

## ***MODULE 5. BUILDING CONSTRUCTION MATERIALS AND TYPE OF BUILDING CONSTRUCTION***

### **Lesson 26**

#### **Choice of building construction materials - Brick, sand, cement, lime etc.**

##### **26.1 Introduction**

The building materials used vary considerably in different parts of the world. Though, basic materials used for the construction of dairy plant are common in almost all countries. More emphasis has been given for the materials which are commonly used in India. The use of cement, bricks, cement concrete, RCC, steel, stone etc. are very common in most countries. In recent years, pre-fabricated blocks and pre-stressed RCC blocks are being employed for various applications. It is necessary to consider several factors such as environmental conditions in the plant, whether conditions, wear and tear, effect of acid and alkalis, safety, cost etc. for the selection of materials for different sections of dairy plants.

##### **26.2 Factors to be considered for selection of building construction materials**

- Effect of atmospheric conditions on the building
- Effect of prevailing conditions in the plant such as water, water vapor, high temperature, acids, alkalis and wear and tear.
- Durability of material under conditions to which it is exposed
- Ease of cleaning and maintenance
- Availability of the materials
- Cost of materials

##### **26.3 Properties of building materials**

The properties of different building materials are discussed in 26.4. Some general properties which are to be considered are discussed here. The use of building materials of organic origin which may be attacked by bacteria and other organisms should be avoided. Whenever soft wood and wood based products are necessary, protection against germs and moisture is very essential requirement. Many hardwoods such as teak have shown good serviceability for use of window frames, doors etc.

Insulating materials must be well protected to prevent entry of water vapour. The use of PUF panels for insulation of cold storage has changed the entire construction requirement of cold storages. The use of paints and bonding materials of organic origin should be avoided. The building materials are exposed to corrosion environment in dairy plant must be protected. Iron under moist condition rusts quickly and hence it must be protected by galvanizing, zinc coating or painting. The condensation of water vapor on a wall or pipelines may cause corrosion of metals and seriously damage the paint. Therefore, removal of water vapour from the processing room be taken into account.

## 26.4 Building Materials

Generally building materials are classified into three groups as under.

- (i) Solid materials – stones, bricks, iron etc.
- (ii) Cement Materials – lime, cement etc.
- (iii) Protective materials – paints, varnishes etc.

### 26.4.1 Bricks

Clay is the basic raw material for the preparation of bricks. Clay for brick is composed of alumina and silica and certain fluxing ingredients such as ferric oxide, lime, magnesia or  $\text{CO}_2$  in quantities up to 20% except in firebrick, which may have silica content as high as 98%.

Bricks are obtained by molding clay in rectangular blocks and then drying and burning of those blocks. It is manufactured by many places throughout the country in unorganized sectors. Brick is widely used as building material for making walls and as compared to other materials used for this purpose, it is cheaper. Brick contains alumina, silica, lime; oxide of iron, magnesia etc. and each constituent imparts specific characteristics in brick.

#### 26.4.1.1 Properties of Brick

- Good quality brick should be well-burnt in kilns, uniform in size and color, clear metallic ringing sound when struck with each other.
- No brick should have crushing strength below  $5.50 \text{ N/mm}^2$ . The bricks should not break into pieces when dropped flat on hard ground from a height of 1 m.
- Absorption of water should be more than 20% of its weight in 16 h immersion in water.
- Crushing strength: As per BIS, minimum crushing strength of brick is  $3.50 \text{ N/mm}^2$   
 $7 \text{ to } 14 \text{ N/mm}^2$  : A grade  
 $> 14 \text{ N/mm}^2$  : AA grade
- Hardness: Bricks should be sufficiently hard.
- Presence of soluble salt: bricks should possess minimum salts.
- Shape and size: Rectangular shape with sharp edges. (Size:  $190 \text{ mm} \times 90 \text{ mm} \times 90 \text{ mm}$  (recommended by BIS))
- Soundness: Clear ringing sound when two bricks are struck with each other.
- Structure: homogeneous, compact, free from any defects like holes, lumps.

### 26.4.1.2 Constituents of good brick

(i) Oxides of aluminum ( $\text{Al}_2\text{O}_3$ ): This ingredient renders the plastic property in the material required for molding. However, excess of it causes the raw brick to shrink & warp, while drying.

(ii) Silica or sand ( $\text{SiO}_2$ ): It prevents the raw bricks from warping, shrinking and cracking. But excess amount of silica may cause brittleness.

(iii) Lime ( $\text{CaO}$ ): Lime helps in preventing the shrinking of the raw bricks. A small proportion of lime present in a finely divided state also acts as a flux and causes the sand to fuse and bind the particles to gather. Excess of lime causes the brick to melt and run out of shape. Lumps of lime become quick lime after burning and when the brick is immersed in water or absorbs moisture from the air, the quick lime slakes, expands and causes the brick to split into pieces.

(iv) Oxides of iron ( $\text{Fe}_2\text{O}_3$ ): A very small percentage of oxide of iron is helpful in (a) causing the sand to fuse a little at low temperature giving a pleasing tint to burnt brick.

(v) Magnesia ( $\text{MgO}$ ): It gives the brick a yellow tint color, if present in small quantities.

### 26.4.2 Fire brick

Fire bricks are very important for high temperature industrial applications. The materials which are capable of resisting high intensity of heat i.e. silica, alumina, magnesite, bauxite and chromate are added in fire brick. The composition of a good fire clay suitable for fire brick is 50-70% silica, 10-25% alumina, 2-2.5% iron oxide or lime magnesia, < 1.5% alkali.

## 26.5 SAND

It consists of small grains of silica ( $\text{SiO}_2$ ). It is formed by decomposition of sandstones due to weather effects.

### 26.5.1 Types of sand

Sands available in market are classified based on the source as under.

(i) Pit sand

(ii) River sand

(iii) Sea sand

Based on the size of the sand, it is classified as under.

- Fine sand: It should pass through 1.59 mm opening (suitable for plastering)
- Course sand: It should pass through 3.18 mm opening (suitable for masonry work)
- Graveled sand: It should pass through 7.62 mm opening (suitable for concrete work)

### 26.5.2 Desired properties of sand

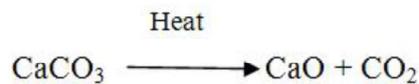
Objectives of mixing sand to prepare mortar are:

- To prevent excessive shrinkage.
- To improve the strength of mortar.
- To improve the setting power. Sand makes the mortar porous, which absorbs CO<sub>2</sub> from air and becomes hard.
- To increase the bulk and thus reduce the cost

The sand used for making mortar should be clean, coarse, hard, free from any clay, dust, mica particles and soft flaky pieces. Sand required for brick work needs to be finer than that for stone work.

## 26.6 LIME

The use of lime as cementing materials has been made since ancient times, but at present cement has replaced lime to a great extent. Lime is produced by calcinations of limestone.



