1

Engineering and Building Materials

1.1. NATURAL BUILDING MATERIALS

1.1.1. Composition of Earth Crust. According to various authorities composition of earth crust is as given in Table 1.1.1

Table 1.1.1. Composition of Earth Crust

Element	*Geika*	*Clarke*	*US Geological Survey*
Oxygen (O)	47.29	49.9	47
Silicon (Si)	27.20	26.0	28
Aluminium (Al)	7.81	7.8	8
Iron (Fe)	5.46	4.1	4.5
Calcium (Ca)	3.77	3.2	3.5
Magnesium (Mg)	2.68	2.1	2.5
Potassium (K)	2.40	2.3	2.5
Sodium (Na)	2.36	2.3	2.5
Titanium (Ti)	0.33	0.4	0.4
Carbon (C)	0.22	0.2	0.2
Hydrogen (H)	0.21	–	0.2
P, Mn, S, Ba, F, CL	–	–	–

Table 1.1.2 Chemical Composition and Physical Properties

Properties Mineral	*Chemical Composition*	*Hardness (Mohs scale)*	*Specific Gravity*	*Streak*	*Colour*	*Lusture*	*Cleavage*	*Durability*
1. Quartz	Silicon dioxide (SiO_2)	7	2.60-2.64		Colourless, white to grey, some-times brown to black	Vitreous	No cleavage (Perfect)	Soluble in hydrofluroic acid, weather well
2. Felspar	Alumonio silicates with potas (orthoclase) Example - $K_2O.Al_2O_3 . 6SiO_2$		2.50-2.60	White			Straight spiltting	
		6			Deep to whitish pink	Vitreous to pearly		Less durable than quartz

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Properties Mineral	*Chemical Composition*	*Hardness (Mohs scale)*	*Specific Gravity*	*Streak*	*Colour*	*Lusture*	*Cleavage*	*Durability*
	Alumino silicates with soda (plagioclase) Example - $Na_2O.Al_2O_3.6SiO_2$; $CaO.Al_2O_3.2SiO_2$		2.60-2.80	Grey to white			Oblique splitting materials	
3. Mica	Silicates of alumina with hydrogen (hydrous alumino silicate) and potash (Muscovite)		2.70-3.00		Colourless or grey to brown	Vitreous to pear-ly transpa-rent	Can be split along one plane into very thin tough plates	Does not weather well
	$KAl_2(AlSi_3O_{10})(OH)_2$	2-3		Colourless to grey				
	Silicates of alumina with hydrogen (hydrous alumino silicates) iron and magnesia (Biotite) $K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$		2.80-3.10		Brown to black	Vitreous to pear-ly opa-que	No cleavate	Does not weather well
4. Am-phibole	Silicate of iron, lime, magnesia or alumina (Hornblende) (Ca-Na) $(Mg, Fe, Al)_5Si_6(SiAl)_2O_{22}(OH)_2$	2-3	2.9-3.5		Dark green to black	Vitreous	Perfect on two planes 124°, but do not seperate and flake like mica	Wheathers fairly well
	Silicates of lime and magnesia (Tremolite) $CaMg_5Si_8O_{22}(OH)_2$	5-6	2.90-3.20	Uncoloured grey or brown	White to grey	Vitreous to silky		Weathers poorly
5. Pyroxene	Silicates of lime, alumina, magnesia and iron (Augite) $X_2Si_2O_6$	5-6	3.20-3.60		Green to black		Good on two planes 93° apart	Weathers fairly well
6. Olivine	Silicates of iron and magnesia $(Mg, Fe)_2SiO_4$	6-5.7	3.20-3.60	No streak	Greenish	Vitreous	Indistinct	Wheather poorly
7. Chlorates	Aluminium silicates with iron and magnesia $(Mg, Fe, Al)_6(Al, Si)_4O_{10}(OH)_8$	2·2.5	2.65-2.95	White to green	Greenish	Vitreous to pearly	No cleavage	
8. Garnet	Silicates of iron and alumina $X_3Y_2(SiO_4)_3$	6.5-7.5	3.5-4.3	No	Red	Vitreous	Poor	Renders stone difficult to dress and polish
9. Serpen-tine	Hydrous silicate of magnesia $Mg_3Si_2O_5(OH)_4$	4.00	2.30-2.60	White	Greenish	Greasy		Soluble in hydrochloric acid and weathers poorly

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Properties Mineral	*Chemical Composition*	*Hardness (Mohs scale)*	*Specific Gravity*	*Streak*	*Colour*	*Lusture*	*Cleavage*	*Durability*
10. Talc	Hydrous silicate of magnesia $Mg_3 Si_4O_{10}(OH)_2$	1.5	2.70-2.80		White to green	Pearly	Splits into thin brittle plates	Weathering results in serpentine
11. Calcite	Calcium carbonate $CaCO_3$	3	2.70	No streak	White when pure	Vitreous	Perfect in three directions	Efferversces in dilute cold hydrochloric acid, not durable
12. Dolomite	Calcium magnesium carbonate $MgCO_3 . CaCO_3$	3.5-4	2.85	Pink and White		Vitreous, to pearly	Perfect	Effervesces in hot dilute hydrochloric acid, not very durable
13. Gypsum	Hydrous calcium sulphate $CaSO_4 . 2H_2O$	2	2.30-2.40	White	Colourless white	Vitreous, pearly or silky	Perfect in one plane	Soluble in hydrochloric acid and slightly in water
14. Limonite	Hydrous sesquioxide of Iron	5-5.5	3.60-4.00	Yellowish brown	Yellow to dark	Dull		No cleavage soluble in hydrochloric acid
15. Manetite	Ferrous and Feric oxide of iron Fe_3O_4	5.5-6.5	4.40-5.20	Black	Black	Metallic	Indistinct	Slowly soluble in hydrochloric acid
16. Pyrite	Iron disulphide FeS_2	6-6.5	4.90-5.20	Green to black	Brassy yellow	Metallic	No cleavage	Oxidises readily when exposed to weather

1.1.2 Chemical Classification of Rocks

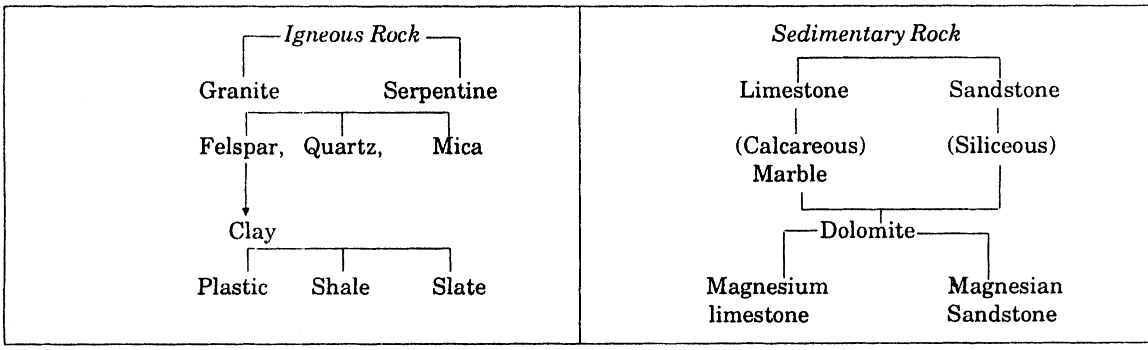
Chemical classification	*Composition*	*Name of the rock*
1. Siliceous	Predominently silica	Granite, sandstone, Basalt, trap.
2. Calcareous	Predominently lime	Limestone, conglomerate
3. Agrillaceous	Predominance of clay	Slate, laterite.

1.1.3. Physical Classification of Rocks

Classification	*Characteristics*	*Typical name*
1. Stratified	Has many strata	Slate
2. Unstratified	Does not have a strata Grains may be granular or otherwise	Granite : Grainular Ovidian : Non-granular
3. Foliated	Has folated structure.	

1.1.4. Evolution of Metamorphic rocks. Metamorphism is the result of recrystallisation and formation of new structures. Granite may be metamorphised to gneiss, sandstone to quartz, shale to slate, limestone to marble.

Table 1.1.3. Evolution of metamorphism



1.1.5. Classification of Igneous rocks. Igneous rocks are primarily classified according to chemical composition as acid rock, intermediate rock, basic rock, ultra-basic rock. (See Table 1.1.4)

Table 1.1.4. Classification of Igneous rocks (I.S. 1805)

Nature of Geological occurrence	*Chemical Nature*			
	Acid *SiO_2 < 66%*	*Intermediate* *SiO_2 65-55%*	*Basic* *SiO_2 < 55%*	*Ultra-Basic*
Plutonic	Granite	Diorite, Syenite	Gabbro	Peridotite
Hypabyssal	Granite Porphyry Pegmatite	Syenite-porphyry Diorite-porphyry	Dolerite Diabase	lamprophyre
Volcanic	Rhyolite	Andesite, Trachyte	Basalt	Olivine-rich Basalt

1.1.6. Classification of sedimentary rocks. Sedimentary rocks are formed by the chemical or mechanical agency of denundation on pre-existing rocks or earth's crust and deposits from suspension or solution in water or air of the products of secular decay and disintegration. (See Table 1.1.5)

Table 1.1.5. Classification of sedimentary rocks (I.S. 1805)

Division	*Sub-division*	*Group*
Based on the mode of transport of material	*Based on the mode of deposition*	*Based on the grain size or chemical nature*
1. Rocks derived from solids in suspension	Sedimentary deposits (Formed by setting of solids)	Rudaceous rocks Carbonate deposits silt rocks Agrillaceous rocks
2. Rocks derived from solids in solution	(*a*) Chemical deposits (Formed by chemical precipitation)	Silicious deposits Carbonate deposits Ferruginous deposits Salts
	(*b*) Organic deposits (Formed through agency of organisms)	Calcareous deposits Phosphatic deposits Ferruginous deposits Carbonaceous deposits

1.1.7. Rock forming minerals

Name of mineral		Composition	*Sp. gr.*	*Hardness*	*General*
1.	Silica	SiO_2	2.65	7	Known as quartz
2.	Felspar	K_2O, Al_2O, SiO_2 or Na_2O or CaO, Al_2O_3 etc.	2.56	6	Available in white grey or pink colour
3.	Mica	Magnesium silicate and calcium silicate	2 to 2.3	2 to 2.5	White mica is produced from muscovite while black mica is produced from biptite
4.	Hornblende	Mg & Ca Silicate	3	6	Very heavy and durable mineral
5.	Calcite	$CaCO_2$	2.5 to 2.8	3	Pure calcite is white or colourless
6.	Dolomite	$CaMg\ (CO_2)$	2.8	4	Similar to calcite. The mineral is found in a number of rock.

1.1.8. Hardness of rock. Hardness of rock is determined by Mohr's scale. Standard hardnesses used in the scale are given in Table 1.1.6.

Table 1.1.6. Hardness scale

Name of the rock	*Standard hardness as per Mohr's scale*
Talc	1
Gypsum	2
Calcite	3
Flourspar	4
Apatite	5
Felspar	6
Quartz	7
Topaz	8
Corundum	9
Diamond	10

1.1.9. Crushing strength of rocks

Nomenclature		*Crushing strength* t/m^2	*Suitability*
1.	Basalt, trap	13400	Road metal
2.	Granite, gneiss	11600	Building work, seashore work Bridge piers, docks, road-metal.
3.	Slate	11600	Roofing work
4.	Sandstone	5500	Building work in sea shore, railway ballast.
5.	Marble	7200	Ornamental work
6.	Limestone	3300	Railway ballast

1.1.10. Identification of rocks. Stone can be identified readily under microscope by the characteristic grain size and texture.

Table 1.1.7. Identification of rocks

Sl. No.	*Name of the stone*	*Identification and uses*
1.	Granite	ISI classification is *A, B, C, D* having maximum compressive strength of 220, 180, 140, 100 N/mm^2 respectively Class A is suitable for use in piers, dams, bridges and abutments. Class *B* for flooring, class *C* for road kerbs and *D* for domestic buildings.
2.	Gneiss	Metamorphic rock similar to graphite with white or coloured bands. It is not affected by scratch of knife. Uses are similar to granite.
3.	Basalt	A very heavy black stone. Can be used as basalt. It is also not scratched by knife.
4.	Syenite	Does not break easily on being hammered.
5.	Rhyolite	Can be readily scratched by knife. Breaks on being hammered.
6.	Sandstone	Sedimentary rock having green, grey or white colour. Can be readily separated into layers.
7.	Limestone	Extensively used as slab and tile. Colour varies from white to grey (Refer IS : 1128-1974)
8.	Dolerite	Not affected by hammer blows.
9.	Flint	Hardness is the same as of syenite. Little affected by scratches of knife
10.	Marble	Metamorphic lime stone (Refer IS : 1130:-1969) High quality limestones are used as substitute for marble. Used for decorative works.
11.	Slate	Metamorphic clay stone. Used for roofing.
12.	Phylite	Metamorphic rock like slate.
13.	Schist	Metamorphic rock containing quartz and mica.
14.	Laterite	Contains silica and iron oxide. Can be readily broken by hammer.
15.	Shingle	These are waterworn pebbles of any kind of stone, bigger in size than gravel. Used as road metal and for concrete work.

1.1.11. Mineral Resources in India

Mineral	*Availability*
Asbestos	Seraikela (Bihar), Cuddapah (Tamilnadu), Hassan (Karnataka)
Barytes	Jabalpur (MP), J & K, Anantapur (AP), Alwar (Rajasthan)
Bauxite	Lohardaga (Bihar), Belgaun (Karnataka), Salem (Tamilnadu), Katni (MP)
Bentonite	Jammu, Jodhpur, Tinpahar (Bihar)
Beryl	Ajmer-Merwara, Mewar (Rajasthan)
Borax	Leh (Kashmir)
Calcite	Nawnagar, Porbandar (Gujrat)
Chalk	Jabalpur (MP)
Chromite	Singhbhum (Bihar), Kistna (Tamilnadu)
Clay	Hasan (Karnataka) Keonjhar (Orissa)
Ball clay	Mangalore (Karnataka), Hyderabad (AP), Jodhpur (Rajasthan)
Cement clay	Tinnevelly (Tamilnadu)

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Mineral	*Availability*
China clay	Bamkura (WB), Monghyr (Bihar), Baroda (Gujrat), Bangalore (Karnataka)
Fire clay	Burdwan (WB), Manbhum (Bihar), Sambalpur (Orissa)
Pottery clay	Jabalpur (MP), Chingleput (Tamilnadu).
Refractory clay	Bangalore (Karnataka), South Arcot (Tamilnadu).
Coal	J & K hills, Nagaland, Makum (Assam), Raniganj, Darjeeling (WB), Jharia, Bokaro, Karanpura (Bihar) Chindwara (MP), Warangal (AP),
Copper ore	Singhbhum (Bihar), Panchamahal (Gujrat), Balghat (MP), Alwar (Rajasthan)
Corundum	Hassan (Karnataka), Rewa (Maharashtra)
Dolomite	Jalpaiguri (WB), Monghyr (Bihar), Jabalpur (MP), Jodhpur (Rajasthan), Sundargarh (Orissa).
Feldspar	Santhal Pargana (Bihar), Panchmahal (Gujrat). Ajmer-Merwar (Rajasthan), Sambhalpur (Orissa).
Graphite	Betul (MP), Vishkapattan (AP), Korapur (Orissa)
Gypsum	Bikaner, Jaisalmer, Jodhpur (Rajasthan) Kashmir, Sourastra
Iron ore	Singhbhum (Bihar) Mayurganj (Orissa), Kadur (Karnataka), Bellary (Tamilnadu), Bokaro (WB), Saleem.
Laterite	Belgaon (Karnataka), Dharwar (Karnataka), Orissa Kerala, Tamilnadu.
Limestone	J & K hills, Ranchi, Sahabad, Bilaspur, Jabalpur, Gwalior, Bellary, Gantur, Sundargarh, Patiala Bundi, Jodhpur, Rewa, Porbandar
Shell limestone	Mangalore.
Marl	Sourastra
Manganese	Singhbhum, Panchmahals, Balghat, Sundergarh, Banswara.
Mica	Hazaribagh, Monghyr, Madurai, Nellore, Ajmer-Merwar
Petroleum	Digboi, Gujrat, Sundarban
Quartz	Dumka (Bihar), Jabalpur, Bangalore, Ajmer-Merwara.
Sand	Jabalpur, Banda, Sourashtra, Katni, Morga (WB)
Silica sand	Jabalpur, Mayurbhanj, Jaipur.
Silica rock	Singhbhum.
STONE QUARTILES :	
Granite, Gneiss	Banda, Cochin
Marble	Jabalpur, Jaisalmer, Makarana (Jodhpur)
Slate	Gurgoan, Jaisalmer, Kurnool.
Limestone (Flooring)	Raipur, Sahabad, Cuddapah, Cuttack.
Sandstone	Jodhpur, Mirzapur
Gravel, Moorum	Simultola, Kaira, Thana, Kurnool, Cuttack, Nilgiri, Banda.
Gravel, Shingle	Dhalbhumnagar
Trap (Ballast)	Pakur
Trap (Road metal)	Baroda, Monghyr, Andheri.
Pebbles (Kankar)	Travancore, Tinnevalley, Jaisalmer, Jodhpur.

