

Continuous handling equipment and systems — Guide to properties of powders and bulk materials

ICS 53.040.01

Confirmed January 2011

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee MHE/9, Continuous mechanical handling equipment, upon which the following bodies were represented:

- Association of Consulting Engineers
- Automated Material Handling Systems Association
- Health and Safety Executive
- Materials Handling Engineers Association
- Minerals Engineering Society
- Quarry Products Association
- Solids Handling and Processing Association
- Co-opted Members

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 13 May 2005

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Amendments issued since publication

Amd. No.	Date	Text affected

The following BSI references relate to the work on this British Standard:
Committee reference MHE/9
Draft for comment
04/30080772 DC

ISBN 0 580 45875 X

Contents

	Page
Committees responsible	Inside front cover
Foreword	ii
Introduction	1
1 Scope	1
2 Normative references	1
3 Terms, definitions, symbols and abbreviations	2
4 General	3
5 Characteristics	3
6 Mechanical strength	9
7 Contact with other surfaces	18
8 Particle properties	19
9 Pneumatic handling	22
Bibliography	26
Figure 1 — Typical particle size histogram	4
Figure 2 — Typical particle size distribution	5
Figure 3 — Moisture contents of a range of sieved size fractions taken from a single sample of coal	8
Figure 4 — Apparatus for measurement of angle of repose	10
Figure 5 — Coulomb failure criterion	11
Figure 6 — Effective angle of internal friction and unconfined yield stress	12
Figure 7 — Jenike split ring shear cell apparatus	12
Figure 8 — Shear stress dependency on moisture content for a typical fine coal	13
Figure 9 — Typical shear cell test observations	14
Figure 10 — Hvorslev's failure surface	15
Figure 11 — Effect of time storage on yield loci	16
Figure 12 — Typical flow functions	17
Figure 13 — Tensile stress and its relation to other stress parameters	18
Figure 14 — Shear cell wall friction test apparatus	19
Figure 15 — Relationship between hardness scales	20
Figure 16 — Permeameter	23
Figure 17 — Fluidization properties	24
Figure 18 — Geldart fluidization classification	25
Table 1 — Useful range of particle size measuring methods	5
Table 2 — Recommended minimum quantity of granular solids to be sieved based on maximum particle size	6

Foreword

This British Standard has been prepared by Technical Committee MHE/9.

The handling, transport and storage of powders and bulk materials represent a large proportion of all industrial activities because of the diversity of the materials involved, the methods in which they are handled and transported, and the sectors of industry which utilize them. Therefore an exact knowledge of powders and bulk materials is necessary for the specification of handling and transport systems.

Because of their extremely varied origins, nature, granular characteristics, processing, etc, powders and bulk materials have very diverse physical characteristics, some of which (for example granulometry, particle shape, particle density) can be described and measured in a precise way, under conditions which are determined and constant, while others (for example angle of internal friction, cohesion) are affected by:

- a) changes in environmental conditions, for example moisture, storage time and temperature;
- b) the mode of movement of the material, for example mechanical handling, gravity flow and pneumatic handling.

This document is comprised of two key areas which take account of these related features.

- Specific properties of powders and bulk materials with regard to their descriptions.
- Underlying principle and methods of measuring these properties.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 27 and a back cover.

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Introduction

Equipment for handling, transporting and storing powders and bulk materials is most likely to operate satisfactorily if the properties of the materials are known and utilized when the equipment is designed and selected. This British Standard is intended to help in the equipment design and selection process by detailing the most important of these properties and appropriate tests by which they can be measured.

The first step in any investigation into the properties of a powder or bulk material is to determine if it is a single component material or a mixture.

The results of material property testing cannot be representative of the material if the sample is inappropriate. Standard test procedures might give guidance on:

- a) sampling and sample preparation procedures;
- b) replicate testing.

