भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS

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व्यापक परिचालन मसौदा

हमारा संदर्भ : सीईडी 43/टी-125 **23 दिसम्बर 2023**

तकनीकी समिति : मृदा एवं नींव इंजीनियरी विषय समिति, सीईडी 43

प्राप्तकर्ता :

1 सिविल इंजीनियरी विभाग परिषद, सीईडीसी के सभी सदस्य
2 मृदा एवं नींव इंजीनियरी विषय समिति, सीईडी 43 के सभी सदस्य
3 आईएस 15284 (भाग 1 और 2) के पुनरीक्षण के लिए पैनल, सीईडी 43:पी16 के सभी सदस्य
4 रूचि रखने वाले अन्य निकाय।

महोदया/महोदय,

निम्नलिखित मसौदा संलग्न है:

प्रलेख	शीर्षक
सीईडी 43 (24471)WC	**भूमि सुधार के लिए डिजाइन और संरचना – रीति संहिता : भाग 2 ऊर्ध्वाधर नालियों का उपयोग करके पूर्व समेकन का भारतीय मानक मसौदा** **[IS 15284 (भाग 2) *का पहला पुनरीक्षण*]** **(ICS No. 93. 020)**

कृपया इस मसौदे का अवलोकन करें और अपनी सम्मतियाँ यह बताते हुए भेजे कि यह मसौदा प्रकाशित हो तो इस पर अमल करने में, आपको व्यवसाय अथवा कारोबार में क्या कठिनाइयॉ आ सकती हैं।

सम्मतियॉ भेजने की अंतिम तिथि: 31 जनवरी 2024

सम्मति यदि कोई हो तो कृपया अधोहस्ताक्षरी को ई मेल द्वारा **madhurima@bis.gov.in** पर या उपरलिखित पते पर, संलग्न फोर्मेट में भेजें।

यदि कोई सम्मति प्राप्त नहीं होती है अथवा सम्मति में केवल भाषा संबंधी त्रुटि हुई तो उपरोक्त प्रलेख को यथावत अंतिम रूप दे दिया जाएगा। यदि सम्मति तकनीकी प्रकृति की हुई तो विषय समिति के अध्यक्ष के परामर्श से अथवा उनकी इच्छा पर आगे की कार्यवाही के लिए विषय समिति को भेजे जाने के बाद प्रलेख को अंतिम रूप दे दिया जाएगा।

यह प्रलेख भारतीय मानक ब्यूरो की वैबसाइट **www.bis.gov.in** पर भी उपलब्ध हैं।

धन्यवाद।

भवदीय
ह/-
(अरुण कुमार एस.)
वै. 'ई'/निदेशक और प्रमुख (सिविल इंजीनियरी)

सलंग्न: उपरिलिखित

भारतीय मानक ब्यूरो
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DOCUMENT DESPATCH ADVICE

Reference	Date
CED 43/T-125	23 December 2023

TECHNICAL COMMITTEE:

SOIL AND FOUNDATION ENGINEERING SECTIONAL COMMITTEE, CED 43

ADDRESSED TO:

1. All Members of Civil Engineering Division Council, CEDC
2. All Members of Soil and Foundation Engineering Sectional Committee, CED 43
3. All Members of Panel for Revision of IS 15284 (Parts 1 and 2), CED 43:P16
4. All other interests

Dear Madam/Sir,

Please find enclosed the following draft:

Doc. No.	Title
CED 43 (24471)WC	**Draft Indian Standard Design and Construction for Ground Improvement — Code of Practice : Part 2 Preconsolidation Using Vertical Drains [*First Revision of* IS 15284 (Part 2)] (ICS No. 93.020)**

Kindly examine the draft and forward your views stating any difficulties which you are likely to experience in your business or profession, if this is finally adopted as National Standard.

Last Date for comments: 31 January 2024

Comments if any, may please be made in the enclosed format and emailed at **madhurima@bis.gov.in** or sent at the above address.

In case no comments are received or comments received are of editorial nature, you will kindly permit us to presume your approval for the above document as finalized. However, in case comments, technical in nature are received, then it may be finalized either in consultation with the Chairman, Sectional Committee or referred to the Sectional Committee for further necessary action if so desired by the Chairman, Sectional Committee.

