Characteristics of Bulk Materials

By
K. P. Shah
Email: kpshah123[at]gmail.com (Please replace [at] with @)
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The information contained in this article represents a significant collection of technical information about characteristics of bulk materials. This information will help to achieve increased reliability at a decreased cost of bulk material handling plants. Assemblage of this information will provide a single point of reference that might otherwise be time consuming to obtain. Most of the information given in this article is from Bureau of Indian Standards' (BIS) specification number IS 8005 and ANSI / CEMA 550. For more information, please refer them. All information contained in this article has been assembled with great care. However, the information is given for guidance purposes only. The ultimate responsibility for its use and any subsequent liability rests with the end user. Please view the disclaimer uploaded on http://www.practicalmaintenance.net.

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Characteristics of Bulk Materials

Basic classification of material is made on the basis of forms. They are gases, liquids, semi liquids and solids. Solids are further classified into two main groups: Unit load and Bulk Material. The successful design of a conveyor belt for bulk material handling begins with an accurate appraisal of the characteristics of the material to be transported. The behavior of bulk materials greatly depends on the moisture content and particle size distribution of the material. Wide variations in material behavior and bulk density with moisture and particle size can lead to unexpected tonnage or capacity issues, excessive spillage or material buildup, and equipment or system malfunction and failure. In view of this, information about characteristics of bulk materials is given in this article.

Unit Load and Bulk Material

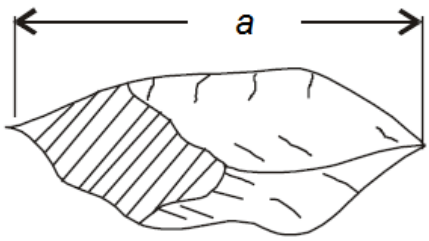
Unit loads are formed solids of various sizes, shapes and weights. Some of these are counted by number of pieces like machine parts and fabricated items. Tared goods like containers, bags, packaged items etc. and materials which are handled en-masse like forest products (logs), structural, etc. are other examples of unit loads. Unit loads have been classified by Bureau of Indian Standards' (BIS) specification number IS 8005.

Bulk materials are those which are powdery, granular or lumpy in nature and are stored in heaps. Example of bulk materials are: minerals (ores, coal, etc.), earthly materials (gravel, sand, clay, etc.), processed materials (cement, salt, chemicals, etc.) and agricultural products (grain, sugar, flour, etc.).

Characteristics of Bulk Materials

Major characteristics of bulk materials, so far as their handling is concerned, are: lump size, bulk weight (density), moisture content, flowability (mobility of its particles), angles of repose, abrasiveness, corrosivity, etc.

Lump Size



Size of a Particle

Lump size of a material is determined by the distribution of particle sizes. As shown in above figure, the largest diagonal size '*a*' of a particle in mm is called the particle size. The materials may be distinguished as sized (classified) or unsized (non-classified) as follows:

Sized (classified) are the materials for which the ratio between the size of the largest lump/particle, a_{max} and smallest lump, a_{min} is less than or equal to 2.5.

Unsized (non-classified) are the materials for which ratio a_{max} / a_{min} is greater than 2.5.

Average lump size of a sized material = (maximum particle size + minimum particle size) / 2

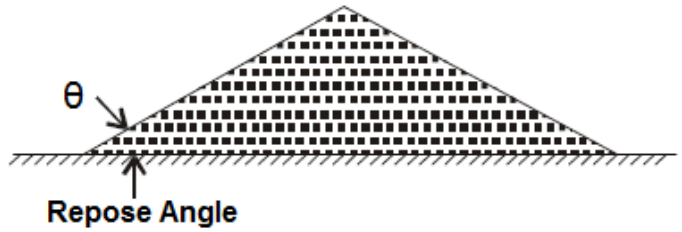
Hence, average lump size of sized bulk material = (a_{max} + a_{min}) / 2

Sized materials are adequately defined by the values a_{max} and a_{min}. Unsized materials, however, require, in most cases, a complete sieve analysis in which the ratio of the lump size shall not exceed 2.5.

Bulk Density

Bulk weight or bulk density of a lumpy material is the weight of the material per unit volume in bulk. Because of empty spaces between the particles in bulk materials, bulk density is always less than density of a particle of the same material.

