

Australian Standard[®]

Execution of prefabricated vertical drains



This Australian Standard® was prepared by Committee CE-020, Geosynthetics. It was approved on behalf of the Council of Standards Australia on 20 October 2011. This Standard was published on 11 November 2011.

The following are represented on Committee CE-020:

- Association of Consulting Engineers Australia
- Australian Geomechanics Society
- Australian Industry Group
- Australian Water Association
- Austroads
- AWTATextile Testing
- Commerce Queensland
- CSIRO Textile and Fibre Technology
- Department of Transport and Main Roads, Qld
- International Geosynthetics Society
- Monash University
- Technical Textile and Nonwoven Association
- Waste Management Association of Australia

The following are represented on Subcommittee CE-020-00-10, Prefabricated Vertical Drains:

- Menard Bachy
 - Port of Brisbane
 - SoilWicks
 - University of Wollongong
-

This Standard was issued in draft form for comment as DR AS 8700.

Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through the public comment period.

Keeping Standards up-to-date

Australian Standards® are living documents that reflect progress in science, technology and systems. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued.

Standards may also be withdrawn. It is important that readers assure themselves they are using a current Standard, which should include any amendments that may have been published since the Standard was published.

Detailed information about Australian Standards, drafts, amendments and new projects can be found by visiting www.standards.org.au

Standards Australia welcomes suggestions for improvements, and encourages readers to notify us immediately of any apparent inaccuracies or ambiguities. Contact us via email at mail@standards.org.au, or write to Standards Australia, GPO Box 476, Sydney, NSW 2001.

Australian Standard[®]

Execution of prefabricated vertical drains

First published as AS 8700—2011.

COPYRIGHT

© Standards Australia Limited

All rights are reserved. No part of this work may be reproduced or copied in any form or by any means, electronic or mechanical, including photocopying, without the written permission of the publisher, unless otherwise permitted under the Copyright Act 1968.

Published by SAI Global Limited under licence from Standards Australia Limited, GPO Box 476, Sydney, NSW 2001, Australia

ISBN 978 0 7337 9965 5

PREFACE

This Standard was prepared by Standards Australia Committee CE-020 Geosynthetics, in response to requests from industry representatives in the field of prefabricated vertical drains, especially in the area of land reclamation.

This Standard is based on BS EN 15237, *Execution of special works. Vertical drainage*.

The objective of this Standard is to establish general principles for the execution, testing, supervision and monitoring of prefabricated vertical drains.

This Standard expands on design only where necessary, but provides full coverage of the construction and supervision requirements.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

Numbers set within parentheses refer to documents referred to during the preparation of this Standard. These references are listed in the Bibliography.

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE.....	4
1.2 NORMATIVE REFERENCES	4
1.3 DEFINITIONS.....	5
1.4 NOTATION.....	6
1.5 INFORMATION REQUIRED BEFORE THE EXECUTION OF THE WORK	7
SECTION 2 MATERIALS AND PRODUCT	
2.1 TESTING STANDARDS FOR SPECIFIC MATERIAL PROPERTIES	10
2.2 RAW MATERIALS OF PREFABRICATED DRAINS.....	10
2.3 FLAT DRAINS.....	11
2.4 PREFABRICATED ROUND DRAIN	14
SECTION 3 DESIGN CONSIDERATIONS	
3.1 GENERAL.....	16
3.2 DESIGN PHILOSOPHY	16
3.3 FIELD TRIALS	18
SECTION 4 EXECUTION	
4.1 METHOD STATEMENT	19
4.2 PREPARATION OF THE SITE	19
4.3 DRAIN INSTALLATION	20
4.4 SPECIAL ASPECTS	20
SECTION 5 SUPERVISION, MONITORING AND RECORDS	
5.1 SUPERVISION	21
5.2 MONITORING.....	21
5.3 RECORDS.....	21
SECTION 6 SPECIAL REQUIREMENTS	
6.1 GENERAL.....	23
6.2 SAFETY.....	23
6.3 ENVIRONMENTAL PROTECTION	23
6.4 IMPACT ON ADJACENT STRUCTURES.....	23
APPENDICES	
A PRACTICAL ASPECTS OF VERTICAL DRAINAGE	24
B ASPECTS OF DESIGN	37
C ESTIMATION OF DRAIN SPACING USING DESIGN CHARTS	45
D TEST STANDARDS	49
BIBLIOGRAPHY.....	50

STANDARDS AUSTRALIA

Australian Standard
Execution of prefabricated vertical drains

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard provides general requirements for the execution, testing, supervision, monitoring and installation methods of prefabricated vertical drain projects. It also includes information on design considerations, and practical and design aspects of vertical drainage.

