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Standard Practice for X-Ray Radiography of Soil Samples[1]

This standard is issued under the fixed designation D4452/D4452M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the determination of the quality of soil samples in thin wall tubes or of extruded soil cores by X-ray radiography.

1.2 This practice enables the user to determine the effects of sampling and natural variations within samples as identified by the extent of the relative penetration of X-rays through soil samples.

1.3 This practice can be used to X-ray soil cores (or observe their features on a fluoroscope) in thin wall tubes or liners ranging from approximately 50 to 150 mm [2 to 6 in.] in diameter. X-rays of samples in the larger diameter tubes provide a radiograph of major features of soils and disturbances, such as large scale bending of edges of varved clays, shear planes, the presence of large concretions, silt and sand seams thicker than 6 mm [¼ in.], large lumps of organic matter, and voids or other types of intrusions. X-rays of the smaller diameter cores provide higher resolution of soil features and disturbances, such as small concretions (3 mm [⅛ in.] diameter or larger), solution channels, slight bending of edges of varved clays, thin silt or sand seams, narrow solution channels, plant root structures, and organic matter. The X-raying of samples in thin wall tubes or liners requires minimal preparation.

1.4 Greater detail and resolution of various features of the soil can be obtained by X-raying extruded soil cores, as compared to samples in metal tubes. The method used for X-raying soil cores is the same as that for tubes and liners, except that extruded cores have to be handled with extreme care and have to be placed in sample troughs (similar to Fig. 2) before X-raying. This practice should be used only when natural water content or other intact soil characteristics are irrelevant to the end use of the sample.

1.4.1 Often it is necessary to obtain greater resolution of features to determine the propriety of sampling methods, the representative nature of soil samples, or anomalies in soils. This practice requires that either duplicate samples be obtained or already tested specimens be X-rayed.

1.5 This practice can only be used to its fullest extent after considerable experience is obtained through many detailed comparisons between the X-ray image and the sample X-rayed.

1.6 *Units*—The values stated in either SI units or inch-pound units [presented in brackets] are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with standard.

1.7 This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

1.8 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.8.1 For purposes of comparing, a measured or calculated value(s) with specified limits, the measured or calculated value(s) shall be rounded to the nearest decimal or significant digits in the specified limits.

1.8.2 The procedures used to specify how data are collected/recorded or calculated, in this standard are regarded as the industry standard. In addition, they are representative of the signification digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis methods for engineering design.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the*

[1] This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and are the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

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*A Summary of Changes section appears at the end of this standard *responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific precaution statements, see Section 7.

1.10 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

E7 Terminology Relating to Metallography

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard relating to soil samples, refer to Terminology D653.

3.1.2 For definitions of common technical terms used in this standard relating to X-ray Radiography, refer to Definitions E7.

4. Summary of Practice

4.1 This standard practice involves the preparation of soil core samples and use of X-ray technology to produce images of soil core samples often contained in metallic tubes or extruded. These images provide insight into the quality of the sample, the type of material contained in the sample and can help guide decision making process when selecting samples or sections of a sample for laboratory test specimens.

5. Significance and Use

5.1 Many geotechnical tests require the utilization of intact, representative samples of soil. The quality of these samples depends on many factors. Many of the samples obtained by intact sampling methods have inherent anomalies. Sampling procedures cause disturbances of varying types and intensities. These anomalies and disturbances, however, are not always readily detectable by visual inspection of the intact samples before or after testing. Often test results would be enhanced if the presence and the extent of these anomalies and disturbances are known before testing or before destruction of the sample by testing. Such determinations assist the user in detecting flaws in sampling methods, the presence of natural or induced shear planes, and the presence of natural intrusions, such as gravels or shells at critical regions in the samples, the presence of sand and silt seams, and the intensity of disturbances caused by sampling.