1.1.12. Classification, Uses and Properties of Stones.

Table 1.1.8. Classification and Uses of Building Stones

Type	*Classification*	*Characteristics*	*Suitability*
Granite	Igneous	1. Sp. gr. 2.63-2.75 2. Water absorption < 1% 3. Compressive strength 77 – 130 N/mm^2 4. Difficult to work with 5. Fine grained variety takes high polish 6. Colour depends upon colour of felspar 7. Excess of felspar causes early decay	Most suitable for important engineering works such as bridge abutments, piers, dams, sea walls, light houses, etc.
Trap and Basalt (green stone, white stone, blue basalt)	Igneous	1. Sp. gr. 2.6-3 2. Compressive strength 150–190 N/mm^2 3. Not easly to work with	Suitable for road metal and concrete aggregate. Its red and yellow varieties are used for decorative features in structures.
Serpentine	Igneous	1. Compact, but soft and easy to work with 2. Affected by smoke and fumes	Suitable for ornamental works for high quality building works.
Syenite	Igneous	Similar to granite	Most suitable for road metal.
Sandstone	Sedimentary	1. Sp. gr. 2.65-2.95 2. Compressive strength 65 N/mm^2 3. Weathers well when free from lime and iron	In the form of flag stone for paving, tile stone for roofing, natural stone for ornamental work and grit for heavy engineering works.
Limestone	Sedimentary	1. Sp. gr. 2.0-2.75 2. Compressive strength 55 N/mm^2 3. Affected by frost and atmosphere 4. Tough but soft enough to be cut	Suitable for flooring, paving and roofing and in the manufacture of lime and cement.
Kankar (impure limestone)	Sedimentary	1. Irregular in shape 2. Porous structure 3. Nodular kankar variety is hard and though	Black kankar is hard and is used as building material. Nodular kankar is used to produce hydraulic lime.
Mooram (Decomposed Laterite)	Sedimentary	1. Strong and hard	Most suitbale for surfacing fancy paths in gardens and bunglows.
Gneiss (Stratified granite)	Metamorphic	1. Strong and durable	Suitable for rough stone masonry works, stone pitching and road metal.
Laterite (Sandy clay stone)	Metamorphic	1. Porous or cellular structure 2. Soft and easy to work with 3. Affected by the action of water	Suitable for rough stone masnory work. The nodular variety yields road metal.
Marble	Metamorphic	1. Specific gravity 2.65 2. Crushing strength 70 N/mm^2 3. Hard and compact 4. Takes fine polish 5. Sufficiently hard and compact	Most suitable for monuments, stattutes flooring, decorative and ornamental works.

Contd...

Type	*Classification*	*Characteristics*	*Suitability*
Slate	Metamorphic	1. Specific gravity 2.89 2. Compressive strength 77 – 210 N/mm^2 3. Hard and tough 4. Splits into thin slabs	Most suitable for roof coverings floorings, damp proofing and partitions.

Table 1.1.9 Stones for the Specific Uses

Type of Work	*Recommended Stone Type*	*Reasons*
Heavy engineering works such as bridge, piers and abutments, break waters, docks and light houses, retaining walls	Granite (of its three varieties, viz. biotite-granite, homblende-granite and tourmaline-granite; biotite-granite is most widely used)	It is heavy strong, durable and is capable of resisting large thrust
Building facing the sea	Granite, fine grained sandstone	These are not affected by the weathering action of sand particles blown by wind
Buildings in industrial areas	Granite, compact sandstone	These are acid fumes and smoke proof
Arches	Fine grained sandstone	Strong, durable
Building face work, carved works, ornamental works and stattutes	(a) Marble, close grained sand stone (*b*) Fine grained granite	These are light weight, soft and easy to work and have pleasing colour and appearance It takes high polish
Fire resisting structure	Compact sandstone	Fireproof
Road metal and agregate for concrete	Granite, Basalt, Quartizite	Hard, tough and has high abrasion resistance
Railway ballast	Coarse grained sandstone, quartizite	These are hard and compact
Electrical switch board	Slate, marble	Poor conductor of electricity

Properties of stones. Stone is a very heavy and compact material, though the texture may be coarse or fine, irregular or regular. It is used for foundations, bridges, dams, docks, roads, flagging, flooring, coping, lintels and aggregate for concrete. (See Table 1.1.10.)

Table 1.1.10. Properties of stones

Stone	*Volume Weight t/m^3*	*Compression N/mm^2*	*Water absorption % in 24 hrs*	*Life (in years)*
Limestone	2.2	90	0.2-5	20-40
Sandstone	2	135	0.41-5.5	25-100
Granite	2.6	200	0.06-.15	50-200

Contd...

Stone	*Volume Weight t/m³*	*Compression N/mm²*	*Water absorption % in 24 hrs*	*Life (in years)*
Gneiss	2.7	130	0.05	50-200
Marble	2.7	100	0.05-.26	50-100
Slate	2.8	70	0.02-.2	75-100
Basalt	2.9	225	0.02	75-200
Trap	3.0	160	0.02	75-200
Laterite	2.3	> 30	< 12	75-100

1. Compressive strength of stones is given by :

$$= \frac{\text{Maximum load in N at failure}}{\text{Area of bearing face of specimen in mm}^2}$$

2. Transverse strength (R) of stones is given by : $\frac{3WL}{20bd^2}$. N/mm²

where, W = Central breaking load in N

L = length of span in mm ; b = average width of test piece at the mid section, in mm and

d = average depth at the mid section of test piece, in mm

3. Shear Strength (S) of stones is given by : $S = \frac{W_t - W_i}{\pi DT}$,

where S = Shear strength in N/mm²

w_t = Total maximum load in N indicated by testing machine ; W_i = Initial load in kg required to bring plunger in contact with the surface of the specimen; D = Diameter of the plunger in mm, and T = Thickness of the test piece in mm.

4. True Specific gravity of stones is given by :

$$= \frac{(W_2 - W_1)}{(W_4 - W_2) - (W_3 - W_2)}$$

where, W_1 = weight of empty specific gravity bottle with stopper ; W_2 = weight of bottle with stopper and powder ; w_3 = weight of bottle with stopper, powder and distilled water and w_4 = weight of bottle with stopper and distilled water.

1.1.13. Selection of stones. Selection of stone for specific purpose is based on : durability, workability, appearance, texture, availability at economic price.

Stonework may be divided into three general classes. (See Table 1.1.11)

1. Rubble work, 2. Ashlar work, 3. Trimmings.

Table 1.1.11. Selection of stones

Work	*Stone and workability*
FOUNDATION :	
bridges	Granite, gneiss
breakwater, dock (marine)	Granite, basalt
highway	Basalt, granite, quartzite
pathway	Gravel, shingle, kankar, moorum.

Contd...

Work	*Stone and workability*
SUPER STRUCTURE	
rubble work	Granite, coarse grained sandstone
ashlar work	Coarse grained sandstone fine tooled on all joints, faces and beds
domes, kerb, coping, sills.	Chisel dressed and fine tooled on faces except back
roofing	Slate sawn parallel to natural bed
flooring	Sandstone, limestone sawn parallel to natural bed
veneering	Marble, granite, closegrained sandstone
devorative and monolithic work	Marble
electric switch board	Slate
aggregate for concrete	Gravel

1.1.14. Preservation of stones

	Name of the preservative	*Characteristics*
1.	Raw linseed oil	Does not change the colour of the stone
2.	Boiled linseed oil	Blackens the surface. The effect lasts longer than raw oil.
3.	Coal tar and bitumen	Imparts black colour. Otherwise good preservative.
4.	Solution of soda or potash.	The material makes a hard film on the surface of the stone.
5.	Mixture of wax in benezene or silicon	Does not react chemically with stone but penetrates inside the pores.
6.	Barium hydrate (BaOH)	Suitable to prevent decay of stone due to chemical sulphate.
7.	Calcium hydroxide	Reacts with CO_2 in the atmosphere and becomes calcium carbonate which makes the stone strong.

Table 1.1.12 (*a*). Compressive strength of different building stones

Name of building stone	*Compressive Strength N/mm²*
Igneous Origin :	
Granite	75 to 135
Synite	90 to 150
Diorite	90 to 150
Basalt	150 to 190
Sedimentary origin :	
Sandstone	65.00
Laterite	1.8 to 3.2
Shale	0.2 to 0.6
Metamorphic origin :	
Gneiss	220 to 375
Slate	75 to 210
Crystalline Limestone (marble)	60 to 150

Table 1.1.12 (b). Average Weight of Some Stones in kN/m³

Granite	26.4
Lime stone	26.4
Sand stone	22.4
Slate	28.8
Basalt	28.5 to 29.60
Marble	27.20

1.1.15. Artificial stones

	Name of stone	*Composition and properties*
1.	Concrete blocks	Made from cement and aggregates
2.	Victoria stone	Made from granite pieces
3.	Ransom stone	Made by mixing sand with soda silicate
4.	Terrazo	Made by mixing marble chips with cement for decorative flooring and walling

1.1.16. Dimensions of natural building stone.

IS: 1127-1957 lays down dimensions of natural building stones. (See Table 1.1.13)

Table 1.1.13. Dimensions of natural building stone

Sl. No.	*Purpose*	*Dimension in mm.*			*Remarks*
		Length	*Breadth*	*Height*	
1.	Ashlar masonry block-in-course	140 190, 240 290, 390, 440, 490 590	140 140, 190 14, 19, 24, 140, 190, 240, 290	140 140, 190 140, 190, 240 140, 190, 240, 290	
2.	RR, uncoursed rubble, rough stone	Not less than 15°		Not less than 10°	
3.	Sills and lintels	890, 1190 1490 1790	90, 190, 290 390, 490, 590 190, 290, 390 490, 590	90, 140, 190 140, 190, 240 290	
4.	Roofing slate	295, 395 395, 495 395, 595, 745 1145	195 295, 395 495, 595 395, 486 595, 790	30, 40, 50 50, 60, 70 70, 80, 90 95 95, 100, 110 120	
5.	Arches, domes, circular mouldings	Dimensions are governed by the curve			
6.	Copings	295, 495 795	200, 300 400, 500, 600	95, 150 200	
7.	Kerb stone	295, 495, 795	100, 200, 300	300, 400 500	
8.	Flooring slabs	195, 295 395, 495 595, 795 895	195, 295 395, 495 595, 795 895	50, 70, 90 70, 90, 125 70, 90, 125 150	

1.1.17. Quarrying and dressing of stones. Quarry is derived from French'care meaning square. The rock may be excavated or exploded for purpose of quarrying.

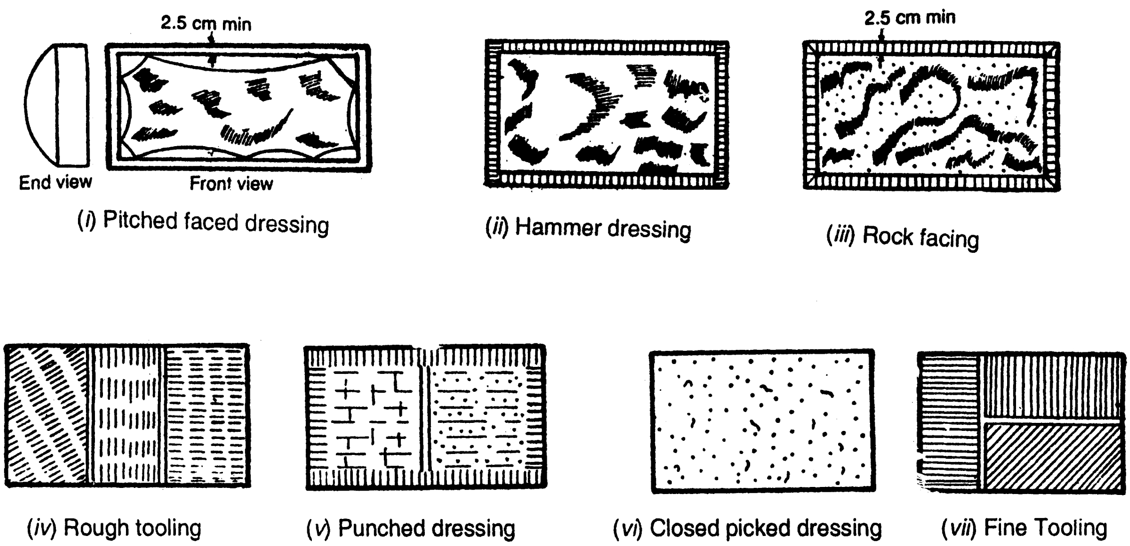


Fig. 1.1.1 Dressing of Stones.

Excavation involves the following:

(*i*) Primary cut by wire saw or drilling.

(*ii*) Driving wedges for separation of block from the parent rock.

(*iii*) Lifting or digging out by crane.

(*iv*) Blasting using explosives, it involves the following:

1. Drilling a hole with jumper or pneumatic drill, about 2.5 cm in dia and 2 cm long.
2. Inserting one end of a length of fuse in the hole and fill the hole with explosive. Tamping the hole with clay.
3. Blasting the explosive.
4. Lifting by crane crow bar.

The various explosives used for blasting are:

(*i*) *Blasting powder.* It contains 75% potassium nitrate along with charcoal and sulphur.

(*ii*) *Dynamite or Nitroglycerene.* The explosive consists of nitroglycerene mixed with special type of earth.

(*iii*) *Gun cotton.* It is a mixture of HNO_3 and H_2SO_4 on clean cotton waste. It is available in blocks or bricks.

