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Characteristic opening size of geotextiles: European intercomparison tests for standardisation

Y. H. Faure
IRIGM University of Grenoble, France

ABSTRACT : The european standardisation of the wet sieving test method to determine the Characteristic Opening Size of the geotextiles is well in progress. A first draft (PrEN ISO 12956) was recently submitted to enquiry to the european countries. At the same time intercomparison tests occurred. Nine laboratories participated to estimate the reproducibility of the procedure and the accuracy of the test method. A sequence of tests was performed on different geotextile structures and different soils. The work demonstrated that the wet sieving test can be used to measure the Characteristic Opening Size of geotextiles with a standard deviation of between 8 to 14 %.

1. INTRODUCTION

For many applications an indication of geotextiles porometry is required. This is a common use for geotextiles in function such as drainage trenches, dams, roads, railways, erosion control, landfills and slope drainage. As the complete porometric curve cannot be determined, a specific index parameter, called the « Characteristic Opening Size » (COS), is defined by the size of the greatest particle which can pass through the geotextile. The easiest method available mostly for geotextiles is a sieving method. But there are mainly three existing national standards : dry sieving in UK, Belgium and the Netherlands, wet sieving in Germany, Austria and Switzerland, and hydrodynamic sieving in France and Italy.

After a lot of discussions, a compromise was obtained : the wet sieving method was adopted by the CEN Technical Committee 189 / Working Group 4. But before to be standardised, this test has to be validated and the influence of some specific parameters have to be precise in order to determine the test conditions which give the best reproducibility, i.e. the lowest deviation when the test is done in a lab or in one another. An intercomparison tests programme was proposed and 9 european laboratories accepted to participate (table 1).

Table 1 : Laboratories participating in Intercomparison Tests

Initials	Name of the laboratory	Town	Country
BAW	Bundesanstalt für WasserBau	Karlsruhe	Germany
BTTG	British Textile Technology Group	Manchester	United Kingdom
CRPHT	Centre de Recherche Public Henri Tudor	Luxembourg	Luxembourg
CEMAGREF	Centre d'Etudes du Machinisme Agricole, du Genie Rural et des Eaux et Forets	Antony	France
ENEL-CRIS	Centro di Ricerca Idraulica i Strutturale	Milan	Italy
LGA	LandesGewerbeAnstalt	Nürnberg	Germany
LNEC	Laboratorio Nacional de Engenharia Civil	Lisbon	Portugal
LRPC	Laboratoire Régional des Ponts et Chaussées	Nancy	France
RSAE	Research Station for Agricultural Engineering	Merelbeke	Belgium

2. DESCRIPTION OF THE TEST PROCEDURE (PrEN ISO 12956).

The goal of this test is to sieve a well graded soil through a geotextile specimen. A sieving machine is used (figure 1). The specimen is supported by a coarse grid. The soil (with a mass of 7 kg/m²) is laid on the geotextile and is watered by mean of spray nozzles. A mainly vertical amplitude of more than 1.0 mm (2 mm swing) is applied and the water flow is adjusted by the operator in order to prevent water to rise above the granular material. Water and soil passing through the geotextile are gathered. The sieving time is 10 minutes. After that, the passed soil is dried and weighted and its particle size distribution (by mass) is determined. COS is given by the d90 of the particle size distribution curve of the passed soil(figure 2). COS is also called O90.

Some countries usually determine d95 and use O95 as COS. So here, O95 is also analysed and its deviation is compared to O90 deviation.