5.2 X-ray radiography provides the user with a picture of the internal massive structure of the soil sample, regardless of whether the soil is X-rayed within or without the sampling tube. X-ray radiography assists the user in identifying the following:

5.2.1 Appropriateness of sampling methods used.

5.2.2 Effects of sampling in terms of the disturbances caused by the turning of the edges of various thin layers in varved soils, large disturbances caused in soft soils, shear planes induced by sampling, or extrusion, or both, effects of overdriving of samplers, the presence of cuttings in sampling tubes, or the effects of using bent, corroded, or nonstandard tubes for sampling.

5.2.3 Naturally occurring fissures, shear planes, etc.

5.2.4 The presence of intrusions within the sample, such as calcareous nodules, gravel, or shells.

5.2.5 Sand and silt seams, organic matter, large voids, and channels developed by natural or artificial leaching of soil components.

NOTE 1—The quality of the results produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself ensure reliable testing. Reliable testing depends on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *X-Ray Radiography Equipment*—Equipment with a peak current of approximately 15 mA is needed for a wide range of applications capable of accommodating commercially available film or detector plates, suitable for the sample sizes to be X-rayed, and suitable for the sample holders. The equipment may be equipped with a fluoroscope.

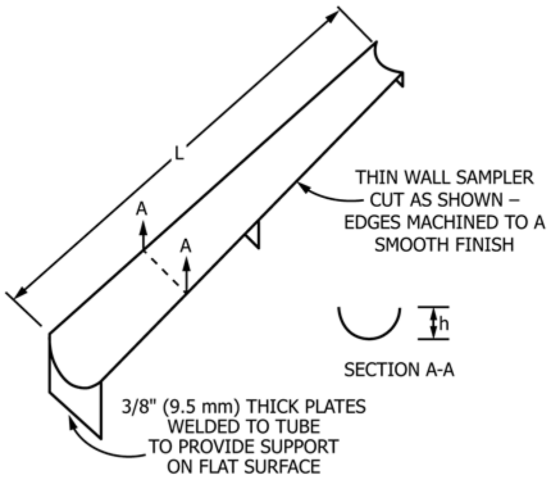
6.1.1 Use of equipment that produces digital images is permitted. Typical digital image pixel resolutions range from 30 to 350 µm [0.001 to 0.014 in.]. Image resolution shall be minimized and adjusted based on the diameter of the soil core to maximize the clarity of the image.

6.2 Although equipment with a voltage output of 100 kV is often used, certain types of samples may require equipment capable of performing at lower voltages (for example, 40 kV). For maximum resolution in certain types of applications a fine focus X-ray tube may be necessary. Persons inexperienced with X-ray radiography should discuss their specific equipment needs and the requirements of these methods with equipment manufacturers prior to purchasing.

NOTE 2—Equipment with beryllium window X-ray tubes may be necessary to perform radiography at low voltages.

6.3 *Soil Slice Trough*—A trough that is formed by cutting the sample tube/liner along its vertical axis through the soil sample. An example trough is shown in Fig. 1.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



d = diameter of the sample to be sliced
h = d – 13 mm [0.50 in.]
L = varies to suit sample length

FIG. 1 Example of Soil Slice Trough

6.4 *Extruded Tube Sample Trough*—A trough that is formed by encasing a halved pipe section in a fine-sand filter retained by a wooden frame. An example of this type of trough is shown in Fig. 2.

6.5 *Thin Wall Tube Trough*—A trough that is formed by encasing the tube/liner in a fine-sand filter retained by a wooden frame. An example of this type of trough is shown in Fig. 3.

6.6 *Measuring Tape,* minimum 900 mm [36 in.] long.

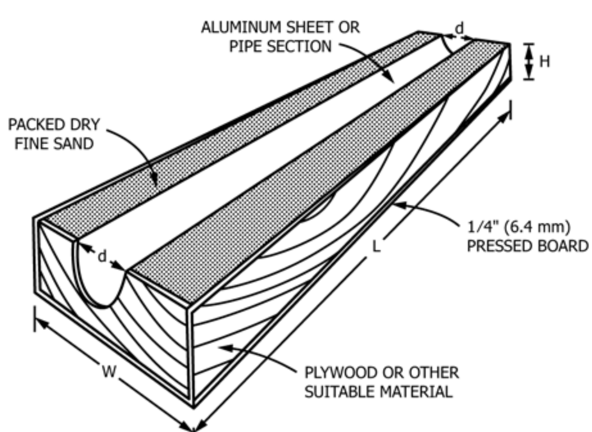
6.7 *Personal Dosimeters or Film Badges.*

6.8 *Small Hand Tools,* such as wire saws, spatulas, and knives.

