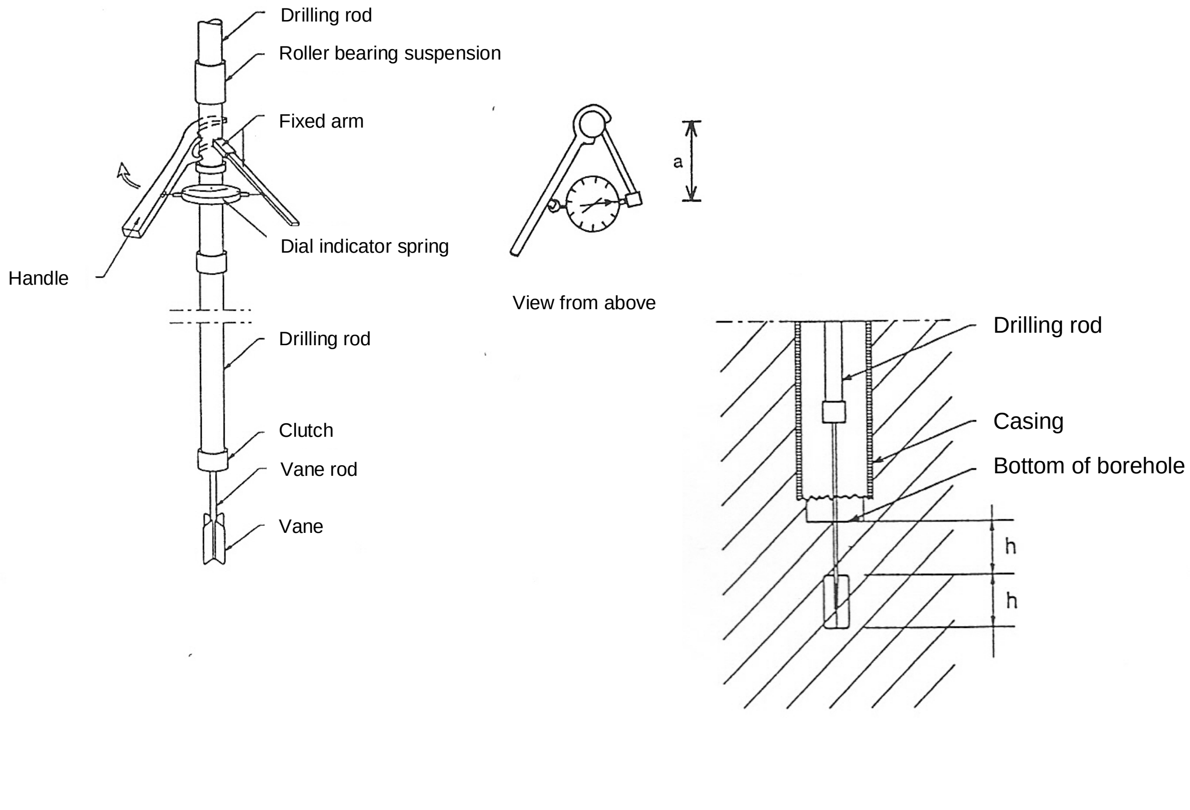

Fig. 2. The deep vane equipment

2.3 Hand vane

Two vane sizes are applied, HVA and HVB, with vane diameters of 33 and 48 mm, respectively (all dimensions are given in Table 1).

The torque is measured by a 25 kg spring scale (an app. 250 N dynamometer). The arm (*a*) shall be 175 mm at 6 kg and 162 mm at full range (25 kg). The equipment is shown in Figure 3. For tests in deep excavations the rod can be extended.