The document is also hosted on BIS website **www.bis.gov.in**.

Thanking you,

Yours faithfully,

Sd/-

(Arun Kumar S.)
Sc. 'E'/Director and Head (Civil Engg.)

Encl: As above

FORMAT FOR SENDING COMMENTS ON BIS DOCUMENTS

(Please use A4 size sheet of paper only and type within fields indicated. Comments on each clause/subclause/table/fig etc. be started on a fresh box. Information in column 5 should include reasons for the comments, and those in column 4 should include suggestions for modified wording of the clauses when the existing text is found not acceptable. Adherence to this format facilitates Secretariat's work) {Please e-mail your comments to madhurima@bis.gov.in }

DOC. NO.	**Doc: CED 43 (24471)WC**
TITLE	**Draft Indian Standard Design and Construction for Ground Improvement — Code of Practice : Part 2 Preconsolidation Using Vertical Drains [*First Revision of* IS 15284 (Part 2)]** **(ICS No. 93.020)**
LAST DATE OF COMMENTS	**31 January 2024**
NAME OF THE COMMENTATOR/ ORGANIZATION	______________________________

Sl No. **(1)**	**Clause/Sub-clause/Para No.** **(2)**	**Comments/ Suggestions** **(3)**	**Modified Wording of the Clause** **(4)**	**Reasons/ Justifications for the Proposed Changes** **(5)**

DOC: CED 43 (24471)WC
December 2023

BUREAU OF INDIAN STANDARDS

DRAFT FOR COMMENTS ONLY

Draft Indian Standard

DESIGN AND CONSTRUCTION FOR GROUND IMPROVEMENT — CODE OF PRACTICE

PART 2 PRECONSOLIDATION USING VERTICAL DRAINS

[*First Revision of* IS 15284 (Part 2)]

Soil and Foundation Engineering Sectional Committee, CED 43	Last date for Comments: **31 January 2024**

FOREWORD

(*Formal clauses to be added later.*)

Whenever soft cohesive soil strata underlying a structure are unable to meet the basic requirements of safe bearing capacity and tolerable settlement, ground improvement is adopted to make it suitable for supporting the proposed structure. Both the design requirements, that is, shear strength and settlement under loading, can be fulfilled by consolidating the soil by applying a preload, before putting into the service condition. This consolidation of soil is normally accelerated with the use of vertical drains.

This standard (Part 2) was published in 2004 as a guideline standard to cover design and construction for ground improvement by pre-consolidation using vertical drains. It has been felt that the provisions regarding different types of vertical drains should be further revised to take into account the recent developments in this field. This revision has been brought out to incorporate these developments.

In this revision of the standard, the following major modifications have been made:

a) The standard was previously brought out as a guideline standard as the experience of ground improvement techniques in the country was limited. With lot of experience gained over the years, it has been decided to bring out the revised standard as a code of practice standard. The title of the standard has been changed accordingly.
b) Definitions of various terms have been modified as per the prevailing engineering practice.
c) Quality control and test requirements for prefabricated vertical drains have been incorporated.
d) Smear effect has been included in design procedure.

e) The factor of safety against possible slip or bearing failure has been reduced to 1.2 to be consistent with other Indian standards.
f) Vacuum consolidation method has been included.
g) Instrumentation and monitoring has been included.

In the formulation of this standard, the following standards of other countries and publications have also been considered:

AS 8700 - 2011	Execution of prefabricated vertical drains
BS EN 15237 : 2007	Execution of special geotechnical works — Vertical drainage
FHWA/RD-86/168 : 1986	Prefabricated vertical drains - Vol. I, Engineering guidelines, U.S. Department of Transportation, Federal Highway Administration

The Part 1 of the standard, namely IS 15284 (Part 1):XXXX 'Design and construction for ground improvement — Code of practice: Part 1 Stone columns (*first revision*)' covers ground improvement using stone columns.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

DOC: CED 43 (24471)WC
December 2023

BUREAU OF INDIAN STANDARDS

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Draft Indian Standard

DESIGN AND CONSTRUCTION FOR GROUND IMPROVEMENT — CODE OF PRACTICE

PART 2 PRECONSOLIDATION USING VERTICAL DRAINS

[*First Revision of* IS 15284 (Part 2)]

Soil and Foundation Engineering Sectional Committee, CED 43	Last Date for Comments: **31 January 2024**

1 SCOPE

This standard (Part 2) covers provisions on design and construction of vertical drains used for improving the ground such that the consolidation under preload is accelerated resulting in improvement of ground to carry envisaged loads.

