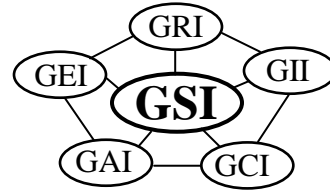


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Revision 2: July 24, 2017
Revision schedule on pg. 9

GRI-GC16 Standard Specification *

Standard Specification for

“Test Methods, Required Properties and Testing Frequency for Prefabricated Vertical Drains (PVDs)”

This specification was developed by the Geosynthetic Research Institute (GRI) with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute (GSI), nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

- 1.1 This generic specification covers prefabricated vertical drains (PVDs), also known as “vertical strip drains”, or “wick drains”, for the purpose of rapid in-situ consolidation of saturated fine-grained foundation soils.
- 1.2 The drainage cores of PVDs are polymeric and consist of various configurations, i.e., flutes, channels, protrusions, dimples, 3-D meshes, etc.
- 1.3 The drainage cores are either wrapped around, or bonded to, the core using geotextiles acting as both separation against the adjacent soil and as a filter to allow water to enter the core and be dispelled under pressure.
- 1.4 This specification sets forth a set of minimum physical, mechanical, hydraulic and endurance properties that must be met, or exceeded by the PVD being manufactured.
- 1.5 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

*This GRI standard specification is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version and it is kept current on the Institute’s Website <<geosynthetic.institute.org>>.

Note 1: A standard guide for selecting PVD test methods (but not providing numeric values) is available as ASTM D6917. See also DFI, 2014 for a method guide.

- 1.6 This standard specification is intended to assure good quality and performance of PVDs in general applications, but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive values for the tests indicated, may be necessary under conditions of a particular application.

2. Referenced Documents

2.1 ASTM Standards

- D 4439 Standard Terminology for Geosynthetics
- D 4491 Standard Test Method for Water Permeability of Geotextiles by Permittivity
- D 4533 Standard Test Method for Trapezoid Tearing Strength of Geotextiles
- D 4595 Standard Test Method for Tensile Properties by the Wide-Width Strip Method
- D 4632 Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
- D 4716 Standard Test Method for Determining the In-Plane Flow Rate and Hydraulic Transmissivity Using a Constant Head Device
- D 4751 Standard Test Method for Determining Apparent Opening Size of a Geotextile
- D 4833 Standard Test Methods for Index Puncture Resistance of Geomembranes and Related Products
- D 6917 Standard Guide for Selection of Test Methods for Prefabricated Vertical Drains (PVDs)
- D 6818 Standard Test Method for Testing Vertical Strip Drains in the Crimped Condition
- D 7238 Standard Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembranes Using Fluorescent UV Condensation Apparatus

2.2 Related References

Holtz, R. D., et al. (1991), "Prefabricated Vertical Drains: Design and Performance," CIRIA Publ., London, 131 pgs.

McGown, A. and Hughes, F. H. (1982), "Practical Aspects of the Design and Installation of Deep Vertical Drains," in Vertical Drains, T. Telford, London, pp. 3-18.

Koerner, G. R. (1998), "Field Installation of Vertical Drains," GRI-11 Conference, Philadelphia, PA, GSI Publ., pp. 277-288.

-----“Wick Drain Guide Specification” (Method), 2014, Deep Foundation Institute, Hawthorne, NJ.

3. Definitions

- 3.1 Prefabricated Vertical Drain - A geosynthetic composite drainage material consisting of a polymer core and geotextile enclosure installed into foundation soils so as to provide rapid in-situ consolidation of saturated fine-grained soils.
- 3.2 Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic material and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.
- 3.3 Consolidation - The geotechnical process by which in-situ saturated soil deposits expel their pore water bringing the soil particles together into a gradually increasing density and shear strength.

Note 2: All geotechnical engineering textbooks address consolidation of soils, it being one of the major cornerstones of the technology.

- 3.4 Minimum Average Roll Value (MARV), n – For geosynthetics, a manufacturing quality control tool used to allow manufacturers to establish published values such that the user/purchaser will have a high degree of confidence that the property in question will meet published values. For normally distributed data, “MARV” is calculated as the typical value minus two (2) standard deviations from documented quality control test results for a defined population sampled in accordance with ASTM D4354, from one specific test method associated with one specific property.