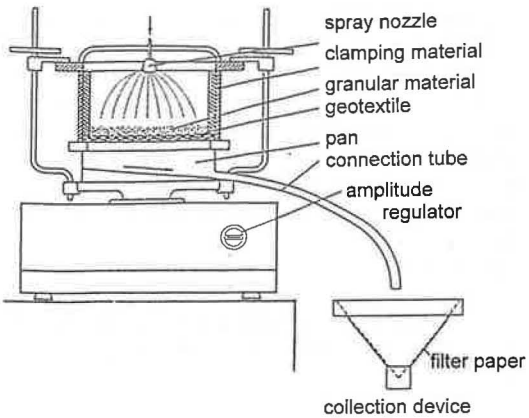

Figure 1 : Example of apparatus

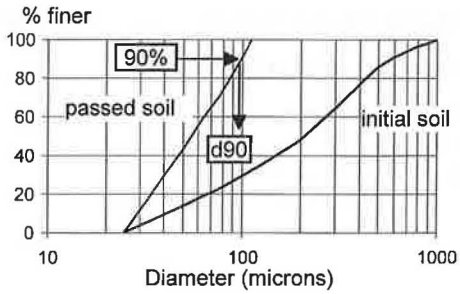

Figure 2 : Example of COS determination.

3. INTERCOMPARISON TESTS PROGRAMME

The main problem is concerning the soil to be used for the test. Generally, from a practical point of view, all the laboratories cannot used the same soil to do the wet sieving test. The CEN draft test method proposes some criteria for selecting it : Uniformity Coefficient of the soil (C_U = d60/d10) must be greater than 3 and the assumed O90 must be between d20 and d80.

Likewise the operator is free enough when adjusting the water flow and the vibrations amplitude.

Intercomparison tests have been realised to show the influence of the soil granulometry and the influence of this operator freedom.

Tests were performed on five fabrics (table 2) : The first fabric, « Reference Textile », is a metallic sieve of woven wires with square meshes. The 4 others are geotextiles of different structure.

Each participating laboratory has used 2 soils : a same soil which was called « Reference Soil » and their own soil they have the habit to use, called « Local Soil », if it satisfies the prEN ISO Standard criteria.

Remark :
The results are rather analysed by the coefficient of variation CV calculated from the values obtained by the different labs.

Table 2 : Fabric tested

Name / Symbol	Structure	Nature	Characteristic
Reference Textile	Woven	metallic	openings : 112 µm
TFD	Heatbonded non-woven	polypropylene	135 g/m²
TGU	Needlepunched non-woven	polyester	130 g/m²
TGX	Needlepunched non-woven	polyester	300 g/m²
THB	Woven (tape / monofilament)	polypropylene	240 g/m²

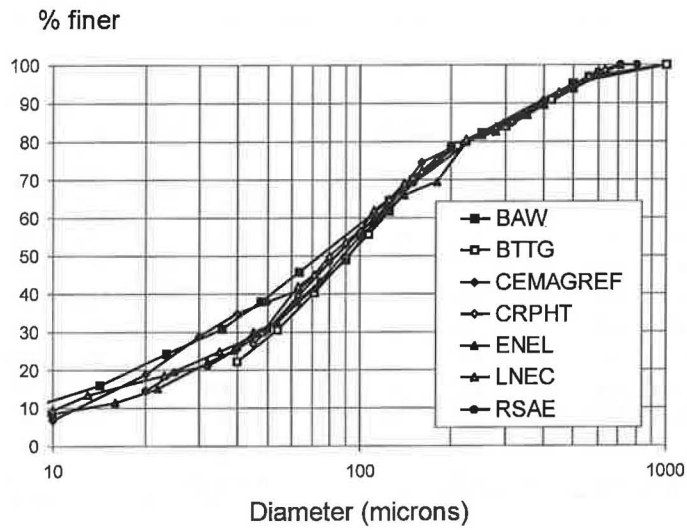

Figure 3 : Sieve analyses of the Reference Soil

4. GRANULOMETRY OF THE REFERENCE SOIL:

In order to test the reproducibility and then the accuracy of the soil sieving procedure used by the laboratories after the wet sieving test, the particle size distribution of the Reference Soil was determined by each lab. As shown on figure 3, the reproducibility is very good for particle greater than 100 µm. For example the coefficient of variation (CV) of the d60 value (d60 mean = 113 µm) is less than 4%, table 3. But for lower values, the CV increases : greater than 7% for d50 (d50 mean = 85 µm). Nevertheless this accuracy is very satisfactory.