(*iv*) *Cordite.* It is a mixture of nitroglycerine and gun cotton with gelatine.

(*v*) *Gelatine dynamite.* The explosive consists of potassium-nitrate and wood pulp and explosive gelatine.

(*vi*) *Gelignite.* The explosive contains 65% blasting gelatine and 35% absorbing powder.

(*vii*) *Rock-a-Rock.* The explosive is formed by mixing Potassium chlorate (79%) and Nitro Benzol (21%)

Table 1.1.14 Composition and Characteristic of Explosives

Sl. No.	*Types of explosive*	*Composition*	*Characteristics*	*Suitability*
1.	Blasting powder or gun powder	Saltpetre 65% Sulphur 15% Charcoal 20%	1. It has great lifting power but a little shattering effect. 2. It is easily ignited. 3. It is cheap.	1. In quarrying large blocks.
2.	Blasting cotton or gun cotton	It is cotton saturated with nitric acid.	1. When dry, it is highly inflammable. 2. It can detonate by a shock or even by sun light. 3. It has good shattering effect but no lifting power.	1. Used where demolitions are required.
3.	Dynamite	It is 75 per cent nitroglycerine absorbed in 25 per cent sandy earth or solids.	1. It is sensitive to friction and shock. 2. It is the most shattering and powerful explosive. 3. It is unsuitable in cold climates. 4. Specific gravity 1.4.	1. In small bore holes. 2. In small quarries. 3. In damp situations, small bore holes.
4.	Cordite	It is gelatenized combination of nitroglycerine and nitrocellulose.	1. It is smokeless explosive. and produces powerful gases. 2. It is similar to dynamite.	1. Under water.
5.	Gelatine dynamite	It is 80 per cent of blasting gelatine with nitrate of potash and wood pulp	1. It is tough, rubber textured explosive. 2. It is the most powerful nitroglycerine explosive. 3. Very high water resistance. 4. High plasticity. 5. Specific gravity 1.5.	1. In deep wells. 2. Underground works. 3. In wet conditions
6.	Gelignite	It is 65 per cent of blasting gelatine and 35 per cent of absorbing powder	1. It is a powerful explosive. 2. It can be handled more conveniently than dynamite.	1. Under water.
7.	Lithofracteor	Nitroglycerine 33% Nitrate of baryata 16% Sulphur 26% Kieselguhr 22% Charcoal 3%	1. Similar to dynamite but has less power.	1. In tunnels.
8.	Rock-a-Rock	Potassium chlorate 79% Nitrobenzol 21%	1. High water resistance.	1. Most effective under water.

1.2. BRICKS

Raw materials. Soil for making bricks should conform to the requirements given in IS: 2117-1963. These requirements and physical properties of brick earth are given in Table 1.2.1.

Table 1.2.1. Requirement and properties of brick earth

Constituent of brick earth	*% by weight*
Clay	20 to 30
Silt	20 to 35
Sand	35 to 40
Property of brick earth	
Lime and magnesia	Below 1.
Liquid limit	27 to 38
Plasticity index	7 to 16
Volumetric change	25 to 30%

1.2.1. Classification of bricks. Following table gives classification on the basis of qualitites :

Type of Bricks	*Crushing Strength N/mm²*	*Water absorption %*
First Class Bricks	7.0-10.5	Not more than 20%
Second Class Bricks	5.0-7.0	Not more than 20%
Third Class Bricks	3.5-5.0	Not more than 25%

Table 1.2.1 (*a*) gives classification of bricks on bricks on basis of compressive strength and other properties.

$$\text{Compressive strength of bricks in N/mm}^2 = \frac{\text{Maximum load at failure in N}}{\text{Average area of the bed face in mm}^2}$$

1.2.2. Manufacture of bricks. IS: 2117-1963 lays down code of practice for manufacture of hand made common burnt clay building bricks. Important features of this code area;

1. *Selection of site*: Availability of suitable earth.
2. *Weathering*: Exposure of dug up earth for one month.
3. *Tempering*: Mixing required quantity of water for right consistency.
4. *Moulding*: May be ground moulded or table moulded.
5. *Drying*: Moulded bricks are allowed to dry till they are bone dry.
6. Setting bricks in the kiln.
7. Starting kiln fire.
8. Unloading the bricks.

About 20t of coal is required to burn one lac of bricks in a Bull's kiln. This produces about 0.6 lacs of first class bricks. Table 1.2.2 gives dimensions of common elliptical kiln.

Table 1.2.1 (*a*)

Name of Class	*Compressive Strength (Minimum) N/mm²*	*Degree of absorption of cold water in 24 hrs. (Minimum)*	*Effore-sence*	*Shape and other Properties*	*Uses*
H_1	44	5	Zero	Smooth, ractangular, edges are sharp, Metallic ringing sound produces when two bricks are strucks	For heavy duty works.
H_{11}	44	5	Zero	Slight deformation in shape edges may be curved, Metallic sound produces when two bricks struck.	
F_1	17.5	12	Very little	Smooth, ractangular, sharp edges, metallic ringing sound produces when two bricks struck.	For facing brick work reinforced brick work and masonry work
F_{11}	17.5	12	Little	Slight deformation in shape, Edges may be curved to a slight extent, metallic sound produces when two bricks struck.	
I	7.0	20	Very Little	Smooth, ractangular, sharp edge, metallic ringing sound produces when two bricks struck.	For ordinary construction work.
II	7.0	20	Little	Slight deformation in shape, Edges may be curved to slight extent.	
L_1	3.5	25	Very Little	Edges sharp, rectangular.	For temporary work
L_{11}	3.5	25	Little	Slight deformation in shape, edges may be curved.	

Table 1.2.2. Size of common elliptical kiln

Description of part	*Dimension (m)*	*Remarks*
Length	61	Gap between
Width	8	Trenches 8 m
Depth	To accommodate 18 layers of bricks.	

1.2.3. Average crushing strength of bricks

Class designation	Average crushing strength	
	Not less than N/mm^2	Strength less than N/mm^2
350	35	40
300	30	35
250	25	30
200	20	25
175	17.5	20
150	15	17.5
125	12.5	15
100	10	12.5
75	7.5	10
50	5	7.5
35	3.5	5.0

1.2.4. Standard size of bricks

Length (mm)	Width (mm)	Height (mm)
(a) Common building bricks.		
190	90	90
190	90	40
(b) Heavy duty bricks, known as engineering bricks, are required in heavy engineering works such as bridge structures.		
190	90	40
190	90	90

1.2.5. Refractory bricks. Common refractory bricks are made from the following :

(*i*) Bauxite, (*ii*) Carbon, (*iii*) Chromite, (*iv*) Diaspor, (*v*) Fire clay, (*vi*) Graphite, (*vii*) Olivine, (*viii*) Pyrofulite.

Refractory bricks are further classified as ; (See Table 1.2.3)

Table 1.2.3. Classification of refractory bricks.

(I) Acid refractory :	25 to 50% Alumina, 50-70% silica
(II) Basic refractory :	Alumina, Magnesite, Dolorite
(III) Natural refractory :	Forsterite : 57% Mg, 43% Silica. Chromite : 30-35% Chromic oxide 12-15% Iron oxide 14-20% magnesis, 13-20% Alumina 3-6% Silica : 1% lime. Silimantite : 63% alumina, 37% Silica.

Basic refractory is used as lining in cement kiln and glass melting tanks.

Magnesite brick is used in copper reverberatory furnaces and steel open hearth furnaces.

Dolomite brick is used as lining in basic furnaces.

Natural refractory bricks is used as lining in copper reverberatory furnaces.

1.2.6. Building Tiles. Tiles are used for flooring, walling, roofing and drains. They are known according to their patent such as Manglore, Allahabad, Raniganj, Sialkot etc. They are also known according to their shape and purpose such as ;

Pan, flat, pot, terracing, hollow clay, PVC, Asbestos, floor, polystyrene, wall, ridge, ceiling etc.

Tiles are normally burnt in circular kiln, clay for tiles is milled in a pug mill and then mixed with water in a vat. The mixture is kept for some time for precipitation of coarse particles to obtain an even texture. The clay water is then run off from the top, into another vat, where water is allowed to dry, leaving plastic clay at the bottom. Requisite colouring matter may be mixed with the clay.

Usual sizes available :

Floor Tiles	*Roof Tiles*
$15 \times 15 \times 1.8$ cm^3	32×21 cm^2
$20 \times 20 \times 2$ cm^3	34×21.5 cm^2
$22.5 \times 22.5 \times 2.2$ cm^3	35×22 cm^2

Table 1.2.4 gives some of the commonly used tiles, their salient features and relevant ISI codes where applicable.

Table 1.2.4. Types of Tiles

Type of tile	*Salient features*
1. Hollow clay	Length 340 to 749 mm, width 200-350 mm Height 80-100 mm. Thickness of any shell shall not be less than 11 mm. Used for floor and roof.
2. Hollow structural.	Length 290-390 mm, width 90-190 mm, Height 125-200 mm. Used as filler material and as structural tiles
3. Burnt clay terracing tile (Machine made)	Length 150-250 mm, width 100-200 mm thickness 15, 20, 25. Used for flat roofing finishing over lime or cement concrete.
4. Burnt clay terracing tile (Hand made)	Compressive strength should not be less than 7.5 N/mm^2.
5. Clay ridge and ceiling	(*a*) Ridge tiles : Length 375, 400 and 436 mm Width 265 mm, Height 100 mm. Thickness not less than 10 mm.
6. Structural (Hollow clay)	Length 300, 450, 600 mm. Width 240 or 190 mm, Height 70 or 90 mm. Used for structural floor and roof.
7. Polystyrene wall tiles.	Standard sizes are, 148. 5×148. 5 mm or 99×99 mm. Used for partitions and ceilings in residential buildings
8. PVC (Vinyl) Asbestos floor tiles.	200 mm square in thickness of 1.5, 2, 2.5 and 3 mm. Present non-absorbent and sanitary surface. Used for flooring in residential buildings.
9. Ceramic inglazed acid resistant.	98.5×98.5., 148.5×148.5, 198.5×198.5 Thickness 15, 20, 25, 30 and 35 mm
10. Glazed earthenware	Used in kitchen, bathrooms, WCs

1.2.7. Earthenware terracotta, and stoneware. Terracotta is used as artificial decorative stone in localities where natural building stone is not available. It is comparatively cheaper than stone. Refractory clay is used in the manufacture of terracotta. The, mould is made of plaster of Paris and interior dimensions of the mould are 5 to 12% larger in all dimensions than the external dimensions of terracotta.

An improved form of terracotta is known as Faience. The latter is burnt twice in the kiln. After the first burning it is cooled, unloaded, glazed, reloaded and fired. The prepared surface is not affected by atmospheric impurities and hence suitable for use in industrial areas.

Another important modification is stoneware which resists chemical attack. The clay for stoneware contains 75% of silica. While stoneware is in the kiln, salt glazing is carried out.

Stoneware is used in sewer pipes, basins and acid containers.

1.2.8. Procelain. Procelain is made from kaolin to which boneash, felspar, etc are added. It is primarily used in electrical industry.

In the maunfacture of spark plugs, special procelain known as Ziron procelain, in the manufacture of which 60% Ziron, 15 to 30% clay, 15%-30% Alkaline Zircanium is used.

1.2.9. Burnt clay hollow blocks. These blocks are light in weight and are used in internal walls and partitions. IS: 3952-1967 covers the dimensions, quality and strength requirement of these blocks.

Table 1.2.5. Standard sizes of burnt clay hollow bricks

Length (mm)	*Breadth (mm)*	*Height (mm)*
190	190	90
290	90	90
290	140	90

1.3. LIME, LIME MORTAR AND LIME CONCRETE

1.3.1. Sources of lime. Lime is chiefly prepared by burning lime stone depending upon the % of calcium carbonate it is classified as A, B and C for masonry work, mortar and white washing respectively.

Table 1.3.1. Classification of lime

Class of lime	*Characteristics*
A	*Highly hydraulic.* Used extensively in building work.
B	*Partially hydraulic.* Used in making mortar
C	*Fat.* Used for whitewashing and finishing coat of plastering.

1.3.2. Manufacture of lime. The manufacture of building lime, which has been a small scale industry has not undergone any marked change.

IS: 1849-1967 covers the principles, design and installation of vertical lime kiln of mixed feed type.

Table 1.3.2. Classification and composition of lime

Name of constituent	*Class A %*	*Class B*		*Class C*	
		Unslaked %	*Slaked %*	*Unslaked %*	*Slaked %*
1. Calcium and Mg oxide					
(*a*) Minimum	60	70	70	85	85
(*b*) Maximum	70	–	–	–	–
2. Silica, Alumina and ferric oxide Minimum	25	15	15	–	–
3. Insoluble portion of HCL	2	3	2	–	–
4. Loss on ignition (Maximum)					
(*a*) Lumps of lime	–	5	5	–	–
(*b*) Ground lime	–	20	20	–	–
5. CO_2 Minimum	5	5	5	5	5

1.3.3. Quick Lime. It is the product obtained after calcination of pure lime. It is obtained in lumps from the lime kiln.

1.3.4. Slaking of lime. The process of mixing water in quick lime is known as slaking of lime. IS: 1635-1975 covers field slaking of lime and preparation of putty.

Both slaked and unslaked lime are used in building work. When the paste of water is prepared after mixing with water, it attains hardness and the phenomenon is known as setting of lime.

1.3.5. Pozzolanic materials. The burnt clay pozzolana (a reactive material) is made by calcination of clay at suitable temperature and grinding the resulting product to desired fineness. This material is different from common surkhi prepared by powdering brick bats.

Table 1.3.3. Physical properties of burnt clay pozzolana

	Physical property	*Requirement*
1.	*Fineness.*	
	(*a*) Specific surface	32 mm^2/gm (minimum)
	(*b*) Residue by weight on 45 microns IS sieve after wet sieving	12% (Minimum)
2.	*Reactivity.*	
	(*a*) Lime reactivity	5 N/mm^2
	(*b*) Compressive strength	
	(I) At the end of 28 day	Not less than 80% of corresponding cement mortar
	(II) At the end of 90 day	28 day strength of cc mortar

Table 1.3.4. Physical properties of lime pozzolana mixture

Physical property		Requirement		
		Type PL 40	*Type PL 20*	*Type PL 7*
1.	Free moisture content (% Max)	5	5	5
2.	Loss on ignition (% Max)	20	20	20
3.	Fineness. % retained on IS sieve 150 micron	10	10	–
4.	Setting time (Hrs)			
	(*a*) Initial	2	2	2
	(*b*) Final	24	24	24
5.	Compressive strength (1 Part lime-pozzolana mix to 3 parts of sand by volume)			
	(*a*) 7 days (minimum N/mm^2)	2	1	0.3
	(*b*) 28 days (minimum N/mm^2)	2	0.7	
	6. Water retention (%)	70	70	70
	PL 40 : For masonry mortar and plasters of grades 3.0 to 5.0 N/mm^2 PL 20 : For masonry mortar and plasters of grades 1.5 to 3 N/mm^2 PL 7 : For masonry mortar and plasters of grades 0.7 to 1.5 N/mm^2			

Table 1.3.5 gives physical properties of lime-pozzolana concrete

Physical property		*Requirement*
1.	Drying shrinkage	0.012 to 0.04%
2.	Bond strength between lime-pozzolana concrete.	1.5 to 2 N/mm^2 when the time interval between laying two layers in roads and other pavement works is not more than one hour.