With regard to the design of mechanical, gravity flow and pneumatic handling systems, the most important properties of powders or bulk materials are considered to be:

- 1) bulk density;
- 2) particle size distribution;
- 3) moisture content and moisture/strength relationship;
- 4) abrasiveness;
- 5) angle of slide on chutes;
- 6) angle of repose;
- 7) minimum fluidization velocity.

To avoid costly errors, such information is necessary at the conceptual design stage of a materials handling scheme because final geometric design details of a materials handling plant are usually fixed at this time.

1 Scope

This British Standard describes the properties of powders and bulk materials that are commonly used when designing continuous handling equipment systems for powders and bulk materials. The standard gives guidance on methods and procedures for the determination of these characteristics.

This standard does not describe the following properties:

- a) combustibility;
- b) electrical properties;
- c) explosibility;
- d) flammability;
- e) thermal properties;
- f) hygiene;
- g) toxicity.

NOTE For information on items a) to e) attention is drawn to The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres (Amendment) Regulations 2001 [1].

This standard is not applicable to the following categories of materials:

- 1) materials that do not behave as powders or bulk materials (for example cakes, sludges, saturated and drained materials, slurries);
- 2) frozen materials;
- 3) chemically reactive materials (for example which solidify on exposure to air) unless an inert atmosphere can be maintained;
- 4) fibrous or stringy materials whose particles interlock.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 410-1, *Specification for test sieves — Part 1: Test sieves of metal wire cloth*.

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this British Standard, the following terms and definitions apply.

3.1.1

particulate solid

material in the form of many discrete and independent particles

3.1.2

granular solid

material in the form of many discrete and independent particles which are so large that interstitial air plays a small role in determining the pressures and flow of large masses of the solid

3.1.3

free flowing granular solid

granular solid whose flowing behaviour is not significantly affected by cohesion

3.1.4

fines

material in the form of many discrete and independent particles having a particle size 100 % less than 850 μm (see Jenike [2])

3.1.5

powder

material in the form of many discrete and independent particles having a mean particle size less than 0.05 mm

3.1.6

dust

material in the form of many discrete and independent particles having a particle size less than 75 μm

3.2 Symbols and abbreviations

For the purposes of this British Standard, the following symbols and abbreviations apply.

C	Permeability factor
c	Cohesion
e	Porosity
FF	Flow function
f_c	Unconfined yield stress
L	Bed length
M	Mass
m	Moisture content
T	Tension
t	Time in days
U	Gas velocity
U_{mf}	Minimum fluidization velocity
Δ_p	Pressure drop
γ	Bulk density
δ	Effective angle of internal friction
θ_c	Angle of slide on chutes
μ	Coefficient of wall friction
ϕ_i	Angle of internal friction
ϕ_e	Effective angle of internal friction (alternative notation)
ϕ_r	Angle of repose

ϕ_t	Tangent angle of internal friction
ϕ_w	Angle of wall friction
ρ	Particle density
σ_m	Major consolidating stress
σ_t	Tensile stress

4 General

The powder or bulk material may be identified by its trade name, its common name or its chemical formula. The name should describe the powder or bulk material as precisely as possible, for example in place of the general term “flour”, the identification might include information about the grain from which it was produced such as oats, rye or wheat etc. Where appropriate, the chemical composition should also be given. This is especially important where knowledge of the constituents might affect safety or environmental issues. Further information is given in the Report of the EFCE [3] and ASTM D 6128 [4].

NOTE Attention is drawn to The Control of Substances Hazardous to Health Regulations 2002 (COSHH) [5] regarding the handling of powders and bulk materials.

A specific property might not have a unique value but might fall within specified bounds of variability.

5 Characteristics

5.1 Particle size and shape

5.1.1 General

Powders and bulk materials consist of large numbers of particles usually of different sizes. For a mass of mono-sized spherical particles, the particle size can be described by a single dimension, the particle diameter. For non-spherical particles additional information on particle shape is required to characterize the particle.

