ROLE OF PLATEN HARDNESS ON INTERPRETATION AND USE OF IN-PLANE FLOW CAPACITY TEST RESULTS FOR GEOCOMPOSITES

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Abstract: The in-plane flow capacity of a geonet drainage composite is measured by the EN ISO 12958 test standard. This standard stipulates the use of soft platen boundary conditions in the test to replicate the soil backfill used on site. Soft platens apply the confining pressure to the geotextile surface of the geonet composite and consequently, the geotextile intrudes into the geonet. In special circumstances, EN ISO 12958 permits hard platen boundary conditions to be tested but only when the intended use of the geonet is between two hard surfaces such as concrete or HDPE geomembranes. Hard platens apply the confining pressure directly to the geonet composite without intrusion of the geotextile. It has, however, become a common practice for geonet composite datasheets to state in-plane flow capacity values with the application of hard platens. Several geonet composite products have been tested on hard and soft platens. The apparent in-plane flow capacity with hard platens is shown to be 100 times higher than the actual flow achieved with soft platens simulated site conditions. These results are significant for designers who have the liability for ensuring competent drainage design.

Keywords: cuspated drainage sheet, drainage, flow capacity, geocomposite drainage materials, hydraulic properties, geonet.

INTRODUCTION

EN ISO 12958 is the International and European standard for in-plane flow tests of geotextiles and related products such as geocomposite drains. This standard, formulated over many years, was launched in 1999 and revised in 2007. Such in-plane flow tests determine the short-term flow performance of geocomposite drains that is published on the product datasheets. The long term flow expected during the design life is related to the creep performance of the geocomposite, which this is outside the scope of this paper and is discussed by Greenwood *et al.* (2008).

The EN ISO 12958 in-plane flow test is most often used to determine the flow in the machine direction (MD) or length of the geocomposite. It can equally be used to test the flow in the cross machine direction (CMD) or width of the geocomposite. Most geocomposites have markedly different in-plane flow performances in the machine direction (MD) and cross machine direction (CMD). The tests conducted for this paper are in the machine direction (MD) as this is the primary direction of flow intended by most geocomposite manufacturers. The in-plane flow tests can be performed with two different boundary conditions using soft foam platens and hard steel platens.

Soft Platens

EN ISO 12958 stipulates the use of closed cell foam rubber (denoted as SOFT boundary conditions) in the flow test to replicate the soil backfill used on site. The in-plane flow tests are performed at hydraulic gradients of 0.1 and 1.0 and at confining pressures from 20 kPa to 200 kPa. The closed cell foam rubber is characterised in EN ISO 12958 by a compression/deflection chart. Work by Zhao & Montanelli (1999) indicates that foam rubber accurately simulates granular backfill but may under estimate the reduction of the in-plane flow when soft soil backfill is used on site. The soft platens apply the confining pressure to the geotextile surface of the geocomposite and consequently, the geotextile intrudes into the geocomposite core causing a reduction of in-plane flow. The closed cell foam rubber (SOFT) platen test condition is the method by which the EN ISO 12958 standard is written and intended to be used because most frequently, geocomposite drains are backfilled on site with soil/gravel. The soft foam can be applied to just one side of the specimen and hard platen on the other side and this is denoted as SOFT - HARD.

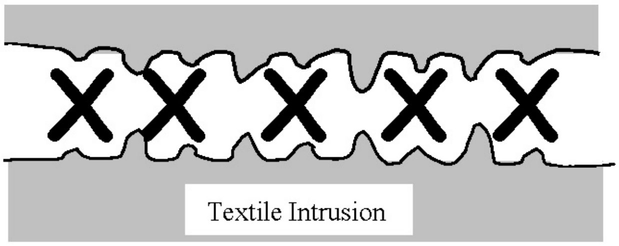

Figure 1. Soft foam applies pressure to the textile surface

Hard Platens

Within EN ISO 12958 is an option to use steel platens (denoted as HARD or RIGID boundary conditions) in the flow test for the unusual event that the intended application of the geocomposite is between two hard surfaces. An example of this would be a leak detection layer between two HDPE geomembranes. The hard platens applies the confining pressure directly to the core of the geocomposite. There is less pressure on the geotextile and consequently less intrusion of the geotextile into the core. In-plane flow tests using hard boundary conditions produce the highest possible in-plane flow capacity of the geocomposite. In compliance with EN ISO 12958, manufacturers are obliged to state on the datasheet that the flow values are on HARD boundary conditions. Most manufacturers however, relegate this information to the very bottom of the datasheet in the small print as R/R or HARD and it is easy for designers to miss the significance of these notes.