1.3.6. Surkhi. It is prepared by powdering brick bats. It is used as substitute for sand for concrete and mortar. It has almost the same function as that of sand but it imparts some strength and hydraulicity.

When clay is specially burnt for making surkhi, an addition of 10 to 20% of quick lime will improve its quality.

Surkhi powder should pass through BS No. 8 sieve.

Surkhi for plaster may be made from slightly under burnt brick and ground very fine. This improves the hydraulicity of fat lime.

1.3.7. Lime mortar. IS: 1628-1971 covers preparation of lime mortar for use in buildings. Depending upon the type of work, mortar may consist of one of the following:

(*i*) Lime and sand (*ii*) Lime surkhi and sand (*iii*) Lime and surkhi (*iv*) Lime and burnt clay (*v*) Cement lime and sand (*vi*) Lime pozzolana.

Table 1.3.6. (*a*) Proportions of lime mortar

Description of mortar	*Lime*	*Ce-ment*	*Lime pozzolana mix*	*Pozzolana*	*Sand*	*Hardening time days*
1. Lime cement	1 C	1	–	–	6	14
2. Lime cement	2 B	1	–	–	9	14
3. Lime pozzolana mix	–	–	1	–	1.5	14
4. Lime cement	3 B or 3 C	1	–	–	12	14
5. Hydraulic lime	1 A	–	–	–	2	14
6. Lime	1 B	–	–	–	3	28

Table 1.3.6. (*b*) Strength development of lime mortar

Age of mortar in days	3	7	14	18	60	90
Relative strength of as % of 28 day strength	25	50	75	100	120	130

1.3.8. Lime plaster. Lime plaster serves the following purposes :

(*i*) Smoothens the surface of the masonry.
(*ii*) Protects masonry surface from weathering.
(*iii*) Covers unevenness of masonry and hides defective workmanship.

Table 1.3.7. Types of lime plaster

Type of plaster	*Composition*
1. Lime sand	Lime : sand 1:2.
2. Lime surkhi	Lime : Surkhi 1:2
3. Lime Surkhi Sand	Lime : Surkhi : Sand 1:1:1
4. Lime Cement Sand	Lime : Cement : Sand 1:1:1
5. Kankar Lime	Kankar lime : white lime : Surkhi 1:1:1
6. Lime Gypsum	Calcination of lime yields plaster of Paris. It shrinks before setting and is therefore useful in filling holes and cracks.
7. Mughal	Lime : Sand : Surkhi 4:3:1. Some molasses, glue and gallnut are also added. Used for roofing and is applied in two coats of 12.5 mm each.
8. Stucco	Ist coat 12 mm thick lime plaster. 2nd coat 9 mm thick limeplaster. Final coat consists of good quality lime mixed with well ground marble or quartz 4 mm thick.
9. Lime punning.	The appearance of plaster improves by providing 3 mm thick layer of mortar made of 1 part shell lime mixed with 3 parts of slaked lime.
10. Putty	Prepared from slaked lime dried to consistency of cream.

1.3.9. Gypsum and its products. Gypsum is found in the form of rock in nature. It is formed by combination of calcium sulphate with water. Table 1.3.8 gives its various products.

Table 1.3.8. Gypsum and its products

Product	*Characteristics*
Propritory	Obtained by double burning of hard burnt plaster.
Plaster.	Used for corners and angles.
Gypsum anhydride	Obtained by draining out water of crystallisation from gypsum rock. Alum or sulphate of potash are added to improve setting.
Plaster board.	
(I) Lath board	Facing paper is rough
(II) Wall board	Facing paper is of self finished type
Pyrocell	Inflated paste hardens in light. Cellular fire resistant mass having insulation and accoustic properties.

1.3.10. Lime concrete. In situations where quick setting and high strength is not required it is an economical for cement concrete.

In addition to lime concrete the following concretes have also been standardised:

(*i*) Broken brick coarse aggregate concrete. (IS: 3068-1965)
(*ii*) Lime pozzolana concrete. For building roads. (IS: 5817-1970)
(*iii*) Cinder aggregate for use in limeconcrete (IS: 2686-1914)

1.3.11. Lime cement cinder solid blocks. These blocks are extensively used in residential buildings for load bearing filler walls and partitions. IS: 3115-1965 covers requirements for lime cement cinder blocks.

Table 1.3.9. Standard dimensions of cement-cinder solid blocks

Size designation	*Nominal size in mm Actual size in mm*					
	L	B	H	L	B	H
A	400	300	200	390	300	190
B	400	200	200	390	200	190
C	400	100	200	390	100	190

The concrete mix consists of the following :

(*i*) 1.3 parts by volume of lime
(*ii*) 1 part by volume of cement,
(*iii*) 18 parts by volume of cinder.

Compressive strength of these blocks shall conform to the following :

(*i*) Not less than 2.8 N/mm^2 for individual blocks and
(*ii*) Not less than 3.5 N/mm^2 for average of 12 blocks.

1.3.12. Lime sand bricks. These are grey bricks made from dolomite lime or high calcium lime mixed with clean washed sand.

1.3.13. Chemical requirements of building lines is given as below :

Sl. No.	*Type of Test*	*Class A*	*Class B*		*Class C*		*ClassD*		*Class E*
		Hydrated	*Quick*	*Hydrated*	*Quick*	*Hydrated*	*Quick*	*Hydrated*	*Hydrated*
1.	Calcium and magnesium oxides percent minimum.	60	70	70	85	85	85	85	25
2.	Mg percent Max.	5	5	5	5	-	—	—	5
	Min.	—	—	—	—	5	5	5	—
3.	Silica, Alumina and ferric oxide percentage Min.	25	15	15	—	—	—	—	—
4.	Unhydrated oxide percent Max.	—	—	—	—	—	8	8	—
5.	Insoluble residue in HCl; Max.	2	3	2	—	—	—	—	—
6.	Insoluble matter in sod. Carbonate solution percent. Max.	5	5	5	5	5	5	5	5
7.	Loss in ignition percent Max.	—	5-7	—	5-7	—	5-7	—	5
8.	CO_2% Max.	5	5	5	5	5	5	5	—
9.	Cementation value Min.	0.6	0.3	0.3	—	—	—	—	—
	Max.	—	0.6	0.6	—	—	—	—	—

(—) indicates no need to test

1.4. CEMENT

1.4.1. Portland Cement. Portland cement is composed of the following material, percentage which ranges in limits shown below :

		Percent
Lime-Calcium oxide (CaO)	-	60 to 65
Silica-silicon oxide ($Si\ O_2$)	-	17 to 25
Alumina-Aluminium oxide ($Al_2\ O_3$)	-	3 to 8
Iron oxide-Ferrous oxide ($Fe_2\ O_3$)	-	0.5 to 6
Magnesia-Magnesium oxide (MgO)	-	0.1 to 4
Soda - Potash ($Na_2\ O + K_2\ O$)	-	0.2 to 1
Sulphur oxide (SO_3)	-	1 to 2.75
Free lime	-	0 to 1

For practical purposes, Portland cement may be considered as composed of four principal compounds namely Lime, Silica, Alumina and Iron oxide.

Table 1.4.1. Constituents of cement

Constituent	%	
Alumina (aluminium oxide)	4-8	To reduce setting time of cement gypsum is added during manufacture.
Silica	20-25	
Calcium oxide	60-65	
Magnesium oxide	1-3	
Ferrous oxide	2-4	
Sulphur oxide	1-2.5	
Soda and potash	1-2.5	

1.4.2. Manufacture of cement. Cement is manufactured by dry process as well by wet process. Dry process involves grinding limestone and clay separately followed by mixing the dry constituents in suitable proportions and making a thin paste by addition of water.

Paste and coal are heated in the kiln and grinded with 3 to 4% of gypsum.

In the wet process 75% of limestone and 25% of clay are powdered in a crusher and mixed with water in the wash mill. The solution is grinded in a wet grinding mill to form a slurry containing 30% of water.

The slurry is tested and stored in storage basin from where it is pumped to the upper portion of rotary kiln.

The rotary kiln (Same for both processes) is an inclined cylinder (1 in 20) 90 to 120 metres in length and 3 to 3.5 m in diameter. By the time the slurry reaches the burning zone it is completely dried. The clinker coming out from the discharge end is cooled. The clinkers are fed into ball mill where 3 to 4% gypsum is added.

1.4.3. Types of cement

Broadly speaking cements produced in India are classified into the following categories :

1. **Portland cement**

(*a*) Ordinary portland cement
(*b*) High strength portland cement
(*c*) Quick setting portland cement
(*d*) Rapid hardening portland cement
(*e*) Extra Rapid Hardening portland cement
(*f*) Ultra Rapid Hardening cement
(*g*) Port land blast furnace slag cement
(*h*) Low heat portland cement
(*i*) Sulphate resisting portland cement
(*j*) White portland cement
(*k*) Coloured portland cement and
(*l*) Flyash cement

2. **Natural cement**

3. **High Alumina cement**

4. **Super Sulphate cement**

5. **Special cement**

(*a*) Masonry cement
(*b*) Expansion cement.
(*c*) Trief cement
(*d*) Oil well cement.
(*e*) Hydrofobic cement
(*f*) Air-entraining portland cement.
(*g*) Water proofing cement
(*h*) Sand cement.
(*i*) Acid resisting cement.

6. **Portland Pozzolana cement**

7. **Magnesium Oxichloride cement.**

Percentage composition and compound content of some important cements is shown in Table 1.4.2 (*a*) and Table 1.4.2 (*b*).

Table 1.4.2 (*a*) Percentage Composition of Portland Cement and Other Cements

	Normal	*Rapid hardening*	*Low heat*	*Sulphate resisting*	*Trief cement*	*High alumina cement*	*Port-land pozzolana*	*Port-land blast furnace slag*
Analysis :								
Lime	63.1	64.5	60.0	64.0	40-50	37.5	—	—
Silica	20.6	20.7	22.5	24.4	25-30	3.8	—	—
Alumina	6.3	5.2	5.2	3.7	10-20	43.5	—	—
Iron oxide	3.6	2.9	4.6	3.0	—	13.1	—	—
Magnesium oxide	4	6.0	6.0	—	—	0.3	6	8
SO_3	2.75	2.75	2.75	—	—	0.4	2.75	3
Insoluble residue	1.5	1.5	1.5	—	—	1.2	—	—

Table 1.4.2 (*b*) Percentage of Compound Content of Portland and Other Cements

	Ordinary	Rapid hardening	*Low heat*	*Sulphate resisting*	White portland
Compounds :					
C_3S	40	50	25	40	51
C_2S	30	21	45	40	26
C_3A	11	9	6	5	11
Iron compound	11	9	14	9	1%
SO_3	—	—	—	—	2.6%

Specific gravity of cement can be computed by $= \dfrac{\text{Weight of cement}}{\text{Displaced volume of liquid}}$

Table 1.4.3 Characteristics of Cement

	Type of cement	*Characteristics*
1.	Ordinary portland	Extensively used in building industry
2.	Masonry cement	Obtained by grinding portland cement clinkers and gypsum with limestone. IS: 346-1967 lays down requirements for masonry cement used for general purpose mortar
3.	Rapid hardening	It hardens and acquires strength early
4.	Quick setting	Initial set starts in 5 minutes and sets completely in 30 minutes. Small % of aluminium sulphate is added during grinding
5.	High Alumina	It acquires the same strength in one day which ordinary acquires in 3 days
6.	Low heat	Useful in mass concrete work
7.	White cement	China clay and white clay are used. It is used as decorative feature
8.	Coloured	The coloured effect is due to addition of pigments
9.	Air entraining	2 to 6% air content is introduced. Weight as well as strength is reduced
10.	Blast furnace slag	Useful for marine work
11.	Magnesium oxychloride	Has good adhesion to cement dust
12.	Water proof	For making waterproof concrete
13.	Expanding	To neutralise shrinkage effect of ordinary cement
14.	Sulphate resisting	Useful for lining of canal

1.4.4. ISI Specification for different types of cement

	Name of test	Cement types					
		Ordinary	*Rapid hardening*	*Low heat*	*Blast Furnace slag*	*Pozzolana*	*Masonry*
1.	Fineness (N/mm^2)						
	(I) Residue on sieve 9%	10	5	–	10	5	
	(II) Specific surface	225	326	320	325	300	500
2.	Consistency	Heat's needle penetration to permit penetration of 5 to 7 mm					
3.	Setting time (minutes)						
	(I) Initial	30	30	30	30	30	9
	(II) Final	600	600	600	600	600	24 hrs
4.	Soundness Expansion (mm)						
	Le-Chatlier	10	10	10	10	10	10
	(II) Autoclave Max. %	0.5	0.5	0.5	0.5	0.1	1.0
5.	Compressive strength N/mm^2.						
	1 day	–	11.5	–	–	–	–
	3 day	11.5	21.0	7.0	11.5	–	–
	7 day	17.5	–	–	17.5	14.8	2.5
	28 day	–	–	26.5	–	–	5.0

Contd...

Name of test		Cement types					
		Ordinary	Rapid hardening	Low heat	Blast Furnace slag	Pozzolana	Masonry
6.	Tensile strength. Min. N/mm^2						
	1 day	–	2.0	–	–	–	–
	3 day	2.0	3.0	–	2.0	–	–
	7 day	2.5	–	–	2.5	–	–
7.	Heat of hydration per gm (calories)						
	7 day	–	–	65	–	–	–
	28 day	–	–	75			

1.4.5. ISI Specification for particle size of sand for ordinary concrete work

IS sieve No.	*% of particles passing through the sieve*
4.75 mm	100
2.36 mm	90-100
1.18 mm	70-100
600 micron	40-100
300 micron	5-70
150 micron	0-15

1.4.6. ISI Specifications for particle size of sand for RCC work

IS Sieve No.	*% of particles passing through the sieve*
4.75 mm	100
2.36 mm	90-100
1.18 mm	70-100
600 micron	40-80
300 micron	5-40
150 micron	0-10

Table 1.4.4. Properties of Cement

Test	*Ordinary Portland Cement IS : 269*	*Rapid Hardening Cement IS : 8041*	*Low Heat Portland Cement IS : 269*	*Portland Blast Furnance Cement IS : 455*	*Portland Pozzoland Cement IS : 1489*	*High Alumina Cement IS : 6452*	*Masonry Cement*	*Super Sulphate Cement IS : 6909*	*Flyash Cement*	*White Portland Cement*	*Air Entrain Cement*	*Port Land Pozzolana Cement*
1. Fineness of Cement : (*a*) Specific surface by Blains air permeability cm^2/gm (Not less than)	2250	3250	3200	2250	3000	2250	5000	3200 to 5000	2250	2250	1750 to 2000	3200
(*b*) Residue to go Micron I.S. sieve must not be more than.	10%	5%	-	10%	5%	8%	15%	-	-	-	-	-
2. Setting Time : Initial (Minimum in minutes) Final setting (Maximum in hours).	30 10	30 10	60 10	30 10	30 10	30 10	90 24	30 10	30 10	30 10	45 10	45 10
3. Soundness by Le Chateliers test in mm is not more than.	10	10	10	10	10	1	10	10	10	10	10	10
4. Compressive strength in 1.3 Cement mortar in kg/cm^2 1 day 3 days 7 days 28 days	 - 166 220 350	 160 275 - -	 - 100 160 350	 - 160 220 -	 - - 175 250	 420 490 - -	 - - 25 50	 - 150 220 300	 - 115 175 -	 - 144 198 -	 - - - -	 - 175 - -
5. Specific Gravity	2.6	2.7	-	-	-	-	-	2.9	2.3 to 2.8	2.6	-	-
6. Loss on Ignition	4%	-	4%	4%	5%	0.2%	-	4%	0.8 to 1%	4%	-	-

1.4.6.1. Cement Concrete. Cement concrete is defined as an artificial stone where the voids of coarse aggregate are filled by fine aggregates and cement which acts as binder for the aggregates.