2 REFERENCES

The standards given below contain provisions which, through reference in this text, constitute the provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
IS 1892 : 2021	Subsurface investigation for foundations — Code of practice (*second revision*)
IS 18309 : 2023	Geosynthetics — Prefabricated vertical drains for quick consolidation of very soft plastic soil — Specification

3 TERMINOLOGY

For the purpose of this standard the following definitions shall apply.

3.1 Ground Improvement using Vertical Drains — Method to improve the load bearing capacity, accelerate the rate of settlement and to reduce the post-construction settlement of a saturated cohesive soil.

3.2 Displacement Type of Installation Process — Installation process in which the soil is laterally pushed or shifted while making the hole due to driving of a tube or a casing.

3.3 Non-displacement Type of Installation Process — Installation process in which the soil is taken out during boring to make the hole.

3.3 Mandrel — The tube (casing) used for installing vertical drains.

3.4 Preconsolidation — Consolidation of soft to very soft saturated clay under an imposed load to increase the shear strength parameters of clay and reduction of post construction settlement potential.

3.5 Sensitivity of Clay — Ratio of the unconfined compressive strength of clay at its natural state to the remoulded state at the same water content.

3.6 Smear Zone — The disturbed area caused due to lateral displacement of the soil around the mandrel accompanied by an overall disturbance effect where horizontal layers with higher permeability are distorted vertically due to driving or boring process.

3.7 Sand Drain — Drain with circular cross-section, built of granular material (sand, gravel) with high permeability.

3.8 Prefabricated Vertical Drain (PVD)/Band Drain — Prefabricated drain with a rectangular cross-section, usually consisting of a central core with a channel system surrounded by a filter sleeve.

3.9 Sand Wick — Prefabricated drain made by filling granular material (sand/gravel) into perforated pipes of flexible HDPE or stockings made using non-woven, permeable fabric, with the bottom end closed.

3.10 Well Resistance — The resistance to the upward water flow in the vertical drains. The well resistance increases with the increase in the length of the drain.

3.11 Anchor Plate — The plate fixed at the tip of the band drain before installation which prevents soil from intruding into the mandrel during installation. The anchor plate also helps anchor the tip thereby preventing chances of the band drain being dragged up when the mandrel is withdrawn.

3.12 Drainage Blanket — Upper, high-permeability drainage layer, which has good contact with the drains and prevents the creation of backpressure in the drains.

4 NECESSARY INFORMATION

4.1 For the satisfactory design and installation of vertical drains with preloading, the following information shall be required.

a) Sub-surface investigation data as laid down in IS 1892 including any other relevant Indian Standard, as applicable for specific projects. Borelogs should be supplemented by penetration tests and other in-situ test results up to the required depth as per IS 1892. Groundwater level and its conditions (such as artesian conditions) should also be incorporated. Site specific information such as the presence of slopes, boulders/other obstructions, cemented layers, uncontrolled fill, proximity to tidal variations, etc which can hinder the installation of vertical drains should be indicated in the investigation report.

b) The general layout of the structure showing the proposed foundation system.
c) Loading pattern and intensity as determined from structural analysis.
d) Existing underground structures, services and known contamination, if any.
e) Construction programme for ground improvement.
f) Unit weight and nature of fill to be used for preloading.

5 TYPE OF VERTICAL DRAINS

Vertical drains can be of the following types:

a) Sand drains; and
b) Prefabricated vertical drains.

5.1 Sand Drains

5.1.1 These shall be installed by any of the following methods:

a) Driven or vibratory closed-end mandrel; and
b) Jetting with water.

5.1.2 The first method is displacement type and the second is non-displacement type. The displacement method should not be used where clay sensitivity is more than 4.

5.1.3 The diameter of sand drains ranges from 150 mm to 600 mm and is largely based on the convenience of the installation technique utilized. The maximum depth of the sand drains is generally up to 30 m.

5.1.4 The sand used for sand drain should be free draining consisting of well graded sand/gravel. The discharge properties of the sand drains shall be kept much higher so that the resultant flow is unaffected by the well resistance.