Figure 2. Hard platens apply most pressure onto the core

Unfortunately the manufacturers of geocomposite drains relish on these high in-plane flow capacities and produce datasheets showing only hard platen flow capacity. This can be misleading as such values will only be achieved in exceptional applications. In most applications, the geocomposite is used on site with a soil or granular backfill and the in-plane flow capacity will be significantly lower than the hard platen flow data. There are design methods that suggest general reduction factors for geotextile intrusion (RF_{IN}), which can be applied to hard platen flow test results to estimate the on-site performance, but RF_{IN} is very product specific. Depending on the application and based on a 1.5 pressure overload, Koerner (2005) suggested RF_{IN} in the range of 1 to 2 but this is nowhere near large enough. Some products would require reduction factors up to 100.

In-Plane Flow

The most practical and reliable method is to test the geocomposite with soft foam simulated soil boundary conditions as stipulated by EN ISO 12958. This test directly yields a reduced in-plane flow capacity, allows products to be compared under simulated site conditions and ensures that the designer is compliant with best practice as stated within the EN ISO standard. Testing of the geocomposite with the actual site specific soil is possible but extremely difficult and therefore only suitable for the most stringent applications.

Geocomposite Applications

Geocomposite drains are used in a wide range of applications. They are installed at any angle from vertical to horizontal, and subjected to confining pressures from 20 kPa to greater than 200 kPa. Table 1 indicates the common applications and the appropriate in-plane test boundary conditions.

Table 1. Geocomposite Application and Appropriate Boundary Conditions

Applications: Drainage of -	Actual Site Boundary	Appropriate EN ISO 12958 Test Boundary		Hydraulic Gradient
Retaining Wall	Soil - Concrete	SOFT – HARD		1
Podium Deck	Sand - Concrete	SOFT – HARD		0.03
Highway Edge Drain	Soil - Soil	SOFT – SOFT		0.03 – 0.1
Landfill Cap - HDPE	Soil – HDPE	SOFT – HARD		0.03 – 0.3
Landfill Cap – GCL	Soil - GCL	SOFT – SOFT		0.03 – 0.3
Landfill Groundwater Drain	Soil - CCL	SOFT – SOFT		0.03 – 0.3
Landfill Leachate Drain	Granular - Textile	SOFT – SOFT		0.03 – 0.3
Landfill Leak Detection	HDPE - HDPE		HARD – HARD	0.03 – 0.3
Internal Basement Drainage	Concrete - Concrete		HARD - HARD	0.03 – 1
Cut & Cover Tunnel	Soil - Concrete	SOFT - HARD		0.03 – 1
Hard Rock Tunnel	Concrete - Concrete		HARD - HARD	0.03 - 1

The involved design engineers, contractors, and CQA engineers need to examine the datasheets of geocomposite drains to determine the tested boundary conditions of either HARD or SOFT to ensure that the in-plane flow values truly represent the site situation.

C.E Mark

In the EU, the Construction Products Directive dictates that geocomposite drains must have a CE Mark. A CE Mark does not indicate Fitness for Purpose, but simply that a specified series of tests have been performed strictly in accordance with the relevant EN standards for the intended application. The legal document is not the product datasheet but the Accompanying Document that is inserted into every roll. For geocomposite drains, the relevant Application Standard is EN 13252 and it states that the Accompanying Document must include the in-plane flow obtained according to EN ISO 12958 at HG1 at 20kPa with SOFT boundary conditions. This is a legal requirement in most EU countries.

There is commonly no correlation between a product's Accompanying Document that arrives on site and its datasheet that was submitted for design or purchase. Manufacturers readily make their datasheets available but tend not to reveal their Accompanying Documents to designers or customers. Datasheets carry the CE Mark logo, but are not referenced in the CE Mark procedures and are therefore not verified by the independent Notified Bodies. Designers should insist on viewing the Accompanying Document for verification of each product datasheet.

Forms of Geocomposite

Geocomposite drains consist of a polymer core bonded to geotextile on one or both sides of the core. There are many forms of polymer core, and the most common being geonet (bi-planar or tri-planar), cuspate (single or double) and random fibre (plain or zig-zag). The most common polymer for the core is High Density Polyethlylene (HDPE), and Polypropylene (PP), while high impact polystyrene (HIPS) or Nylon (PA) are also used.

Table 2 shows published datasheet values from representative rolls of a bi-planar geonet, a single cuspate, and a random fibre zig-zag geocomposites tested using a range of hydraulic gradients (HG). Each product is obtained from separate manufacturers and all products are of European origin and therefore within the scope of the CE Mark regulations.