Repose Angle

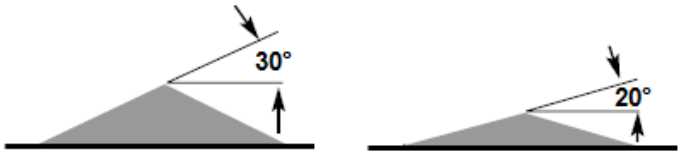


As shown in above figure, when bulk material is dropped on the horizontal surface (ground), it forms a conical heap with certain inclination (angle) with the horizontal surface. The angle of repose (θ) of a material is the natural angle formed by gravity discharge of the material and measured from a horizontal base.

Repose angle dependent on flowability of the material. The higher value of repose angle signifies less flowability of the material. The repose angle for liquid is zero.

The repose angle of a material is an important parameter because it decides the shape and volume of material in stockpiles and storages. It may be noted that the repose angle of a material is susceptible to variation in moisture content.

Surcharge Angle



Repose and Surcharge Angles

However, if the material is dropped on the horizontal surface which is in vibrating condition or is having internal agitation, the material tends to settle/spread and will have lesser inclination with the horizontal surface. This reduced inclination is known as surcharge angle.

During belt conveying, the material is lying on moving belt. Since the belt sags down between two idlers and rises up when passing on an idler, material particles on the belt is made to move up and down along the belt as it travels forward. This creates presence of vertically fluctuating inertial forces in the body of the bulk material. The belt also opens out slightly between two idlers and closes when passing on the idler. Thus material particles are

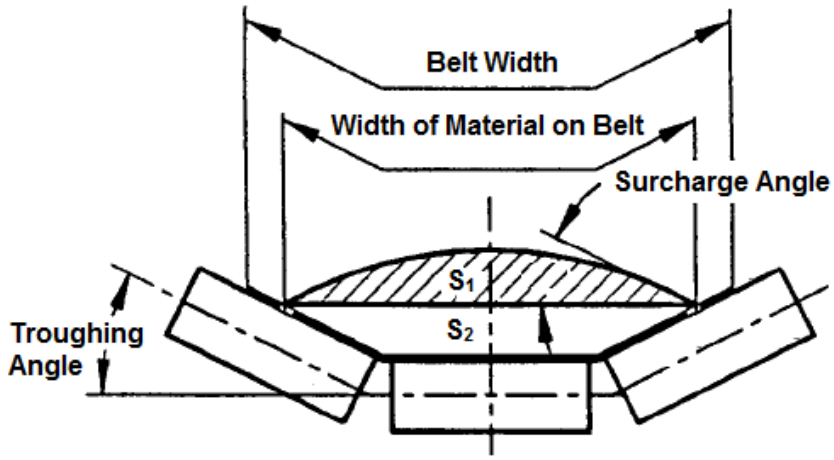
also oscillating horizontally. This phenomenon results in internal agitation to the material on belt and therefore the material's external faces assume inclination at surcharge angle. The angle of surcharge of a material is the angle to the horizontal which the surface of the material assumes while the material is at rest on a moving conveyor belt. Thus belt's ability to accommodate material is governed by surcharge angle instead of repose angle. In general, the surcharge angle is 5 to 15 degrees less as compared to repose angle. However, in some materials it may be as much as 20 degrees less.

Abrasivity

The property of particles of bulk materials to wear away the surface they come in contact with when in motion is called abrasivity. The abrasiveness of the material affects the wear of belt and other components of conveyor / material handling equipment (like hoppers, chutes, skirtboards, buckets, chain links, etc.) coming in contact with the material. At loading point, the incoming material's velocity is different than the belt velocity. Material takes some time to acquire belt velocity resulting in momentary sliding of the material on belt and causes belt wear. Due to this, for lesser wear, the conveyor handling more abrasive material should have lesser belt speed whereas less abrasive material can be conveyed at higher speed. The agitated condition of material on a belt also causes wear on the belt surface continuously from loading point to discharge point.

Conveyor Capacity

Belt conveyor is required to convey certain quantity of material per hour. As shown in the figure given below, the material is accommodated on the belt forming certain cross-section of the material [S = S_1 (Upper Section) + S_2 (Lower Section)]. This cross-section multiplied by belt velocity provides volume of material being transported in unit time. Thus belt conveyor's ability to transport material is volumetric in nature.



