# INTRODUCTION. CHARACTERISTICS OF LIFTING AND CONVEYING MACHINES



## 1. Definition and scope of materials handling

Expressed in simple language, **materials handling** is loading, moving and unloading of materials. To do it safely and economically, different types of tackles, gadgets and equipment are used, when the materials handling is referred to as **mechanical handling of materials**. Since primitive men discovered the use of wheels and levers, they have been moving materials mechanically. Any human activity involving materials need materials handling. However, in the field of engineering and technology, the term **materials handling** is used with reference to industrial activity. In any industry, be it big or small, involving manufacturing or construction type work, materials have to be handled as raw materials, intermediate goods or finished products from the point of receipt and storage of raw materials, through production processes and up to finished goods storage and dispatch points.

Materials handling as such is not a production process and hence does not add to the value of the product. It also costs money; therefore it should be eliminated or at least reduced as much as possible.

However, the important point in favour of materials handling is that it helps production. Depending on the weight, volume and throughput of materials, mechanical handling of materials may become unavoidable.

In many cases, mechanical handling reduces the cost of manual handling of materials, where such materials handling is highly desirable. All these facts indicate that

the type and extent of use ofmaterials handling should be carefully designed to suit the application and which becomes cost effective.

Based on the need to be of optimum design and application specific to different type of industries, materials handling can be as diverse as industries themself. As a consequence, unfortunately, there is no universally accepted definition of materials handling. One of the definition adopted way back by the American Materials Handling Society is: **Materials handling is the art and science involving the moving, packaging and storing of substances in any form(1)***.Some of the other definitions are:

• Materials handling is the movement and storage of materials at the lowest possible cost through the use of proper methods and equipment.

• Materials handling is the moving of materials or product by any means, including storage, and all movements except processing operations and inspection.

• Materials handling is the art and science of conveying, elevating, positioning, transporting, packaging and storing of materials.

There are other definitions also, but above few jointly bring out the salient features of materials handling.

It is referred to as an art and science because to most of the materials handling problem no uniquesolution exists and more than one solution may be prescribed. Lot of subjective considerations of the materials handling engineer go into it. At the same time many scientific factors are also considered to arrive at the solution. In one of the definitions, all the functions of materials handling have been refered to which are conveying, elevating, positioning, transporting, packaging and storing. Storage or warehousing is very much a part of materials handling. Materials handling uses different equipment and mechanisms called **Materials Handling Equipment**. Though in one of the definitions, processing operations and inspection have been specifically excluded from scope of materials handling operations, it is worth mentioning that in specific cases processing or inspection of materials may be accomplished simultaneously with

handling activity. One definition also covers the important objective of materials handling which is **lowest cost solution**.

The essential requirements of a good materials handling system may be summarized as:

(*i*) Efficient and safe movement of materials to the desired place.

(*ii*) Timely movement of the materials when needed.

(*iii*) Supply of materials at the desired rate.

(*iv*) Storing of materials utilising minimum space.

(*v*) Lowest cost solution to the materials handling activities.

Functional scope of materials handling within an industry covers the following:

(*i*) Bulk materials as well as unit materials handing. Bulk handling is particularly relevant in the processing, mining and construction industries. Unit materials handling covers handling of formed materials in the initial, intermediate and final stages of manufacture.

(*ii*) Industrial packaging of in-process materials, semi finished or finished goods, primarily from the point of view of ease and safety of handling, storage and transportation. However, consumer packaging is not directly related to materials handling.

(*iii*) Handling of materials for storage or warehousing from raw materials to finished product stage.

Often materials handling extends beyond the boundary of the industry in the form of movement of raw materials from the sources to the plant or in the form of finished goods from the plant to the points of consumption. These long distance movements of materials are generally termed as **transportation of materials** through various modes of transport like, road, rail, ship or air. Transportation is generally excluded from the scope of materials handling. However, at each of the sources and destinations, loading and unloading of materials is necessary and these are referred to as materials handling of these locations.

Some production equipment are fitted with facilities for handling of the materials being processed. Such materials handling equipment are generally considered to be an integral part of the production equipment. A few typical examples are : (*i*) the feeding mechanism in an automatic machine, (*ii*) coiler and de-coiler in a strip rolling mill or (*iii*) paper feeding and transportation arrangement in a multi-station printing machine. Essentially these are special material handling devices, but when integrated with specific production machines, they become specialized parts of those machines. Such special devices and their functions are generally not considered to be within the scope of materials handling. However, materials handling at the workplace is an area which is drawing greater attention after introduction of concepts of machining cells fitted with robotic handling devices. This aspect has been further discussed under chapter 9 titled ‘‘Robotic Handling System’’.

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## 2 Importance of materials handling

The foremost importance of materials handling is that it helps productivity and thereby increases profitability of an industry. Many enterprises go out of business because of inefficient materials han dling practices. In many instances it is seen that competing industries are using same or similar production equipment, and one who uses improved materials handling system stays ahead of their competitors.