4. Overview and Background

- 4.1 The historical progression of PVDs for this particular application as used by geotechnical engineers has been as follows:
 - soil consolidation by expulsion of pore water in a vertical direction only (1930’s to 1970’s)
 - accelerated soil consolidation by installing vertical sand drains thereby inducing horizontal pore water flow (1970’s to 1990’s)
 - accelerated soil consolidation by installing PVDs also inducing horizontal flow which has altogether replaced the use of sand drains (1990’s to present)
- 4.2 PVDs consist of a plastic drainage core in the form of flutes, corrugations, protrusions, dimples, 3-D meshes, etc. Excess pore water under pressure flows up and/or down in the core depending on the in-situ soil stratigraphy.



Figure 1. Assortment of prefabricated vertical drains, or PVDs.

- 4.3 Of necessity the drainage core must be protected against adjacent soil intrusion and clogging. This is generally accomplished by use of a geotextile (acting as both a separator and filter) surrounding, or attached, to the drainage core. See Figure 1.
- 4.4 The as-manufactured PVD products are usually 100 mm (4.0 in.) wide by 3-5 mm (1/8-1/4 in.) thick. They are wound up on large spools as shown in Figure 2.

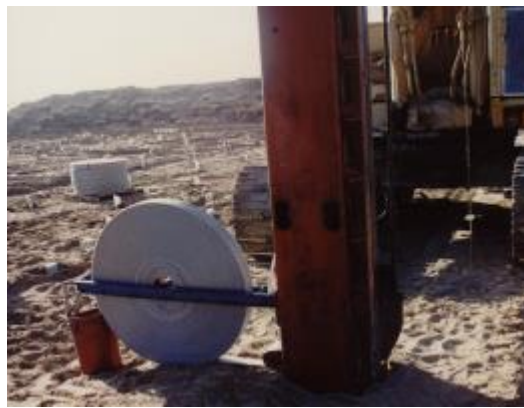
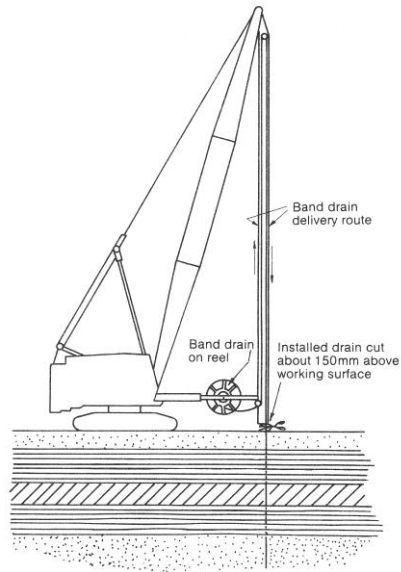


Figure 2. Spools of PVDs as manufactured.

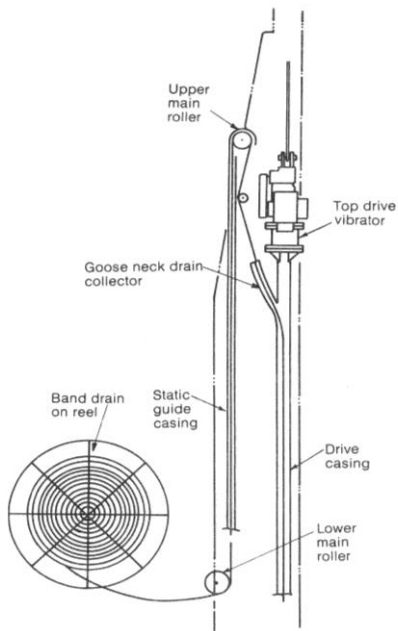
- 4.5 Some aspects of PVD installation are shown on the photographs and sketches of Figure 3.



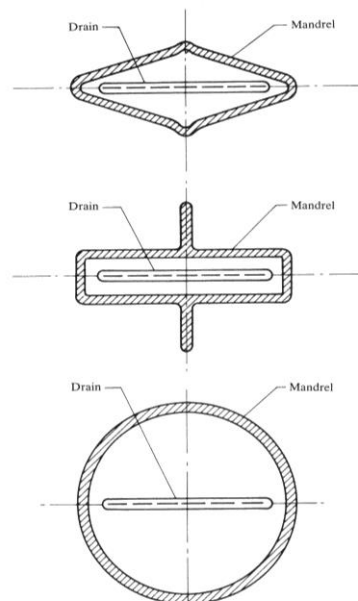
(a) Adapted Pile Driving Rig
(compl. American Wick Drain)



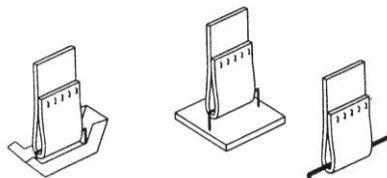
(b) Details of Installation System
(ref. McGown and Hughes, Vertical Drains, 1982, T. Telford)



(c) Details of PVD Delivery System
(ref. McGown and Hughes, Vertical Drains, 1982, T. Telford)



(d) Various Hollow Drive Casings
(ref. Prefabricated Vertical Drains) Holtz, et al., 1991, CIRIA)



(e) Various "Shoes" to Anchor PVDs
(ref. Koerner, G. R., "Field Installation of PVDs", GRI-11 Conf., 1998)

Figure 3. Selected photos and sketches of the PVD installation process.