6.9 *Industrial Type X-Ray Film,* or equivalent.

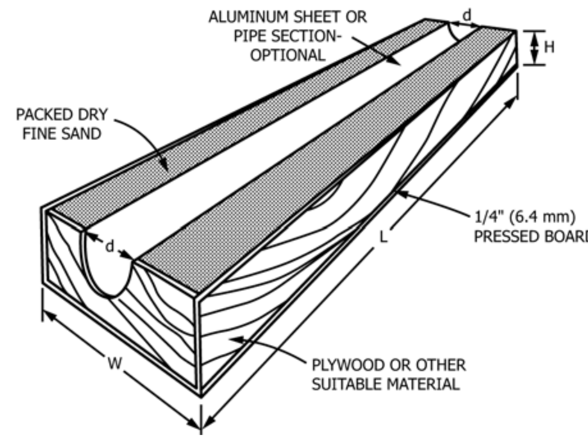
6.10 *Intensifying Screens,* made of sheets of thin lead.

6.11 *Alphanumeric Lead Markers.*



L = variable length to suit the length of the sample
d = outside diameter of sampling tube
W = d + 50 mm [2 in.]
H = d + 6.5 mm [0.25 in.]

FIG. 2 Example of Extruded Tube Sample Holder



L = variable length to suit the length of sampling tube
d = outside diameter of sampling tube
W = d + 50 mm [2 in.]
H = d + 6.5 mm [0.25 in.]

NOTE 1—Aluminum sheet or pipe section is optional. Samples in tubes can be placed in the box and sand can be packed around and under it to conform with the dimensions shown.

FIG. 3 Example of Thin Wall Tube Holder

7. Hazards

7.1 Radiation hazard safety and policies for the use of X-ray radiography machines applicable to this standard should be established based on national, state, and institutional requirements meeting acceptable radiation safety standards.

8. Procedures

8.1 *Tubes and Liners:*

8.1.1 Place the thin wall tube or liner holding the soil sample in the appropriate size sample holder, such as the one shown in Fig. 3. If such a holder is not available, pack the tube sample in sand, clay, or plaster of Paris, filter, forming an approximately rectangular cross-section, as shown in Fig. 3.

NOTE 3—Some requesting agencies may require that tubes and/or liners remain vertical through the duration of this standard. If so, a sample holder should be constructed similar to Fig. 3 but modified to facilitate vertical placement of the tube/liner and retention of the filter material. This may be easier to accomplish with the use of clay or plaster of Paris as a filter.

8.1.2 Set up the equipment for imaging. If using film, an intensifying lead screen may be placed in contact with the film.

8.1.3 Position the sample and adjust the equipment so that the distance from the X-ray source to the film or detector plate provides the best possible radiograph. Experience has shown that a distance of not less than 760 mm [30 in.] is appropriate for most samples. Place the alphanumeric lead identification markers next to, or on, the portion of the sample that was closest to the ground surface *in situ* that will be included in the X ray. If more than one exposure is required to cover the entire length of the sample, a lead marker should be placed to serve as a match mark.

8.1.4 Adjust the output to a level which will provide the clearest radiograph, fluoroscopic or digital image of the sample. The output is to be determined by the user.

8.1.5 Expose the film or detector plate an appropriate length of time. Process the results as recommended by the manufacturer. The exposure time may vary with equipment, type of soil, or type of tubing material used. It is advisable to experiment with the exposure time, keeping the distance of the specimen from film or detector plate constant until well-defined, clear, X-ray radiographs are obtained. Adjustments also can be made by keeping the exposure time constant and by varying the distance of the X-ray source from the film or detector plate.