The lime which is obtained by calcinations of comparatively pure limestone is known as quick lime. It is made in kilns. Addition of water (about 32% of CaO) to the quick lime to prepare hydrated lime is called slaking of lime.



A thin suspension of slaked lime is known as the milk of lime.

### 26.6.1 Use of lime

- Mortar for masonry work
- White washing
- Purification of water and sewage treatment
- Many industrial application

## 26.7 Limestone

Limestones (CaCO<sub>3</sub>) either in pure or mixed with impurities is the parent material from which lime and cements are produced. Limestone is inert and insoluble in water in its natural condition. When limestone is burnt in kiln or calcined, CO<sub>2</sub> is separated and driven out in the form of gas and what remains is CaO in the form of lumps, called quick lime, which is soluble in water. When water is sprinkled on quick lime, it breaks in to powder, which is Ca(OH)<sub>2</sub> known as hydrated lime. The process is called slaking.

## 26.8 CEMENT

The ordinary cement was invented by a Joseph Aspdin in England in the year 1824. The inventor took a patent and called it Portland cement as it resembles in its color after setting to a variety of stone found in Portland. The raw materials for cement are (i) lime stone (ii) coal (iii) clay and (iv) gypsum. Cement can be made by two different processes (i) dry and (ii) wet process.

### 26.8.1 Composition of ordinary/Portland cement:

Lime (CaO) : 62%

Silica (SiO<sub>2</sub>) : 22%

Alumina (Al<sub>2</sub>O<sub>3</sub>) : 5%

Calcium sulphate (CaSO<sub>4</sub>) : 4%

Iron oxide (Fe<sub>2</sub>O<sub>3</sub>) : 3%

Magnesia (MgO) : 2%

Sulphur (S): 1%

### 26.8.2 Function of cement ingredients:

The properties of cement depend upon its composition, burning treatment and fineness of grinding. Good quality cement should provide strength, binding and water resistant in addition to working, quick setting and plasticity during construction work. The role of different constituents of Portland cement is presented below.

1. Lime: It provides strength and setting property but excessive lime makes the cement unsound and causes the cement to expand and disintegrate. Its deficiency causes less strength and quick setting.
2. Silica: It imparts strength due to formation of dicalcium and tricalcium silicate. The excess of silica improves strength but causes prolonged setting.
3. Alumina: It imparts quick setting property and acts as flux. The excess of it weakens the cement.
4. Calcium Sulphate: This ingredient is in the form of gypsum and its function is to increase the initial setting time of cement.
5. Iron oxide: It imparts color, hardness and strength to the cement.
6. Magnesia: It imparts hardness and color. The excess of it makes the cement unsound.
7. Sulphur: A very small amount of sulphur is useful in making cement sound. The excess of it causes cement to become unsound.
8. Alkalies: The excess quantity causes staining in concrete.

### 26.8.3 Setting action of cement

When water is added to cement, the ingredients of cement react chemically and form various chemical compounds. The mixture goes on thickening till it achieves a rock like state. It is found that ordinary cement achieves about 70% of its final strength in 28 days and about 90% in one year.

The important compounds formed during setting action of cement are as under.

- Tricalcium aluminate (3CaO. Al<sub>2</sub>O<sub>3</sub>): It forms within 24 h after addition of water to the cement.

- Tetra-calcium alumino ferrite ( $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$ ): It forms within 24 h after addition of water.
- Tricalcium silicate ( $3\text{CaO} \cdot \text{SiO}_2$ ): It forms within a week after addition of water to the cement. It is responsible for imparting strength in early period of setting.
- Dicalcium silicate ( $2\text{CaO} \cdot \text{SiO}_2$ ): It forms slowly and imparts progressive strength.

The above 4 compounds in Portland cement are designated in short as  $\text{C}_3\text{A}$ ,  $\text{C}_4\text{AF}$ ,  $\text{C}_3\text{S}$  and  $\text{C}_2\text{S}$  respectively.

## 26.8.4 Types of Cement

### 26.8.4.1 Rapid hardening cement/ high early strength cement:

The setting time of this cement is the same as that of the ordinary cement. The high strength at early age is due to finer grinding, burning at higher temperature and increased lime content in the composition. This cement costs a little more than ordinary cement. The strength developed by this cement in four days equals that acquired by ordinary cements in 28 days. Thus, it is very important in increasing the speed of construction.

### 26.8.4.2 Quick setting cement

Under normal conditions, quick setting is considered as a defect, as it does not allow sufficient time for the concrete to be properly mixed and placed. The addition of 3 to 4 % of gypsum is added to the ordinary cement just to retard the setting action. But under certain conditions, when concrete is to be laid under water or in running water, quick setting cement is required. Fineness of grinding and the addition of a small percentage of aluminium sulphate accelerate the setting action. The setting action of such cements starts within 5 minutes after addition of water and it becomes stone hard in less than half an hour.

### 26.8.4.3 High Alumina cement:

This is manufactured by melting a mixture of bauxite and lime and grinding the resulting clinkers. Total alumina content shall not be less than 32% and the ratio by weight of alumina to lime shall not be less than 0.85 nor more than 1.3. It is not only rapid hardening cement, but has also higher ultimate strength. It gives 6000 psi compressive strength against 2500 psi compressive strength obtained in 7 days for Portland cement. Its initial setting time is more than 3.5 hours and final setting time is 4 to 5 hours as against 0.5 hours and 10 hours respectively in case of ordinary cement. It therefore allows longer time for mixing and placing concrete before it begins to set.

High Alumina cement is immune to thermal shocks and great heat is evolved during setting and hardening. It does not expand on setting. It possesses great resistance to corrosion action of acid and also to high temperatures. Thus it is found very useful in chemical plants, mines, dairies etc. and also for lining the furnaces. It is also high resistant to sea water.

### 26.8.4.4 Acid resistance cement

The addition of additives like sodium fluosilicate accelerates the hardening process and it increases the resistance to acid and water. It also contains acid resistant aggregates.

### 26.8.4.5 Colored cement:

The cement of desired color may be obtained by mixing pigments with ordinary cement. The amount of coloring material may vary from 5-10%. The use of chromium oxide and cobalt pigments imparts green color

and blue color respectively while iron oxide and manganese oxide gives brown/red color and black or brown color respectively.

#### **26.8.4.6 White cement**

It is prepared without coloring oxides. The process of making the cement is slightly different as coal is not used for burning. White cement is used for fixing marbles, filling of joints in flooring and glazed tiles. It is relatively costly as compared to Portland cement.

### **26.9 MORTAR**

The paste prepared by adding required quantity of water to a mixture of binding material like cement and sand is known as mortar. The proportion of cement to sand varies between 1:2 and 1:6 depending on the use of mortar. It is desirable to use the mortar within 30 minute after addition of water. After setting of mortar, it should be kept damp or wet by sprinkling water to avoid drying of mortar for about 7 to 10 days.