Table 3 : Sieve analyses of the Reference Soil

Reference soil		
Laboratory	d50 (µm)	d60 (µm)
BAW	74	105
BTTG	91	120
CEMAGREF	84	112
CRPHT	83	113
ENEL	92	116
LNEC	80	112
RSAE	88	117
Mean	85	114
Ecart type	6.1	4.4
CV (%)	7.2	3.8

5. CHARACTERISTIC OPENING SIZE OF THE REFERENCE TEXTILE:

5.1 Reference Textile and Reference Soil

The next step was to check the wet sieving procedure with a fabric of which the opening size is known. The Reference Textile has an opening mesh size of 112 µm. Theoretically, no particle greater than 112 µm could be collected after the wet sieving test and O90 should be smaller than 112 µm.

A theoretical O90 can be calculated assuming that all the particles smaller than 112 µm, passed through the fabric (figure 2). Table 4 compares theoretical and experimental O90 of the fabric. As the CV of the theoretical O90 is less than 3%, the CV of the experimental O90 is very good : only about 5%. However, some too great values have been carried out. When O90 is 115µm, it means that 10% of the passed soil particles, greater than 115mm, are passed through a mesh of 112µm! A particular attention should be paid because that could not occur theoretically.

This experimental O90 CV value equal to 5% represents the best accuracy it could be obtained experimentally with geotextiles : the Reference Textile is very uniform product without any variability and all its openings have the same size.

Note that if not all the smallest particles passed through the fabric, the O90 increases but it remains smaller than 112µm.

Table 4 : Results obtained with the Reference Soil

	Reference Textile /Reference Soil				
d = 112 µm	O90		O95		Passed
Laboratory	Exp (µm)	Theo (µm)	Exp (µm)	Theo (µm)	(%)
BAW	104	89	115	100	61
BTTG	103	96	113	104	46
CEMAGREF	97	93	103	102	57
CRPHT	101	92	109	102	54
ENEL	102	98	110	105	62
LNEC	97	97	105	105	62
RSAE	115	94	?	102	61
Mean	103	94	109	103	58
Ecart type	1.7	5.4	2.8	4.0	5.4
CV (%)	1.6	5.3	2.9	3.7	9.3

Table 5 : Results obtained with Local Soils

	Reference Textile / Local Soil			
d = 112 µm	O90		O95	
Laboratory	Exp (µm)	Theo (µm)	Exp (µm)	Theo (µm)
BAW	116	106	123	109
BTTG	112	95	118	103
(ref.) CEMAGREF	97	93	103	102
(ref.) CRPHT	101	92	109	102
ENEL	94	80	105	98
LNEC	101	101	108	106
RSAE	114	98	119	105
Mean	105	95	112	103
Ecart type	8.1	7.5	7.1	3.4
CV (%)	7.7	7.9	6.4	3.3

Mass of passed soil : a check of the test could be possible by analysing the passed soil mass percentage. This is available only for the reference soil because this percentage is depending on the granulometry of the soil itself. The theoretical mass percentage of the passed soil through the Reference Textile is about 60 %. The experimental results are in agreement with this theoretical one.

5.2 *Reference Textile and Local Soils*

The laboratories tested the Reference Textile with their own soil. The particle size distribution curves of the local soils are presented figure 4. CEMAGREF and CRPHT used the Reference Soil. It is the finest one. The ENEL soil is the coarsest and it is not so continuous. The BAW and the BTTG ones are the steepest. In the same way as with the Reference Soil, the theoretical O90 values can be calculated, table 5. The influence of the particle size distributions is clearly shown. The CV of theoretical O90 values is about 8% whereas it was less than 3% with the Reference Soil. Note that theoretical O95 values are less sensitive to particle size distributions : CV is 3.3% with the reference Soils and 1.6% with the Reference Soil.