Table 1.4.5. Properties of cement concrete

	Property	*Description*
1.	Tensile strength	Measured in direct tension and bending
2.	Impact and fatigue strength	Depends on the type of aggregate
3.	Resistance to abrasion	Higher degree is obtained by well compacted concrete.
4.	Shrinkage	Depends on modulus of elasticity
5.	Creep	Increases rapidly near ultimate stresses

1.4.6.2. Quantity of material for different mixes of concrete

Maximum size of coarse aggregate	*Normal mix by volume*	*Quantity of material required*		
		Cement bag	*Fine aggregate. cu.m*	*Coarse aggregate. cu.m*
10-20 mm	1:1.2:2.4	10.1	0.42	0.84
10-20 mm	1:1.5:3	8.5	0.44	0.88
10-20 mm	1:2:3	77-5	0.583	0.995
20-40 mm	1:2:4	67	0.648	1.044

Table 1.4.6. Nominal mix concrete

Grade	*Total quantity of dry aggregate by mass per 500 N of cement*	*Proportion of fine aggregate to coarse aggregate by mass*	*Quantity of water per 500 N of cement*
M 5	8000 N	1:2	600 N
M 7.5	6250 N	1:2 to 1:2.5	450 N
M 10	4800 N	1:2 to 1:2.5	340 N
M 15	3500 N	1:2 to 1:2.5	320 N
M 20	2500 N	1:2 to 1:2.5	300 N

1.4.8. Fineness modulus method. This is a simple and rational method of getting void free concrete.

Fineness modulus of coarse and fine aggregate is obtained by dividing the cumulative percentages of aggregates retained on the specified IS sieves by 100.

The sieves used and the method of determining fineness modulus are given in Table 1.4.3.

Table 1.4.7. Determination of fineness of sand

ISI sieve No.	*% retained in sieve*	*Cumulative % retained in sieve*
480	4	4
240	10	14
120	15	29
60	30	59
30	35	94
15	6	100
	Cumulative total	300
	Fineness modulus	300/100 = 3.00
Fineness modulus of fine aggregate should be between 2 and 2.5 and of coarse aggregate between 6 and 8		

1.4.9. Water-cement ratio. Once the mix proportion has been fixed, the quantity of water should also be fixed. Professor Abram has established that the strength of concrete does not increase by addition of extra cement unless amount of water is reduced. A minimum water is required for the following reasons:

(*a*) To help chemical action and (*b*) To impart workability.

1.4.10. Tests on cement concrete

Test	*Description*
1. *Slump test*	The slump is given by the reduction in the height of concrete when the mould is withdrawn. Values of slump for different works are :
(*i*) Plain concrete work :	25 to 30 mm
(*ii*) RCC work (beams and slabs)	50-100 mm
(*iii*) RCC work (Thin column)	75 to 125 mm
(*iv*) Partition wall	40 to 60 mm
2. *Compaction factor.*	Compaction factor is given by : $\frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$
3. *Compression test* : 3, 7, 14, and 21 days.	The test is performed on 150 mm cubes on Cubes are tested on compression testing

1.4.11. Design of concrete mixes. The various methods adopted in the design of concrete mixes are ;

1. Minimum voids method
2. Fineness modulus method
3. Trial mix method
4. Arbitrary method.

1.4.12. Hollow cement blocks. IS: 2815-1967 covers the requirements of hollow concrete blocks.

This type of masonry provided facility for conceiling electric conduits, water and soil pipes.

Table 1.4.8. Standard dimensions of hollow concrete blocks.

Size designation	*Nominal size mm*			*Actual size mm*		
	L	B	H	L	B	H
Size A	400	300	200	390	300	190
Size B	400	300	200	390	200	190
Size C	400	300	200	390	100	190

1.5. TIMBER

1.5.1. Classification of timber. Timbers are classified into the following two categories ;

1. *Endogeneous*, (Endogens) which grow upwards such as, bamboo, coconut, palm and cane.

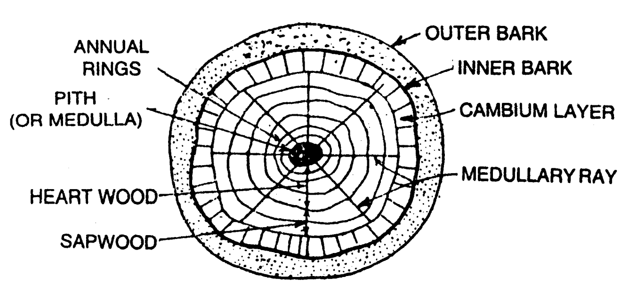


Fig. 1.5.1. Components of exogeneous tree section.

2. *Exogeneous*, (Exogens) development of these trees takes place by addition of one annular ring every year. (See Fig. 1.5.1)

Trees are also identified as hard and soft wood. Sal, teak, sheesham, mohogany, which do not contain any resinnous material are known as hard wood. They have greater strength and durability. Chir, fir and other conifers fall under soft wood trees. This type of wood can be sawn easily.

Table 1.5.1. Different types of trees and their use

Name of timber	Identification and uses
Teak	Strong and hard. Suitable for use for any important work
Deodar	Soft wood. The heart wood portion is not affected by white ants
Sheesham	Heavy and strong. Used for furniture making
Sal	Strong, heavy and hard. Used in railway sleepers and building construction
Mango	Grey coloured wood having coarse grains. Used for less durable works
Kail	Soft wood used for furniture making and railway sleepers
Chir	Soft wood grown in Himalayas. Used in light furniture, railway sleepers and packings
Toon	For furniture and musical instruments
Rosewood	For furniture
Babul	Used for wheels
Seemal	Used for well curbs
	For wheel and light roofing

1.5.2. Properties of timber. As a building material, timber has many valuable properties. They have been discussed under following headings :

1. Identification of wood-physical properties
   (*a*) Colour and Lustre
   (*b*) Odour and taste
   (*c*) Grain
   (*d*) Texture
2. Density according to structure *i.e.* specific gravity
3. Moisture content and Absorptivity
4. Thermal Expansion
5. Heat transmission
6. Electrical characteristics
7. Strength properties-structural properties.

1. **Identification of wood.** By seeing the specimen of wood, the identification regarding its family, genus, species and even of its variety can be made. But as the number of varieties of timber is so large, it is not easy to identify a wood by simply seeing its physical properties like colour, odour, grains etc.

(*a*) **Colour and Lustre.** Wood inherently possess a wide variety of colours ranging from white to black. Some woods have been named only because of their typical colour. By appearance of colour, a possibility regarding group can be made but it does not give any idea regarding its strength properties.

Similarly lustre is also variable feature but sometimes help in distingushing certain species.

(*b*) **Odour and Taste.** Odour occurs due to certain chemical deposits. It is more pronounced in heartwood than that of sapwood. A wood which is green, if cut, always shows a woody odour. Only a few specimens of wood can be identified with odour.

Taste is closely related to odour, Sugarpine derives its name from the sweet exudations found on wounds on the living tree.

(*c*) **Grain.** It is a descriptive term applied to the adjustment of cells and tissus. Some of the more common uses of the word are the following :

(*i*) **Coarse and fine.** These terms refer to the size of annual rings as appear on finished wood. If these rings are wide, wood is called coarse grained, if they are narrow called as fine grained. These words are also refered to texture of the surface whether smooth or rough in appearance.

(*ii*) **Open and close.** If a wood is having large pores it is called open grained wood whilst a wood having fine pores is called as close grained wood.

(*iii*) **Even and Uneven.** If a specimen of wood shows a marked difference in the character strick of spring wood and summerwood, the wood is said to be uneven grained. If the properties are much alike wood is called evengrained. Evengrained wood can be worked easily.

(*iv*) **Rough and Smooth.** A wood may be quite smooth but if it has rough appearance, it is called rough grained.

A wood is called straight-grained wood if the alignment of grains is parallel to the axis of tree. If the grains are aligned spirally in the standing tree, wood is said to be twisted grained. If the original tree was straight grained but the boards cutout of it were not cut parallel to the trunk, the fibres in the resulting boards are not parallel to the side and such pieces are called diagonal grained. If the alignment of grains is neither parallel to axis of trunk nor in a single spiral, it is called interlocked grain.

It is generally accepted that grain refers to the direction of the fibres. Timber exists its greatest tensile and compressive strength along the grain. Hence timber should not be loaded in the direction perpendicular to the grain. In this direction strength is found minimum. The strength of the timber is affected according to the slope of grain with reference to the longitudinal axis as shown in Fig. 1.5.2.

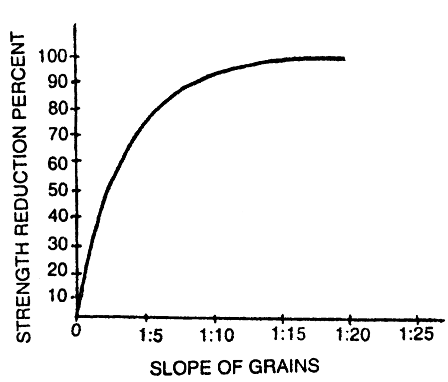


Fig. 1.5.2

(*d*) **Texture.** It refers to the relative arrangement of the cells in any given piece of wood, their size and proportion in unit volume.

2. **Specific-gravity.** It is only specific gravity which indicates all other properties of wood in the best possible way. Though it changes according to the moisture content but if it is kept constant, the apparent specific gravity gives a good indication of its strength properties. The true specific gravity of the seasoned wood is always constant. Strength of the timber depends largely upon density. Different specimen from same tree also show a marked difference in density. It is always determined on air dry basis which is defined as 12 per cent moisture content based upon oven dry weight.

3. **Moisture content and absorptivity.** Moisture content in timber changes due to the absorption of water by cell walls. Thus the volume of sample also changes accordingly. More moisture content softens the wood and thus reduces its mechanical strength. Moisture content also depends upon density of wood. Dense specimen absorbs less water than that of lighter specimen. More the density stronger the wood and hence lesser the moisture content.

It is one of the most important physical property of the wood. It causes swelling and shrinkage of specimen and causes attendent changes in dimensions. Most of the defects and blemishes found in timber are only due to moisture content. At water saturation point (Fibre saturation point) moisture in wood is found approximately 25 per cent to 30 per cent of the oven dry weight of the wood.

Moisture occurs either due to fill of water in cell cavity or by due to its penetration in the cell wall which have it due to their porous structure. Water which is held by cells is only responsible in modifying the properties of wood.

Above fibre saturation point, if a wood is in wet surroundings, it continuously absorbs moisture. The total amount of absorption of water depends upon its specific gravity. Some lightwoods may absorb as much as 250% of their oven dry weight whilst some of heavy woods absorb only a little amount above fibre saturation point.

This property of wood is very much important in case of application of preservatives to the timber, because dense specimen will absorb less preservative and hence will be economical.

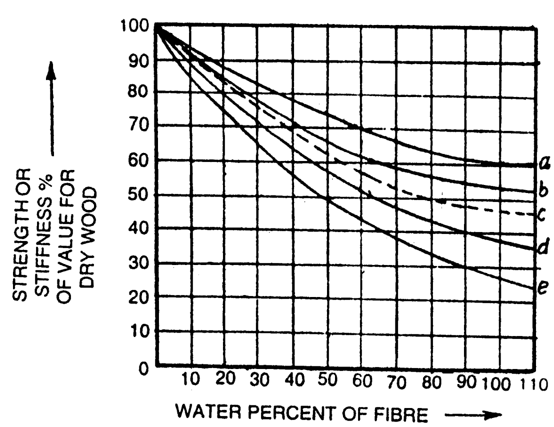


Fig. 1.5.3

SATURATION POINT

(*a*) Stiffness (*E*) in cross bending (*b*) Stiffness (*E*) in compression along grain
(*c*) Ultimate shear strength along grain (*d*) Ultimate bending strength
(*e*) Ultimate strength in compression along grain.

Effect of Moisture on Strength of Wood

4. **Thermal expansion.** This property of timber is not of much important. Its coefficient of linear expansion is very low compare to other metals. Its coefficient of expansion parallel to the grains is 1.0 to 5.3×10^{-6} and perpendicular to the grains is 15 to 34.0×10^{-6} approximately.

5. **Heat insulation.** Wood is a good heat insulating material being porous in structure. It increases with increase in moisture content.

6. **Electrical characteristics.** Wood is a poor conductor of electricity. Its conductivity is highly depends on change in moisture content. At zero percent moisture wood is considered to be best insulator. As moisture pecentage increases its insulating power decreases.

7. **Strength properties structural properties.** In order to utilize wood as a potential structural material, it is necessary to understand its behaviour on application of some external load. On subjecting to loading tests, there are three kinds of direct stress to which timber can be subjected *viz.*, tensile, compressive and shearing.

1.5.3. Optimum moisture and seasoning of timber. Excess of moisture content causes decay and deterioration of timber. ISI has specified the following moisture content for timber.

Table 1.5.2. Optimum moisture content specified by ISI

Particulars of timber	*Optimum moisture content*
1. Timber for doors, windows, decks of ships etc.	15%
2. Automobile industry, toys and domestic articles	12%
3. Beams, rafters and agriculture tools	20%

Moisture content in timber is brought to permissible limits by seasoning. The various methods of seasoning are ;

1. *Natural seasoning.* This is carried out by water seasoning or by air seasoning.
2. *Artificial seasoning.* The various methods adopted are.
   (*a*) Kiln seasoning ;
   (*b*) Electrical seasoning ;
   (*c*) Vapour seasoning ; and

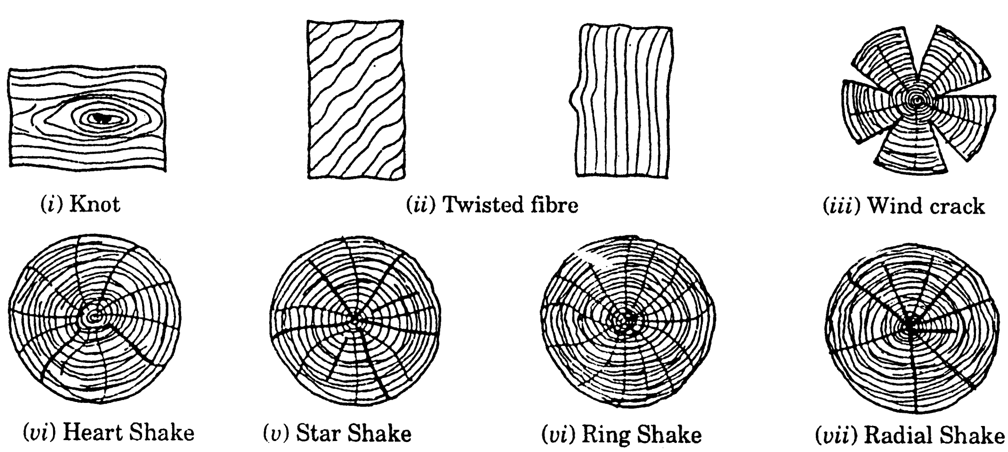


Fig. 1.5.4. Defects in Timber.