Prefabricated vertical drains are used for the improvement of low-permeability, highly compressible soils, and in on-land and marine constructions for—

- (a) (pre)consolidation and reduction of post-construction settlements; speeding up the consolidation process by decreasing the path lengths for pore water dissipation;
- (b) increasing soil stability (by increasing effective stresses in the soil);
- (c) groundwater lowering; and
- (d) mitigation of liquefaction effects.

In each case there is an overall treatment of the soil (the volume of the drains is small in relation to the soil volume treated).

Prefabricated vertical drains may also be combined with other foundation or ground improvement methods (e.g. sand drains, vacuum consolidation, electro-osmosis, piles and compacted sand piles, rigid inclusions, dynamic compaction and deep mixing).

NOTES:

- 1 See References 1, 2, 3 and 4 in the Bibliography.
- 2 Guidance on practical aspects of prefabricated vertical drains, such as investigation of drain properties, execution procedures and equipment, is given in Appendix A.
- 3 Guidance on the evaluation of soil characteristics and design considerations is given in Appendix B.

1.2 NORMATIVE REFERENCES

The following are normative documents referenced in this Standard:

NOTE: Documents referenced for informative purposes, including material referred to during the preparation of this Standard, are listed in the Bibliography.

AS

- 1726 Geotechnical site investigations
- 2001 Methods of test for textiles
- 2001.2.15 Part 2.15: Physical tests—Determination of thickness of textile fabrics
- 2001.2.3.2 Part 2.3.2: Physical tests—Determination of maximum force using grab method (ISO 13934-2:1999, MOD)

AS	
3706	Geotextiles
3706.2	Part 2: Methods of test—Determination of tensile properties—Wide-strip method
3706.6	Part 6: Methods of test—Determination of seam strength
3706.7	Part 7: Methods of test—Determination of pore-size distribution—Dry-sieving method
3706.9	Part 9: Methods of test—Determination of permittivity, permeability and flow rate
ASTM	
D4716	Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
EN ISO	
12958	Geotextiles and geotextile-related products—Determination of water flow capacity in their plane
ISO	
12117-2	Earth-moving machinery—Laboratory tests and performance requirements for protective structures of excavators Part 2: Roll-over protective structures (ROPS) for excavators of over 6 t

1.3 DEFINITIONS

For the purposes of this document, the definitions below apply.

1.3.1 Auger installation method

Installation method by means of a screw type auger or continuous flight hollow stem auger to prebore stiff/dense soils.

1.3.2 Discharge capacity (q_w)

The cross-sectional area of the drain multiplied by its overall permeability in longitudinal direction (the volume of water that flows out of the drain per time unit under a hydraulic gradient equal to unity).

1.3.3 Displacement installation method

Installation method of drains by means of a hollow tube with end closed off with an anchor plate.

1.3.4 Drain anchor plate

Anchor plate fixed at the end of prefabricated vertical drains before installation, which prevents soil from intruding into the mandrel during installation and the drain from being dragged up when the mandrel is withdrawn.

1.3.5 Drainage blanket

Upper high-permeability drainage layer, which has good contact with the drains, prevents the creation of backpressure in the drains and facilitates egress from the soils.

1.3.6 Dynamic installation method

Drain installation method using dynamic action (impact or vibratory hammer).

1.3.7 Mandrel

Open steel tube used to push the drain below ground.

NOTE: The drain is located inside the mandrel and attached to an anchor plate at the base of the mandrel. Mandrel, with the drain inside, is pushed to the design depth or until a firm layer is encountered. Then the mandrel is withdrawn leaving the drain and the anchor in place. Generally mandrels have a cross-sectioned area of 6000 mm² to 8000 mm² and 8 to 10 mm wall thickness.

1.3.8 Prefabricated vertical drain (PVD)—Wick drain

- 1 A prefabricated drain with a rectangular cross-section, usually consisting of a central core with a channel system surrounded by a filter sleeve (commonly known as a flat drain).
- 2 A prefabricated drain consisting of an annular-corrugated and perforated open circular core, surrounded by a filter sock, commonly known as a round drain.

