Carbonaceous Refractories are manufactured from graphite or coke. These have refractoriness above 1700° C and are resistant to attack by molten slags.

Properties

Refractories are capable of withstanding high temperatures, thermal shocks and rough usage. The expansion and contraction of these materials is minimum. They are chemically inactive at high temperatures and are resistant to the fluxing action of slags and corrosive action of gases. Refractories are good thermal insulators and have low electrical conductivity.

15.4 GLASS

Glass is an amorphous substance having homogeneous texture. It is a hard, brittle, transparent or translucent material. It is the most common material glazed into frames for doors, windows and curtain walls. The most common types used in building construction are sheet, plate, laminated, insulating, tempered, wired and patterned glass. Most ordinary colourless glasses are alkali-lime silicate and alkali-lead silicate with tensile and compressive strengths of about 30–60 N/mm^2 and 700–1000N/mm^2, respectively and modulus of elasticity in the range 0.45×10^5 to 0.8×10^5 N/mm^2. The strength is very much afftected by internal defects, cords and foreign intrusions. The main shortcoming of glass is its brittleness which depends on a number of factors, the chief one being the ratio of the modulus of elasticity of the material to its tensile strength.

Constituents

The raw materials used in manufacturing glass are sand, lime (chalks) and soda or potash which are fused over 1000° C. Oxides of iron, lead and borax are added to modify hardness, brilliance and colour. The functions of the various ingredients are as follows.

Silica is used in the form of pure quartz, crushed sandstone and pulverised flint; should be free from iron contents for best quality glass. Since it melts at very high temperatures (1710° C) carbonates of sodium or potassium are added to lower down the fusing temperature to about 800° C. These also make liquid silica more viscous and workable.

Lime is used in the form of limestone, chalk or pure marble and sometimes marl. The addition of lime makes the glass fluid and suitable for blowing, drawing, rolling, pressing or spinning. It also imparts durability and toughness to glass. Excess of lime makes the molten mass too thin for fabrication.

Soda acts as an accelerator for the fusion of glass and an excess of it is harmful.

Potash renders glass infusible and makes glass fire resistant.

Lead Oxide imparts colour, brightness and shine. When 15–30% of it added to substitute lime it lowers the melting point, imparts good workability, while its transparency is lost with the glass becoming brittle and crystalline.

Cullets are broken glasses added to act as a flux to prevent loss of alkali by volatisation during the process of forming glass and also to lower the fusion temperature. However, flux may reduce the resistance of glass to chemical attack, render it water-soluble or make it subject to partial or complete devitrification (crystallisation) on cooling. These crystalline areas are extremely weak and brittle. Stabilizers are added to overcome these defects.

Titanic acid, oxides of Nickel and Cobalt are used for chromatic neutralisation.

Note: Iron is not desirable as a constituent. However, when present it imparts a bottle green colour to the glass. To overcome this manganese dioxide known as glass maker's soap is added which washes the liquid glass and removes the colour.

Manufacture

Glass is manufactured in the following four steps:

Melting The raw materials — lime, soda and sand — separately cleaned, ground, sieved (called 'Batch') in definite proportion and mixed with water are fused in a continuous type (tank) furnace or batch-type (pot) furnace. The charge in the first stage melts, forming a bubbly, sticky mass, and as the temperature is raised (1100° C–1200° C) it turns to a more watery liquid and the bubbles rise to the surface. The melting process in case of ordinary soda-glass involves the following series of reactions:

$$CaCO_3 + SiO_2 \longrightarrow CaSiO_3 + CO_2\uparrow$$

$$Na_2CO_3 + SiO_2 \longrightarrow Na_2SiO_3 + CO_2\uparrow$$

When all the carbon dioxide has escaped out of the molten mass, decolourisers such as MnO_2 or nitre are added to do away with ferrous compounds and carbon. The colouring salts are added at this stage. Heating is continued till the molten mass is free from bubbles and glass balls. As the glass cools (800° C), it is ready to be drawn or floated to its desired thickness and size at the other end of the furnace as shown by a flow diagram in Fig.15.1.