8.1.6 Rotate the sample 90° about its longitudinal axis and repeat the procedure. Identify the 0° and 90° exposures with lead markers.

8.1.7 For some applications it may be sufficient to prepare samples as in 8.1.1 – 8.1.3 and simply observe various features on the fluoroscope; in such cases, eliminate 8.1.5.

8.2 *Extruded Samples:*

8.2.1 *Specimen Preparation:*

8.2.1.1 Place the specimen horizontally on the soil slicing trough.

8.2.1.2 Slice the specimen using a clean wire saw or other acceptable cutting device.

8.2.1.3 Remove the top portion of the specimen by placing a 180° segment of appropriate diameter thin wall tube over the specimen. Turn the thin wall tube segment, the specimen, and the slicing trough upside down in unison, so that the sliced specimen rests in the thin wall tube segment.

8.2.1.4 Remove the slicing trough and the portion of the specimen contained within. Discard the portion of the specimen removed from the slicing trough.

8.2.1.5 Wipe the slicing trough clean.

8.2.1.6 Place the portion of the specimen held in the thin wall tube segment in the trough with the sliced plane facing up.

8.2.1.7 Repeat 8.2.1.2.

8.2.1.8 Place a 6-mm [¼-in.] thick window glass or clear acrylic plate over the exposed face of the sample.

8.2.1.9 Holding the glass plate with one hand and the specimen trough with the other, turn the glass plate, the specimen, and the trough over.

8.2.1.10 Remove the trough and the portion of the specimen remaining within. This should leave a 10-mm [⅜-in.] thick soil slice specimen on the glass plate.

8.2.2 *Procedure:*

8.2.2.1 Set up the equipment for imaging. If using film, an intensifying lead screen may be placed in contact with the film.

8.2.2.2 Position the specimen and glass plate and adjust the distance from the X-ray source to the film to provide the clearest radiograph. Place the alphanumeric lead identification markers on the glass plate next to the specimen.

8.2.2.3 Repeat 8.1.3 and 8.1.4.

8.2.2.4 If a permanent radiography image is not required, see 8.1.7.

9. Interpretation of Results

9.1 The interpretation of X-ray radiographs must be done by personnel experienced in analyzing X-ray radiographs of soils.

9.2 X-ray radiographs show variations in the ability of X-rays to penetrate matter. These variations are exhibited as varying shades of gray color burned on the X-ray image.

9.3 The following factors may be discerned from the radiograph:

9.3.1 *Voids*—Open void spaces will show as dark dots, or spaces, or channels, depending on the shape of the void (Fig. 4).

9.3.2 *Bedding*—Horizontal, inclined, or distorted bedding will show as layers of various shades of gray easily identifiable as bedding (Fig. 5).

9.3.3 *Turning of Edges*—Turning or bending of edges of various thin layers show as curved down edges on the sides of the specimen. In extreme cases this turning down is accompanied by a symmetrical curving of the distorted layers. This may be an indication of improper sampling or extrusion methods (Fig. 6).

9.3.4 *Distortion and Tension Cracking*—Distortion or tensions cracks will appear as small intertwined, irregular dark lines typically transverse to the sample. Other forms of distortion and orientation of tension cracks can be seen as observed if twisting of the sample occurred within the tube or during extrusion (Fig. 7).

9.3.5 *Peat, Organic Matter, Roots*—Peat and organic matter will appear as dark or black spots (Fig. 8), while roots will appear as black, irregular, often interconnected lines (Fig. 9).

9.3.6 *Shells and Invertebrates*—They will appear as light colored shapes, generally easily identified from their profile (Fig. 10).

9.3.7 *Shear Fractures*—Shear fractures will appear as either dark lines (open fractures) or as lines identifiable only by the abrupt displacement and discontinuance of a number of bedding planes across the shear zone (Fig. 11).