1.3.9 Static installation method

Drain installation method by means of static load (pushing).

NOTE: This is the most commonly used method.

1.3.10 Vibro installation method

Installation method of drains by means of a top vibrator mounted on a hollow mandrel or by a depth vibrator.

1.3.11 Working platform

Platform created for access and support of the drain installation machines to the treatment area.

1.4 NOTATION

Symbol	Definition
A	= area
a	= width of the prefabricated flat drain
a_v	= coefficient of compressibility of soil
b	= thickness of the prefabricated flat drain
c_h	= coefficient of consolidation for horizontal drainage
c_v	= coefficient of consolidation for vertical drainage
D	= diameter of influence zone
D_{15}	= diameter of soil particles corresponding to 15% passing
D_{50}	= diameter of soil particles corresponding to 50% passing
D_{85}	= diameter of soil particles corresponding to 85% passing
d_m	= diameter of mandrel
d_s	= diameter of smear zone
d_w	= diameter of drain
e	= void ratio
f_{cr}	= creep factor
k_{filter}	= permeability coefficient of filter
k_h	= horizontal permeability coefficient in undisturbed zone

k_s	=	horizontal permeability coefficient in smear zone
k_{soil}	=	permeability coefficient in soil
k_v	=	vertical permeability coefficient
k_w	=	drain permeability coefficient
l	=	length of the drain
O_{90}	=	apparent opening size
O_{95}	=	equivalent opening size
O_{50}	=	apparent opening size
q_p	=	in-plane flow capacity
q_w	=	discharge capacity of drain
R	=	radius of influence zone
r	=	radial distance from centre
S	=	drain spacing
t	=	consolidation time
T_h	=	dimensionless time factor for horizontal drainage
T_v	=	dimensionless time factor for vertical drainage
$\bar{U}_h$	=	average degree of horizontal consolidation
U_t	=	required degree of consolidation
U_v	=	degree of consolidation for vertical drainage
u	=	excess pore pressure
z	=	depth
γ_w	=	unit weight of water

1.5 INFORMATION REQUIRED BEFORE THE EXECUTION OF THE WORK

1.5.1 General

Prior to the execution of the work, all necessary information shall be available.

1.5.2 General information required

The following are required:

- Relevant information regarding the site conditions.
- The location of main grid lines for setting out.
- Design and construction drawings with the location and length of the drains.
- Any legal or statutory restrictions.
- Method statement for the vertical drain installation (see Clause 4.1).
- Characteristics of the drains (physical and hydraulic characteristics).
- Specification for the drains and other materials to be used (see Section 2) and the schedule of any testing and acceptance procedures for materials incorporated in the works.
- Description of a suitable quality management system, including supervision and monitoring.

1.5.3 Information on site conditions

1.5.3.1 General

The information for the site conditions shall be documented. Where relevant, the documentation shall cover the following:

- (a) The geometry of the site (boundary conditions, topography, access, slopes, headroom restrictions, etc.).
- (b) The ground properties of the site that may influence the execution of the vertical drains (see Clause 1.5.3.2), that is—
 - (i) soil description (soil type, soil stratification and existence and frequency of sand and silt layers, hard layers);
 - (ii) penetration resistance (e.g. results of penetration tests);
 - (iii) composition, lateral extent, thickness and firmness of the surface stratum, tree roots, fill; and
 - (iv) presence of cobbles or boulders or cemented layers that can cause difficulties for the execution or could require special installation equipment.
- (c) The following climatic and environmental information:
 - (i) Weather information in areas with extreme climatic conditions.
 - (ii) Marine conditions (currents, tidal movements, wave heights, etc.).
 - (iii) Environmental hazards (any water and subsoil contamination or acid sulfate potential that could affect the execution method, the safety of the work or the discharge of excavation material from the site, including the presence of hazardous gas and the rare but possible occurrence of unexploded ammunition).
- (d) The existing underground structures, services, known contamination and archaeological constraints.
- (e) The environmental restrictions, including noise, vibration, for dynamic installation method and use of mandrel (see Clauses 1.3.7 and 1.3.10) and pollution.
- (f) Planned or ongoing construction activities, such as dewatering, tunnelling and deep excavations.
- (g) Previous experience from drain installation work adjacent to the site.
- (h) The characteristics of the working platform and the drainage layer (physical and hydraulic properties).
- (i) The conditions of structures, roads and services adjacent to the work.