S = Total Cross Sectional Area of Material = S_1 + S_2

Cross Sectional Area Occupied by Material

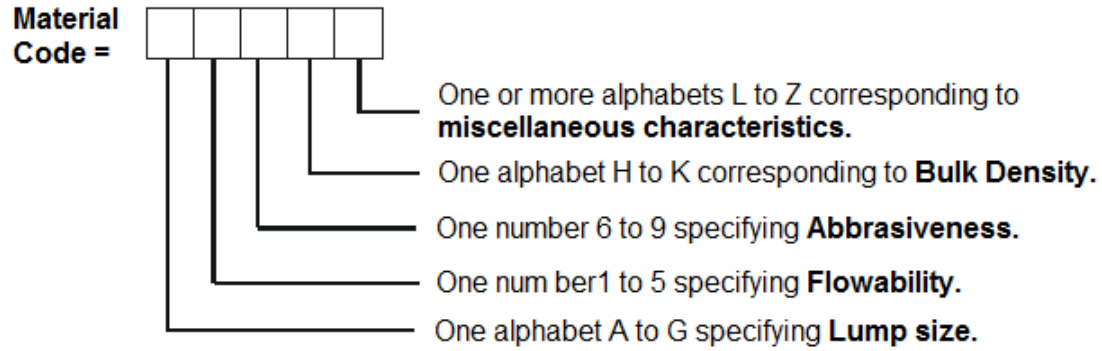
The transported volume is converted into tonees (1 metric tonee = 1000 kg) by multiplying it with the 'Bulk Density' of the material, in the condition as it is on the belt.

Classification and Codification of Bulk Materials

Information on classification and codification of bulk materials as per IS 8730: 1997 (Reaffirmed 2002) and ANSI / CEMA 550 - 2003 - R2009 is given in this section.

Codification System as per IS 8730

Classification and codification of bulk materials (being handled by continuous material handling equipment) based on lump size, flowability, abrasiveness, bulk density and various other characteristics have been specified by the Bureau of Indian standards (BIS) specification number IS 8730. Following figure shows the alphanumeric codification system as per this specification (IS 8730: 1997, Reaffirmed 2002).



Alphanumeric Codification System as per IS:8730

In this material code, if any of the above characteristics is not known, corresponding number or alphabet is dropped from the material code.

The following table shows the descriptions and limits of the different classes of material characteristics.

Classification of Bulk Materials as per IS 8730			
Material Characteristics	**Description of characteristics with Typical Examples**	**Limits of Characteristics**	**Class**
1. Lump size	Dusty material (cement)	"a_{max}" upto 0.05 mm	A
	Powdered material (fine sand)	"a_{max}" upto 0.05 to 0.50 mm	B
	Granular material (grain)	"a_{max}" upto 0.5 to 10 mm	C
	Small sized lumpy (crushed, iron ore)	"a_{max}" upto 10 to 60 mm	D
	Medium sized lumpy (chipped wood)	"a_{max}" upto 60 to 200 mm	E
	Large lump materials	"a_{max}" upto 200 to 500 mm	F
	Especially large lump size (boulder)	"a_{max}" over 500 mm	G
2. Flowability	Very free flowing (cement, dry sand)	Angle of repose: 0°- 20°	1
	Free flowing (whole grains)	Angle of repose: 20°- 30°	2
	Average flowing (anthracite coal, clay)	Angle of repose: 30°- 35°	3
	Average flowing (bituminous coal, ores, stone)	Angle of repose: 35°- 40°	4
	Sluggish (wood chips, bagasse, tempered foundry sand)	Angle of repose: > 40°	5
3. Abrasiveness	Non-abrasive (grains)	-	6
	Abrasive (alumina)	-	7
	Very abrasive (ore, slag)	-	8
	Very sharp (metal scraps)	Cuts belting of conveyors.	9
4. Bulk density	Light (saw, dust, peat, coke)	Up to 0.6 t/m^3	H
	Medium (wheat, coal, slag)	0.6 to 1.6 t/m^3	I
	Heavy (iron ore)	1.6 to 2.0 t/m^3	J
	Very heavy	2.0 to 4.0 t/m^3	K
5. Miscellaneous characteristics	Please refer the following table.	Note: Sometimes more than one of these characteristics may apply.	L to Z

Miscellaneous Characteristics of Bulk Materials as per IS 8730	
Miscellaneous Characteristics	**Class**
Aerates and develops fluid (or dual operating) characteristics	L
Contains explosive (or external) dust	M
Sticky	N
Contaminable affecting use or saleability	P
Degradable, affecting use or saleability	Q
Gives off harmful fumes or dust	R
Highly corrosive	S
Mildly corrosive	T
Hygroscopic	U
Oils or chemicals present. May affect rubber products.	W
Packs under pressure	X
Very light and fluffy (or very high flowability and dusty). May be wind swept	Y
Elevated temperature	Z

BIS specification number IS 8730:1997 lists 486 different bulk materials with their bulk densities, flowability properties and codes.

Material characteristics and codes as per IS 8730:1997 for some common materials are given in the following table.