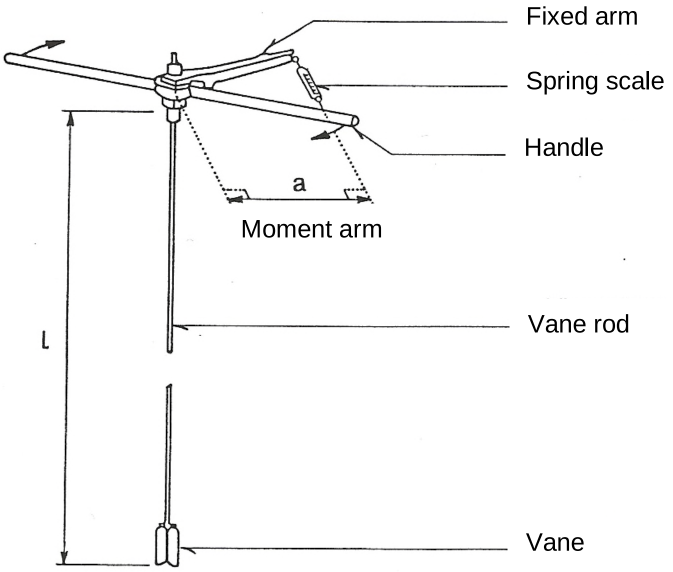

Fig. 3. The hand vane equipment

3. TEST PROCEDURE

Before the execution of a vane test it shall be controlled that the vane blades are undamaged. The vane size should be chosen with respect to the actual soil in order that the maximum value at failure will occur in the upper 2/3 of the total range of the device.

Before all tests in boreholes loose soil at the base of the hole must be removed and it shall be assured that an excess pore pressure exists in the borehole.

The vane shall be pressed or hammered gently into the soil without rotation, until the base of the blades is two blade heights below the base of the borehole or the soil surface. However, a depth of 0.2 m below the base of the borehole is normally used for vane numbers V4, V5, HVA and HVB, while depths of 0.3 m and 0.6 m are used for vane number V7.5 and V9.2, respectively.
Normally the test is carried out immediately after the vane has been installed.

The turn of the handle shall be performed in a steady manner as slowly as possible. The maximum speed of rotation should be 1 rpm (revolution per minute). The size of the vane and the measured maximum torque must be written in a test report together with the depth below soil surface to the base of the blades.

After each test in undisturbed soil the vane shall be given 10 revolutions and the test is repeated. If less than 10 revolutions are applied this must be stated in the test report. The measured maximum torque must also be written in the test report.

When vane numbers V4 and V5 are used the procedure mentioned above (test in undisturbed and remoulded soil) may be repeated 0.2 m below the first test. This is called a double test. Tests and double tests in boreholes are normally carried out per 1.0 m depth. Tests with vane numbers HVA and HVB are normally carried out per 0.2 m depth.

During the execution of the test the following incidents shall be observed:

a. A large variation of the resistance e.g. because of stones. The observation shall be reported, but no measurement is written in the test report.
b. Uneven resistance e.g. because of sand grains. The observation shall be reported and the measurement is written in the test report.

4. TEST REPORT

The results of all vane tests shall be specified in the test report. The specifications must include the following information:

a. Test number and position.
b. Vane size.
c. Identification of the spring.
d. Depth below soil surface to the base of the blades.
e. Maximum load in undisturbed soil.
f. Maximum load in remoulded soil.
g. Observations e.g. because of sand, gravel or stones.

5. INTERPRETATION OF TEST RESULTS

The vane strength of the soil shall be determined by using the equation:

$$c_v = \frac{P g a}{M}$$

Where:

c_v is the undrained vane strength in undisturbed soil. It may be substituted by the remoulded strength c_{vr}

$P g$ is the measured force on the handle (P is in kg and therefore multiplied by g = 9.807 m/s^2)

a is the moment arm in m

M is the static moment of the total shear surface in m^3.

M has three components:

$$M = M_1 + M_2 + M_3$$

Where M_1 concerns the vertical edges of the blades, M_2 concerns the top and base of the blades and M_3 concerns the circular corners of the blades:

$$M_1 = \frac{1}{2}\pi d^2 (h - 2r)$$

$$M_2 = \frac{4}{3}\pi (\frac{d}{2} - r)^3$$

$$M_3 = 2\pi^2 r (\frac{d}{2} - r)^2 + \pi^2 r^3 + 8\pi r^2 (\frac{d}{2} - r)$$

a varies typically 10% (dependent on the load) for vane numbers HVA and HVB, whereas it is almost constant for vane numbers V4-V9.2. *a* complies approximately with:

$$a = \alpha + \beta P$$

Then the vane strength is written:

$$c_v = \frac{Pg(\alpha + \beta P)}{M} = K_1 P + K_2 P^2$$

Where:

$$K_1 = \frac{\alpha g}{M} \qquad K_2 = \frac{\beta g}{M}$$

In Table 2 values are given for all the vane sizes mentioned previously, and the vane strength at maximum load can be calculated.

