In actual practice, the system concept of materials handling means the different types of materials handling needed at different parts of an industry and associated suppliers' and customers' end are to be considered in totality. Only this approach will ensure an overall cost effective materials handling solution for the industry.

From a traditional point of view, a materials handling engineer may consider the materials handling problem of a particular area as an individual, isolated case and produces the solution. He may have produced the most economic solution for that problem alone, but it may not lead to the overall lowest cost solution for the entire plant. There are many industries who are using more than hundred sizes of containers/boxes within the same plant! This is the result of solving materials handling problems of different areas in isolation. From systems point of view, the materials handling problem of a plant along with its associated suppliers' and customers' problems should be considered as one system and the subsystems have to be designed and operated accordingly. This systems concept is a logical approach which can achieve the objective of any materials handling scheme which is lowest cost solution.

1.4 CHARACTERISTICS AND CLASSIFICATION OF MATERIALS

Method to be adopted and choice of equipment for a materials handling system primarily depends on the type of material/s to be handled. It is, therefore, very important to know about different types of materials and their characteristics which are related to methods and equipment used for their handling.

As innumerable different materials are used and need to be handled in industries, they are classified based on specific characteristics relevant to their handling.

Basic classification of material is made on the basis of **forms**, which are **(*i*) Gases, (*ii*) Liquids, (*iii*) Semi Liquids and (*iv*) Solids**.

Following characteristics of gases, liquids and semiliquids are relevant to their handling.

For gases it is primarily pressure, high (25 psi and more) or low (less than 25 psi). Chemical properties are also important.

For liquids the relevant characteristics are density, viscosity, freezing and boiling point, corrosiveness, temperature, inflammability etc. Examples of common industrial liquids are: water, mineral oils, acids, alkalies, chemicals etc. Examples of common semi-liquids are: slurry, sewage, sludge, mud, pulp, paste etc.

Gases are generally handled in tight and where required, pressure resisting containers. However, most common method of handling of large volume of gas is through pipes by the help of compressor, blower etc. This process is known as **pneumatic conveying**.

Liquids and semiliquids can be handled in tight or open containers which may be fitted with facilities like insulation, heating, cooling, agitating etc. as may be required by the character of the liquid. Large quantity of stable liquids/semiliquids are generally conveyed through pipes using suitable pumps, which is commonly known as **hydraulic conveying**.

Solids form the majority of materials which are handled in industrial situation. Solids are classified into two main groups: **Unit load** and **Bulk load (materials)**.

Unit loads are formed solids of various sizes, shapes and weights. Some of these are counted by number of pieces like machine parts, molding boxes, fabricated items. Tared goods like containers, bags, packaged items etc. and materials which are handled en-masses like forest products (logs), structurals, pig iron etc. are other examples of unit loads. The specific characteristics of unit loads are their overall

dimensions, shape, piece-weight, temperature, inflammability, strength/fragility etc. Hoisting equipment and trucks are generally used for handling unit loads. Certain types of conveyors are also used particularly for cartons/packaged items and metallic long products like angles, rods etc.

Unit loads have been classified by Bureau of Indian Standards' (BIS) specification number IS 8005:1976[2]. The classifications are based on:

(*a*) **Shape of unit loads** - (*i*) basic geometric forms like rectangular, cylindrical, pyramidal/conical and spherical; (*ii*) typical or usual forms like pallets, plate, containers, bales and sacks; (*iii*) irregular forms like objects with flat base dimension smaller than overall size, loads on rollers/wheels and uneven shapes.

(*b*) **Position of C.G. (stability) of load.**

(*c*) **Mass of unit load** in 10 steps from 0-2.5 kg to more than 5000 kg.

(*d*) **Volume per unit** in 10 steps from 0-10 cm^3 to more than 10 m^3.

(*e*) **Type of material** in contact with conveying system like metal, wood, paper/cardboard, textile, rubber /plastics, glass and other materials.

(*f*) **Geometrical shape** (flat, concave, convex, irregular/uneven, ribbed etc.) and **physical properties** (smooth, slippery, rough, hard, elastic etc) **of base surface of unit load.**

(*g*) **Specific physical and chemical properties** of unit loads like abrasive, corrosive, dust emitting, damp, greasy/oily, hot, cold, fragile, having sharp edges, inflammable, explosive, hygroscopic, sticky, toxic, obnoxious, radioactive etc.

(*h*) **Loads sensitive** to pressure, shock, vibration, turning/tilting, acceleration/deceleration, cold, heat, light, radiation, damp etc.

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

Major characteristics of bulk materials, so far as their handling is concerned, are: lump-size, bulk weight, specific weight, moisture content, flowability (mobility of its particles), angles of repose, abrasiveness, temperature, proneness to explosion, stickiness, fuming or dusty, corrosivity, hygroscopic etc.

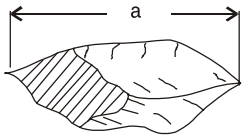


Fig. 1.4.1. Size of a particle

Lump size of a material is determined by the distribution of particle sizes. The largest diagonal size '*a*' of a particle in mm (see Fig.1.4.1) is called the particle size. If the largest to smallest size ratio of the particles of a lumpy material is above 2.5, they are considered to be unsized.