1.5.3.2 Geotechnical investigations

The geotechnical investigations carried out for the design of prefabricated vertical drainage work shall be in accordance with the requirements of AS 1726 and provide information for the installation of the vertical drains [see Clause 1.5.3.1(b)].

The geotechnical investigation report shall be available in sufficient time to allow for planning, design and execution of the vertical drainage works.

Apart from the general geological description and the details listed in AS 1726, the site investigation report shall contain information regarding ground conditions for the execution of vertical drain installations and for loading.

NOTES:

- 1 For information on the practical aspects to be taken into consideration for vertical drainage, see Appendix A.
- 2 For information on aspects of design, see Appendix B.

Information about ground conditions shall also include the following:

- (a) Piezometric levels of groundwater, its variation and possible deviation from hydrostatic pressure conditions.
- (b) Undrained shear strength.
- (c) The ground level and location at any point of investigation, which shall be established relative to the recognized national datum or to a fixed reference point.

1.5.4 Information for the loading operation

For the loading operation, the following design and construction information shall be available:

- (a) Program for loading.
- (b) Preloading (temporary and permanent loading).
- (c) Time schedule for loading and possible preloading.
- (d) Unit weight of fill used for preloading.
- (e) Current and post construction/long-term groundwater levels.
- (f) Notice of any restrictions such as construction phasing required in the design.
- (g) Monitoring program.

1.5.5 Reporting procedures

The following procedures shall also be given:

- (a) Reporting procedure for unforeseen circumstances, or conditions revealed that appear to be different from those assumed in the design.
- (b) Reporting procedure, if an observational method of design is adopted.

SECTION 2 MATERIALS AND PRODUCT

2.1 TESTING STANDARDS FOR SPECIFIC MATERIAL PROPERTIES

All properties listed in Table 2.1 shall be tested according to at least one nominated Standard, and shall be documented by the manufacturer/supplier of prefabricated vertical drains shown in Table 2.1.

NOTE: It is recommended that Australian Standards be used when available for any property to be assessed unless circumstances dictate equivalent Standards to be adopted.

TABLE 2.1
SPECIFIC STANDARDS USED FOR THE TESTING AND DETERMINATION OF
PROPERTIES OF PREFABRICATED VERTICAL DRAINS

Property to be tested	Applicable Standard
Maximum tensile force, in kilonewtons (kN)	AS 3706.2
Elongation at maximum tensile force, in percent (%)	AS 3706.2
Tensile strength of filter, in kilonewtons per metre (kN/m)	AS 3706.2
Tensile strength of seams and joints, in kilonewtons per metre (kN/m)	AS 3706.6
Grab tensile strength, whole drain	AS 2001.2.3.2
Grab tensile strength, filter	AS 2001.2.3.2
Permittivity/permeability, in millimetres per second (mm/s)	AS 3706.9
Pore size of filter (O_{90} or O_{95}), in micrometres (μm)	AS 3706.7
Discharge capacity of the drain, in cubic metres per year (m^3/year)	EN ISO 12958 or ASTM D4716 (see also Appendix A)
Thickness, in millimetres (mm)	AS 2001.2.15

NOTES:

- 1 It is acknowledged various ISO and ASTM standards exist that are equivalent to Australian Standard test methods. Appendix D lists the common methods.
- 2 The tensile strength tests tabled above are based on a 200 mm wide standard specimen. For these drains and the filter, a 200 mm wide specimen may not be possible in which case the test shall be conducted on the available width of specimen and a note to that effect shall be included in the results.

2.2 RAW MATERIALS OF PREFABRICATED DRAINS

A prefabricated drain comprises a synthetic polymer, typically synthetic polypropylene, polyethylene polyester or polyvinyl chloride and is used in applications in soils with a pH-value between 4 and 9 and at a soil temperature less than 25°C. A service lifetime of up to 5 years is applicable.

NOTE: For longer term applications, reference should be made to HB 154 where additional testing may be required to confirm longer term durability and further durability tests may need to be undertaken.

The use of up to 10% internal regenerate (e.g. raw material made out of unused core) for the production of the core is permitted. The composition shall be known and the material shall be processed in the same way as the original product. Recycled material may be used provided it can be verified that it is not causing pollution of the soil or groundwater.

Any additional or deviating requirements shall be established and agreed upon prior to the commencement of the works.

