Designation: D7891 – 24

Standard Test Method for Shear Testing of Powders Using the Freeman Technology FT4 Powder Rheometer Shear Cell[1]

This standard is issued under the fixed designation D7891; 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 method covers the apparatus and procedures for quantifying the incipient failure properties of a powder as a function of the normal stress for a given level of consolidation. The method also allows the further determination of the unconfined yield strength, internal friction angles, cohesion, flow function, major principal stress and wall friction angle (with the appropriate wall coupon fitted to the correct accessory).

1.2 These parameters are most commonly used to assist with the design of storage hoppers and bins using industry standard calculations and procedures. They can also provide relative classification or comparison of the flow behavior of different powders or different batches of the same powder if similar stress and shear regimes are encountered within the processing equipment.

1.3 The apparatus is appropriate for measuring the properties of powders with a maximum particle size of 1 mm. It is practicable to test powders that have a small proportion of particles of 1 mm or greater, but it is recommended they represent no more than 5 % of the total mass in samples with a normal (Gaussian) size distribution.

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

1.4.1 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 significant 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.

1.5 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

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

1.7 *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:*

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

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

D6128 Test Method for Shear Testing of Bulk Solids Using the Jenike Shear Tester

D6682 Test Method for Measuring Shear Stresses of Powders Using Peschl Rotational Split Level Shear Tester (Withdrawn 2017)[2]

D6773 Test Method for Bulk Solids Using Schulze Ring Shear Tester

3. Terminology

3.1 *Definitions*—For definitions of common technical terms used in this standard, refer to Terminology D653.

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.24 on Characterization and Handling of Powders and Bulk Solids.

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[2] The last approved version of this historical standard is referenced on www.astm.org.

*A Summary of Changes section appears at the end of this standard

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *conditioning, v—in storing, handling, and processing bulk solids using industrial equipment*, the process of homogenizing the state of consolidation of a test specimen by use of a specialized blade attachment.

3.2.2 *wall friction coupon, n—in storing, handling, and processing bulk solids using industrial equipment*, a test piece used in the wall friction test that is manufactured from a material that represents the material of construction of the silo/bin/hopper that stores the powder.

4. Summary of Test Method

4.1 *Selection of the Appropriate Testing Regime*—The particular consolidating stress level or levels used to evaluate the flow properties of the powder depend on the reason for generating the data, as outlined in Section 5, and should broadly reflect the stresses that the powder is subjected to in its processing environment.

4.2 *Measurement of Shear Stress*—The instantaneous shear stress is measured by establishing the consolidating stress with the shear head and pre-shearing the test specimen until a steady state condition is reached. The test specimen is then subjected to a reduced normal load and then sheared until the shear force reaches a maximum and then decreases.

4.3 *Measurement of Wall Friction as a Function of Normal Stress*—The kinematic shear stress is measured by establishing the consolidating stress with the wall friction attachment, fitted with a wall friction coupon, representing the material against which the powder is required to flow. A single pre-shearing cycle is completed until a steady state condition is reached. The test specimen is then subjected to a reduced normal load and sheared until the shear force reaches a maximum and then decreases. The shear is maintained such that the kinematic shear stress can be calculated.

5. Significance and Use

5.1 The test can be used to evaluate the following:

5.1.1 *Classification or Comparison of Powders*—There are several parameters that can be used to classify powders relative to each other, the most useful being the measured shear stresses, cohesion, flow function and angle of internal friction.

5.1.2 *Sensitivity Analysis*—The shear cell can be used to evaluate the relative effects of a range of powder properties or environmental parameters, or both, such as (but not limited to) humidity, particle size and size distribution, particle shape and shape distribution, water content and temperature.

5.2 *Quality Control*—The test can, in some circumstances, be used to assess the flow properties of a raw material, intermediate or product against pre-determined acceptance criteria.

5.3 *Storage Vessel Design*—Mathematical models exist for the determination of storage vessel design parameters which are based on the flow properties of powders as generated by shear cell testing, requiring shear testing at a range of consolidating stresses as well as the measurement of the wall friction angle with respect to the material of construction of the storage vessel. The methods are detailed in Refs. (**1-3**).[3]

NOTE 1—The quality of the result produced by this test method 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 test method are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors (**4**).

Practice D3740 was developed for agencies engaged in the testing and/or inspection of soil and rock. As such it is not totally applicable to agencies performing this test method. However, users of this test method should recognize that the framework of Practice D3740 is appropriate for evaluating the quality of an agency performing this practice. Currently there is no known qualifying national authority that inspects agencies that perform this test method.

6. Apparatus[4]

6.1 The FT4 Powder Rheometer is shown in Fig. 1. It is a computer-controlled instrument which simultaneously measures the force and torque required to mobilize a powder contained in a range of vessel types using a series of spindle-mounted attachments driven by an electric motor located on a carriage, driven by another electric motor, which moves the attachments in the vertical direction.

6.1.1 The force is measured by a force transducer located beneath and fixed to the table that supports the test vessel during the measurement process.

6.1.2 The torque (shear resistance) is evaluated by measuring the moment on the attachment using a torque transducer.

6.2 The shear cell vessel is shown in Fig. 2 (assembly described in 7.2). It consists of a serrated base, made from a suitable engineering plastic such as polyoxymethylene (POM), onto which are mounted two borosilicate glass cylinders (50-mm × 85-mL vessel) connected by a POM leveling assembly. The test vessel is located on the powder rheometer using a POM clamp ring which attaches to a stainless steel clamping device. A POM funnel is also fitted to assist with the filling of the test vessel.

NOTE 2—The glass cylinders are defined as '*x* mm × *y* mL', which indicates the glass cylinder's internal diameter, *x*, (50 ± 0.04 mm) and the precise volume of the lower section of the test vessel with the base fitted, *y*.

6.3 The attachments to facilitate the various test procedures are shown in Fig. 3. They consist of a twisted blade (Fig. 3(A)) to condition the test specimen, a compaction piston (Fig. 3(B)) to compress the test specimen to achieve the desired consolidating normal stress, a shear head (Fig. 3(C)) to generate shearing within the powder and a wall friction head with interchangeable wall friction coupon (Fig. 3(D)).

NOTE 3—The construction material of the attachments (Fig. 3) is

[3] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[4] The sole source of supply of the apparatus known to the committee at this time is Freeman Technology Ltd, 1 Miller Court, Severn Drive, Tewkesbury, Gloucestershire, GL20 8DN, United Kingdom. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.