#### **26.9.1 Properties of mortar**

The properties of good mortar are listed below.

- Good adhesion with the building.
- Capable of developing required stresses.
- Capable of resisting penetration of water
- Durable
- Good workability-mobility
- Good placeability

#### **26.9.2 Uses of mortar**

- Binding material for building materials (bricks, stone etc.)
- Plaster work
- Bedding layer for building units
- Joining of cement pipes, filling of cracks.

### **26.10 CEMENT CONCRETE**

The cement concrete is a mixture of cement, sand, pebbles or crushed rock and water which when placed in the skelton of forms and allowed to cure, becomes hard like a stone. The cement concrete in which steel reinforcement is placed at suitable places to increase tensile stress is called Reinforced Cement Concrete (RCC). The proportion of cement, sand and coarse aggregates varies from 1:2:4 to 1:3:6 depending on the nature of work. As per BIS, the concrete is designated in 7 grades. These grades are M 10, M 15, M 20, M 25, M 30, M 35, M 40 (M refers the mix and number indicates the compressive strength of 28 days in  $N/mm^2$ ). The following points are important for R.C.C.

- $< M 15$  should not be used in R.C.C. work
- Water-cement ratio by weight should be 0.45 –0.55

- Weight of water = 28-30% weight of cement + 4-5% weight of total aggregate.
- Thickness of R.C.C. work : 80 to 150 mm
- Proper mixing of all materials – using mechanical mixer is very essential.
- Placing of concrete within 30 minutes
- Consolidation using vibrator helps in reducing air bubbles and increases the strength of R.C.C . Hand consolidation which includes ramming, tamping, spading, slicing with suitable tools.
- Provide expansion and contraction joints if length exceeding 12 m.
- Dummy joint – 3 mm width and  $1/3$  to  $1/5^{\text{th}}$  of slab thickness in depth and it is filled with filler materials.

### 26.10.1 Curing of concrete

The concrete surface is kept wet for certain period after placing of concrete so as to promote hardening of the mixture. Curing period is about 7 to 14 days. Ponding with water, covering with wet jute bags, intermittent spraying with water etc. may be used for curing.

### 26.10.2 Water proofing cement concrete

The impermeability of concrete is very essential. If concrete is made dense and free from cracks, it is watertight. This can be achieved by closely adhering the following points.

- (i) Using high class Portland cement
- (ii) Adopt correct proportioning of sand, cement and aggregate.
- (iii) Using clean and non-porous aggregates
- (iv) Proper mixing at optimum water quantity.
- (v) Careful placing, tamping and curing.

Using suitable water proofing compound.

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## Lesson 27

### Building materials – stones, wood, metal, glass etc.

#### 27.1 INTRODUCTION

Selection of building materials mainly stones, wood, metal and glass are very important for dairy plants, because each and every section has its specific requirements. There are different types of stones used for flooring and skirting and it should have desirable properties to with stand to prevailing conditions of different sections. Similarly requirement of type of wood depends on its position in a windows, doors and other applications, soft woods requires seasoning treatment and application varnish and oil paints to prevent yeast and mould growth. Selection of metal depends on type of vessels used for processing, particularly to with stand high pressure and to meet sanitary standards. The glasses used in the dairy are specifically designed with wire mesh inside, so that no glass pieces will fall in the product. In certain sections like, butter, ghee and cheese manufacturing, glasses are used to control sun light particularly UV light to prevent oxidation of fat and related defects in the product.

#### 27.2 STONES

Stones are obtained from rock, a portion of the earth's crust having no definite shape or chemical composition. Stones are used as the construction material for the following.

- Material for foundations and walls of buildings, dams, bridges
- Material for road and concrete making in the form of either broken or crushed stones called aggregates/ gravels/ pebbles.
- Used as thin slabs for paving/flooring.
- Used as roofing tiles
- Lime stones are used as a flux material in the blast furnaces
- In view of several artificial materials developed recently for flooring and roof, the use of natural stone in many applications has become limited.

#### 27.3 Requirements of good structural stones

When stone is used as structural material, the following considerations are to be considered.

(i) Strength: It should be sufficiently strong against crushing. The stones having more compact grains with higher density are stronger. A dense and compact stone has very few or no pores and thus does not absorb water. A stone of igneous origin is stronger than one of sedimentary formation. A crystalline stone is superior to a non-crystalline one and the finer the crystalline structure, the stronger it is. The specific gravity of good stone should not be less than 2.7. It is desirable to have crushing strength of building stone more than 100 N/mm<sup>2</sup>. The crushing strength of some commonly used stone is given below.

- Granite: 75-127 N/mm<sup>2</sup>
- Sand stone: 64 N/mm<sup>2</sup>
- Lime stone: 54 N/mm<sup>2</sup>

- **Durability:** It depends on (a) chemical composition (b) physical structure (c) weathering effects and (d) place or position in the structure. It depends on type of stone and working conditions.
- **Appearance:** The appearance of a stone in relation to the design is of great importance from an architectural point of view. Appearance depends on the color and the ease with which stone can be dressed, rubbed or polished, for which slightly softer stone is selected. It is desirable that the color of stone is uniform, no weathering effect, and free from clay holes.
- **Dressing properties:** The ability of stone for cutting, carved etc is important for building material. In order to perform dressing operations with ease, it should be relatively soft with compact grains. Stone should be homogeneous in texture rather than crystalline. The development of many machines and advancement of technology, the dressing of even hard stone has become quite easy for many applications of stones.
- **Hardness:** It is expressed in terms of co-efficient of hardness. The common accepted norms for various categories of hardness are greater than 17 considered as high, between 14 to 17 as medium hardness and less than 14 as poor hardness.
- **Wear percentage:** If the value of wear is more than 3 percent, then the stone is regarded as unsatisfactory.
- **Seasoning and Weathering:** After quarrying stone should be seasoned for 6-12 months and there should not be any change in various properties. A good quality of stone should not show remarkable weathering effect.
- **Texture:** Stone should be free from cavities, cracks etc.
- **Toughness:** It is expressed in terms of toughness index. The common accepted norms for various categories of toughness are greater than 19 considered as high, between 13 to 19 as moderate toughness and less than 13 as poor toughness.
- **Water absorption:** The absorption of water should not exceed 0.6 % of weight.

#### **27.4 Basis of classification of stones**

There are 4 basis of classification of stones as under.

- 1) Geological (based on mode of formation)
- 2) Physical (depending upon structure)
- 3) Chemical (depending on composition)
- 4) Practical (based on use)

#### **27.5 Use of stone**

Use of natural stone is various purposes is given below.

- (i) Structure (ii) Face work
- (iii) Paving (iv) Basic material

#### **27.6 Stone Quarrying**

The process of taking out stone from natural rock is known as quarrying.