5.2 Prefabricated Vertical Drains

5.2.1 The prefabricated vertical drains can be of the following two types;

a) Sand wicks; and
b) Band shaped drains.

5.2.2 Sand wicks are made by filling pre-formed pipes of permeable high density polyethylene (HDPE) or other stockings made using non-woven, permeable fabric with well graded coarse to medium sand or any other suitably graded material having permeability in the range of 10^{-5} to 10^{-3} m/s. The prepared sand wick shall be saturated by keeping it in a water vat just prior to installation. After driving the mandrel to the specified depth, the flexible sand wick is inserted into the tube and the tube is withdrawn.

5.2.3 A mandrel is often pushed into the soil along with the prefabricated drain with the help of a hydraulic power/mechanical pulley system. Anchor plates are generally used for the installation of band-shaped drains. During installation, the anchor plate ensures that the bottom of the band-shaped drain is anchored at the desired depth.

5.2.4 Prefabricated band drains typically consist of a central core surrounded by a filter sleeve made using geotextile. Any biodegradable material (for example, jute or coir) can also be used for the fabrication of vertical drains. However, the product should be tested for the parameters as mentioned in **5.2.5** and shall comply with project design requirements. The width of the band drain is typically 100 mm and they are rectangular in shape and their thickness ranges from 2 mm to 10 mm. The core consists of a profiled strip or mat with an open or closed structure that provides regular hydraulic flow capacity. Band drains with tears or defects affecting water flow characteristics shall not be used.

5.2.5 The specification of prefabricated vertical drain shall conform to the requirements of IS 18309.

6 DESIGN

6.1 The design procedure of vertical drains for preloading consists of the following steps:

a) Determination of the depth and spacing for a given drain size based on the soil properties and stratification. Normally the drains are arranged in equilateral triangle or square grid pattern; and
b) Determination of the rate of loading, stages, and pause period of preload without causing plastic flow or any detrimental effect on the ground based on the soil properties, stratification, and topography of the adjoining ground.

6.2 The depth of vertical drains for a given soil profile shall be so determined that the drains extend through the most significant compressible strata that account for the major consolidation settlement during preloading.

6.3 In general, preloading is done by an applied pressure, which is at least equal to the service load condition. However, depending on the soil strength and the magnitude of required load, preloading may be done in stages allowing the desired percentage (as per design requirement) consolidation to occur under each stage of loading.

6.3.1 At drain installation project locations where the stability conditions are unsatisfactory or where preload material is not available in the required quantity, then the surface load can be replaced or augmented by the vacuum loading method. In this case, the drainage blanket is overlain by an airtight cover and sealed hermetically along its outer borders. The drainage blanket is connected to a vacuum pump, which produces under-pressure in the drains in relation to the pore water pressure in the soil and results in consolidation. The under-pressure achieved by the vacuum method is a maximum of 80 kPa.

6.4 At each stage of preload the degree of consolidation achieved by radial and vertical drainage shall be determined. Improvement of shear strength shall also be evaluated and considered to determine the magnitude of the next stage of preload. The stability at each stage of loading shall be examined by finding the factor of safety against a possible slip or bearing capacity failure. A factor of safety of 1.2 is considered adequate for each preload stage.

6.5 As per the theory of three-dimensional consolidation:

$$U = 1 - (1 - U_z)(1 - U_r)$$

where

U = degree of consolidation for three-dimensional flow;
U_z = degree of consolidation for vertical flow; and
U_r = degree of consolidation for radial flow.

U_z and U_r are functions of the time factors T_v and T_r for vertical and radial consolidation, respectively.

6.5.1 The time factor for vertical flow, T_v is given by the following equation:

$$T_v = \frac{C_v t}{H^2}$$

where

C_v = coefficient of consolidation for vertical flow;
T = time elapsed since the application of a preload; and
H = thickness of consolidating layer depending on one way or two way drainage (this depends on the presence of drainage layer, if any at bottom of treated soil since drainage blanket is essential at ground level).

For the given value of C_v, t and H, T_v can be computed, and corresponding U_z can be obtained (*see* Fig. 1 and Table 1).