Material Characteristics and Codes as per IS 8730:1997				
Material	**Average Bulk Density, kg/m^3**	**Angle of Repose, Degrees**	**Recommended Maximum Inclination, Degrees***	**Material Code**
Alumina	800-1040	22	10-12	B27M
Ashes, fly	640-720	42	20-25	A58
Bagasse	112-160	-	-	E56Y
Bauxite, mine run	1280-1440	31	17	B38
Cement, Portland	1500	39	20-23	A27M
Cement, Clinker	1200-1520	30-40	18-20	D38
Clay, dry, lumpy	960-1200	35	18-20	D37
Coal, anthracite, sized	960	27	16	C27
Coal, bituminous, mined, classified	960	35	16	D36QT
Coke, petroleum calcined	560-720	-	20	D37Y
Copper ore	1920-2400	-	18-20	D28
Earth as excavated dry	1120-1280	35	20	B37
Iron ore	1600-3200	35	18-20	D37
Iron ore, crushed	2160-2400	-	20-22	C27
Iron ore, pellets	2500-2880	20	12	D28 & D28Z
Lignite, air dried	720-880	-	-	D26
Lignite, raw, heavy	900-960	38	22	D37T
Limestone	1360-1440	30-45	-	-
Limestone, crushed	1360-1440	38	20	A26M
Limestone, dust	1360-1520	38-45	18	A57M
Phosphate acid, fertilizer	1440	26	13	B26TQ
Phosphate, triple, super, ground fertilizer	800-880	45	30	B56T
Phosphate rock, broken, dry	1200-1360	25-30	12-15	D27
Phosphate rock, pulverized	960	40-42	25	B37
Rock, crushed	2000-2320	-	-	D27
Salt, common dry, coarse	720-800	30-45	18-22	C27TU
Salt, common dry, fine	1120-1280	25	11	D27TUW

Sand, bank, dry	1440-1760	35	16-18	C37
Sand, foundry, prepared	1440	39	22	D38
Sand, foundry, shakeout	1440	39	22	D38
Sand, silica, dry	1440-1600	30-35	10-15	B28
Sulphur, crushed	880-960	30-45	16	C36MS
Sulphur, powdered	880-960	30-45	21	B36MW
Urea, prills	700	23-27	13	C26SU

* The angle of inclination is for conventional belt conveyors which allow free rollback of material.

Material Classification and Code System as per ANSI / CEMA 550 - 2003 - R2009

CEMA is the Conveyor Equipment Manufacturers Association (6724 Lone Oak Boulevard, Naples, Florida, USA 34109 239-514-3441 www.cemanet.org) and is an industry group dedicated to the advancement of the conveyor industry.

CEMA material code consists of actual bulk density, loose and code designations for size, flowability, abrasiveness and miscellaneous properties or hazards as per the following table.

Material Classification and Code System as per ANSI / CEMA - 550 - 2003 - R2009		
Major Class	**Material Characteristic Included**	**Code Designation**
Density	Bulk Density, Loose	Actual Lbs/Cu Ft
Size	Very Fine - No. 200 Sieve (.0029") And Under	A_{200}
	Very Fine - No. 100 Sieve (.0059") And Under	A_{100}
	Very Fine - No. 40 Sieve (.016") And Under	A_{40}
	Fine - No. 6 Sieve (.132") And Under	B_6
	Granular - 1/2” And Under	C ½
	Granular - 3" And Under	D_3
	Granular - 7" And Under	D_7
	Lumpy - 16" And Under	D_{16}
	Lumpy - Over 16" To Be Specified, X=Actual Maximum Size	D_X
	Irregular - Stringy, Fibrous, Cylindrical, Slabs, Etc.	E
Flowability	Very Free Flowing - Flow Function >10	1
	Free Flowing - Flow Function >4 But <10	2
	Average Flowing - Flow Function >2 But <4	3
	Sluggish - Flow Function < 2	4
Abrasiveness	Mildly Abrasive - Index 1 - 17	5
	Moderately Abrasive - Index 18 - 67	6
	Extremely Abrasive - Index 68 - 416	7
Miscellaneous Properties or Hazards (More than one may apply)	Builds Up and Hardens	F
	Generates Static Electricity	G
	Decomposes - Deteriorates in Storage	H
	Flammability	J
	Becomes Plastic or Tends to Soften	K
	Very Dusty	L
	Aerates and Becomes Fluid	M
	Contains Explosive Dust	N
	Stickiness-Adhesion	O
	Contaminable, Affecting Use	P
	Degradable, Affecting Use	Q
	Gives Off Harmful or Toxic Gas or Fumes	R
	Highly Corrosive	S
	Mildly Corrosive	T
	Hygroscopic	U
	Interlocks, Mats or Agglomerates	V

	Oils Present (May Affect Rubber)	W
	Packs under Pressure	X
	Very Light and Fluffy - May be Wind Swept	Y
	Elevated Temperature	Z
Angle of Repose	Loose	-
Maximum Angle of Inclination	Conveyor	-

More information on flowability and abrasiveness is given below.