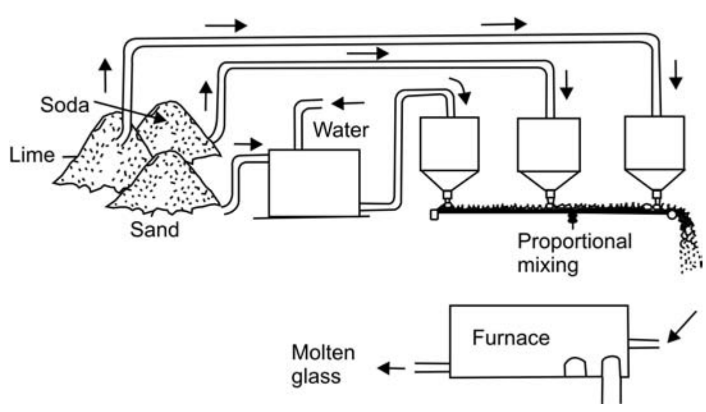

Fig. 15.1 Glass Manufacturing Process

Forming and Shaping The molten glass can be fabricated to desired shapes by any one of the following methods:

Blowing A 2 m long and 12 mm diameter blow pipe is dipped in the molten glass and taken out. It is held vertically and is vigorously blown by the operator. The sticking molten glass takes the shape of a hollow ball. On cooling it is reheated and the blowing operation repeated a number of times till the desired articles are ready.

Flat Drawing The process of drawing the glass up into a sheet begins when an grille (bait) is lowered into the glass in the kiln. In a short time the liquid molten glass adheres to the bait, and as the bait is slowly lifted it draws a sheet of glass. The bait and the drawn sheet of glass are then drawn through rollers, the bait is cracked off and a continuous sheet of glass is drawn up. This sheet is then slowly cooled in a chamber and annealed for cutting into proper size. A machine for vertical drawing of glass is shown in Fig. 15.2.

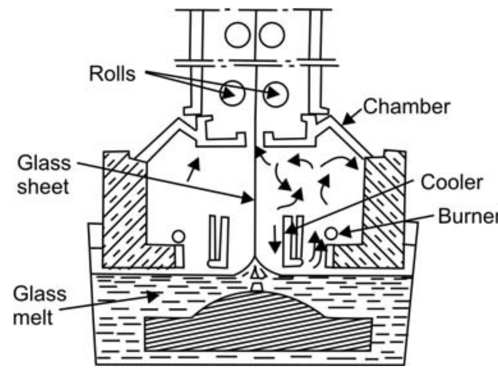

Fig. 15.2 Machine for Vertical Drawing of Glass

Compression Moulding In this process moulds are used to obtain the articles of desired shapes.

Spinning A machine is used to spin the molten glass. The fibres so produced are very fine and are used for heat and sound insulation.

Annealing Glass articles are allowed to cool under room temperature by passing through different chambers with descending temperature. If cooled rapidly, the glass being bad conductor of heat, the superficial layer cools down first and strain develops in the interior portions, which causes unequal expansion and the articles are likely to crack.

Finishing After annealing the glass articles are cleaned, ground, polished, cut and sand blasted.

Classification

Depending upon the constituents glasses are classified as soda-lime glass, lead glass and boro-silicate glass.

Soda-lime Glass is also known as *soda-ash glass*, *soda glass* or *soft glass*. Soda-lime glass is obtained by fusing a mixture of silica, lime and soda. The quality of this glass can be improved by adding alumina and magnesium oxide and the glass is then called *crown* glass. This is the most common type of glass used in doors, windows and for making glass-wares such as bottles.

Lead Glass also known as *flint* glass is obtained by fusing a mixture of silica, lead and potash. It is free from iron impurities and is colourless. Lead glass has high shining appearance and can take polish. It is not affected by temperature. Electric bulbs, optical glasses, cut glass, ornamental glass works and radio valves are some of the articles made from it.

Boro-silicate Glass is obtained by fusing a mixture of silica, borax, lime and felspar. The examples are *pyrex* glass and *heat resisting* glass. Boro-silicate glass can withstand high temperatures and is most suitable for making laboratory equipments and cooking utensils.

Commercial Forms

Sheet Glass is used for glazing doors, windows and partitions and is obtained by blowing the molten glass into the shape of a cylinder. The ends of the cylinder so produced are cut away and the cylinder is flattened over a plane tray. It is available in thicknesses of 2, 2.5, 3, 4, 5, 5.5 and 6.5 mm and up to 1750 × 1100 mm size and is classified as

Type	Uses
Ordinary glazing quality	General engineering purpose
Selected glazing quality	Class works
Special selected quality	Superior quality works such as show cases and cabinets etc.