Table 2. Calculation of vane strength at maximum load

Vane No.	α **[mm]**	β **[mm/kg]**	***M*** **[m³]**	K_1 **[kN m⁻² kg⁻¹]**	K_2 **(kN m⁻² kg⁻²]**	P_{max} **[kg]**	$c_{v,max}$ **[kN/m²]**
V4	300	0	$0.2097\cdot10^{-3}$	14.030	0	50.0	701
V5	300	0	$0.4096\cdot10^{-3}$	7.183	0	50.0	359
V7.5	300	0	$1.3820\cdot10^{-3}$	2.130	0	50.0	106
V9.2	300	0	$4.7588\cdot10^{-3}$	0.6182	0	50.0	31
HVA	179.1	-0.6842	$0.1201\cdot10^{-3}$	14.624	-0.0558	25.0	331
HVB	179.1	-0.6842	$0.3703\cdot10^{-3}$	4.743	-0.01812	25.0	107

The vane strengths at loads from zero to maximum are given in Table 3.

Table 3. Conversion to vane strength

P [kg]	c_v [kN/m^2]					
	HVA	**HVB**	**V4**	**V5**	**V7.5**	**V9.2**
1	15	5	14	7	2	0.6
2	29	9	28	14	4	1.2
3	43	14	42	22	6	1.9
4	58	19	56	29	9	2.5
5	72	23	70	36	11	3.1
6	86	28	84	43	13	3.7
7	100	32	98	50	15	4.3
8	113	37	112	57	17	4.9
9	127	41	126	65	19	5.6
10	141	46	140	72	21	6.2
11	154	50	154	79	23	6.8
12	167	54	168	86	26	7.4
13	181	59	182	93	28	8.0
14	194	63	196	101	30	8.7
15	207	67	210	108	32	9.3
16	220	71	224	115	34	9.9
17	232	75	238	122	36	10.5
18	245	80	253	129	38	11.1
19	258	84	267	136	40	11.7
20	270	88	281	144	43	12.4
21	282	92	295	151	45	13.0
22	295	96	309	158	47	13.6
23	307	100	323	165	49	14.2
24	319	103	337	172	51	14.8
25	331	107	351	180	53	15.5
26			365	187	55	16.1
27			379	194	57	16.7
28			393	201	60	17.3
29			407	208	62	17.9
30			421	215	64	18.5
31			435	223	66	19.2
32			449	230	68	19.8
33			463	237	70	20.4
34			477	244	72	21.0
35			491	251	75	21.6
36			505	259	77	22.3
37			519	266	79	22.9
38			533	273	81	23.5
39			547	280	83	24.1
40			561	287	85	24.7
41			575	294	87	25.3
42			589	302	89	26.0
43			603	309	92	26.6
44			617	316	94	27.2
45			631	323	96	27.8
46			645	330	98	28.4
47			659	338	100	29.1
48			673	345	102	29.7
49			687	352	104	30.3
50			701	359	106	30.9

6. QUALITY ASSURANCE

The moment arm, i.e. the distance from the axis of rotation to the axis of the load cell, shall be 300 mm when P = 35 kg in tests with vane numbers V4-V9.2. Likewise it must be 175 mm and 162 mm at 6 kg and 25 kg, respectively in tests with vane numbers HVA and HVB. As an alternative to table 3 the calculation of c_v may be based directly on the measured values of the moment arm.

The load cells shall be calibrated frequently. Well known weights may be used for this purpose. A defective load cell must not be employed.

It shall be controlled that the vane blades have no damages after each series of tests. Blades that are twisted or defer from the dimensions described in section 2.1 must not be employed.

In tests with vane numbers V4-V9.2 it shall be assured frequently that the ball bearings installed to reduce friction are working properly. The vane should be rotated one revolution when it is just above the base of the borehole.

The total inaccuracy of the equipment is expected to be within ±10 % when the described conditions are fulfilled. However, worn vane blades may increase this value.