9.3.8 *Soil Transition*—Changes in soil type or transition zones or layering of a coarse-grained soil and a fine-grained soil will appear as a change in texture (Fig. 12). Also, coarser sand or gravel that may be surrounded by a finer matrix of soil will appear as isolated lighter colored semi-regularly shaped object (Fig. 13).

9.3.9 *Improper Sample Preparation*—If the use of plugs or wax are used to seal the sample from moisture loss, improperly placed plugs, soil trimming or gaps between the plug and soil can be directly viewed (Fig. 14). If wax was not properly set before movement of the sample, slumping of the wax may be observed. In each case, loss of water from the sample may be suspected.

10. Report: Test Data Sheet(s)/Form(s)

10.1 The methodology used to specify how data are recorded on the data sheet(s)/form(s), as given below, is covered in 1.8.

10.2 Record as a minimum the following general information (see Appendix X1, Sample Report Form):

10.2.1 Original radiograph, or digital copy, a negative print, or a contact print of the radiograph,

NOTE 4—When contact prints are used instead of negative prints the photographic process reverses the colors of the X ray.

10.2.2 Description of the soil specimen,

10.2.3 Location and depth from which the sample was obtained,

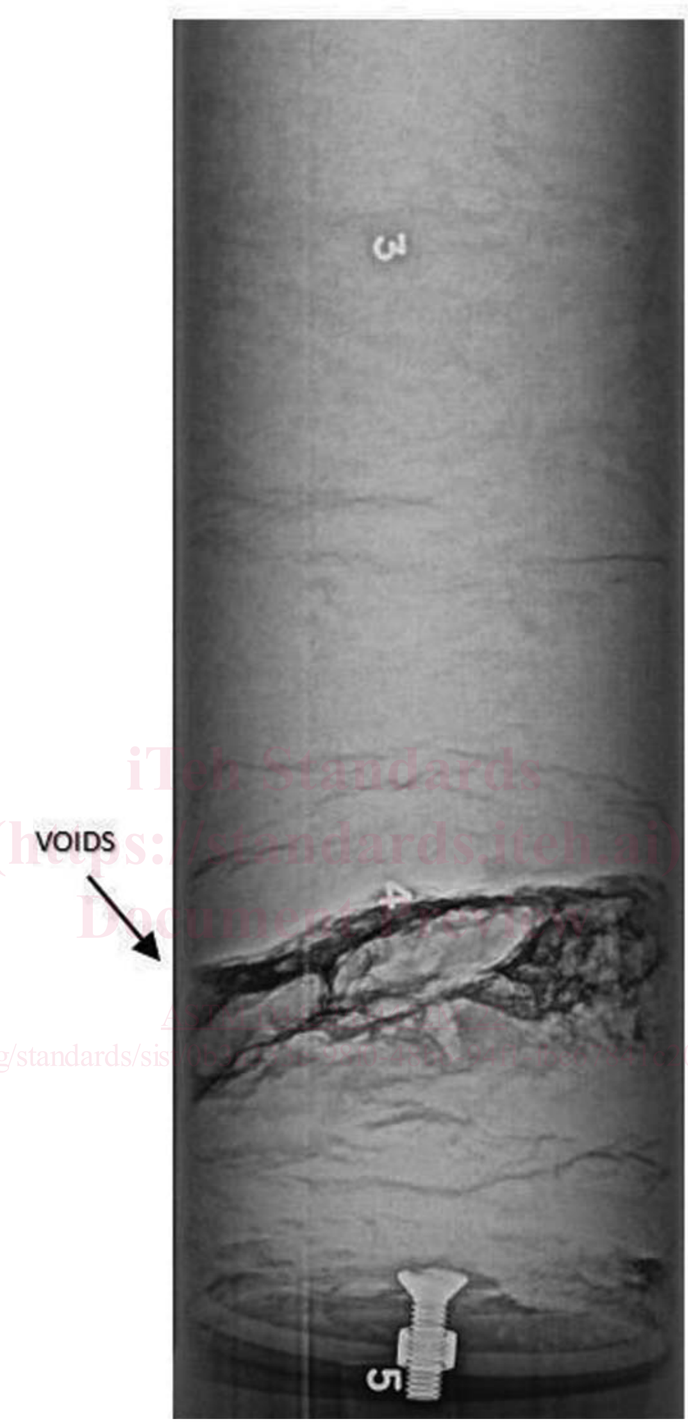


FIG. 4 Open Void Spaces

10.2.4 Type and size of sample or specimen used for radiography, (for example, 127 mm [5 in.] diameter sample in thin wall tube),