### **27.7 Artificial stones**

- Cement concrete blocks
- Mosaic tiles
- Terrazo

### **27.8 WOOD:**

Wood is of two types – hard wood and soft wood. Hard wood is used for building construction and soft wood is mostly used for packaging material and boxes. Plywood is obtained from inferior quality wood after some processing, and it is used for making furniture. Hardwood is seasoned to reduce moisture content and is also treated with creosote oil. Hard woods are used in the room where moist conditions prevail and it is properly seasoned to prevent any kind of mould growth and contamination. Soft woods are used in the dairy for cold store doors and covered with stainless steel sheet.

Soft wood is obtained from trees of Deodar, Kali, Chir, Pine, Walnut and Spruce etc. Soft woods are resinous and light in color. It is general characteristics that trees having needle like leaves give soft wood.

Sal, Teak, Shisham, Pyngado, Oak, Beach and Ash are some of the examples of hard wood obtained from broad leaf trees. Hard woods are relatively darker in color, heavy, close grained and strong. They are non-resinous.

#### **27.8.1 Timber wood**

Timber wood is suitable for building or engineering purposes. When in living tree, the timber is called ‘standing timber’. When trees are cut down, it is called ‘rough timber’ and when it is sawn into various market sizes, such as beams, battens, posts, planks etc., it is called ‘convert timber’

#### **27.8.2 Seasoning of wood**

The growing tree contains a large amount of moisture which may be 150% of the dry weight of the timber. The process of removal by drying the excess moisture from the wood in a controlled manner to prevent the shrinkage which occurs, causing cracks and other defects is called seasoning. Seasoning may be natural or artificial. Natural seasoning is best but it takes long time. Artificial seasoning may be water seasoning, boiling or kiln seasoning.

#### **27.8.3 Preservation of wood**

Timber is liable to attack by dry rot and other fungi. The function of a preservative is to poison the food matter in the timber. But this poison should not be dangerous to carpenter and must not wash out in rain. The best time to apply preservatives is the early summer. The usual methods of preservation are tarring, charring, painting, creosoting, solignum paints and Ascu treatment.

Tarring consists of coating the timber with hot coal tar. Tarring is adopted only for work of rough character such as timber fences, ends of doors and window frames built into walls.

Charring is adapted to the portions which are embedded in the ground. The ends of posts are charred over a wood fire to a depth of about ½” and then quenched with water. Painting consists of applying 3 or 4 coats of an oil paint. Solignum paints are effective preservatives against attack by white ants. The process of Ascu treatment for the preservation of wood has been developed at the Forest Research Institute at Dehradun. The

powder developed for the purpose is dissolved in water. Six parts of powder are dissolved in 100 parts of water and then applied or sprayed on timber.

#### **27.8.4 Fire proofing**

Wood can catch fire very easily and it is difficult to make it fireproof. However, chemicals such as 2 coats of 2% solution of Borax or sodium arsenate are effective in retarding the action of fire.

### **27.9 METALS**

Metals are used in the dairy for different purposes. Mild steel is used for fabrication of sheds, grills, foundations, pipelines, and as structural steel. Cast iron is used for drainage of effluent as well as for the fabrication of various components of machines. Stainless steel is used for fabrication of dairy equipment and milk pipelines.

#### **27.9.1 Stainless steels (SS):**

Stainless steels were invented to overcome the problem of corrosion which is a major concern of food and many other industries. The alloy of steel containing iron-chromium-nickel is known as stainless steels which do not rust in sea water and are resistant to acids and several other chemicals. Stainless steels typically contain between 9 and 30 percent chromium and varying amounts of nickel, molybdenum, copper, sulfur, titanium, niobium, etc., may be added to obtain the desired mechanical properties and service life. Having all these properties, SS are widely used in dairy and food industry. Stainless steel is considered noble metal for use in dairy industry. Stainless steels are classified based on the chemical composition and it provides information to overcome many types of corrosion. Some of the limitations of SS employed in food and dairy industry are attack by lactic and malic acids at elevated temperature and poor thermal conductivity. However, these limitations may be overcome by carefully selection & fabrication, optimized operating condition, care and maintenance of the equipment.

##### **27.9.1.1 Classification of SS:**

Stainless steels are basically classified as austenitic, ferritic, martensitic, duplex and super-austenitic grades. Each of these main groups contains a number of alloys that are defined according to the chemical composition and specified in European and American international standards. Apart from chromium, the alloy constituents molybdenum, nickel and nitrogen are of great importance to the corrosion resistance. Carbon will always be present to a certain degree, and it is important for the welding properties. In addition, copper, manganese, sulphur, titanium and niobium are used as alloy constituents to impart certain properties. Stainless steel is typical wrought alloy AISI (American Iron and Steel Institution) series designations, includes: 200 (high manganese austenitic), 300 (austenitic), and 400 & 500 (ferritic & martensitic). Martensitic and ferritic steels are magnetic and martensitic steels are typically hardened by heat treatment and are not easily formable. Austenitic steels harden when cold worked. Duplex grades (austenitic/ferritic) are more resistant to stress corrosion cracking than austenitic and are tougher than ferritic grades.

##### **27.9.1.2 Desirable properties of SS :**

The properties of stainless steel play an important role in the design of various equipments. The use of high quality SS in fabrication of processing equipments helps not only to prevent corrosion but also ensures purity of food product handled in those equipments. In addition to this, stainless steels are easy to clean and maintain and a number of different products can be manufactured in the same equipment. If properly utilized, equipment made of stainless steel can be expected to last for many years. In selecting austenitic stainless steels, a number of factors other than corrosion performance should be considered. Among these are their usually attractive appearance, good mechanical properties, and excellent fabrication characteristics. On a life-cycle basis, the

alloys are often the most cost-effective. Important characteristics to be considered in selecting the proper type of stainless steel for a specific application are listed below.

- Corrosion resistance
- Resistance to oxidation and sulfidation
- Strength and ductility at ambient and service temperatures
- Suitability for intended fabrication techniques
- Suitability for intended cleaning procedures
- Stability of properties in service
- Toughness
- Resistance to abrasion, erosion, galling, and seizing
- Surface finish and/or reflectivity
- Physical property characteristics such as magnetic properties, thermal conductivity and electrical resistivity
- Total cost, including initial cost, installed cost, and the effective life expectancy of the finished product

### **27.10 Steel**

Steel is an intermediate stage between cast iron and wrought iron. The cast iron contains 2-4 % carbon while wrought iron has carbon content less than 0.15%. In steel, the carbon content varies between 0.25 to 1.5 %. There is no graphite in the steel. The steel becomes harder and tougher as its carbon content increases. Steel is used for various applications in dairy industry.

### **27.11 Aluminum**

Aluminum is used as frame work for doors and windows in dairy and food processing plants. The desirable properties of aluminum which makes it suitable are light weight, softness, and appearance. Its use is limited by the fact that it is tarnished and corroded by ordinary alkaline dairy cleaners and sterilizers.