For predominantly coarse materials such as mineral aggregates, sands and fillers the following classifications are used (see Wilkinson et al. [6]):

- a) rounded;
- b) irregular;
- c) angular;
- d) flaky;
- e) elongated;
- f) flaky and elongated.

For powders having a maximum dimension of 1 000 μm , BS 2955 gives definitions of the following terms:

- 1) acicular;
- 2) angular;
- 3) crystalline;
- 4) dendritic;
- 5) fibrous;
- 6) flaky;
- 7) granular;
- 8) irregular;
- 9) nodular;
- 10) spherical.

5.1.2 Measuring methods

There are many methods of determining the particle size of a powder or bulk material. Three commonly used methods are as follows:

- a) sieving (or screening);
- b) sedimentation/elutriation;
- c) microscopy.

These methods are described in BS 1796-1, BS 3625 and BS ISO 13317.

5.2 Particle size distribution

5.2.1 General

A particle size distribution is one possible outcome of submitting a representative sample of powder or bulk material to particle size analysis. It relates the distribution of the particle size fractions that comprise the sample.

For materials that are not mono-sized, two methods of presenting the data are commonly used. The first is a histogram relating the percentage between certain particle sizes, on a mass basis, as shown in Figure 1.

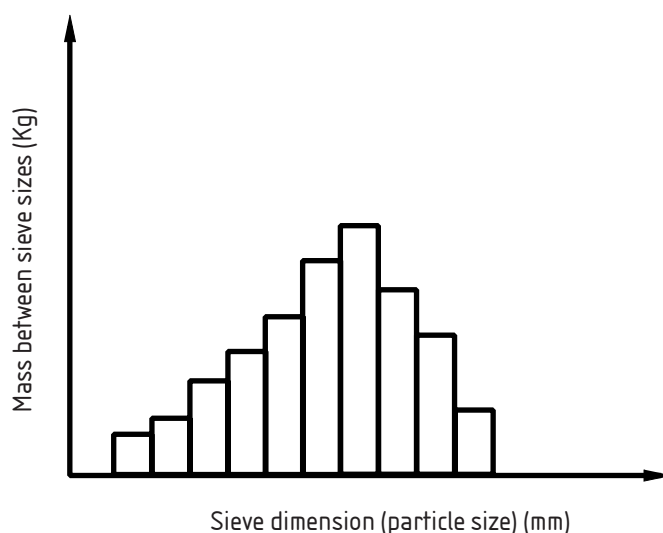


Figure 1 — Typical particle size histogram

The other method of presenting the particle size distribution is by a cumulative percentage frequency graph as shown in Figure 2. If a fully detailed size analysis is not available, sufficient points on the graph should be given, designated d_x , where d is the particle size below which there is x % less than by mass. The percentages preferred to provide an adequate distribution are d_{10} , d_{50} and d_{90} together with the largest particle size.

Where

- d_{10} is the particle size at which there is 10 % less than by mass;
- d_{50} is the particle size at which there is 50 % less than by mass;
- d_{90} is the particle size at which there is 90 % less than by mass.