The average lump size of sized bulk material is

$$= \frac{1}{2} \text{ (maximum particle size + minimum particle size)} = \frac{1}{2} (a_{max} + a_{min})$$

Bulk weight or bulk density of a lumpy material is the weight of the material per unit volume in bulk. Because of empty spaces within the particles in bulk materials, bulk density is always less than density of a particle of the same material. Generally bulk load can be packed by static or dynamic loading. The ratio of the bulk density of a packed material to its bulk density before packing is known as the **packing coefficient** whose value varies for different bulk materials and their lump size, from 1.05 to 1.52. Bulk density is generally expressed in kg/m^3.

Mobility not flowability of a bulk material is generally determined by its **angle of repose**. When a bulk material is freely spilled over a horizontal plane, it assumes a conical heap. The angle 'ϕ' of the cone with the horizontal plane is called the angle of repose. Less is 'ϕ', higher is the flowability of the bulk material. If the heap is shaken, the heap becomes flatter and the corresponding angle of repose under dynamic condition is referred to as dynamic angle of repose ϕ_{dyn}, where ϕ_{dyn} is generally considered to be equal to 0.7ϕ.

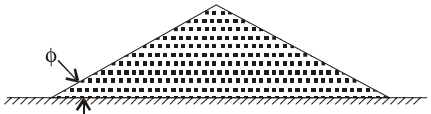
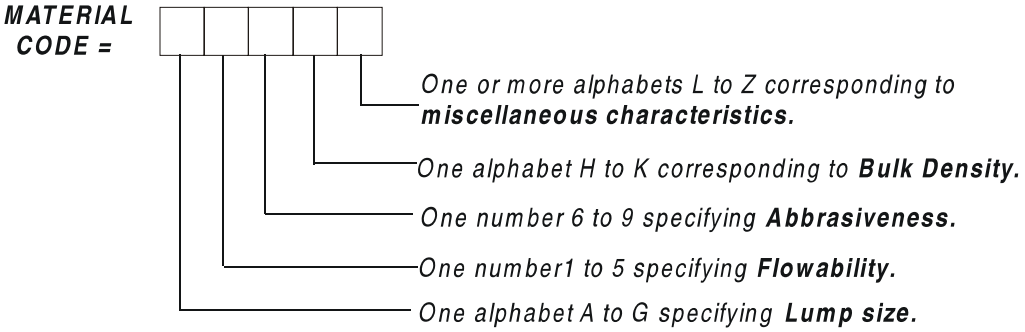


Fig. 1.4.2. Heap created by a free flowing material

Classification and codification of bulk materials based on lump size, flowability, abrasiveness, bulk density and various other characteristics have been specified by the BIS specification number **IS:8730:1997**[3]**.** The alphanumeric codification system as per this specification is shown below:



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

Table 1.4.1 shows the descriptions and limits of the different classes of material characteristics.

Table 1.4.1 Classification of Bulk Materials

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 0.10 mm	C
	Small sized lumpy (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 (boulder)	"a_{max}" upto 200 to 500 mm	F
	Especially large lump size	"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, store)	Angle of repose: 35°-40°	4
	Sluggish (wood chips, bagasse, 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 coveyors.	9
4. Bulk density	Light (saw, dust, peat, coke)	Upto 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	Aerates and develops fluid	-----	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 swept by wind	Y
	Elevated temperature	-----	Z

Table 1.4.2 lists a few of the typical materials, which are handled in bulk, with their average bulk density, angle of repose and classification code as per IS:8730:1997. This BIS specification lists 486 different bulk materials, with their bulk densities, flowability properties and codes.

Table 1.4.2 List of a Few Typical Bulk Materials with Codes

Sl.No.	Material	Average Bulk Density, kg/m^3	Angle of Repose, degrees	Code*
1	Alumina	800–1040	22	B27M
2	Bauxite, crushed, 75mm and under	1200–1350	---	D38
3	Cement, Portland	1500	39	A27M
4	Coal, anthracite, sized	960	27	C27
5	Iron ore	1600–3200	35	D37
6	Lime, hydrated	560–720	40	---
7	Rice, hulled or polished	720–768	20	B16
8	Sand, foundry, prepared	1440	39	D38
9	Slag, blast furnace, crushed	1280–1440	25	A28
10	Stone, crushed	1360–1440	–	–
11	Wheat	720–768	28	C26N
12	Wood chips	290–320	–	E56WY

* Code of the materials may vary according to exact condition of the materials during handling.

Bulk materials are generally handled by belt-conveyor, screw conveyor, pneumatic conveyor, bucket elevator, grab bucket, skip hoist, stacker-reclaimer, dumper-loader etc. It can be handled by cranes / trucks when collected in containers or bags. Small lump (powdered / granular) materials can be handled pneumatically or hydraulically. Bulk materials are generally stored on ground / floor in the open or under shed, and also in bunkers / silos.

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