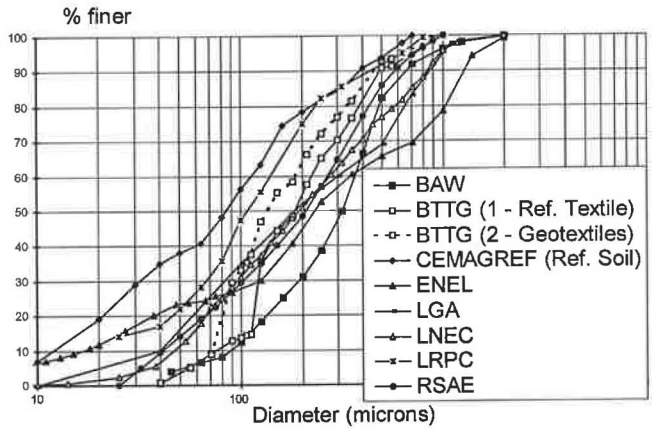

Figure 4 : Particle size distributions of the local soils.

The laboratories obtained experimental O90 greater than theoretically (105 µm against 95 µm) but the experimental CV (7.7%) is quiet the same as the theoretical one and lightly greater than the experimental CV carried out with the Reference Soil only (5.3%).

Neither the mean experimental O90 nor O95 are modified using the Reference Soil or the Local oils.

6. GEOTEXTILES COS DETERMINATION

6.1 Geotextile COS determination using Reference Soil:

The COS results, obtained using the Reference Soil, of the heatbonded TFD, the thin needlepunched TGU, the thick needlepunched TGX and the woven THB are presented in the tables 6 to 9.

The CV values are greater than CVs obtained with the Reference Textile. They are highest for the non-wovens TFD, TGU and TGX : 13 to 14%. For the woven THB, the O90 CV value is only equal to 8%. So we can consider there is a good agreement between the labs for the woven geotextiles.

For the non-woven geotextiles, this deviation could be explained by :

- the non-woven geotextiles are not so homogeneous as the wovens. The CVs could be significant of the variability of the products. But this is not so strongly true for the following reasons :

* the specimens sent to the labs were taken in the same sample. In these conditions the variability is limited ;

Table 6

TFD Textile / Reference Soil			
Laboratory	O90 (µm)	O95 (µm)	Passed (%)
BAW	147	160	63
BTTG	94	108	29
CEMAGREF	125	143	72
CRPHT	127	141	71
ENEL	105	117	47
LNEC	115	135	69
RSAE	125	148	51
Mean	120	136	57
Ecart type	15.6	16.6	14.6
CV (%)	13.1	12.2	25.4

Table 7

TGU Textile / Reference Soil			
Laboratory	O90 (µm)	O95 (µm)	Passed (%)
BAW	154	173	71
BTTG	109	127	50
CEMAGREF	109	123	67
CRPHT	125	137	66
ENEL	139	159	63
LNEC	111	130	67
RSAE	122	151	63
Mean	124	143	64
Ecart type	15.7	17.3	6.1
CV (%)	12.7	12.1	9.6

Table 8

TGX Textile / Reference soil			
Laboratory	O90 (µm)	O95 (µm)	Passed (%)
BAW	144	159	65
BTTG	108	122	44
CEMAGREF	98	107	58
CRPHT	114	129	36
ENEL	132	149	66
LNEC	108	127	67
RSAE	98	133	56
Mean	114	132	56
Ecart type	16,0	15,7	11,2
CV (%)	14,0	11,9	19,9

Table 9

THB Textile / Reference Soil			
Laboratory	O90 (µm)	O95 (µm)	Passed (%)
BAW	176	198	76
BTTG	146	176	54
CEMAGREF	161	185	82
CRPHT	186	208	82
ENEL	178	193	80
LNEC	154	182	80
RSAE	177	198	79
Mean	168	191	76
Ecart type	13,8	10,3	9,2
CV (%)	8,2	5,4	12,0

* it seems that some labs give systematically highest O90 values (BAW for example) and others lowest values (BTTG and LNEC).
- the pore size distribution of the non-wovens is not uniform. Then the mass of soil trapped in the smallest pores is depending on the test conditions, particularly the spray water flow and the vibrations amplitude.
- although the Reference Soil is a cohesionless soil, it contains a lot of small particles : about 10% smaller than 10μm and its particles are crushed particles, not very rounded ones. So there retention is more at random, depending on test conditions.