(*d*) *Chemical seasoning*. The chemical used in this process is creosote and the method of treatment is known as Boulton method. Wood dipped in creosote is dried in a cylinder by boiling in vacuum.

1.5.4. Defects in timber

	Defect	Characteristics
1.	Knots	Discontinuation in the timber section. They are solid, loose, and dead. Only solid knots form with adjoining section are acceptable
2.	Twisted fibre	Due to twisting of fibres planks get warped
3.	Heart shake	Fibres get separated from fibres of wood
4.	Ringshake	Cracks develop between two annular rings
5.	Radial shake	Shake starts from external portion
6.	Rupture	Due to external injury or impact
7.	Ring gall	Caused due to chipping of branch.
8.	Wind crack	Caused due to change in atmospheric conditions. (See Fig. 1.5.2)

1.5.5. Properties, classification and uses of timber trees

Table 1.5.4. Characteristics of structural timber

Group	*Modulus of Elasticity, E kg/cm*^{2}
A	126
B	98 – 126
C	56 – 98

Table 1.5.5. General characteristics of wood

Group	*Trade name*	*Average unit weight at 12% m.c. kg/m*^{3}	*Durability*
A	Khair	1010	High
	Sal (UP)	881	High
B	Babul	785	Low
	Cedar	720	High
	Mahua	785	High
	Ecualyptus	850	High
	Jaman	850	Moderate
	Oak	865	Moderate
	Sal (MP)	865	High
	Teak	640	High
C	Neem	830	–
	Chestnut	625	Moderate
	Deodar	545	High
	Cyprus	515	High
	Rosewood	755	High

Contd...

Group	*Trade name*	*Average unit weight at 12% m.c. kg/m³*	*Durability*
	Sissoo	785	Moderate
	Mango	690	Low
	Kail	515	Low
	Chir	575	Low
	Hollock	610	Low
	Arjun	800	Moderate

Table 1.5.7 (a). Permissible stresses for Indian Timber

			Permissible stresses in kg/cm² for grade I											
Species	*Average unit weight at 12% moisture content in kg/cm²*	*Modulus of Elasticity tonnes/cm³*	*Bending tension along grain extreme fibre bare*			*Compression parallel to grain*			*Compression prependicular to grain*			*Shear horizontal along grain*		*Durability*
			I	*O*	*W*	*I*	*O*	*W*	*I*	*O*	*W*			
Khair	1010	134	202	168	134	138	123	100	77	60	49	14	22	High
Dhaman	785	148	182	152	124	120	106	88	60	46	38	13	19	Moderate
Red Sanders	1105	127	250	209	167	181	161	131	112	91	75	17	24	Moderate
Babul	785	108	182	154	124	112	102	80	65	50	41	15	22	Low
Jaman	850	112	151	126	102	91	84	67	58	45	36	12	17	High
Indian oaks	865	125	148	124	98	92	80	66	45	35	29	12	17	Moderate
Sal	865	127	168	140	112	106	94	78	45	35	29	9	13	High
Tak	640	96	140	116	94	88	78	64	40	31	25	10	14	High
Kindal	770	105	130	108	88	88	78	64	36	28	23	9	13	Moderate
Deodar	545	95	102	88	70	78	70	56	26	21	17	7	10	High
Rosewood	755	93	168	140	112	106	92	78	64	50	41	12	17	High
Sissoo	785	89	152	126	102	94	84	66	46	36	29	12	17	Moderate
Mango	690	91	124	102	80	74	66	52	31	24	19	9	14	Moderate
Chir	575	98	84	70	60	64	56	46	22	17	14	6	9	Low
Bonsum	530	86	116	94	78	78	66	56	24	19	15	8	11	Low
Rohini	1155	122	215	179	143	15	134	109	129	101	82	16	23	

Symbols :
I—Inside location
O—Outside location
W—Wet locations.

1.5.6. Grading of Structural Timber

The cut sizes of structural timber should be graded, after seasoning into (*a*) Select grade, (*b*) Grade I and (*c*) Grade II.

Select grade wood in one which may not contain defects. The estimated effect of these defects may tend to reduce its basic strength by more than 12.5 per cent. Grade I timber may also not contain defects but presence of it may tend to reduce its basic strength. Grade II timber is that which should not contain any defects but the strength may be reduced by 37.5%.

Permissible stresses. The premissible stresses for group A, B and C for different locations applicable to grade I structural timber are as shown in Table 1.5.7 (*b*). These permissible stresses for timber are applicable for timbers of high and moderate durability which have been given suitable treatment where necessary.

Table 1.5.7 (*b*). Permissible Stresses for Grade I Timber

S.No.	*Permissible stresses kg/cm²*		*Group A*	*Group B*	*Group C*
(*i*)	Bending and tension along grains	Inside location	182	123	84
		Outside location	152	102	70
		Wet location	120	81	60
		Horizontal all* locations	12	9	6
(*ii*)	Shear	Along grain all locations	17	13	9
(*iii*)	Compression parallel to grain	Inside location	120	70	64
		Outside location	106	63	56
		Wet location	88	58	46
(*iv*)	Compression perpendicular to grains	Inside location	60	22	22
		Outside location	46	18	17
		Wet location	38	15	14

*The value of horizontal stress to be used only for beams. **In all other cases shear along grain to be used.

For other grades the permissible stresses given in Table 1.5.7 (*b*) should be multiplied by the following factors to obtain permissible stresses

For select grade timber 1.16 ; For grade II timber 0.84

For timbers with low durability the permissible stresses can be obtained by multiplying the permissible stresses ontained for high and medium durability by 0.8.

Timber columns. Solid columns shall be classified as short, intermediate and long depending upon slenderness ratio *s/d* being below 11, between 11 and k_8 and greater than k_8 respectively, where k_8 = a constant equal to $0.702\sqrt{E/f_{cp}}$.

Table 1.5.8. Classification of Columns

Classification of column	*Permissible compressive stress*	*Remarks*
Short column	$f_c = f_{cp}$	f_c = Permissible stress in axial compression in kgf/cm² f_{cp} = permissible stress parallel to grain in kgf/cm²
Intermediate	$f_c = f_{cp}\left[1 - \frac{1}{3} - (s_{k_8})^4\right]$	
Long	$f_c = \frac{0.0329\,E}{(s/d)^2}$	In solid columns of timber *s/d* ratio shall not exceed 50

1.5.7. Timber Products.

1. **Veeners and plywood.** Veeners are thin sheets of wood which are cut by knife edge or by sawing and are used for decorative purposes. The thickness of each veener vary from 0.35 mm to 6 mm are more.

Plywood is used for sub-flooring, wall and roof sheathing, webs of arches. These are also used in prefabricated construction and for lining concrete forms when a smooth finish concrete is desired. For interior works, it is used for walls, panelling, sub-flooring cabinets, counters etc.

2. **Timber concrete decks.** Timber concrete decks are used in mills, docks and highway trestles.

3. **Binding boards.** Insulating boards composed of various fibers glued together and made into sheets and slabs of a considerable range of sizes and thickness. These are used in buildings considerably.

4. **Hard boards.** These are homogeneous fibre building boards. They are classified according to their density and method of manufacture and other related mechanical and physical properties :

(*a*) Semi hard board density 4.8 – 8 kN/m^3. (*b*) Hard board density 8 to 12 kN/m^3.

(*c*) Super hard board or high density board.

All hard boards should have at least one smooth surface. These boards are used in interior decoration works.

5. **Wood wool board.** It is a material made from wood fibres (wood wool) and cement. Wood wool is saturated with cement slurry and compressed in the form of a board. After gaining strength, the board is a sufficiently durable material.

It is used in buidings as a cladding material for walls, in partitions and as a permanent shuttering for concrete and in ceiling. It is also used for roofing purpose also. Recent studies have shown that this material can be used for roofing corrugated sheets also.

6. **Coir-Waste :** This material has been used to produce good quality sheets with OPC.

7. **Rubber wood :** The extremely durable, cheap, and easily available rubberwood is fast emerging as the timber of future as a popular substitute for expensive conventional timbers facing extinction due to overuse and deforestation.

The rubberwood can be used for doors, windows, furnitures, cabinets, toys; rafters, purlins etc. It is also used for sports materials like carrom board, bats etc. Cable drums, picture frames, flush door frames for black boards are also manufactured by rubberwood.

8. **Marine-plywood :** It is a quality material used to resist very high pressures and is waterproof in nature. It is further treated with durable preservatives for greater resistance to termites, rots, funges and other wood destroying organisms.

1.6. FERROUS METALS

1.6.1. Introduction. Iron is one of the most important engineering materials but pure iron (Fe) does not exist in natural state. It may be obtained by electrolytic deposition, remelted in vacuum, hot rolled and normalised. Pure iron possess density of 7.9 at 20°C, tensile stress 280 N/mm^2, brinell number 80, melting point 1537°C, specific heat 109, electrical resistivity 9.71.

Iron and steel are different substances, manufactured in different processes, in different varieties, having different constituents. Indian iron ores are one of the finest and largest in the world and possesses about one-fourth of the total world reserve of iron ore.

1.6.2. Pig iron. The first product in the process of conversion of iron ore is pig iron. It is the virgin metal, having its name from the shape, for re-melting.

Pig iron is manufactured by smelting iron ore and lime stone in the upper part of the blast furnace.

Once the blast furnace is set in operation it works non-stop for months. The production from blast furnace varies from 700 to 7000 *t* of iron per day.

Table 1.6.1. Chemical analysis of foundry pig iron

Class	*Grade*	*Si*	M_n	*S*	*P*	*Graphic*	*Combined*	*Details of fractine*	*Application*	*Marking (IS : 224)*
	No 1 Foundry	2.75 3.25	0.5 1.5	0.05	0.40	3.5	0.5	Dark grey, highly crystalline	Casting of ornaments nature	White
	No 2	2.25	,,	,,	,,	3	0.6	Light grey Smaller grain	Medium grade, casting blending with other grades	Red
Grey	Foundry	2.75								
	No 3	1.75	,,	,,	,,	2.8	0.9	Light grey close grained	General foundry work	Yellow
	Foundry	2.25								
	No 4 Foundry	1.25	,,	,,	,,	2.8	0.38	Lightest colour, closest grain	Exceptionally hard castings	Green
Mottled	–	0.7	0.2	,,	,,	1.4	1.8	Mottled with white iron in matrix of grey rich	Malleable casting	–
White		0.3	0.2	,,	,,	Trace	3.0	Almost white, Very close grained	,,	–

1.6.3. Cast iron. Cast iron is obtained from pig iron by burning it with lime stone and coke into cupola furnace. It contains about 4% impurities when it comes out from the cupola furnace.

Table 1.6.2. gives various types of cast iron depending upon the composition of pig iron ore;

Table 1.6.2. Types of cast iron

Type of cast iron		*Characteristic and uses*
1.	White	Used for making wrought iron
2.	Chilled	Hardness of cast iron is improved by rapid cooling
3.	Grey	Used for high quality casting
4.	Mottled	Obtained by addition of hametite in the furnace. Used for small castings
5.	Malleable	Obtained by heating cast iron with an oxidising agent. Used for railway track equipment
6.	Nickel alloy	By adding one or two % nickel, cast iron becomes tough and can be machined.

1.6.4. Wrought iron. Wrought iron is a ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron. It is produced from pig iron by subjecting it to the process of refining, puddling, shingling and rolling.

1.6.5. Steel. Steel is a very important engineering material. The raw material for manufacture of steel is pig iron obtained from blast furnace. The process is basically an oxidation process for removal of carbon, silicon, manganese, phosphorous, and sulphur to the grade of steel required.

Blister steel or cementation steel is produced by heating wrought iron and charcoal in alternate layers.

Cast steel is manufactured from wrought iron or from blister steel. This steel is very hard and homogeneous.

Steel is manufactured by one of the following three processes ;

1. *Bessemer process :* Pig iron is fed into the converter either after melting or directly from the blast furnace converter.
2. *L.D. Process :* It is modification of Bessemer process in which expenditure is reduced and output in increased due to :
   (*i*) Instead of injecting air for oxidisation, 20% oxygen is supplied.
   (*ii*) Blast of pure oxygen produces high quality steel.
3. *Open hearth process :* Hot air and coal gas are used as fuel.

1.6.6. Hot treatment of steel. Properties of steel can be changed widely by heating and cooling steel in solid state. It serves the following purposes ;

(*i*) Changes strength and hardness
(*ii*) Relieves internal stresses
(*iii*) Makes steel resistant to heat and corrosion
(*iv*) Changes electrical and magnetic properties
(*v*) Improves texture.

Heat treatment comprises of the following four treatments :

1. Hardening
2. Tempering
3. Normalising and
4. Annealing.

Table 1.6.3. Important mechanical properties of steel

S. No.	*Property*	*Mild steel carbon content 0.28%*	*Medium carbon steel carbon content 0.55%*	*High carbon steel carbon content 0.8%*
1.	Ultimate tensile strength	400 to 600 N/mm^2	750 N/mm^2	900 N/mm^2
2.	Elastic moduluss E	2.1×10^5 N/mm^2	2.1×10^5 N/mm^2	2.1×10^5 N/mm^2
3.	Percent Elongation	31.5 percent	21 percent	.01 percent
4.	Brinells Hardness	150	200	240
5.	Shear Modulus	0.8×10^5 N/mm^2	—	—

Table 1.6.4. Applications of various types of steel

S. No.	*Type*	*Carbon content, %*	*Application*
1.	Low carbon steel	0.1-0.125	Wire, rod, thin sheets, solid drawn tubes etc.
		0.15-0.30	Boiler plates, Steel-Joist, steel sections, reinforcing bars
2.	Medium carbon steel	0.30-0.55	Shafts, high tensile tubes, wires, fish-plates, electric-discs, dies, gears, railway-wheel, steel tyres, agricultural tools
3.	High carbon steel	0.55-0.7	Rails, wheel tyres, large foging dies, laminated springs, keys torsion bars, diesel engine liners
		0.7-0.90	Springs, small forging dies, shear blades, wood chiesel, laminated springs, large dies for cold pressings
		0.9-1.1	Coldchiesel, press dies, punches, screwing dies, wood working tools, axes, picks, mint-dies, milling cutters
		1.1-1.4	Hard files, razors, drills, gauges, turning and planning tools, reamers

1.6.11. Different methods of shaping steel. Ignots obtained during the manufacture of steel are further treated by one of the following processes to convert it into commercial forms. The commonly used forms are plates, sheets, rods, pipe tubes and other sections. The important processes are ;

(*i*) Rolling
(*ii*) Forging
(*iii*) Pressing and
(*iv*) Casting.