Materials used to manufacture the drains shall not cause pollution of the soil or the groundwater.

2.3 FLAT DRAINS

2.3.1 Shape and structure of flat drain

The flat drain is a prefabricated drain with a rectangular cross-section, usually consisting of a central core with a channel system surrounded by a filter. The width of the core of the flat drains is typically 100 mm and the thickness is between 2 mm and 5 mm.

The core shall consist of a profiled strip, with or without perforation, or a profiled mat with an open or closed structure. It shall have a structure that provides uniform hydraulic flow capacity.

Tears and/or other defects shall not be allowed to occur. Visual inspections for damage shall be made regularly as part of the production quality control.

2.3.2 Measurements

The roll length, width and thickness of the core of the flat, at any given place, shall comply with the dimensions given by the manufacturer (within allowable deviations given by the manufacturer) as part of quality control information.

2.3.3 Durability

The drain shall be protected against weathering during storage on the site.

The product shall not be exposed longer than the time nominated by the manufacturer unless the product is protected by a wrapping material or stored in-house. The recommendations of the supplier shall be followed.

2.3.4 Tensile strength and elongation

The required tensile strength of the flat drain is dependent upon the type of installation machine, installation technique and depth of the drain. Tensile strength of the flat drains in the longitudinal direction shall be high enough to prevent breakage during and after installation.

Testing of tensile strength and elongation of the flat drain shall be made in accordance with the relevant Standards listed in Table 2.1 (modified with regard to the width of the product).

NOTE: The following characteristics of a flat drain are recommended:

- (a) Elongation $\geq 2\%$ at failure of the weakest element.
- (b) Elongation $\leq 10\%$ at a tensile force of 0.5 kN (20% if exposed to frost).
- (c) Minimum tensile strength of 7 kN/m at failure of the complete drain, modified with regard to the actual width of the product test specimen.

The strength of the seam, measured according to the relevant Standards in Table 2.1 in a range of temperatures that apply to the project site, shall be at least 1 kN/m.

The grab tensile strength shall be greater than 1.6 kN for the composite drain and 0.3 kN for the filter.

2.3.5 Discharge capacity

The discharge capacity and the filtration characteristics are the most important properties. The following factors influence the discharge capacity:

- (a) Due to increasing lateral effective pressure during the consolidation process, the filter is squeezed into the channel system of the core, which reduces the channel area.
- (b) The vertical compression of the soil that takes place during the consolidation process may lead to buckling of the relatively incompressible flat drains, which may reduce the discharge capacity.

- (c) Fines may intrude through the filter into the core and cause blocking of the channel system.
- (d) Soil temperature has an influence on the compression resistance and creep of the drains and thus on the discharge capacity.

The required discharge capacity of the flat drain is largely dependent upon the purpose of ground improvement, the consolidation parameters of the soil, the drain spacing and the depth of drain installation (see Note 1).

The discharge capacity shall be high enough to satisfy the design requirements (see Note 2).

The discharge capacity test shall be carried out in accordance with the relevant Standards listed in Table 2.1 and with the appropriate modifications (see Note 3).

For usual applications, the discharge capacity test shall be performed at the laboratory temperature and then the test report shall be referred to a temperature of 20°C. For applications in tropical environment, the discharge capacity test shall be performed at a temperature corresponding to the soil temperature at the place of drain installation and then the test report shall be referred to that specific temperature.

The test period shall be long enough to yield a constant value of discharge capacity; preferably at least two days at the maximum static pressure stipulated by the designer.

NOTES:

- 1 For design aspects, see Appendix B.
- 2 The recommended value of the discharge capacity is given in Appendix B.
- 3 For recommended modification, see Appendix A.

2.3.6 Filter of flat drains

The filter sleeve of the flat drain shall be composed of a non-woven material consisting of fibres that are mechanically, chemically or thermally bonded.

The occurrence of creases, tears, holes and/or other defects shall not be allowed. The seams of the filter sleeve shall be constructed in such a way that fines cannot intrude into the core of the flat drain.

Visual inspections for damage shall be made regularly during production in accordance with the factory production control plan.

2.3.7 Tensile strength per unit width of filter

The tensile strength of the filter shall be sufficient to prevent breakage during and after installation.

Testing shall be carried out in accordance with the relevant Standards listed in Table 2.1. The average of the individually measured values for the tensile strength shall be not lower than 7 kN/m in the longitudinal direction.