The percentage of the passed soil mass is not correlated to the O90 values and the deviation obtained for the percentage of passed soil is very different of the COS deviations.

The O95 CV values are not better than the O90 CVs, only for the woven fabric.

6.2 Geotextile COS determination using Local Soils:

As the particle size distribution of the soils is not the same, the masses of the passed soil cannot be compared (tables 10 to 13). The general comments

Table 10

		TFD Textile Local Soils	
	Laboratory	O90 (μm)	O95 (μm)
	BAW	159	183
	BTTG	144	149
(ref)	CEMAGREF	125	143
(ref)	CRPHT	127	141
	ENEL	131	155
	LGA	107	124
	LNEC	125	144
	LRPC	120	139
	RSAE	131	145
	Mean	130	147
	Ecart type	13.9	14.8
	CV (%)	10.7	10.1

Table 11

		TGU Textile Local Soils	
	Laboratory	O90 (μm)	O95 (μm)
	BAW	154	172
	BTTG	137	144
(ref)	CEMAGREF	109	123
(ref)	CRPHT	125	137
	ENEL	168	194
	LGA	121	139
	LNEC	133	149
	LRPC	122	136
	RSAE	119	133
	Mean	132	147
	Ecart type	17.5	20.7
	CV (%)	13.3	14.1

Table 12

		TGX Textile Local Soils	
	Laboratory	O90 (μm)	O95 (μm)
	BAW	148	157
	BTTG	136	143
(ref)	CEMAGREF	98	107
(ref)	CRPHT	114	129
	ENEL	148	178
	LGA	105	112
	LNEC	116	128
	LRPC	117	131
	RSAE	114	135
	Mean	122	136
	Ecart type	17.0	20.5
	CV (%)	14.0	15.1

Table 13

		THB Textile Local Soils	
	Laboratory	O90 (μm)	O95 (μm)
	BAW	215	240
	BTTG	195	214
(ref)	CEMAGREF	161	185
(ref)	CRPHT	186	208
	ENEL	209	223
	LGA	191	248
	LNEC	180	201
	LRPC	175	193
	RSAE	192	216
	Mean	189	214
	Ecart type	15.5	19.6
	CV (%)	8.2	9.1

are the same as previously :
- a better reproducibility is obtained with the woven THB than with the non-wovens TFD (heatbonded) and TGU and TGX (needlepunched).- some labs give systematically higher O90 values than the others. Here they could be divided into two groups : those which obtained highest values (BAW, BTTG, and ENEL for needlepunched) and those which give lowest ones (CEMAGREF, LGA and the others...). The non homogeneity of the non-wovens cannot be the main parameter of the deviation. In this case it could be the influence of the shape of the particle size distribution curves.

7. INFLUENCE OF THE C_U OF THE SOIL

As it was said previously, the BAW and BTTG soils are the steepest and the ENEL soil is the coarsest one (figure 3). A theoretical deviation occured, figure 5, depending of the uniformity coefficient (C_U) of the tested soil. For example, let us compare (table 4) theoretical O90 values obtained with ENEL soil (C_U = 20) and O90 value obtained with BAW (C_U = 4) with the Reference Textile (112 µm mesh size):

BAW Soil C_U = 4 O90 = 106 µm
ENEL Soil C_U = 20 O90 = 80 µm
i.e. 26 µm in-between.

Theoretically, the influence of the uniformity coefficient on COS should be smaller using O95 as representative parameter of COS (figure 5):

BAW soil O95 = 109 µm
ENEL soil O95 = 98 µm
The difference is only 11 µm.