1.6.12. Engineering properties and uses of different steels

Nomenclature of steel	*Engineering properties Uses*	*Uses*
1. Cast iron	Compressive strength 700 N/mm^2 Ultimate tensile strength 150 N/mm^2	Used for columns & base plates
2. Wrought iron	Compressive strength 200 N/mm^2 Tensile strength 375 N/mm^2	Plain and corrugated sheets
3. Low carbon or mild steel	Compressive strength 475 N/mm^2 Ultimate tensile strength 550 N/mm^2	Beams, girders angle iron, T and I sections
4. High carbon or hard steel	Compressive 1200 – 2500 N/mm^2 Tensile 800 – 1600 N/mm^2	Tools, cutlery and machine parts
5. High tensile	Ultimate tensile strength 700 N/mm^2.	For prestressed concrete construction
6. Spring steel	Carbon 0.6% to 1.7%	Suitable for springs
7. Plain carbon.		
(*a*) Chisel steel	Carbon 0.3 to 0.4% Chromium 2% Nickel & Tungsten 2 to 3%	Chisel, punch, cutter, pick axe
(*b*) Shear steel	Carbon 0.85% Vanadium 1%	——
(*c*) Die steel	Carbon 6% Nickel 1%	Making die

Contd...

Nomenclature of steel	*Engineering properties Uses*	*Uses*
8. High speed steel		
(*a*) Tungsten high	Carbon 0.6 to 0.7% Tungsten 12 - 18% Cr 0.4%, Vanadium 1%	Cutter, turning and boring steel
(*b*) Molybdenum high speed	Carbon .7% Molybdenum 8.5% Cr 0.4%, Vanadium 1%	— Do —
(c) Tungsten, Molybdenum high speed	Carbon 0.8% Tungsten 5.75% Molybdenum 4.5% Cr 4%, Vanadium 1.5%	— Do —
9. Nickel steel	Carbon .25% to .4% Cr 1.5%, Nickel 3 to 3.5%	Making armour plates and boiler plates with 3.6% Nickel it is known as Invar
10. Manganese Steel	Very hard, non-magnetic	Used for rails under heavy traffic
11. Vanadium steel	Hard and cut resisting	Axle, spring and propeller shaft
12. Chromium steel	Cr. restricted to 2%	Ball bearing, file safe, cutting tools and projectiles.

1.6.13. Stainless steel. This steel contains 0.15% carbon, 11 to 14% or, below 1% manganese and silica combined. Used for household utensils and for making turbine blades.

1.6.14. Rusting of steel. Humidity and atmospheric pollution accelerate the process of rusting.

1.6.15. Corrosion. Primary cause of corrosion rusting is of metal.

Various methods adopted to prevent rusting are ;

(*i*) Coal tarring. Painting with or dipping into coal tar.

(*ii*) Painting. Treating the surface with special paints.

(*iii*) Enamelling. Suitable enamelling material is melted over the surface.

(*iv*) Electro-plating. Electric current is passes through a solution.

(*v*) Tin-plating. Article is immersed in a bath of molten tin.

(*vi*) Sheardising. Covering the surface with molten Zinc.

(*vii*) Galvanising. Dipping the surface into tank of molten Zinc.

1.6.16. Commonly used structural sections. Commonly used structural sections are ;

Equal angles, Unequal angles, T-section, channel section, trough section. I section, corrugated sheets, Expanded metal.

1.7. NON-FERROUS METALS

1.7.1. Properties of Aluminium. Pure aluminium is very soft and ductile. Therefore, it is alloyed with other metals like copper, magnesium, silicon, mangnese etc. which increases its tensile strength and hardness with retaintment of its characteristics of lightness and durability. Aluminium is highly resistant to corrosion and very conductive to heat and electricity. The specific gravity of aluminium is 2.7. The only drawback of aluminium is its low tensile strength *i.e.* about 100 N/mm^2. It is mechanically weak. This tensile strength can be overcome by alloying small amounts of other elements such as copper, iron, tin, zinc etc.

It has poor resistance to alkalies and common salt solution. Its resistance against corrosion can be improved by anodizing it. After anodizing a thin and adherent oxide film is formed on its surface which is resistance to corrosion.

Its melting point is 660°C, thermal conductivity is 0.52 cal/sq. cm/cm/°C/sec and coefficient of thermal expansion is about 0.0000125/°F.

Uses. Aluminium is one of the important metal and used very much for different works. Window frames, Glazing bars, wire rods made of aluminium are most common. Corrugated aluminium sheets for roofing are also used. Aluminium powder is made by pounding, aluminium foil into flats of extreme fineness. This powder has a bright silver colour and is used as a pigment in paints. Aluminium in its pure form is very useful for Civil Engineers. It is used as a protective coating to steel structures in bridges, electricity poles, steel sheets etc. It is also used very much as transmission wires.

Bauxite is the primary source of aluminium.

IS : 7092 (Part I)-1976 gives specifications for aluminium alloy tubes (welded for irrigation purposes. Table 1.7.1 gives characteristics of wrought aluminium and alloys.

Table 1.7.1. Characteristics of wrought aluminium and its alloys

Material Symbol	*Composition %*	*Characteristics*	*Availability*
PIB	Cu < 0.5, Si < 0.8, Fe < 0.4 Mn < 0.03, Zn < 0.1 (Cu + Si + Fe + Mn + Zn) < 0.5	High purity Al (990% Al)	Sheet, Plates
PIC	Cu < 0.16, Si < 0.5, Fe < 0.7 Mn < 0.1 (Cu + Si + Fe + Mn + Z) < 1.0	Commercially Pure (Al 99%)	do
NP3	Cu < 0.1, Si < 0.6, 5Fe < 0.7 Mn 1 to 1.5	Al alloy. Stronger and harder than PC has good welding ability	do
PN4	Cu < 0.1, Mg 17 to 28; Si < 0.7 Fe < 0.7, Mn < 0.5, Cr < 0.25	Al alloy, Strength increases with Mg content.	Sheet, rod
NP6	Cu < 0.1, Mg 4.5 to 55, Sr < OH, Fe < 0.7, Mn 1.0, Cr < 0.3	Al alloy, Highly resistive to corrosion	Sheet, Tube
NP8	Cu < 0.15, Hg 4 to 4.9, Si < 0.4 Fe < 0.7, Mn 0.5 – 1.0, Cr < 0.25	Al alloy. „ Plate, forgings	Sheet, Tube
HP 20	Cu 0.15 to 0.4, Mg 0.8 – 1.2, Si 0.4 – 0.8 Fe < 0.7, Mn 0.2 – 0.8, Cr 1.5 – 0.35	Al allow. Medium strength corrosion resistant	Sheet, plate
HP 30	Cu < 0.1, Mg 0.4 to 1.4, Si 0.4 – 18 Fe < 0.6, Mn 0.4 – 1.0, Cr < 0.3	A medium strength alloy. Corrosion resistant and weld a lile	Sheet, plate
HP 14	Cu 3.5 – 4.5, Mg 0.4 – 1.2, Si .2 – 7 Fe < 0.7, Mg .4 to 1	Strong Al alloy having good ductility	Tube forging, wire, rod.
HP 15	Cu 3.8 – 4.8, Mg 0.2 – 0.8, Si 0.5 – 0.9 Fe < 0.7, Mn 0.3 – 5.2	Alloy having strong ductility	Sheet, plate, tube, wire and forging.
Note :	Symbolic representation by B : Bolt and screw stock PC : Clad Plate P : Plate N : Non-head-treatable alloy H : Heat treatable alloy	Letters is as below :	

1.7.2. Copper Physical properties :

Colour—Flesh—pink

Specific gravity—8.93

Melting point—1083°C

Melting point—2310°C

Thermal conductivity—0.92 cal/cm^2/cm/°C/sec.

Coeff. thermal expansion—16.6×10^{-6}/°C.

Electrical resistivity—1.7241 microhm/m at 20°C.

Specific heat —0.092.

Mechanical properties :

Tensil trength —Working - 100 N/mm^2

—Ultimate - 300 N/mm^2

Hardness Brinell - 60

Elongation per cent on 5 mm dia— 30 to 40%

Modulus of Elasticity - 1.24 to 10^6 N/mm^2

Poisson's Ratio - 0.3

Copper is obtained from the following :

(*i*) Copper glance (Cu25), (*ii*) Malachite ($CuCO_3$) (*iii*) Copper pyrite ($CuFeS_2$)

The metal can be rolled, forged, drawn into wires and worked hot and cold. It is used for the following :

(*i*) Light gauge tubing. (*ii*) Gas and sanitation services. (*iii*) Electric wires and cables, (*iv*) Sheathing in roofing. DPC and flashing. (*v*) Protective coat for other metals. (*vi*) Dowels in stone masonry, (*vii*) Lightning arrester, (*viii*) Principal constituent of brass and bronze alloys.

1.7.3. Principal alloys of bronze and brass

	Name of alloy	*Composition %*	*Uses*
(A) Bronze			
1.	Gun metal	Cu 88, Sn 10, Zn 2	Bearings
2.	Phospherbronze	Cu 89, Sn 10, Ph 1	Bearings, Gear, Pump rod, boiler tube
3.	Bell metal	Cu 45, –60, Zn 30–35 Sn 5–35	Electric goods, utensils
4.	Mn Bronze	Mn 2–30, Cu remainder	Door, window sash and frame
5.	Coinage bronze	Cu 95, Sn 3	Coins
(B) Brass			
1.	Muntz metal	Cu 60, Zn 40	Casting work, rod, bolt, tube
2.	Manganese brass	Cu 60, Zn 36, Fe 3 Mn 1	Pumping rod, pinion

Contd...

	Name of alloy	Composition %	Uses
3.	Naval brass	Cu 60, Zn 39, Sn 1	Pump parts, condenser tube, Marine work
4.	Cartridge brass	Cu 70, Zn 30	Cartridges
5.	Ordinary brass	Cu 75, Zn 25	Name plate, bolt, lock door and window handles
6.	Delta metal	Cu 60, Zn 37, Fe 3	Suitable substitute for mild steel work It is resistant to corrosion

1.7.4. Different Brasses and Bronze Alloys and their uses are shown below :

Table 1.7.4. Brasses [Cu and Zn alloys]

Name	Cu%	Zn%	Tin%	Uses
(1) Commercial brass	90%	10%		For hardware, forgings, screws, costume etc.
(2) Dutch metal	80%	20%		Cheap jewellery, drawing and forming flexible bases.
(3) Cartridge brass	70%	30%		For condenser tube, sheets for cold drawing and pressing purpose.
(4) Muntz metal or yellow brass.	60%	40%		For casting, hot stamping, screw, springs, chain etc.
Special brass				
(*a*) Admiralty brass	70%	29	1	Propellors and marine works.
(*b*) Naval brass	62	37	1	Naval work.
(*c*) Aluminium brass	75	23	2	For condenser tubes and marine works.
(*d*) German Silver	50%	20	30% Ni	For making utensils, table ware, bolts, screws, ornaments, plating and small machine parts.
(5) Manganese brass	50-60%	36	3	Bush, pinion, pump, rod. Very little affected by salt water.
(6) Delta Metal	60	37	3% Iron	Used in place of mild steel. Corrosion resisting capacity is high.
(7) Ordinary brass	75	25		Door handle, lock, bolt, name plate.

Table 1.7.5. Bronze

Name	Cu %	Sn %	Pb %	Zn %	Any other %	Uses
(1) Common bronze	89-92	11-8				Pump, valves, wires, coins, utensils, statues, architectural ornaments etc.
(2) Phosphorus bronze	90%	7	2		P = 1%	Springs, bushes, fibres for moving galvanometers, bearings, gear wheel etc.

Contd...

Name	*Cu %*	*Sn %*	*Pb %*	*Zn %*	*Any other %*	*Uses*
(3) Gun metal	85	5	5	5		Foundry works, Hydraulic fittings, other castings etc.
(4) Aluminium	93				Al = 7%	Valves, bushes photoframes artificial ornaments etc.
(5) Nickel bronze	90				Ni = 9, Fe = 1	Unhardened shafts, valves, bodies fittings and general semi-hard bearing purposes.
(6) High Nickel bronze		3		12	Ni = 15-20 Mg = 0.1	Tensile strength—30 kN/mm^2 used in contact with sea water or other containing corrosive salts.

1.7.5. Zinc. Zinc is a weak and brittle metal. Tensile strength in cast condition is above 50 N/mm^2. Due to its brittleness, it is rolled at 100° to 150°C. Melting point is 419°C. Zinc is obtained from zinc blende or black track which contains 30 to 50% zinc.

It is a bluish white metal and is used for the following :

(*i*) Galvanising sheets (*ii*) Zinc plating (*iii*) Die casting (*iv*) Brass making. (*v*) In preparation of paints.

1.7.6. Tin. Tin has a low melting point (232°C) and is poor conductor of heat and electricity. Tin exists in two allotropic modifications—grey tin, which is stable below 18°C and white tin, which is stable—between 18°C and the melting point. If white tin is cooled below 18°C, a transformation to powdery grey tin takes place. The most rapid conversion takes place at – 48°C. Tin is soft, very malleable and ductile, but possess low tensile strength. It does not corrode or tarnish in the atmosphere but react with dil. HCl.

Tin is extracted in the same way as copper. The ore is found in Sumatra, Java, Malasia, Australia, China and Burma. It is used for the following.

(*i*) For soldering, (*ii*) Alloying metal in brass, (*iii*) Alloying metal in bronze, (*iv*) Tin plating.

1.7.7. Lead. Lead has good casting properties and has poor ductility. It has low tensile strength, 10 N/mm^2 and low melting point of 328°C.

Lead is found in Burma, North America, Spain and England as galena (PbS)

Apart from batteries, it is used for the following purposes

(*i*) Roofing sheets (*ii*) DPC. (*iii*) Water service pipes, soil and gas pipes (*iv*) Gutters and cistern lining (*v*) Lead wool and solder for plumbing (*vi*) Ornamental work in buildings, (*vii*) In the manufacture of paints, (*viii*) Lead connections for sanitary fittings.

1.7.8. Nickel. Nickel is obtained from ferrous magnetic pyrites containing 3 to 8% metal. The metal resembles steel in colour.

Castings of nickel-copper alloys are used where even chromium nickel stainless steel are not adequate from consideration of corrosion resistance.

1.7.9. Solder. Solder is used for joining two materials. Fusion of solder should be well below that of the metal it is to join.