In most cases, case 1(a) of Fig. 1 becomes applicable and can be used without much compromise on the accuracy of results. If, however, there is clear evidence of the applicability of any one of the other cases as illustrated in Fig. 1, then the corresponding method of estimation should be used.

6.5.2 The time factor for radial flow is given by the following equation:

$$T_r = \frac{C_r t}{(2R)^2}$$

where

C_r = coefficient of consolidation for radial flow (*see* **6.6**), and
$2R$ = well spacing (*see* Fig. 2).

For the given value of C_r, t and R, T_r can be calculated.

Degree of consolidation for radial flow, $U_r = 1 - e^{-A}$

where

$$A = \frac{8T_r}{F_n}$$

where

$$F_n = \left(\frac{n^2}{n^2 - 1}\right)\left[\left(\frac{2R}{d_s}\right) - \left(\frac{k_h}{k_s}\right)\left(\frac{d_s}{2r_w}\right) - \frac{3}{4}\right]$$

where

$$n = \frac{R}{r_w}$$

r_w = radius of the drain;
d_s = diameter of zone of smear;
k_h = horizontal permeability of soil in undisturbed zone; and
k_s = horizontal permeability of soil in smear zone.

Various correlations between d_s and r_w, d_s and d_m, and k_h and k_s have been proposed in the literature and it is left to the designer to decide the appropriate correlation to be used. However, in the absence of more detailed information, the following correlations may be used:

a) d_s/d_m = 2.5 to 3, where d_m is the diameter of a circle with an area equal to the mandrel's cross-sectional area;

b) d_s/r_w = 3 to 6; and

c) k_h/k_s = 1.2 to 1.5.