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## Lesson 28

### General requirement of dairy floors and floors for different sections

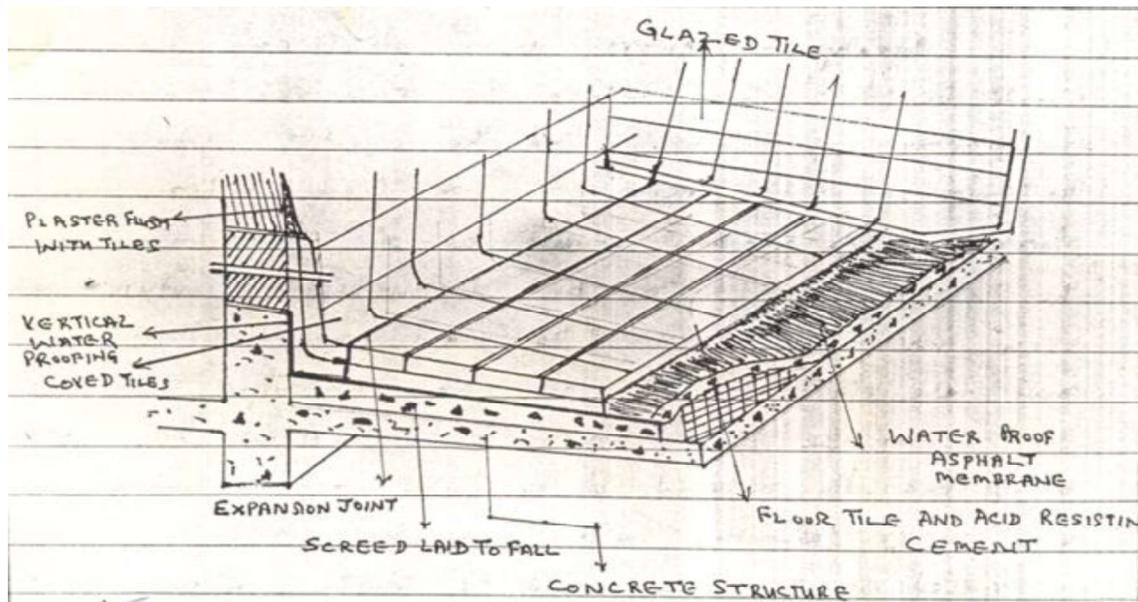
#### 28.1 INTRODUCTION

Flooring requirements for different sections of dairy plant has specific needs depending on the type of sections. The flooring of process section has its typical requirement of resistance against lactic acid, alkalies and thermal shocks, this will be met by specific type of stones e.g. mandana stones. The flooring of cold store has specific requirement of non-slippery flooring with hygienic conditions to be maintained, such requirements will be met by semi vitrious tiles. The flooring of RMRD has specific requirement of good mechanical strength, resistance against the detergents, less noise problem etc. The flooring of section for fermented products like, Dahi, Cheese, Yoghurt etc., requires vitrious category of tiles to maintain hygienic conditions. Thus, flooring materials for different sections are selected based on the need of the particular section to meet sanitary standards.

#### 28.2 GENERAL REQUIREMENT OF DAIRY FLOORS

It is necessary to use different types of the flooring material depending upon the use of the flooring surface. One single type of floor in the entire dairy plant is not possible if wear is to be kept to a minimum. Dairy floor requires different types of flooring in order to cope with hazards and other problems of various sections of a dairy plant. It is desirable that dairy floors should impervious, durable and long lasting. The material of flooring should be such that it can be cleaned easily cleaned, non-slippery and cost effective. The flooring is designed considering the effect of washing and cleaning as well as and the ability to withstand changes of temperature by provision of adequate expansion joints.

The provision of adequate fall and drains helps not only to avoid the possibility of water pools but also assists the rapid removal of milk spillage and cleaning solutions. This helps in reducing the corrosion effect to the flooring materials. Normally, the fall should not be less than 1 in 80 for effective removal of liquids. Drainage channels should be at least 15 cm from the wall and drainage channels should not be placed along side walls, as far as possible. Water seepage may cause corrosion of structural steel and weakens the flooring base or R.C.C. Fig. 28.1 shows a cross section of construction of floor.



**Fig. 28.1 Floor Construction**

### 28.3 STRUCTURAL BASE

The structural base is usually of concrete or R.C.C. A concrete structural base may be cast as a slab directly on the ground/R.C.C. or it may be suspended slab pre-cast concrete units. It should be designed to resist all the static and dynamic stresses with provision of heavy foundation required for installation of equipments. The structural base should be made of good concrete and thoroughly compacted.

### 28.4 WATERPROOF MEMBRANE

One of the most important features at the time of planning and designing of the dairy floor is the use of water proof membrane in the floor to prevent liquids from penetrating to the base structure. The membrane should be impervious to water, resistant to corrosion, tough enough to resist damage during repairs of the floors and support loads. All joints should be thoroughly sealed to provide a continuous membrane surface. The membrane should be laid to have falls at the base structure and be extended to some distance up the walls. The material used for the membrane must be strong and yet flexible. Acid resistant asphalt laid at least 10-12 mm thick on a layer of bitumen felt is most commonly used. The best results are obtained when the asphalt is laid in two layers with all construction joints broken, i.e. two layers don't have their joints coinciding. Good quality bituminous roofing filled with lap joints sealed with bituminous compounds is also used. Plastic films of polyethylene, polysorbetylene and polyvinyl chloride are also used for the purpose. Properties of water proof membrane are as under.

- Water proof membrane should be impermeable to water.
- It should be resistant to corrosive liquids and substances.
- It should be strong enough to support the required load.

#### 28.4.1 Types of water proof membranes

- Plastic sheet
- Chemicals
- Asphalt or Bitumen layer in the form of a thicker layer which is applied on walls to prevent leakage of water.

## 28.5 FLOORING MATERIALS

Portland cement concrete is mostly commonly used as flooring material. The floors are resistant to abrasion and alkali. However, it is vulnerable to weak acids and deteriorates under the influence of milk waste.

High alumina cement concrete resists acid solution above a pH 5.0 and is favorable than plain Portland cement. However, it is attacked by weak solutions of alkali and it loses its strength and resistance to abrasion under hot moist conditions. Hence, it is not regarded as a suitable flooring material for dairy plant.

Portland cement concrete often gives good service even where milk spillage occurs provided that regular cleaning takes place to remove the milk wastes. Concrete floor shrink for several months after laying, but subsequently it expands and contracts with variations of temperature and moisture content. Such expansion and contraction may be of the order of 0.05% which may give rise to cracking or curling. Where plain concrete floors are likely to wet, joining gaps of about 12-13 mm (0.5") width should be left open down to the waterproof membrane, and after the concrete has set, they should be filled with asphalt or other suitable joining material. The dairy floors which may be subjected to considerable attrition and abrasion, the structural base should be covered by a topping of more resistant granolithic concrete.