Table 2. Published Datasheet Information for apparently broadly similar products

					Mean Short Term (MD) In-Plane Flow (l/m/sec)		
Type of Geocomposite	**Thickness (mm) Mass (g/m²)**	**Test Standard**	**Stated Boundary Conditions**	**Confining Pressure (kPa)**	**HG 1.0**	**HG 0.3**	**HG 0.1**
Single Cuspate 	4.7 / 570	EN ISO 12958	SOFT	20	0.95	-	0.25
				50	-	-	-
				100	0.71	-	0.17
				200	0.59	-	0.14
				500	-	-	-
Bi-Planar Geonet 	4.8 / 740	EN ISO 12958	HARD HARD (in notes)	20	0.62	-	0.13
				50	0.51	-	0.09
				100	-	-	-
				200	0.35	-	0.07
				500	0.24	-	0.03
Randon Fibre Open Zig-Zag 	6.5 / 660	EN ISO 12958	? NOT STATED	20	1.3	0.65	0.33
				50	1.2	0.60	0.30
				100	1.0	0.55	0.25
				200	-	-	-
				500	-	-	-

All above products have broadly similar performance and are at the lower end values of each manufacturers range. These geocomposites were tested at a laboratory accredited by UKAS for EN ISO 12958 in-plane flow tests with soft and hard platens.

RESULTS

The results of the in-plane flow tests based on EN ISO 12958 for representative geocomposite samples of each form are presented in Table 3. There is a significant difference in the in-plane flow between the tests using hard platens and soft platens. The difference is the largest for the random fibre zig-zag geocomposite, followed by the bi-planar geonet and the least for the single cuspated geocomposite. This demonstrates that the single cuspate geocomposite provides good support for the geotextile and consequently, the geotextile intrusion into the core is minimal even at high confining pressures. The single cuspated geocomposite, although the lightest and the thinnest, gave the best performance on both hard and soft platens. The difference between the in-plane flow on hard and soft platens increases as the confining pressures increase. The hard platen flow rate results decrease with increasing confining pressures due to increasing compression of the core. The soft platen flow rate results decrease even more with increasing confining pressures due to the combination of increasing core compression and increasing intrusion of the geotextile into the core. The difference between the in-plane flow on hard and soft platens increases as the hydraulic gradient decreases. The difference between the hard and soft platen flow rate results is less at high hydraulic gradient probably due to the more turbulent flow. The single cuspated geocomposite has the least difference of 20% reduction at 20kPa and HG1, and the random fibre zig-zag geocomposite has the largest reduction of 99% at 200kPa and HG0.1.

Comparing the measured in-plane flow values with the datasheets for each product reveals several interesting facts. With soft boundary conditions, the single cuspated geocomposite datasheet and tested values are generally in agreement. Using hard platens, the bi-planar geonet datasheet and the tested values are also generally in agreement.

The random fibre zig-zag geocomposite datasheets did not state the boundary conditions but the test result reveals that the datasheet values to be hard platen results.

For designers these results are significant, because the three apparently similar products based on the datasheets are in fact substantially different. The short-term in-plane flow that would be achieved on site in a landfill cap application at 20kPa confining pressure and HG0.1 are approximately 0.25 l/m/s for the single cuspated geocomposite, 0.04 l/m/s for the random fibre zig-zag geocomposite and 0.02 l/m/s for the bi-planar geonet. Similarly, the short-term in-plane flow that would be achieved on site behind a 20 metre deep (100kPa) retaining wall (HG1) are approximately 0.71 l/m/s for the single cuspated geocomposite, 0.06 l/m/s for the random fibre zig-zag geocomposite and 0.03 l/m/s for the bi-planar geonet. Based on the datasheets, the designer would mistakenly assume that the random fibre zig-zag geocomposite gave the highest performance whereas actually under simulated site conditions, it is the single cuspated geocomposite that provides the highest in-plane flow (i.e. 10 times higher).

All of the geocomposites tested, being of EU origin, should comply with the CE Mark Application standard EN 13252 but based on the datasheet information, only the single cuspated geocomposite provides the required in-plane flow rate at 20kPa and HG1 on soft platens to EN ISO 12958. The datasheets for the bi-planar geonets is clearly based on hard platens tests and the random fibre zig-zag geocomposite appears to be on soft platen test but is not. Both of these datasheets are in fact based on hard platen tests to EN ISO 12958 and should only be used for applications with hard surfaces. This is no comfort for the unfortunate designer who has failed to check the significance of flow tests on soft versus hard platens. Only tests on soft platens will replicate the in-plane flow actually achieved on sites with soil/gravel backfill.