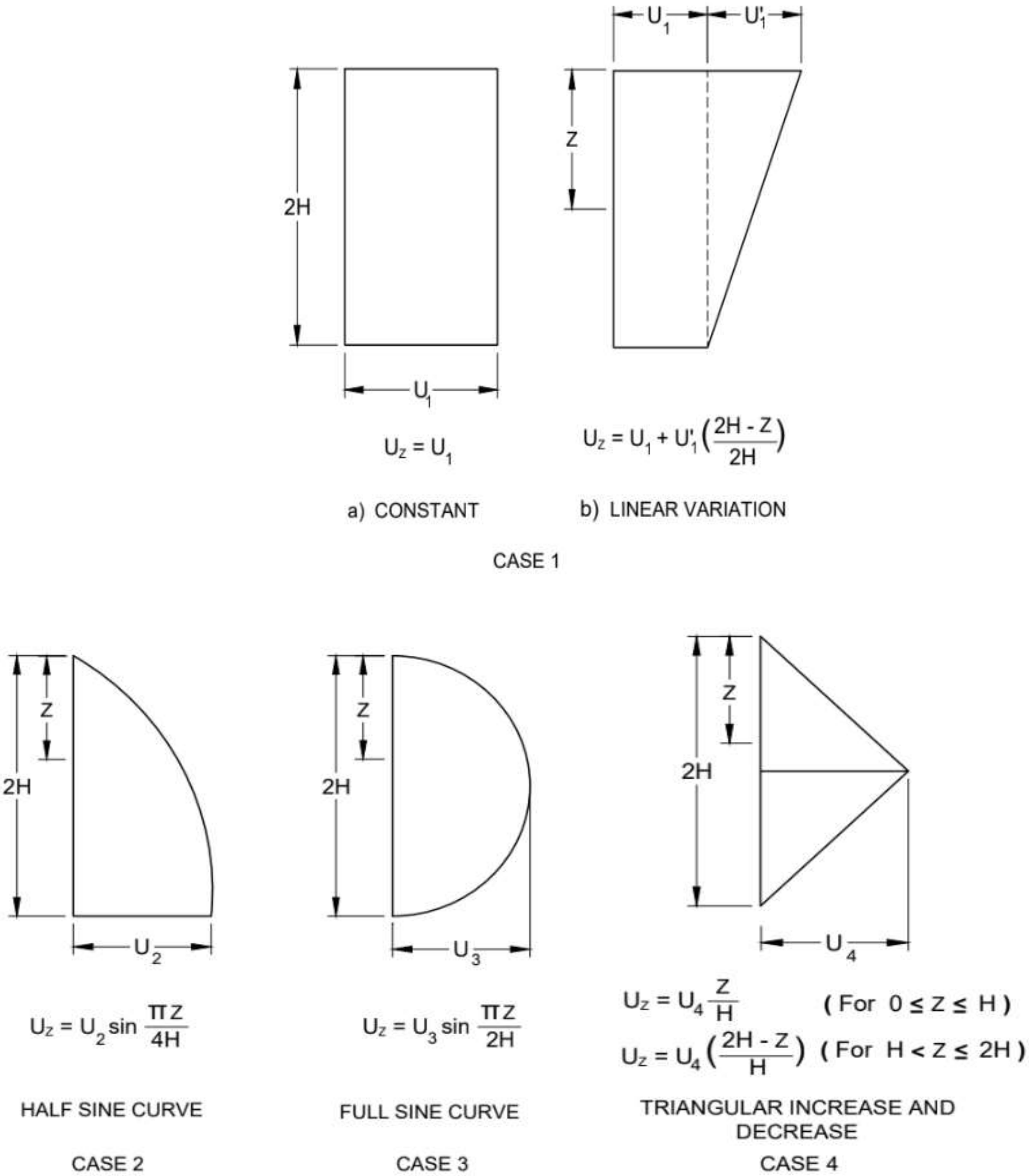

FIG. 1 FOUR CASES OF INITIAL EXCESS PORE PRESSURE DISTRIBUTION WITH DOUBLE DRAINAGE

Table 1 Values of U_z for Various Values of T_v
(*Clause* 6.5.1)

Sl No.	T_v	U_z (Percent Consolidation)			
		Case 1	**Case 2**	**Case 3**	**Case 4**
(1)	(2)	(3)	(4)	(5)	(6)
i)	0.004	7.35	6.49	0.98	0.85
ii)	0.008	10.38	8.62	1.95	1.62
iii)	0.012	12.48	10.49	2.92	2.41
iv)	0.020	15.98	13.67	4.81	4.00
v)	0.028	18.89	16.38	6.67	5.60
vi)	0.036	21.41	18.76	8.50	7.20
vii)	0.048	24.64	21.96	11.17	9.50
viii)	0.060	27.64	24.81	13.76	11.98
ix)	0.072	30.28	27.43	16.28	14.36
x)	0.083	32.33	29.67	18.52	16.46
xi)	0.100	35.62	32.88	21.87	19.76
xii)	0.125	39.89	36.54	26.54	24.42
xiii)	0.150	43.70	41.12	30.93	28.86
xiv)	0.175	47.18	44.73	35.07	33.06
xv)	0.200	50.41	48.09	38.95	37.04
xvi)	0.250	56.22	54.17	46.03	44.32
xvii)	0.300	61.32	59.50	52.30	50.32
xviii)	0.350	65.82	64.21	57.83	56.49
xix)	0.400	69.73	68.36	62.73	61.54
xx)	0.500	76.40	76.28	70.88	69.94
xxi)	0.600	81.56	80.69	77.25	76.52
xxii)	0.700	85.59	84.91	82.22	81.65
xxiii)	0.800	88.74	88.21	86.11	85.66
xxiv)	0.900	91.19	90.79	89.15	88.80
xxv)	1.000	93.13	92.80	91.52	91.25
xxvi)	2.000	99.42	—	—	—