Granolithic concrete contains more cement than ordinary cement concrete and gives good results in dairies, although its surface can be corroded slowly by lactic acids, milk residues and acid detergents. There is no shrinkage after laying concrete tiles which is made of granolithic concrete and cured under controlled conditions. They are laid in cement mortar of ratio 1:3. The joints between 1/8 and 1/2 inches wide must be completely filled with the same mortar. Concrete tiles may be tinted and similarly tinted mortar should be used for the joints.

Ceramic floor tiles can be used for flooring where moderate resistance to wearing is expected. These tiles are resistant to attacks by acids and alkalis. These tiles are available in different sizes such as 6" x 6", 9" x 4.5", 9" x 6", 9" x 9", 12" x 12" etc. These tiles should be thick so as to resist impact damage. Coved tiles should be used at joints between floors and walls. The tiles should be properly laid using appropriate bedding mortar and high grade filling material.

### 28.5.1 Requirements of a dairy floor or characteristics of a dairy floor

- They should be impervious, smooth and easy to clean.
- It should be able to withstand the effect of lactic acid.
- It should be able to resist the effect of the cleaning solution, steam or hot water.
- It should be strong enough to withstand the effect of falling objects, cans, boxes (impact resistance)
- It should have high resistance to abrasion (wear and tear).
- It should have desired slope towards drains
- In processing section, the slope should be 1:80.
- In bottling section and RMRD, the slope should be 1:40.

### 28.5.2 Different types of floor:

- Cement concrete floor
- Terrazzo floor used in offices
- Tile floor having either natural stones or synthetic tiles
- Metal floor
- Grill floor

## **28.6 BEDDING AND JOINTING FOR TILE FLOORS**

The optimum result can be achieved by adopting most appropriate way of laying and filling the joints. The materials used for the purpose mainly depend on the type of flooring material used in different sections of a dairy plant. Some of the ways of bedding and joining the floor tiles are given below.

### **28.6.1 Portland cement**

Portland cement mortar is most commonly used for bedding material for fixing floor tiles/stones. Portland cement mortar is resistant to alkalis, but it is attacked by acids and dairy wastes. It is necessary to take adequate care to make water tight joint.

### **28.6.2 Super sulfated cement**

Super sulfated cement is a mixture of ground blast furnace slag, calcium sulfate and Portland cement. It requires special care during hardening after laying. It is resistant to acidic and alkalis.

### **28.6.3 Rubber latex cements**

Rubber latex cements are available for in situ floorings and are based on polyester and epoxy resins. Unsaturated polyesters which in the presence of a catalyst, react with another resin such as styrene, are usually employed for polyester flooring. It is susceptible to attack by alkalis and therefore cannot be used in dairy plants.

## **28.7 Metal tiles, plates and grids**

Metal tiles of two main types.

- 1) anchor steel plates
- 2) cast iron metal tiles

Both types are very suitable to resist impact and abrasion in dairies. They also resist the action of alkalis but they are subject to attack by weak acids.

The anchor plate is usually 12" x 12" size made of 10 gauge steel in the form of a shallow tray of about 7/8" thickness and the wearing surface is punched to give downwardly projected twisted anchors which anchor the plate to the bedding material. For laying the anchor plates, upturned tray is filled with concrete and after inversion it is tamped into position until it is firmly embedded in the concrete.

The cast iron metal steel is made of a square or a right angled triangle, apart from the hypotenuse, the sides of each type are 12" long and the tile is about 1" thick and has a projecting foot at each corner. These tiles are bedded in cement mortar and tamped down until the feet rest firmly on the structural base, so that the stresses on the tile are transferred evenly to the structure.

Metal plates are used frequently on dispatch docks and in cold stores to provide very durable wearing surfaces over concrete flooring. Metal grids are sometimes incorporated in floor surfaces as reinforcement against abrasion and are embedded in the topping so that the upper side of the grid is flush with the floor surface.

### **28.7.1 Cast iron grill floor**

Cast iron tiles have a hollow honey comb-like structure which gives a strong surface and has no slipperiness. This type of tiles has no problem of looseness from concrete surface. It gives less noise than metal tiles when cans are moved over it. This floor has high impact and abrasion resistance. Some time, concrete part of cast iron grill floor may be eaten away due the action of h milk or acid. .

### **28.7.2 Cement Concrete Floor**

The general construction includes a structural base of RCC or concrete, a screed laid to fall, a water proof membrane, a bedding mortar and a top finishing surface or layer or a wearing surface.

### **28.7.3 Curing of concrete:**

Curing of concrete is necessary to increase the strength and water tightness as cement reacts with water at a slow rate and it then becomes hard. The aggregate then formed has no reaction but it forms a strong bond and fills in the pores. Normally the structural base is 10-15 cm thick. Concrete of dairy comprises cement to sand to aggregate in the ratio 1:3:5.

### **28.8 Bedding mortar:**

The layer of the bedding mortar is generally kept around 2-3 cm thick. It has a ratio of cement to sand as 1:3. Its function is to give attachment to the top surface.

### **28.9 TERRAZZO FLOOR**

It is similar to concrete floor, and is generally used in offices, labs and such other places where decorative effect is required. Before hardening the top surface, marble chips of irregular shape are fixed on the upper surface and pressure is applied so that the marble chips get embedded on the wet top surface of the cement floor. After hardening, the surface is finished smooth so that the marble chips fixed on the top give a good appearance. Colored cement may be used to impart better look. Its main limitation is that it cracks when it comes in contact with hot and cold water due to thermal expansion and contraction.

### **28.10 TILE FLOOR:**

Two types of tiles can be used viz. natural stone or synthetic (artificial) tiles.

#### **28.10.1 Natural Stone or Kota Stone:**

It is obtained from quarries and is then cut to the required size. They are available in different colors like red, buff, light green, brown and yellow. Acid resistant Kota stone (popularly known as *Mandana* stone) is also available, which can be used in the dairy industry. In order to be used in the dairy plants, the stone should have a minimum thickness of about 3 - 4 cm. They may be square or rectangular and should have a 90<sup>0</sup> angle edges. The top surface should be polished and the bottom is kept unpolished to get better gripe with bedding mortar.

#### **28.10.2 Concrete or Cement Tiles/ Artificial Tiles**

These tiles can be made by making the desirable size mould using mortar and then hydraulic pressure is applied to make it non-porous and stronger. Marble chips of different colors may also be included in this type of tiles. Cement may be high alumina cement or colored cement. The size of the tiles may be 12" x 12", 18" x 18" etc. These tiles are cured in water for 5-7 days and subsequently laid on bedding mortar. Various types of grinders

are employed for surface finish of the floor. These types of tiles are rarely used as many other varieties of tiles are available.