10.2.5 Type of radiographic equipment used, voltage, amperage, and exposure time, digital image resolution,

10.2.6 Distance from the X-ray source to the film surface or detection plate, and

10.2.7 Descriptive interpretation of the radiograph and its meaning in terms of the quality of the sample.

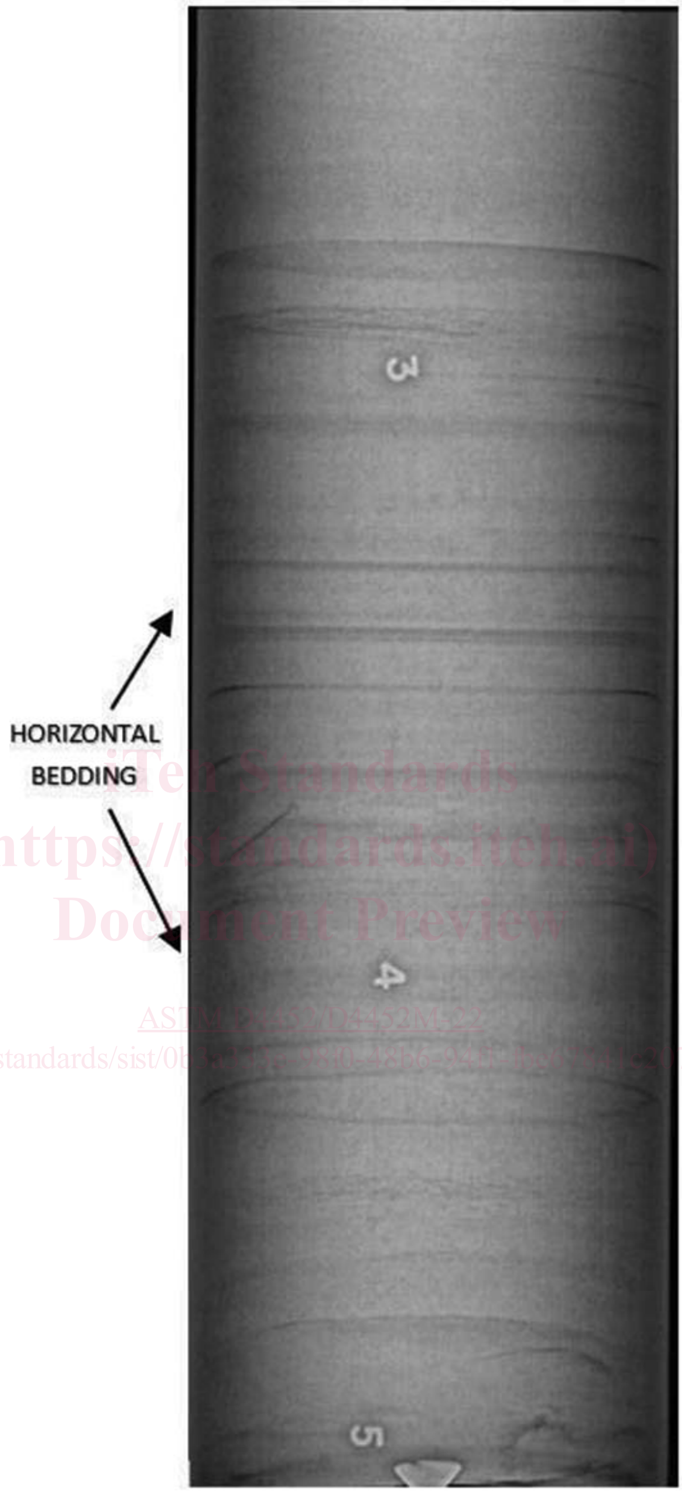


FIG. 5 Bedding

11. Precision and Bias

11.1 This practice provides qualitative and general information, therefore, a precision and bias statement is not applicable. The reliability of X-ray interpretation of soil samples is commensurate with the training and experience of the personnel.