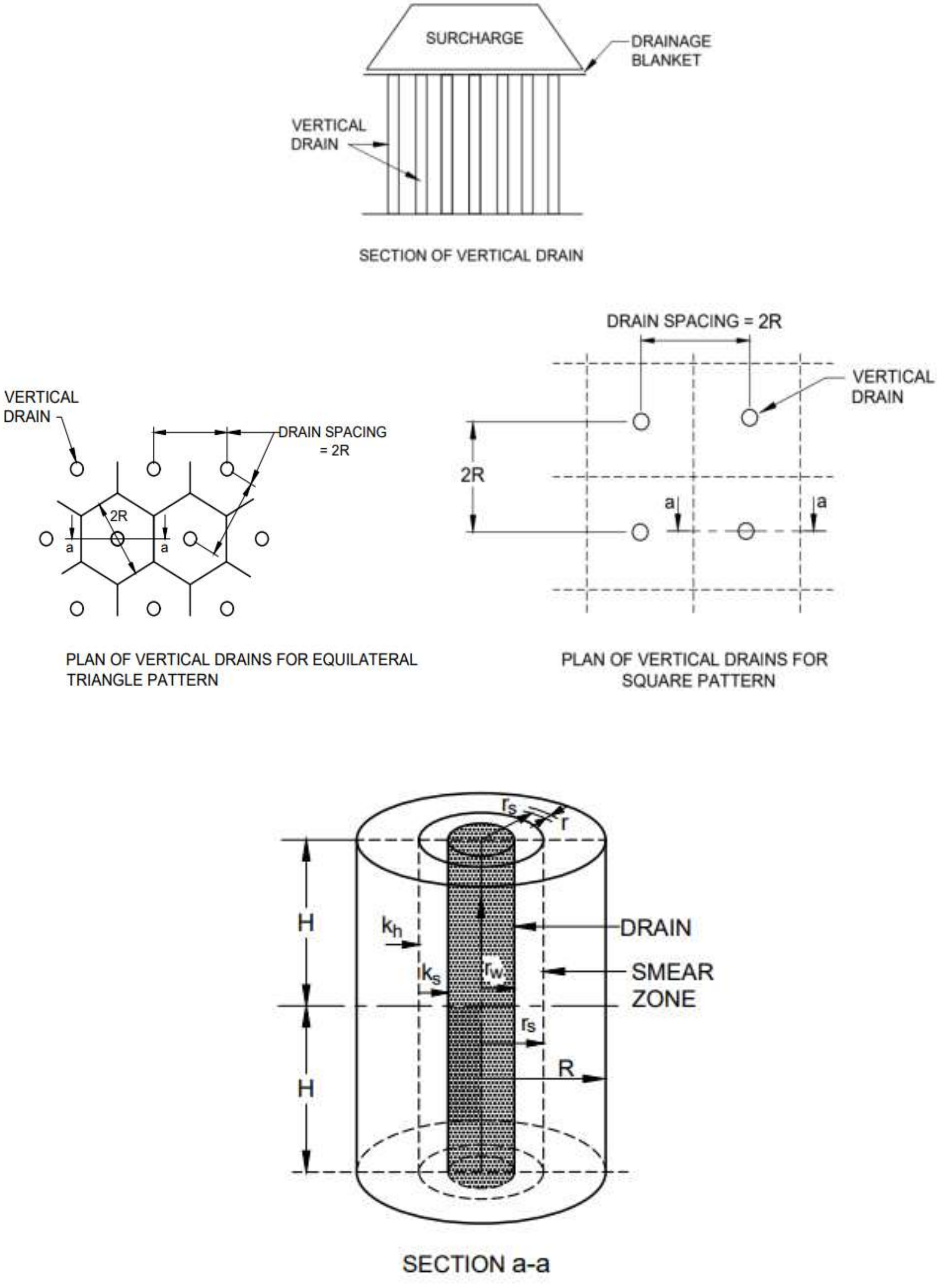

FIG. 2 SCHEMATIC DIAGRAM OF INSTALLATION OF VERTICAL DRAINS

6.6 The C_r value is generally different from C_v because of anisotropy and the nature of soil deposition. It is preferable to conduct a laboratory consolidation test on samples cut in the horizontal direction to get a direct measurement of C_r, otherwise, C_r may be estimated from a realistic evaluation of the ratio of horizontal to vertical permeability. In varved clay, *in-situ* permeability tests may be done.

6.6.1 The coefficient of consolidation and the permeability in horizontal direction should be evaluated from cone penetration tests with a pore pressure measurement (CPTu). This is done by intermittent sounding accompanied by a study of the excess pore pressure dissipation caused by the sounding operation.

6.7 If the *U* percent obtained for a time '*t*' for the assumed spacing of vertical drains is not sufficient then the spacing is adjusted to get the desirable *U* percent. Experiences with preloading in the field suggest that 75 to 80 percent consolidation can be achieved in about 8 to 12 weeks with vertical drains spacing of 1.0 to 2.0 m.

6.8 In the case of soft soil and especially where the final load is high, preloading is done in stages. At each load stage, similar calculation as given in **6.5** shall be done to check if the desired percentage consolidation is complete or not.

6.9 Depending on the percentage consolidation at each stage, the shear strength of the soil will be improved proportionally. The gain in shear strength can be considered while checking the safety against failure under the next stage of preload.