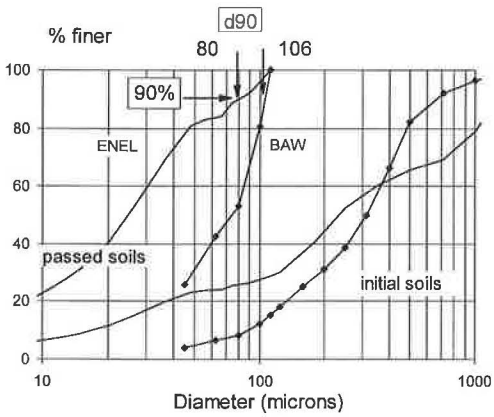

Figure 5 : Influence of C_U of particle distribution of the soil on theoretical O90.

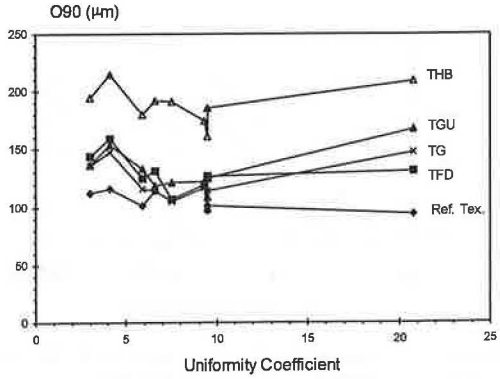

Figure 6 : Variation of O90 with C_U

But this effect is not experimentally carried out neither with the four geotextiles nor the Reference Textile : O90 CV and O95 CV values are very similar. And as shown on figure 6, O90 is experimentally few depending on Uniformity Coefficient of the soil used.
- CV of TFD Opening Size O90 measured with Local Soils (10%) is lower than CV obtained with the Reference Soil (13%). This fabric is, may be, more sensitive to the finest fraction of the soil.

8. CONCLUSION

The sequence of tests performed as follows :
- Reference Soil and Reference Textile,
- Local Soils and Reference Textile,
- Reference Soil and individual Geotextiles,
- Local Soils and individual Geotextiles,

has identified the contributions of the variability of the test.

Although the Reference Soil contains too many fine and unrounded particles, the found deviations are not so tremendously bad compared to that obtained with the Local Soils. For geotextiles, the mean O90 values obtained with the Reference Soil are 10 µm smaller than the mean values obtained with the Local Soils.

Theoretically O95 is less depending on C_U than O90 but the intercomparison tests did not show such results.

A proposal is made for the particle size distribution of the soil to be used in the test : in order to reduce the deviation and even if experimentally the Uniformity Coefficient does not influences the O90 it is proposed to use a soil of which particle size distribution curve is in a zone not too large (fig. 7). Then a correlation between the Characteristic Opening Size and the percentage of the passed soil could be establish by the laboratories. It could be full of interest to select the sieves they

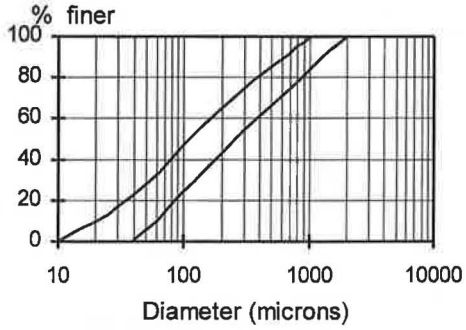

Figure 7 : Example of range suggested for the particle size distribution curve of the soil

have to use and to control the validity of the tests results.

The variability is greater for non-wovens and this may be attributed partly to the variability of the non-wovens themselves.

The work demonstrated that the wet sieving test can be used to measure the Characteristic Opening Size of geotextiles with a standard deviation of between 8 to 14 %.

9. FUTURE WORK

The work of these intercomparison tests is not completely finished. It is also decided :

- to test a very thick non-woven geotextile (600 g/m²) to reduce the effect of the variability of the non-woven,
- to used the same spray water flow as much as possible. The water flow is depending of the permeability of the soil. If the soil has the same particle size distribution, that could be possible
- to use an amplitude of 1 mm (in the draft standard, the amplitude « should be greater than 1 mm »)

ACKNOWLEDGEMENTS

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