Plate Glass is used for all engineering purposes and is superior to sheet glass. A plate glass differs from a sheet glass in that it has a parallel, distortion-free surface obtained by grinding or floating process. It is produced by pouring the molten glass on casting tables and levelling it to an uniform thickness. Both the glass surfaces are then ground, smoothened and polished. Glass so produced is clear and contains unblemished true plane surfaces and is available in thicknesses of 3 to 32 mm and sizes up to 2750 × 900 mm. It is classified as

Type	Uses
Ground glass quality	Showcases, cabinets, counters, shop fronts, etc.
Selected glazing quality	Making mirrors
Special selected quality	High class works, wind screen of vehicles

Tempered Glass is made from plate glass by reheating and sudden cooling and is 3 to 5 times stronger than plate glass. Although not unbreakable, it resists bending stress better than plate glass and, when broken, the pieces are relatively small in size. It is used extensively in sports arenas, sliding doors and curtain walls.

Wired Glass is produced by embedding wire nets 0.46 to 0.56 mm into the centre of sheet glass during casting. The minimum thickness of wired glass is 6 mm. When broken it does not fall into pieces. It has higher melting point than ordinary glass. Wired glass is used for fire resisting doors and windows, for sky lights and roofs. A special example of this is wired-refrax glass which transmits 100 per cent more light than the other glasses.

Obscured Glass is made comparatively opaque to sunlight. Also known as *patterned* glass. They are classified as frosted, rolled and ribbed.

Frosted glass is produced by subjecting the polished face of the glass to a sand blast which grinds off the surface. It can also be produced by etching on glass by hydrofluoric acid.

Rolled glass has a series of waves of desired pattern on the surface and is also known as *figured* rolled glass.

Ribbed glass A series of triangular ribs are produced in the glass during casting.

Laminated Glass is made by sandwiching a layer of polyvinyl butyral between two or more layers of plate or sheet glass. It is also lso known as *safety* glass. The examples are heat proof glass, sound proof glass and bullet proof glass.

Heat and sound proof glasses Two or more glass plates are sandwiched by a tinted plastic inner layer. It provides high resistance to heat and glare. By increasing the thickness of plastic layer the glass can be made more sound resistant.

Bullet proof glass is produced by placing vinyl plastic and glass in several alternate layers and pressing them with outer layers of glass. It is used in banks, jewellery stores and display windows.

Insulating glass is composed of two glass plates into which a layer of 6–13 mm thick dehydrated air is sealed. The round edges are formed by fusing together the two glass plates. These glasses reduce the heat transmission by 30–60 per cent.

Heat absorbing Glass is bluish green in colour and cuts ultra violet rays of sun. The example is *calorex*. It is used in railway carriages, factories, hospitals, health clubs and kitchens.

Ground Glass In this type of glass one face of plate or sheet glass is made rough by grinding. It is used for maintaining privacy by obstructing vision and at the same time allowing light. The ground glass is used for bedrooms, toilets and for making black boards.

Block Glass is hollow sealed made by fastening together two halves of pressed glass. It is used for making partitions.

Coloured Glass is produced by adding oxides of metals to molten glass:

Types of glasses	*Metal oxide*
Ruby red glass	Lead glass, 1 per cent of cupric oxide and 1 per cent of magnetic oxide of iron
Ruby rose glass	Gold chloride is used as colouring agent. Brownish red colour is obtained by adding oxide of iron, bluish red shade is obtained by adding 2 per cent MnO_2 and –4 per cent nitre (KnO_3).
Blue glass	0.1 per cent of cobalt oxide in ordinary glass.
Yellow glass	
(a) Uranium glass (greenish yellow)	2–3% of alkali uranate.
(b) Selenium glass (orange)	Selenite and a reducing agent or ferric oxide and MnO_2.
Green glass (emerald green)	Oxide of chromium Cr_2O_7.
Violet glass (violet)	MnO_2
Black glass	Oxide of Co and Mn.

Opal Glass is also known as *milk glass*. It is produced by adding bone ash, oxide of tin and white arsenic to vitreosil (99.5% silica glass known as clear silica glass). The composition is 10 parts of sand, 4 parts cryolite and 1 part zinc oxide.

Enamel Glass is produced by adding calcined lead and tin oxide to the ordinary glass. The composition is 10 parts sand, 20 per cent lead and tin oxide and 8 parts potash.

Optical Glass contains phosphorus, lead silicate and a little cerium oxide, the latter capable of absorbing ultraviolet light injurious to eyes. They are used for making lenses.