2.3.8 Permittivity/permeability of filter

Testing shall be carried out in accordance with the relevant Standards listed in Table 2.1. The average of the individually measured values shall comply with the recommended average values. In case of drain installation for liquefaction problems, the filter pore size shall be adapted to ensure adequate permeability of the filter for this application.

2.3.9 Pore size of filter

The pore size of filter shall be selected to ensure sufficient discharge capacity and avoid serious loss of discharge capacity due to clogging of the filter and/or the core by soil particles. The seams of the filter shall not have an opening size larger than that of the geotextile filter.

Primarily, the requirements for the filter sleeve characteristics shall be given in the project, considering the soil properties at the site and the installation conditions (dry or wetland, offshore).

The value of the pore size O_{95} shall be not greater than 80 μm .

NOTES:

- 1 The value of O_{95} may be influenced by project-specific requirements and higher values may be acceptable.
- 2 Some guidance on filter selection is provided in Paragraph B4.2.1, Appendix B.

2.3.10 Quality control

The flat drain shall comply with this Standard and the conformity assessment procedures that apply to it.

The on-site testing frequency shall be decided between the parties involved.

NOTE: The filter and drain characteristics and corresponding testing methods, as well as the proposed testing frequency, are given in Table 2.2.

TABLE 2.2
PROPOSED TESTING FREQUENCY FOR FABRICATION CONTROL

Property	Proposed test frequency	Required Standard
Filter		
Thickness	25 000 m ²	AS 2001.2.15
Mass per unit area	25 000 m ²	AS 2001.2.13
Pore size	500 000 m ²	AS 3706.7
Permittivity/Permeability	200 000 m ²	AS 3706.9
Tensile strength in the longitudinal direction	200 000 m ²	AS 3706.2
Tensile strength in the cross-direction	200 000 m ²	AS 3706.2
Tensile strength of filter seam	500 000 m	AS 3706.6
Grab tensile strength	500 000 m	AS 2001.2.3.2
Drain composite		
Width and thickness	25 000 m	AS 2001.2.15
Mass per unit length	25 000 m	AS 2001.2.13
Tensile strength in the longitudinal direction	100 000 m	AS 3706.2
Grab tensile strength	500 000 m	ASTM D4632, ISO 13934-2, AS 2001.2.3.2
Elongation at maximum tensile force	100 000 m	AS 3706.2
Discharge capacity straight	500 000 m	(see Note)
Discharge capacity buckled	500 000 m	(see Note)

NOTES:

- 1 Guidance for testing for discharge capacity is given in Appendix A.
- 2 The tensile strength tests tabled above are based on a 200 mm wide standard specimen. For these drains and the filter, a 200 mm wide specimen may not be possible in which case the test may be conducted on the available width of specimen and a note to that effect should be included in the results.
- 3 It is acknowledged that various ISO and ASTM Standards are equivalent to Australian Standard test methods. Appendix D lists common test methods.

2.3.11 Delivery quality assurance

The need for on-site verification should be agreed by the parties involved, in consideration of the risks and the scale of the project.

Should on-site testing be deemed necessary, Table 2.3 provides guidance on the frequency for delivery or on-site testing.

TABLE 2.3
PROPOSED TESTING FREQUENCY FOR DELIVERY
QUALITY ASSURANCE

Property	Proposed test frequency
Filter	
Mass per unit area	100 000 m ²
Permittivity/Permeability	100 000 m ²
Tensile strength in the longitudinal direction	100 000 m ²
Drain composite	
Width and thickness	100 000 m
Mass per unit length	100 000 m
Tensile strength in the longitudinal direction	100 000 m
Elongation at maximum tensile force	100 000 m

2.4 PREFABRICATED ROUND DRAIN

2.4.1 Shape and structure of round drain

A round drain consists of an annular-corrugated and perforated open circular core, surrounded by a filter sock. The drain diameter is typically 30 mm to 50 mm in outer diameter and 5 mm in wall thickness.

Tears and/or other defects shall not be allowed to occur in a round drain. Visual inspections for damage shall be made regularly as part of the production quality control.

2.4.2 Measurements

The diameter and thickness of the core shall comply with the dimensions given by the manufacturer (within allowable deviations given by the manufacturer).

2.4.3 Durability

The durability requirements for round drains shall be in accordance with Clause 2.3.3.