Flowability

As per following table.

Flowability					
Very Free Flowing 1*	Free Flowing 2*	Average Flowing 3*			Sluggish 4*
Equivalent Flow Function Ranges FF					
>10	>4 to <10	>2 to <4			<2
Angle of Surcharge (degrees)					
5	10	15	20	25	30
Angle of Repose (degrees)					
10-19	20-25	26-29	30-34	35-39	>40
Uniform size, very small rounded particles, either very wet or very dry, such as dry silica sand, cement, wet concrete, etc.	Rounded, dry polished particles of medium weight such as whole grain and beans	Regular granular materials such as fertilizer, sand and washed gravel.	Irregular, granular or lumpy materials of medium weight, such as anthracite coal, cotton seed meal, clay etc.	Typical common materials such as bituminous coal, stone, most ores, etc.	Irregular, stringy, fibrous, interlocking material such as wood chips, bagasse, tempered foundry sand, etc.

* Numerical rating refers to Material Code

Relative Abrasiveness of Particles

Abrasiveness is a combination of the physical characteristics of a material that enables it to abrade particles from surfaces with which it comes into moving contact. It seems from observations that the following 4 characteristics are those which would contribute to the abrasive character of a material.

- Particle hardness
- Particle shape
- Bulk material density
- Particle size

Hence the following factors are assigned to each of the above characteristics to determine the relative abrasiveness of particles.

Hardness:

Mohs No.	1	2	3	4	5	6	7	8	9	10
Factor	1	4	9	16	25	36	49	64	81	100

Density:

Wt./Ft.^{3}	0-60	61-120	121-180	181-240	241-300	301-460	461-520
Factor	1.0	1.1	1.2	1.3	1.4	1.5	1.6

Shape:

Shape Type	Rounded	Subround, Subangular	Sharp Angular
Factor	1.0	1.5	2.0

Size:

Class Code for Size	A	B	C	D	E
Factor	1.0	1.1	1.2	1.3	1.3

To determine the relative abrasiveness of a particle, determine the factors from observation of the material. Multiply the factors together to determine the abrasive index number.

Compare this number to the abrasive index range in the table below to determine the CEMA abrasive code number.

Characteristics	Code Number	Abrasive Index Range
Mildly Abrasive	5	1 thru 17
Moderately Abrasive	6	18 thru 67
Extremely Abrasive	7	68 thru 416

ANSI / CEMA Standard 550 (Classification and Definitions of Bulk Materials) classifies over 500 bulk materials.

Following table lists some common materials and their CEMA classifications

Material Description	Loose Bulk Density (lbf/ft^3)	CEMA Material Code	Angle of Repose (degrees)	Max. Allowable Angle of Conveyor Inclination (degrees)
Alumina	55-66	58$B_6$27MY	22	12
Bark, Wood, Refuse	10-20	15E45TVY	45	27
Bentonite, 100 mesh	50-60	55A_{100}25MXY	42	20
Cement, Clinker	75-95	85$D_3$36	30-40	18-20
Coal, Powder River Basin	40- 55	50D35LV	38	15
Coal, Bituminous, Mined	45-55	50D_X35	38	15
Coal, Lignite	37-45	41$D_3$35TN	38	15
Coke, Petroleum, Shot	45-63	50C36LTWZ	35-40	14
Coke, Petroleum, Sponge	45-63	50C36LTWZ	35-40	14
Copper, Ore	120-150	125D_X36	30-44	20
Cullet, Fines	80-120	120C$^1/_2$37	30-44	20
Earth, Wet, Containing Clay	100-110	105D_{16}46OV	45	23
Gravel, Pebbles	90-100	95$D_3$27	30	12
Kaolin, Clay, 3 in. & Under	63	63$D_3$25	35	19
Lime, Hydrated	40	40$B_6$35LM	40	21
Limestone, Crushed	85-90	88D_X36	38	18
Phosphate, Rock, Pulverized	60	60$B_6$36	40	25
Rice, Hulled	45-49	47C$^1/_2$25P	19	8
Sand, Foundry, Prepared	65-75	70$B_6$47X	30-44	24