12. Keywords

12.1 intact samples; radiography; sample disturbance; samples; soil; soil investigations; soil testing; X-rays

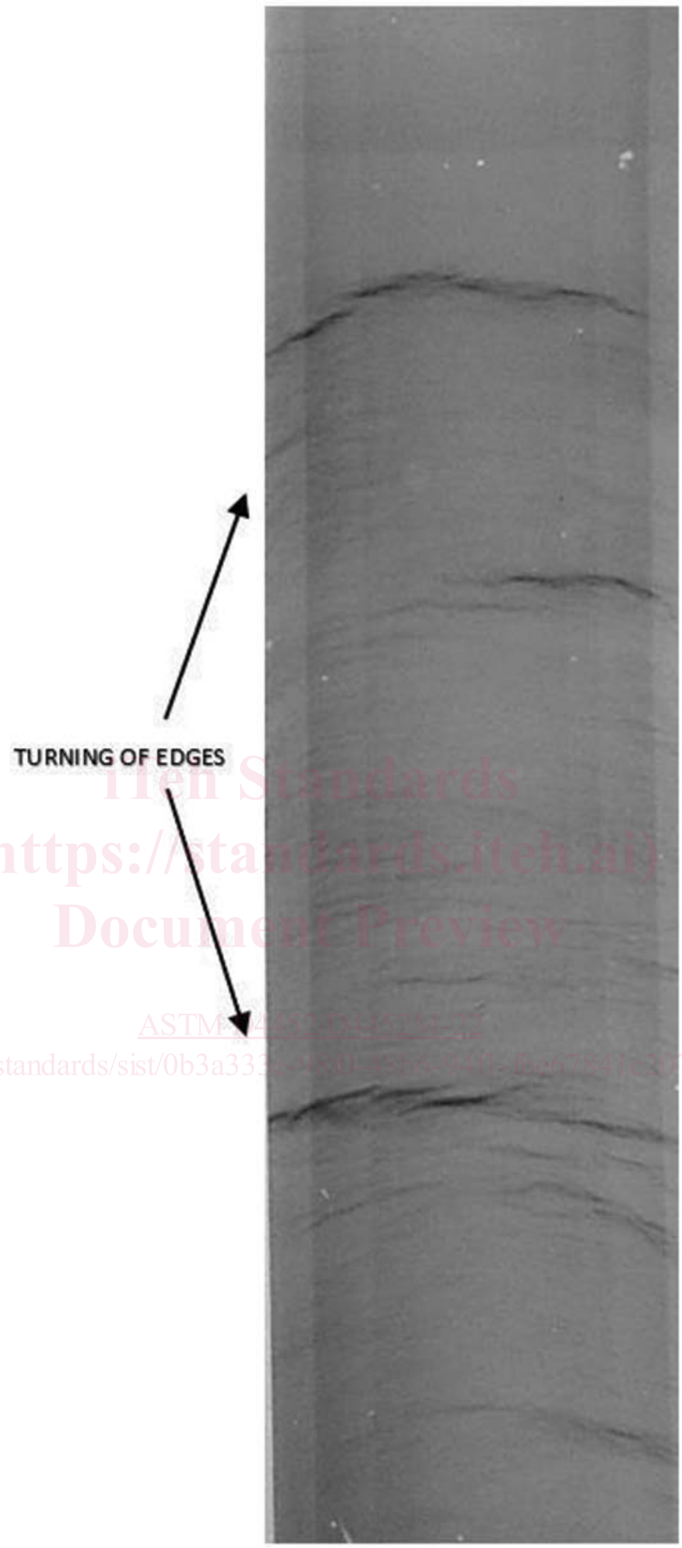


FIG. 6 Turning of Edges