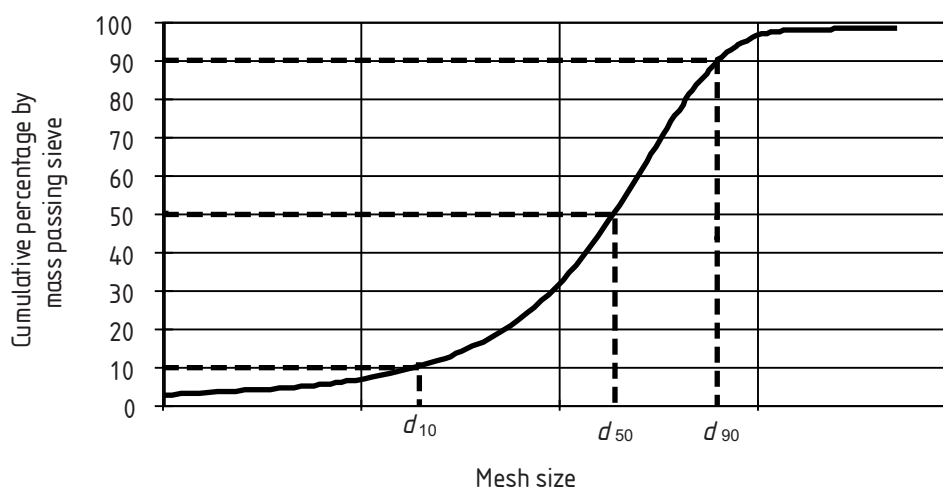


Figure 2 — Typical particle size distribution

5.2.2 Measuring methods

There are many methods of determining the particle size distribution of a powder or bulk material. Three commonly used methods are as follows:

- a) sieving (or screening);
- b) sedimentation/elutriation;
- c) microscopy.

These methods are described in BS 1796-1, BS 3625 and BS ISO 13317. The approximate useful range of each method is indicated in Table 1.

Table 1 — Useful range of particle size measuring methods

Method	Approximate useful range μm
Dry sieving	100 000 to 50
Wet sieving	100 000 to 10
Electrical sensing zone	800 to 1
Microscopy (light)	150 to 1
Sedimentation and elutriation	75 to 2
Microscopy (electron)	1 to 0.01

5.2.3 Representative sampling for granular materials

For dry and wet sieving, an adequate quantity of powder or bulk material should be sized to obtain a representative size analysis. Table 2 gives the minimum quantities of powder or bulk material required for results of accuracies specified in BS ISO 13909-3.

NOTE The recommended quantities given in BS ISO 13909-3 for coal may be taken as a guide for other materials if account is taken of the bulk density which for coal is $\gamma \approx 800 \text{ kg/m}^3$.

Table 2 — Recommended minimum quantity of granular solids to be sieved based on maximum particle size

Maximum particle size mm	Minimum mass for a precision of 1 % kg	Minimum mass for a precision of 2 % kg
50.0	280	70
45.0	200	50
38.0 ^a	130	30
31.5	65	15
22.4	25	6
16.0	8	2
11.2	3	0.7
10.0	2	0.5
8.0	1	0.25
5.6	0.5	0.25
4.0	0.25	0.25
2.8	0.25	0.25

^a The equivalent sieve size for 38 mm particles is a 37.5 mm sieve conforming to BS 410-1.

5.3 Particle and bulk density

5.3.1 Particle density (ρ)

5.3.1.1 General

True particle density is the mass of a particle divided by the volume of the particle excluding open and closed pores.

NOTE Closed pores are cavities not communicating with the surface of the particle.

Apparent particle density is the mass of a particle divided by the volume of the particle excluding open pores but including closed pores.

Effective particle density is the mass of a particle divided by the volume of the particle including both open and closed pores.

5.3.1.2 Measuring method

The method for measuring particle density is simple and is usually based on the principle of liquid displacement. However it varies from one powder or bulk material to another, and from one size grade to another for a particular material. Further information on the methods for measuring particle density for different materials are given in BS EN ISO 787-10, BS EN 196-6, BS 812-2, BS 1016-108.5 and BS 1377-2.

5.3.2 Bulk density (γ)

5.3.2.1 General

Bulk density is the mass of a powder or bulk material, inclusive of moisture, divided by the volume occupied by the particles, the voids and moisture. In general for materials handling, the determination of bulk density varies depending on circumstances relating to the sample taken and how the material is stored and handled. Further information on bulk density is given in Wilkinson et al. [6] and Svarovsky [7]. Bulk density can be evaluated under the following three main states.

- As poured.* The bulk density that results from pouring the material from a given height into a heap or container in the absence of any applied compacting force.
- Compacted.* The bulk density created by the application of compacting forces, for example impacts or vibrations.
- Aerated.* The bulk density created when particles are separated from each other by an air film as in the case of dry powders.