6.10 Depending on the installation process there will be a disturbed zone (smear zone) extending to some distance away from the drains. The extent of the smear zone will depend upon the sensitivity of soil and the method of installation of drains. This aspect shall be considered in the design as given in **6.5**.

6.11 The treatment area, that is, vertical drains and the preloaded area should be sufficiently extended beyond the outer edge of the proposed loaded area/foundation area depending on the size of the loaded area.

7 CONSTRUCTIONAL ASPECTS

7.1 The site preparation shall be carried out in accordance with design specifications and specific project requirements. This shall include suitable access for plant and machinery, levelling of the working platform, providing adequate ground bearing capacity for equipment, and installation of a drainage blanket.

7.2 When the drainage blanket serves as a working platform and is installed directly on the ground surface, it should have a minimum thickness of 0.5 m with an initial horizontal surface. However, if a working platform is available prior to placement of the drainage blanket then the thickness of the drainage blanket should be at least 0.3 m. It should consist of gravelly sand or sandy gravel, containing less than 5 percent of the material with grain size < 0.075 mm.

7.2.1 In the case of drain installation in marine environment, the drainage blanket should consist of granular material, preferably sandy gravel, with a minimum thickness of 0.5 m. The drainage blanket shall be placed before the drain installation

7.2.2 The drainage blanket should be protected from the ingress of fine-grained material that can detrimentally affect its permeability. If the material used for preloading contains significant fine grain material, a non-woven geotextile separator layer should be used between the drainage blanket and preload fill.

7.3 Where it is impossible to install a drain as a result of obstructions, another drain shall be installed as close as possible.

7.4 During the installation of vertical drains, the following parameters shall be recorded:

a) Drain identification number;
b) Date and time of installation;
c) Depth of installation;
e) Location; and
f) Details of band drain/sand wick material used.

7.5 Splicing of drains is permitted as long as the drainage path is not obstructed and the tensile strength of the splice complies with the design requirements.

7.6 Before band drains are installed into the soil, they should be provided with an anchor, which keeps the drain in place when the mandrel is withdrawn from the soil. The soil should be prevented from intruding into the mandrel during installation.

7.7 After the mandrel is withdrawn, the band drains shall be cut so that the drains are in adequate hydraulic connection with the drainage blanket, preferably 0.2 m to 0.25 m above the surface of the working platform

7.8 The working platform shall have sufficient bearing capacity to carry the load of the installation rig.

7.9 During the drain installation works, in case two or more installation rigs are working on the same working platform, they should be separated horizontally by a distance larger than the total height of the rigs.

7.10 In the case of drain installation close to existing power lines or underground utilities, attention should be paid to relevant safety regulations.

7.11 Where sensitive structures or unstable slopes are present in the vicinity of the site or the possible sphere of influence of the works, their condition should be carefully observed and documented prior to and during the works.

8 INSTRUMENTATION AND MONITORING

8.1 The instrumentation and the extent, frequency and procedures of monitoring shall be decided by the designer in consultation with the client keeping into consideration the variation of geotechnical information, loading condition as well as type of loading (for example, step-wise loading, vacuum, etc), etc.

8.2 The consolidation process shall be monitored by appropriate settlement observations. The final primary consolidation settlement can be estimated with good accuracy from the time-related settlement observations.

8.3 The consolidation process should also be verified by appropriate methods of pore pressure observations (for example, piezometer). The piezometers should be placed in the centre between the drains where the rate of consolidation is a minimum. The interpretation of the results of pore pressure measurements can be quite intricate. The results will depend on the position of the piezometer in relation to the drain. If the groundwater table in the location of the piezometer gets influenced due to close proximity to tidal variation then this needs to be carefully evaluated keeping in mind that the timing of the tide keeps changing on a daily basis.

8.4 Where relevant, lateral time-related movements along the outer boundaries of the loaded area shall be monitored. Appropriate methods shall be used to evaluate these movements, for example, by using inclinometers.

8.5 Monitoring instruments should be installed early enough to have stable reference values before the start of the loading process.

8.6 When relevant, the strength increase of the ground should be confirmed by means of *in-situ* tests and/or laboratory tests. The location of the test shall be decided so as to minimize the effect of vertical drain installation.