2.4.4 Tensile strength and elongation

The required tensile strength of the round drain is dependent upon the type of installation machine, installation technique and depth of the drain.

Tensile strength of the drain in the longitudinal direction shall be high enough to prevent breakage during and after installation.

Testing of tensile strength and elongation of the round drain shall be made in accordance with the standard tensile test with modified clamps (see Table 2.1).

The strength of the seam, measured according to the relevant Standards listed in Table 2.1 (with modified clamps) in a range of temperatures that apply to the project site, shall be at least 1 kN/m.

The grab tensile strength of the filter shall be greater than 0.3 kN.

2.4.5 Discharge capacity and filtration characteristics

The discharge capacity of the round drains is usually much larger than is required for soil consolidation. It may decrease if the round core is crushed due to an increase of lateral effective pressure during the consolidation process and/or buckling.

The perforation of the pipe (core) shall not be sealed due to compression of the filter sleeve.

The pipe and filter of drains used for longer term applications shall consider longer term durability aspects (see Clause 2.2).

2.4.6 Filter of round drain

The filter of round drains shall comply with the requirements of Clause 2.3.6.

2.4.7 Tensile strength per unit width of filter

The tensile strength per unit width of filter for round drains shall comply with the requirements of Clause 2.3.7.

2.4.8 Permittivity/permeability of filter

The permittivity/permeability of the filter of round drains shall comply with the requirements of Clause 2.3.8.

2.4.9 Pore size of filter

The pore size of filter for round drains shall comply with the requirements of Clause 2.3.9.

2.4.10 Quality control

The round drain shall comply with this Standard and the applicable conformity assessment procedures.

NOTE: The filter and drain characteristics and corresponding test methods, as well as the testing frequency, are given in Table 2.2, except that the discharge capacity tests (straight and buckled) need not apply.

SECTION 3 DESIGN CONSIDERATIONS

3.1 GENERAL

The scope of the application of vertical drainage is to handle and solve problems associated with the following aspects of geotechnical engineering:

- (a) Consolidation settlement in low-permeability soils (resulting from surface loading or groundwater lowering).
- (b) Stability (of structures and embankments).

Other applications of vertical drainage include treating soils exposed to the effects of dynamic and cyclic loading (e.g. in seismic regions or under rail tracks), as a result, the impacts of which can be reduced as well as the effects of vibrations on structures reduced. Vertical drainage may also be used for remediation of contaminated ground and for mitigation of liquefaction potential.

Vertical drainage design encompasses two phases, as follows:

- (i) *Functional design* Functional design is the first phase and the need for vertical drainage has to be quantified. This phase defines the loading and drain spacing necessary to produce the desired effects on rate of consolidation and settlements. Treatment of soft soils with vertical drainage followed by preloading provides ground improvement by accelerated consolidation resulting in gain in the undrained shear strength of the soil. It results in a reduction, post-development, of in-service settlements under design loads and also in creating satisfactory drainage paths for pore water in the case of liquefaction.
- (ii) *Process design* Is the second phase, the method of drain installation and its functioning in practice has to be designed. This phase accounts for effects of drain installation on the ground, geometry, the nature and the dimensions of the drains and for effects such as possible buckling in case of excessive strains in some soil layers.

3.2 DESIGN PHILOSOPHY

Vertical drainage may be used for different purposes as outlined in Clause 3.1; however, the process of designing vertical drainage generally follows the operations listed in Figure 3.1. The objective (design basis) and the ground properties (first row of boxes) interact with the settlement and stability analyses to satisfy the requirements put on the targeted outcome from the effect of the drains; that is to reach a given degree of global and/or local consolidation within a specific period of time.

Ground treatment by vertical drainage and the associated subsequent preloading shall be designed and executed in such a manner that the structure, embankment or paved area supported by the treated ground, during its intended life and with an appropriate degree of reliability and cost-effectiveness, will remain fit for the intended use and sustain all actions and influences that are likely to occur.

The serviceability requirements for the development of the soft soil site shall be specified by the client. The observational method, which involves adapting the design in a planned manner, is an important part of the design.

The design shall take into account the loads that could occur during construction and service. It shall account for the known effect of the drain installation on the properties of the ground and the effects of the initial and longer term groundwater levels and the impacts such levels may pose on the preloading design.

The installation of vertical drains may also induce excess pore water pressure creating a short-term reduction of the undrained shear strength.