A well designed materials handling system attempts to achieve the following:

(*i*) Improve efficiency of a production system by ensuring the right quantity of materials delivered at the right place at the right time most economically.

(*ii*) Cut down indirect labour cost.

(*iii*) Reduce damage of materials during storage and movement.

(*iv*) Maximise space utilization by proper storage of materials and thereby reduce storage and handling cost.

(*v*) Minimise accident during materials handling.

(*vi*) Reduce overall cost by improving materials handling.

(*vii*) Improve customer services by supplying materials in a manner convenient for handlings.

(*viii*) Increase efficiency and saleability of plant and equipment with integral materials handling features.

Apart from these, for certain industries, like process industries, heavy manufacturing industries, construction industries, mining industries, shipbuilding or aircraft industries etc., the materials are so large and heavy that these industries just can not run without appropriate materials handling system.

All the above points clearly show the importance of materials handling in an industry or a material transportation system. However, the negative aspects of materials handling should also not be overlooked.

These are:

(*i*) Additional capital cost involved in any materials handling system.

(*ii*) Once a materials handling system get implemented, flexibility for further changes gets greatly reduced.

(*iii*) With an integrated materials handling system installed, failure/stoppage in any portion of it leads to increased downtime of the production system.

(*iv*) Materials handling system needs maintenance, hence any addition to materials handling means additional maintenance facilities and costs.

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## 3. Systems concept

In the previous sections materials handling has already been referred to as a system, and it will be repeated many times in future. It is, therefore, important to understand the **systems concept of materials handling**.

The term ‘‘system’’ has many meaning depending on the field where applied. A general definition of the term could be: **a complex unity formed of many often diverse parts subject to a common plan or serving a common purpose**. The important

characteristics of a system is that the parts, called subsystems, are interrelated and guided by an objective for which the system exists.

In an industry, materials handling is a subsystem (or part) of the production system. Materials handling itself can also be considered to be a system whose subsystems are (*i*)design or method to be adopted, (*ii*) types of materials handling equipment to be used, (*iii*) different operations like packing /unpacking, movement and storage involved, (*iv*) maintenance required for the equipment employed, (*v*) mode of transportation by the raw materials suppliers, distributors / customers, waste / scrap collectors etc. The common objective by which the different subsystems are guided is the lowest cost solution of the materials handling system for that industry.

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.

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## 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 numberof 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 cm3 to more than 10 m3.

(*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.

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.

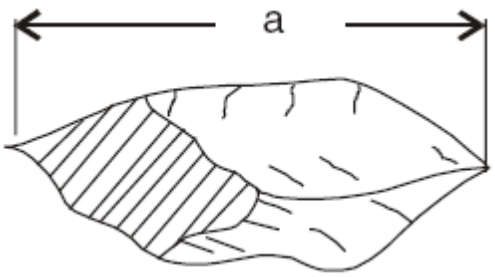
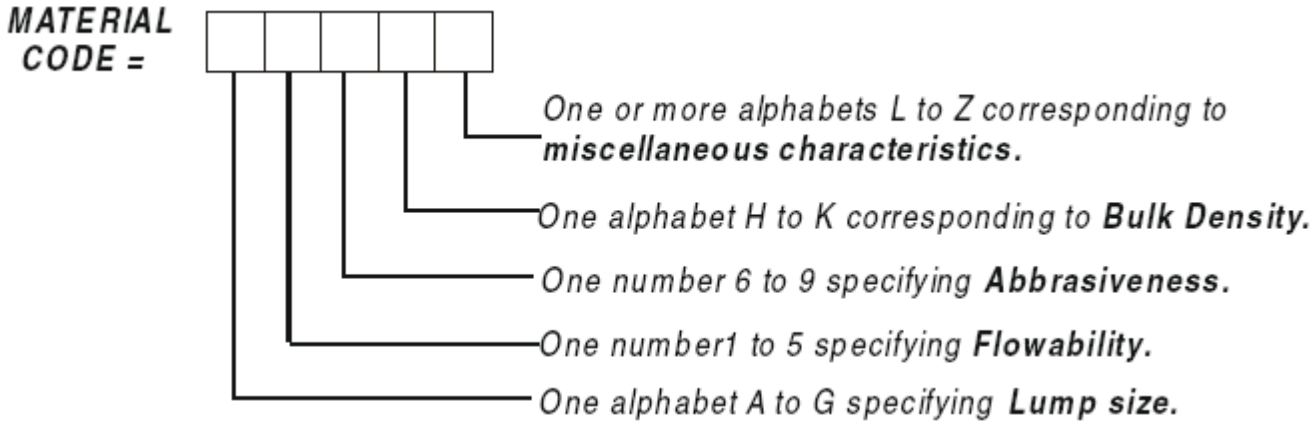



Fig. 1. Size of a particle

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 '$\varphi$' 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 φdyn, where φdyn is generally considered to be equal to 0.7φ. 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 shows the descriptions and limits of the different classes of material characteristics.

Table 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 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 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 |

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 theopen or under shed, and also in bunkers / silos.

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