6. Workmanship and Appearance

6.1 The finished PVD product shall have good appearance qualities. It shall be free from defects that would affect the specific properties of the product, or its proper functioning.

6.2 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling, Testing, and Acceptance

7.1 PVD products shall be subject to manufacturing quality control (MQC) sampling and testing to demonstrate conformance with this specification as set forth in the specific test methods within Table 1. In the absence of purchaser's testing, verification may be based on manufacturer's certifications.

7.2 Testing shall be performed in accordance with the method referenced in this specification for the indicated application, for consolidation of saturated in-situ fine-grained soil deposits.

8. MQC Retest and Rejection

8.1 If the results of any MQC test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality control documents. In general, if any roll fails only the rolls bracketed by passing rolls need to be rejected.

9. Shipment and Storage

9.1 PVD labeling, shipment, and storage shall follow ASTM D 4873 for Geosynthetic Rolls and Samples. Product labels shall clearly show the manufacturer or supplier name, style, roll number and date of production. Each shipping document should include a notation certifying that the material is in accordance with this specification.

9.2 PVD rolls shall be adequately covered to protect them from the following: construction damage, precipitation, extended ultraviolet radiation including sunlight, chemicals that are strong acids or strong bases, flames including welding sparks, temperatures in excess of 70°C (160°F), root intrusion, and any other environmental condition that may damage the property values of the product involved.

10. Certification

10.1 The manufacturer shall provide to the engineer a certificate stating the name of the manufacturer, product name, style number, and the composition of the PVD.

- 10.2 The manufacturer is responsible for establishing and maintaining a quality control program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available upon request.
- 10.3 The manufacturer's certificate shall state that the finished PVD meets requirements of the specification as evaluated under the manufacturer's quality control program. A person having legal authority to bind the manufacturer shall attest to the certificate.
- 10.4 Either mislabeling or misrepresentation of materials shall be reason to reject the products involved in this specification.

**Adoption and Revision Schedule
for
GRI-GC16 Standard Specification for Prefabricated Vertical Drains (PVDs)**

Adopted: May 24, 2017

Revision 1: June 27, 2017; Changed puncture strength test of geotextile (by itself) from pin puncture to CBR puncture per ASTM D6241.

Revision 2: July 24,2017; Lowered permittivity and tightened AOS under consideration that the soils consolidated using PVD are always fine-grained silts and clays.

Table 1. Prefabricated Vertical Drain (PVD) Specification

Property	ASTM Method	Value	MQC Testing Frequency
<u>Composite Product</u>			
Discharge capacity ¹	D4716	6.0 lpm (1.6 gpm)	2500 m (8200 ft)
Roll length	direct measure	200 (660 ft.)	2500 m (8200 ft)
Roll width	direct measure	100 mm (4.0 in.)	2500 m (8200 ft)
Tensile strength (min.)	D4595 (modified) ²	1000 N (225 lb)	2500 m (8200 ft)
<u>Geotextile (by itself)</u>			
Permittivity	D4491	0.3 sec ⁻¹	MARV ³
Apparent opening size	D4751	250 μm	MaxARV ⁴
Grab tensile strength	D4632	500 N (112 lb)	MARV
Grab tensile elongation	D4632	50%	MARV
Puncture strength (CBR) ⁵	D6241	550 N (125 lb)	MARV
Trapezoidal tear	D4533	245 N (55 lb)	MARV
UV resistance after 1000 hr.	D7238	70% ⁵	yearly

1. In an as-received condition with a normal stress of 50 kPa (72 psi) and hydraulic gradient of 1.0. In this regard, core kinking (ASTM D6918) reduction of discharge capacity must be independently evaluated and included in the design as a reduction factor (this is a design decision; see DwG for a procedure)
2. Modification to ASTM D4595 is changed from 200 m (8 in.) to 100 mm (4 in.) wide specimen
3. Minimum Average Roll Value (ASTM D4439)
4. Maximum Average Roll Value (ASTM D4439)
5. Refers to grab tensile strength of geotextile by itself