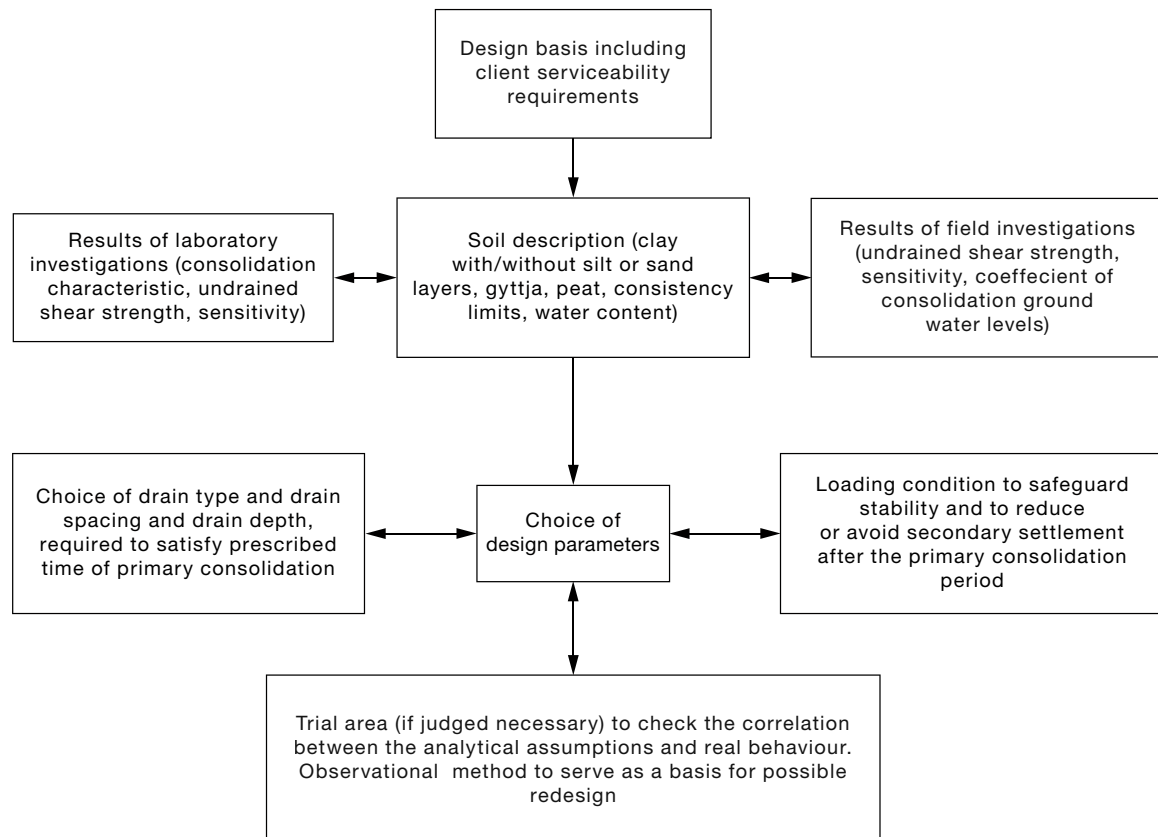


FIGURE 3.1 CHART OF DESIGN PROCESS, INCLUDING LABORATORY AND FIELD INVESTIGATIONS, FUNCTIONAL DESIGN AND FIELD TRIALS

The design shall consider the following:

- (a) *Subsurface characterization* Generally using field and laboratory investigations, special attention shall be given to assess the preconsolidation stress, drainage boundary conditions and the consolidation characteristics of the soils.
NOTE: It may be worthwhile to carry out trials at an early stage to assess the performance of PVDs and the soils.
- (b) *Developed land use and associated loadings* Account shall be taken of the final ground level after development and the long-term loading conditions.
- (c) *Current and future groundwater levels* The groundwater level is essential to determine the effective stress of the soils at the current state as well as in the future. Special attention shall be given to the groundwater level if it is located within or intrudes into the fill placed for preloading operations.
- (d) *Acceptable in-service settlements* While the acceptable in-service settlement has to be ultimately the decision of the client, geotechnical consultants may be needed to advise on the consequences and the related risks. For example, the client may accept a higher settlement for a road if the expected differential settlement and grade are small with low risk for traffic, saving vertical drainage costs.