### 28.11 Maintenance of floors

The following points should be considered for the maintenance of the floor of different sections of dairy plant.

1. Regular cleaning dairy floors is essential for hygiene, safety and long life of floor.
2. All the joints should be carefully observed for any water/milk/chemical penetration through the joints. Seal the joints using cementing material, if any defect is noticed.
3. Remove milk/waste water etc. from the floor in order to cause insanitary or slippery conditions.
4. Floors soiled with oil should be cleaned by scrubbing with detergent and water.
5. Lactic acid are formed as milk sours, therefore, early removal of spilled milk is desirable.
6. Use appropriate chemicals or combination of chemicals for floor cleaning. Don't sprinkle chemicals on the floor as it may damage the floor surface. Use mild detergent solution with low free sulphate is recommended for floor cleaning.
7. Hand scrubbing with brushes or electric scrubbing followed by rinsing with clean water is recommended.

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## **Lesson 29**

### **Structural Aspects of Foundations, Roofs, Ceilings, Walls, Doors and windows**

#### **29.1 INTRODUCTION**

Structural aspects of dairy building are very important as it is necessary to design the plant considering strength and vibrations of machines. The design aspects of roofs, ceilings, walls etc. are carefully designed to maintain required hygienic conditions in the plant. The basic principles of design of dairy building are the same as that of normal factory building. Adequate care is necessary to consider sanitary aspects while designing and selecting building materials.

#### **29.2 FOUNDATION**

Foundation of building should be strong enough to support super structure and to resist vibrations and impact load of heavy machineries. The design of foundation depends upon the nature of structure which they have to carry and the properties of soil the soil. The structure may consist mainly of load bearing columns/walls which are required to support the structure. It is necessary to work out the total load to be supported. The actual design of foundation is based on these aspects as well as the quality of sub-soil.

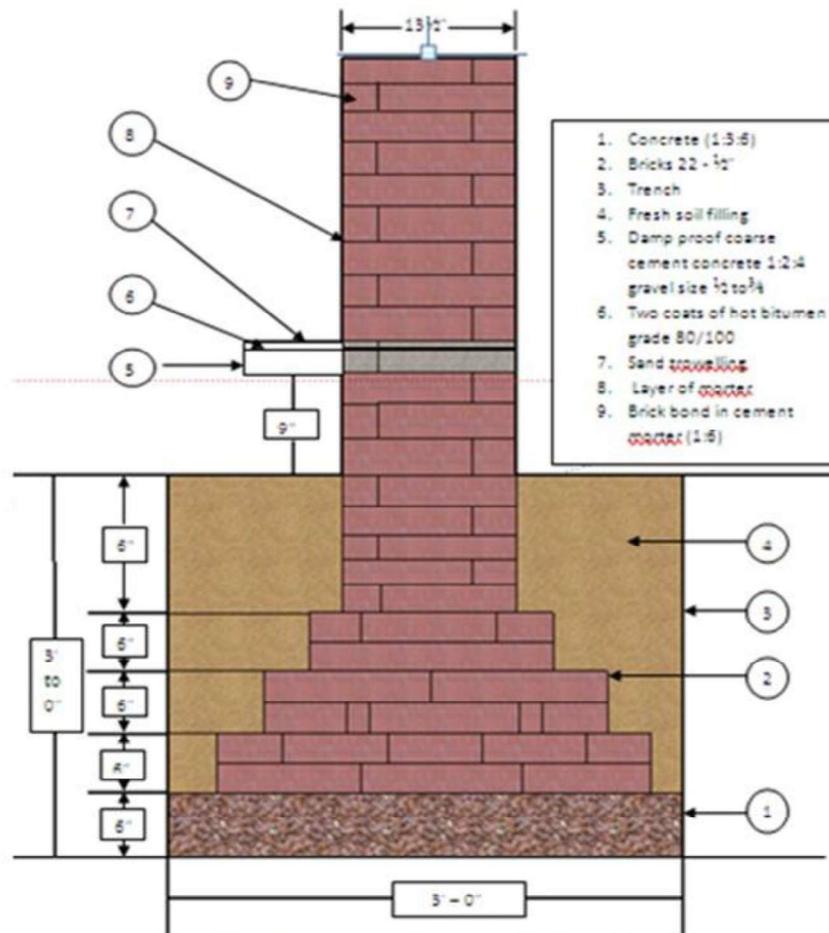
##### **29.2.1 Traditional strip foundation**

This is the most usual variety and consists of concrete say 9 inches thick laid at the bottom of the trench 3 feet deep. The width that the concrete extends beyond the faces of the wall depends upon the bearing capacity of the soil. It is necessary to follow standard guidelines to decide the width of the concrete. These aspects depend on the local soil conditions as well as factor of safety to consider in the design of the building. It is not possible to generalize the design aspects of foundation. There are regions where the traditional foundation with load bearing wall is not recommended owing to soil conditions reveling in that area. Column and beam type of structure may be required to support the load and other stresses.

##### **29.2.2 Stepped foundation**

The foundation of building should be strong enough to support the superstructure. The size of foundation is governed by its depth and width which are determined by the soil type and load acting on it. The size of the foundation should be determined on the basis of bearing pressure of the soil in which it is built.

A typical section of stepped foundation for 13.5 inch thick wall is shown in Figure 29.1



**Fig. 29.1 Section of stepped foundation**

### 29.3 WALLS

Walls for plant buildings are made of brick, concrete, concrete block, aluminum and glass. Bricks are widely used for the construction of walls. It is relatively cheaper and proper plastering and painting makes the walls quite water proof. In many sections, glazed tiles are laid up-to the height of 7 feet or more for ease of cleaning. With adequate care, repairs can be made without spoiling the appearance of the building.

Concrete walls are relatively costly and repairing is difficult. Provision is necessary to tackle the need of unsightly repairs. Aluminum partition walls can be made using flat panel construction or corrugated sheets. Glass panels used in building give good lighting but it is essential to keep the glass surfaces clean.

Walls which are made up of brick or stone are mainly two types.

- Partition wall: To divide an area into two or more compartments or cabinets, etc. The width of partition wall using standard brick is about 4".
- Load bearing wall: Walls which can take loads of structure of ceiling or of superstructure. The width of the load bearing wall using standard brick is 14" or 9".

### 29.3.1 Construction of brick walls

The dairy buildings are of two types namely single or two storey building having load bearing walls. Another type of building is having column and beams which supports the entire load of the building. The load of the building is transferred to the soil by beam and columns. It may be multi-storied building or even single storied building. In this case, walls are simply dividing the area in to different portions/sections. The strength of wall is not much important as the entire load is taken by beams and columns. If the size of room is small in case of load bearing structure, beam is not required. The external walls take the load and transfer it to the soil. In construction of walls using bricks, it is desirable to staggered the joints. Mortar of suitable proportion of cement to sand ratio is recommended for different types of walls. Optimum quantity of water is necessary in the mortar for proper spreading and setting of plaster.