Table 3. Test results for in-plane flow to EN ISO 12958

		Short Term MD In-Plane Flow (l/m/sec)				
Type of Geocomposite	**Test Boundary Conditions**	**Confining Pressure (kPa)**	**HG 1.0**	**HG 0.03**	**HG 0.1**	**HG 0.01**
Single Cuspate 	SOFT – SOFT and SOFT - HARD	20	0.97	-	0.25	0.05
		50	-	-	-	-
		100	0.71	-	0.14	0.04
		200	0.52	-	0.07	0.02
	HARD - HARD	20	1.18	0.72	0.31	0.05
		50	-	-	-	-
		100	1.01	-	0.27	0.04
		200	0.88	0.62	0.22	0.03
Bi-Planar Geonet 	SOFT - SOFT	20	0.13	-	0.022	-
		50	0.071	-	0.010	-
		100	0.032	-	0.0034	-
		200	0.012	-	0.0006	-
	HARD – HARD	20	0.55	-	0.10	-
		50	0.46	-	0.085	-
		100	0.38	-	0.069	-
		200	0.28	-	0.051	-
Randon Fibre Open Zig-Zag 	SOFT - SOFT	20	0.34	0.093	0.041	0.040
		50	0.12	0.044	0.019	0.0028
		100	0.061	0.015	0.0064	0.0012
		200	0.018	0.024	0.0005	0.0003
	HARD - HARD	20	1.06	0.51	0.23	0.024
		50	0.99	0.46	0.21	0.020
		100	0.88	0.40	0.19	0.018
		200	0.64	0.28	0.13	0.014

Reduction Factor for Intrusion R_{IN}

The concept of the reduction factor for intrusion is that the in-plane flow can be tested on hard platens and a reduction factor applied to estimate the actual in-plane flow under actual site backfill conditions. Generally, it is assumed that such reduction factors are based on the applications. The results of the in-plane flow tests to EN ISO 12958 on soft and hard platens produce the reduction factors shown in Table 4.

If HG1 and 200kPa represent a vertical wall application and HG0.1and 20kPa a highway edge drain, then the reduction factors are indeed dependent upon application. The most significant fact, however, is the variation in reduction factor dependent on the type of geocomposite. At HG0.1 and 100kPa, the range is 1.93 for a single cuspate to 29.69 for a random fibre zig-zag geocomposite. These values are many times larger than suggested by Koerner (2005). Therefore, generalisation of reduction factors for intrusion are unreliable. Geotextile intrusion is of such significance to the in-plane flow capacity that the most reliable result is obtained by testing to EN ISO 12958 with soft foam platens to simulate the actual site backfill conditions.

Table 4. Reduction factors for geotextile intrusion

	Confining Pressure (kPa)					
	20		**100**		**200**	
Type of Geocomposite	**HG 1**	**HG 0.1**	**HG1**	**HG 0.1**	**HG1**	**HG 0.1**
Single Cuspate 	1.22	1.24	1.42	1.93	1.69	3.14
Bi-Planar Geonet 	4.23	4.55	11.85	20.39	23.33	85.00
Random Fibre Open Zig-Zag 	3.12	5.61	14.43	29.69	35.56	260.00

Platen Hardness

Soft platens simulate soil/granular backfill and hard platens simulate a solid surface such as concrete. EN ISO 12958 requires the use of soft platens for most intended geocomposite drain applications but does permit tests on hard platens in specific circumstances. The test results on soft and hard platens show that in-plane flow testing on the appropriate platens is the most significant factor and is absolutely essential for the correct design of geocomposite drains. The in-plane flow of geocomposite drains is not linearly proportional to the hydraulic gradient. The in-plane flow capacity reduces as the confining pressure increases. Designers therefore, having calculated their required drainage flow, should state the required long term flow capacity based on EN ISO 12958 soft platens (in most cases) at the site working pressure and hydraulic gradient. It is then for the geocomposite drain manufacturer to show suitable short term test data and long term reduction factor.

CONCLUSIONS

- The effect of boundary conditions (platen hardness) is the most significant factor on the in-plane flow performance of geocomposite drains;
- Short term in-plane flow capacity of geocomposite drains tested on hard platens can appear to be 100 times higher than the actual flow achieved on site simulated by soft platens;
- Generally, published reduction factors for intrusion are not high enough and need to be product specific (e.g. RF_{IN} range from 1.2 to 100);
- In-plane flow testing to EN ISO 12958 with soft platens to simulate site conditions provides more credible values than hard platen flow tests and generalised reduction factors;
- Datasheets that present in-plane flow values to tests values in accordance to EN ISO 12958 clearly demonstrates SOFT platens are the most reliable for design;
- The single cuspated geocomposite tested was thinner and lighter than the bi-planar geonet and random fibre zig-zag geocomposite but achieved 20 to 40 times the in-plane flow when tested under simulated site conditions;
- Designers need to read the small print on datasheets and understand the significance of the variations within the test methods; and,
- Finally, who checks that the data published on CE Accompanying Documents actually corresponds with the data published on CE marked datasheets?

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