### 29.3.2 Surface finishing for walls

Plastering using cement to sand ratio of 1:2 or 1:3 is used for surface finish of walls. The plaster is generally applied in two coats (1) floating coat and (2) finished coat. The floating coat of the plaster is 1.5 to 2.0 cm thick. The main purposes of plastering are as follows.

- To hide irregularity of walls (grooves)
- To avoid unevenness of wall during construction
- To improve the appearance of the wall
- It provides or facilitates the application of suitable paint
- It also prevents deterioration and protects the wall from external atmospheric effect.

Ceramic glazed tiles/vitrified tiles are also used for the purpose of wall finish.

## 29.4 Ceramic/Glazed Tiles

Glazed tiles are laid up to the height of 2 m in the processing room and other sections of dairy plant. The use of glazed tiles provides a surface which can be easily cleaned and hygienic conditions can be maintained. These tiles also make the wall waterproof.

### 29.4.1 Classification of Tiles

- **Non – vitreous:** Non-vitreous tiles has a high degree of moisture absorption greater than 7% of the weight of the tiles. Even though, it does not prevent the tiles from having high degree of strength and it also facilitates installation because of their adherence to the mortar.
- **Semi-vitreous:** These tiles have a high density that limits the moisture adsorption to 3-7% of the weight of the tiles.
- **Vitreous:** These tiles have a moisture absorption of 0.5 to 3.0%.
- **Impervious:** These tiles are the hard and their moisture absorption is less than 0.5% and they are readily cleaned off stains and dirt.

In lower portion of the wall of RMRD and cold store, damage may occur. Skirting is provided in the processing room to make lower portion of the wall hard. Bumper rails in cold store and railing on the walls are provided to prevent the damage due to crates/cans. Wherever walls are not covered with tiles, they are plastered and painted. Use of good quality paint is recommended for painting of walls.

## 29.5 Doors and windows

Doors and windows are subject to grueling condition existing in milk plant. The door of stainless steel is the best choice in many dairy plants. Hard wood or water proof plywood may be used for making doors and

windows. Aluminum or aluminum alloys can be used but the alkaline cleaning materials which are used in milk plants may spoil the surface. Doors of ordinary steel sheet on a steel base are sometimes used, but in such cases, the whole door must be galvanized or protected against corrosion.

Plastic sheet can be used with a wooden or metal frame. There are many options available for the selection of doors and windows. It depends on the requirement, cost, maintenance etc.

Doors for cold rooms must be thermally constructed from timber/PUF panels and cladding of S.S. may be used for protection of insulation. All door fittings should be of rust proof material and of robust construction, particularly in case of swing doors. The locking mechanism for cold store room doors must always be such that it can be operated from inside the cold room.

### **29.5.1 DOORS**

The provision of doors in a building should be carefully made considering the movement of materials, persons, location of door, size requirement, type of door etc. The height of the door should be more than 2m inside the frame. Regarding the width of the door, it should be designed for the particular requirements. Usually, it varies from 0.75 m to 1.5 m depending on the type of the room. When the width is more than 1 m, double shutters may be used. The normal height of door is 2 m but it may be more in case of workshop, boiler room and garages. A rolling shutter may be used for large size doors especially in boilers, garages and workshop. The number of doors depends on the type of room and size of the room. Hardwood or laminated plywood may be used for preparation of doors. Wood or plywood doors should be protected from moisture and water by painting.

#### **25.5.2 Types of doors**

- Ledged door
- Ledged and braced door
- Frame and ledge door
- Frame and paneled door
- Louvred door
- Flush door
- Door without hinges
- Sliding door
- Rolling steel door
- Collapsible door
- Revolving door

Flush doors are manufactured in standard sizes to facilitate mass production. It consists of a skeleton or hollow frame of rails and stiles covered with plywood or any other type of reconstructed wood. Louvered doors maintain free flow of air and also maintain privacy. The door without hinges such as sliding door, rolling door etc. are used in large size doors.

#### **25.5.2 WINDOWS**

The purpose of providing windows in building is to get ventilation and natural light. Openable windows provide both air and light, while non-open able windows provide only light. The size of window and its location are very important to achieve optimum advantage. In deciding the location of windows cross ventilation is kept in mind for office building. Fixed glass windows are also provided in dairy building to get natural illumination. It is recommended that

1/10<sup>th</sup> of the floor space is allowed for the window, of which one half should be capable of opening, when required. Another thumb rule adopted is that window area is equal to the square root of the cubic contents of the room.

The exact location of the windows depends also on the purpose for which the room is used. For example, in an ordinary living room, the sill of the window should be kept at about 2.5 feet over the floor level while in bathrooms or a lavatory. The window will be kept at a higher level, so that even when the shutter is open, there should be privacy to the occupant. The window sill should be at a height of about 0.8m height from the floor. The height and width of the window depends on the type of window and number of windows. Entry to dust and insects should be prevented in the product processing room by providing a wire mesh. Total window area may be 20-25% of floor area.

## 25.6 ROOFS AND CEILINGS

The use of R.C.C. is widely used for roofs and ceilings. The R.C.C. is designed and executed properly to prevent leakage of water. Water proofing work is necessary to eliminate the chances of water penetration in the R.C.C. Use of good quality materials and proper workmanship during R.C.C. work is necessary to get better result. It is necessary to carry out curing of R.C.C. immediately after setting of the R.C.C. White ceramic/glazed tiles may be laid on the terrace to reduce the heating effect and to make the R. C. C. water proof. It depends on the local weather conditions to decide the need of water proofing requirements.

Slope is provided on the top to facilitate drainage of water. The thickness of the slab varies from 10 cm to 15 cm depending on the size of the room and other structural considerations. Height of processing section is more in order to facilitate the service pipelines.

Roofs are classified as flat, semi-steep and steep depending on the slope provided. Flat roofs have rise from zero (level) to 8 inches per horizontal foot. The rise in semi-steep roofs varies from 3.25 to 12 inch rise per horizontal foot. The rise of steep roofs varies from 13 to 24 inch rise per horizontal foot. In many factories and food plants roofs are generally flat or semi-steep type.

The roof sheet of different materials such as PVC, fibre glass (FRP), polycarbonate etc. in various design are available for making roof of factory. These materials have advantage of light in weight and color choice based on the requirement of the plant. Construction of a satisfactory roof is possible only when high standards are maintained during all phases of its construction. The selection of material for roof mainly depends on the weather conditions of the place. There are options available to select the best possible roof for the plant. Ceilings of the dairy plant must be smooth and impervious so that it can be easily cleaned and maintained. In the plants where air ducting is necessary, it is carefully planned with false ceiling of appropriate material.

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