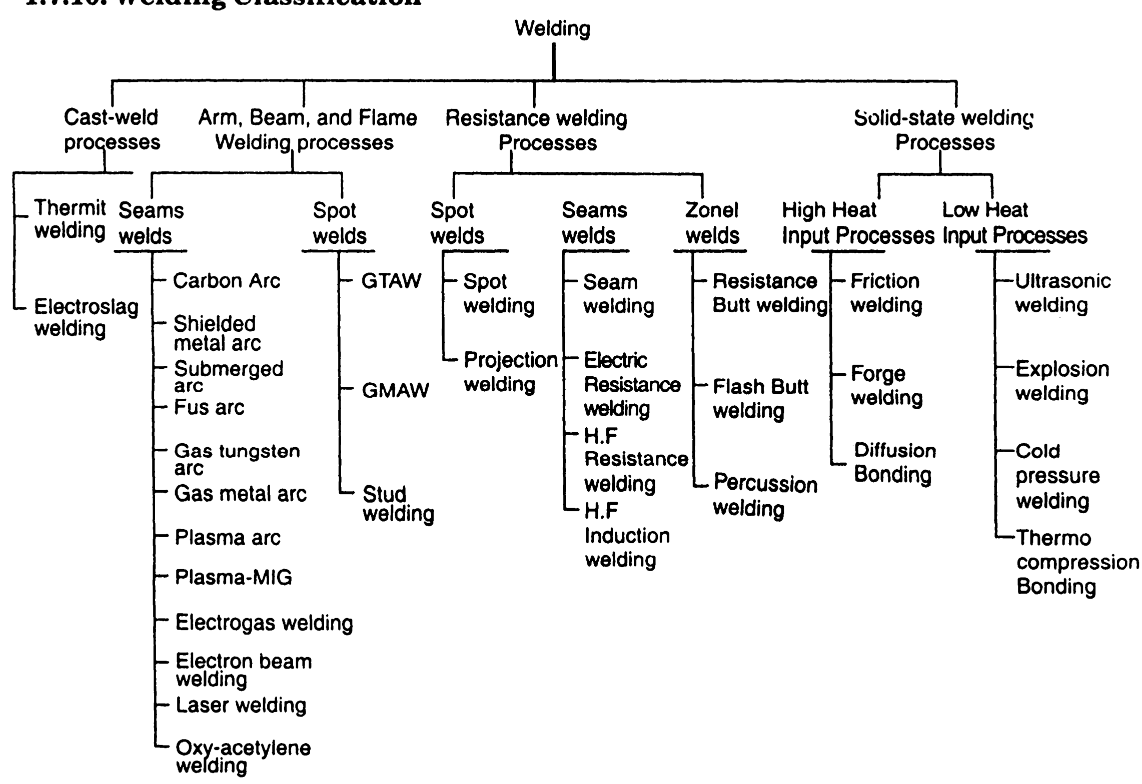
Table 1.7.6. Types of solders

Solder type	*Composition and use*
1. Hard solder	
(*i*) Brazing	Cu 4.9 to 81%, Zn the rest. To join steel parts
(*ii*) Copper brazing	Joining metal is copper wire. The wire is heated to 1159°C in the presence of hydrogen
(*iii*) Al solder	Molten metal is poured over the surface to be joined.
(*iv*) Silver solder	Cu 14 to 30%, Zn 9 to 20%, Ag 42 to 62%. Used for very strong joints in steel
2. Soft solder	Sn 33.3%, Pb 66.7%. For plumber's work. Paste for soldering material is made in NH_4 CL or $ZnCl_2$ solution.

1.7.9.1. Methods of jointing metals. Welding, soldering and brazing are some of the common methods of jointing metals.

1. *Welding*. Various types of welding are ;
   (*a*) Plastic. This type of welding is further divided into forge. resistance and
   (*b*) Fusion. This type is further divided into gas, electric arc and thermit
2. *Soldering*. It is the process of jointing metals by using an alloy which melts at comparatively low temperature.
3. *Brazing :* It is similar to soldering but is used for joints requiring higher strength by using higher strength filler.

1.7.10. Welding Classification



1.8. PLASTIC

1.8.1. Introduction. Plastics are resinous organic products based on synthetic or natural resins or their compounds of high molecular weight.

1.8.2. Advantages of plastics. The following advantages make the plastic suitable as building material.

(*i*) Smooth, neat and pleasing in appearance.
(*ii*) Available in a number of shades.
(*iii*) Can be readily drilled, punched or sawn.
(*iv*) Good insulator of heat and electricity.
(*v*) Maintenance free.
(*vi*) Considerably cheaper as compared to other materials.
(*vii*) Available in various degrees of strength.

Plastics are however unsuitable as load carrying members.

1.8.3. Classification of plastics

Nomenclature	*Characteristics*
(A) Thermosetting	
(*i*) Phenol Formaldehyde	Obtained by passing wood charcoal over heated platinum or copper. Extensively used in plywood, canvas and paper industry.
(*ii*) Phenol Furfuraldehyde	Obtained by the reaction of waste products. The plastic is black in colour but it can withstand high temp.
(*iii*) Urea Formaldehyde	Prepared by combination of ammonia gas and carbon dioxide. It is transparent and offers high resistance to electric current. Used for optical industry, lighting components, electric arc.
(*iv*) Cellulose	
(*a*) Cellulose Nitrate	Obtained by nitration of cotton with sulphuric acid and nitric acid. It is used for drawing board accessories, slide rules, fountain pens.
(*b*) Cellulose Acetate.	Made by immersing bleached and washed cotton lintels in a mixture of acetic acid and acetic anhydride in the oresence of H_2SO_4. The plastic is used for wire insulation and general insulator.
(B) Thermoplastics	
(*i*) Acrylic	Coal, petroleum, air and water are used in its production. Main properties of this plastic are : (*i*) Highly transparent (*ii*) Tougher and stronger than glass (*iii*) Does not shatter into pieces It is used in making surgical instruments, motor car and aeroplane industry, fountain pen industry.

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Nomenclature	*Characteristics*
(*ii*) Vinyl plastics	
(*a*) Poly vinyl	
Acetate (PVA)	Obtained by polymerisation of vinyl acetate. Used for insulation of wires, flooring, PVA sheets. It is also used for the following :
	1. Film making, 2. cloth industry, 3. Paper industry and 4. Paints.
(*b*) Poly Vinyl Chloride (PVC)	Obtained by polymerisation of vinyl chloride. It may be transparent or opaque. PVC sheets of 0.10 to 12.5 mm thickness are manufactured by calendering, extrusion or calendering followed by extrusion. The sheets are classified into four types as shown in Table 1.8.1.

Table 1.8.1. Sheet classification of PVC sheets

Type	*Softening point °C*	*Tensile strength N/mm²*	*Use*
(I)	75	45	General purpose
(II)	75	45	General purpose
(III)	65	38	High impact strength general purpose
(IV)	50	38	Suitable for deep draw vacuum forming

1.8.4. Products of plastics in civil engineering construction. The various uses of plastics in civil engineering construction are ;

(*i*) Plastic drainage pipes (*ii*) Plastic glazing (*iii*) Plastic laminates (*iv*) Plastic pipes (*v*) Plastic water proofing membrane.

1.9. INSULATING MATERIALS

It is seen that good insulator of heat is also good insulator of sound and electricity. Table 1.9.1 gives names and uses of some of the common insulating materials.

Table 1.9.1. Common insulating materials

Nomenclature	Use
(*i*) Cork rock wool	For rigid insulation
(*ii*) Foam slag aggregate	Honeycomb slag used for making light weight heat resistant blocks.
(*iii*) Aluminium foil	Used for packing medicine and chocolates
(*iv*) Asbestos	Extensively used for the following :
	1. Fire proofing material
	2. Joints of steam pipes
	3. Roofing sheets
	4. DPC course
	5. Corrugated sheets for various purposes

Contd...

Nomenclature	Use
	6. Corrugated fibre boards. These boards are extensively used for packing boxes on account of the following : • Excellent protection • Minimum storage space. • Low labour cost in fabrication • Suitable for inner and outer containers. IS : 2771-1965 has standardised the use of this material

1.10. GLASS

1.10.1. Manufacture of glass. When silica with some alkali (NaOH) or (KOH) along with calcium or lead oxide are melted in a furnace transparent material glass is formed. Common furnaces used in the manufacture of glass are ;

1. Pot furnace and 2. Tank furnace

Table 1.10.1. Types and uses of glass

Nomenclature	*Use*
1. Safety glass	Formed by joining two glass plates by plastic Provides safety
2. Perforated glass	Perforations permit circulation of air.
3. Wired glass	Wire acts as reinforcement
4. Vita glass	Permits transmission of ultraviolet rays used in hospitals.
5. Ribbed glass	Transmits light but maintains privacy
6. Pyrex glass	Resists heat
7. Anti. acitic glass	Obstructs heat without obstructing light
8. Perpex	Unbreakable. Used for roofing and slab work
9. Glass block	Provides insulation against heat and sound. Formed by joining two blocks with gap in between
10. Commercial sizes and uses of glass	See table 1.10.1 (*a*)

Table 1.10.1. (a) Commercial sizes and uses of glass

Nomenclature	*Use*
1. Sheet glass	
(*i*) Ordinary quality (OQ)	Used as glazing glass
(*ii*) Selected glazing (SQ)	Used for superior work
(*iii*) Special selected (SSQ)	High quality glazing work

Contd...

Nomenclature	*Use*
2. Plate glass (*i*) Ground glass (*ii*) Chipped glass (*iii*) Corrugated glass (*iv*) Figured or patented glass	Permit entry of light inside but at the same time afford privacy

1.10.3. Annealing glass. Annealing of glass is carried out by keeping the glass in the furnace and reducing the temperature gradually. Without annealing unequal shrinkage takes, which reduces the strength of the glass.

1.11. BITUMINOUS MATERIALS

Bitumen has been defined as "Mixture of hydrocarbons of natural or pyrogenous origin or combination of both. Table 1.11.1 gives the nomenclature and characteristics of various asphaltic materials.

Table 1.11.1. Nomenclature and characteristics of bituminous materials

Nomenclature	*Characteristics*
1. Asphalt	Bitumen found in natural state.
2. Road tar	Obtained by destructive distillation of organic matters (wood, shale). The residual material is termed pitch. It is foured with various quantities of tar to get various grades of tar.
3. Cutback bitumen	Asphaltic bitumen mixed with volatile material to improve workability. It is further classified as (*i*) Slow curing, (*ii*) Medium curing and (*iii*) Rapid curing
4. Emulsion	It is a mixture of two immiscible liquids. The emulsifying agent is soap or resin. Emulsions are classified as ; (*i*) Rapid setting (RS) (*ii*) Medium setting (MS) (*iii*) Slow setting (SS)

Tables 1.11.1. *a*, *b*, *c*, *d*, *e* give requirement of cut back bitumen.

Table 1.11.1 (a) Road tar and Emulsion

Sl No	*Characteristics*	*RC-D*	*RC-1*	*RC-2*	*RC-3*	*RC-4*	*RC-5*	*Remarks*
1.	Say bolt Furol Viscosity in Secs (*a*) 75°C (*b*) 50°C (*c*) 60°C (*d*) 82°C	 75 to 100 – – – –	 – 75-106 – –	 – – 75-150 –	 – – 250 to 500 –	 – – 125 to 250 ,,	 – – 300 to 600 ,,	Tests 3 and 4 are on residue from distillates
2.	Flash Point (min) °C	–	–	26.5	26.5	26.5	26.5	upto 360°C

Contd...

Sl No	*Characteristics*	*RC-D*	*RC-1*	*RC-2*	*RC-3*	*RC-4*	*RC-5*	*Remarks*
3.	Penetrational 25°C 109 m, 5 secs 1/100 cm	80-120	80-120	80-120	80-120	80-120	80-120	
4.	Ductility as – 25°C min	100	100	100	100	100	100	

Table 1.11.1. (*b*) Requirement of MC Cum back bitumen

Sl No.	*Characteristics*	*MC-0*	*MC-1*	*MC-2*	*MC-3*	*MC-4*	*MC-5*	*Remarks*
1.	Saybolt Furol Viscosity in secs (*a*) 25°C (*b*) 50°C (*c*) 60°C (*d*) 82°C	 75-100 – – –	 – 75-150 – –	 – – 100-200 –	 – – – 250-300	125-250	300-600	Tests 3 and 4 are on residue from distillates upto 360°C
2.	Flash point (min) in °C	38	38	65.5	65.5	65.5	65.5	
3.	Penetration at 25°C in 1/100 cm	120-300	120-300	120-300	120-300	120-300	120-300	
4.	Ductility at 25°C in cm (min)	100	100	100	100	100	100	

Table 1.11.1. (*c*) Requirement of SC cut back bitumen

Sl No	*Charac-teristics*	*SC-0*	*SC-1*	*SC-2*	*SC-3*	*SC-4*	*SC-5*	*Remarks*
1.	Say bolt Furol Viscosity in secs at (*a*) 25°C (*b*) 50°C (*c*) 60°C (*d*) 82°C	75-150 – – –	– 75-125 – –	– – 100-200 –	– – 250-500 –	– – – 125-500	– – – 300-600	Test 4 is on residue from distillate upto 360°C
2.	Water % by Vol (max)	0.5	0.5	–	–	–	–	
3.	Flash Point (min) °C	65.5	65.5	79.4	93.3	107	121	
4.	Ductility at 25°C in cm (min)	100	100	100	100	100	100	

Table 1.11.1. (*d*) Requirement of Road Tar

Sl No	*Characteristics*	*Limits of grade*				
		RT-1	*RT-2*	*RT-3*	*RT-4*	*RT-5*
1.	VISCOSITY (*i*) Temp of test °C (*ii*) Viscosity in Secs	35 30-50	40 30-55	45 35-60	55 40-60	
2.	Softening Point	-	-	-	-	45-60
3.	Softening Point of residue (Max) °C	48	50	52	54	56
4.	Water % by vol (Max)	0.5	0.5	0.5	0.5	0.5
5.	Sp. gr at 25°C	1.16 to 1.26	1.16 to 1.26	1.18 to 1.28	1.18 to 1.28	1.18 to 1.28

Table 1.11.1. (*e*) Requirements of Bitumen Emulsion

Sl No	*Characteristics*	*Rapid setting, (RS)*	*Medium setting, (MS)*	*Slow Setting, (SS)*
1.	Viscosity by standard Saybolt Furol Viscometer in secs at 25°C	20-100	20-100	20-100
2.	Water Content % by weigh	Not more than 45		
3.	Settlement, 5 days % (max)	3	3	3
4.	Cement mixing test % (max)	-	-	2
5.	Sieve test % Max	0.10	0.10	0.10

1.11.1 Applications of Bituminous Materials

Bitumen and tar binders find application for preparing asphaltum concretes, for manufacturing roof waterproofing and steam proofing materials and items, roof-waterproofing pastes, and for making roof coverings and waterproofing and road construction mastics and emulsions.

Bitumen emulsions (bitumen 5%, emulsifier content 0.01 to 5%) are used for making water and steam-proof coatings, priming surfaces in preparation for waterproofing glueing piece and coil materials and making the surfaces of items hydrophobic. Bitumen pastes are prepared from bitumen, water and emulsifiers. The latter are non-organic finely dispersed mineral powders, containing active colloidal particles smaller than 0.005 mm, which are added to water to produce pastes. Common emulsifiers are lime, clay and ground tripoli. Bitumen paste is employed to protect water-and steam-proofing coatings, to prime surfaces before they are insulated, to fill roof joints and to prepare cold mastics, in which it plays the part of a binder.

Mastics are used for roofing and waterproofing. Bituminous wall and sheet materials for roofing and waterproofing are widely employed in building practice. These are generally of the following two types: ones prepared by impregnating special card board with petroleum bitumens or tar compounds and subsequently coating it with a compound of higher melting temperature and a granular material (gravel or sand); ones fabricated by calendering thermally and mechanically processed mixtures of binders and additives into sheets of prescribed thickness.

Impregnated roll materials are subclassified by the kind of binder into bitumen, tar, tar-bitumen, petroleum asphalt and bitumen-polymer varieties. By structure, impregnated roll materials are subdivided into coated and non-coated types. Coated impregnated cardboard roll materials include roofing felt, tar paper, tar-bitumen and petroleum asphalt materials.

Roofing felt is a roll material prepared by impregnating roof cardboard with soft bitumen, subsequently coating it one or both sides with high-melting bitumen and finally facing it with finely-ground mineral powder, mica or coloured mineral granules. Roll roofing fibreglass cloth and felt are manufactured by combining fibreglass backing with bitumen, rubber-bitumen or bitumen-polymer films and coating them on one or both sides with a granular material. Fibreglass cloth and felt are laid on hot-or-cold-process mastics and used in multi-layer flat roofs, and as a glued-on-water-and steam-proofing material.

Asphalt reinforced mats are manufactured by coating impregnated fibreglass cloth on both sides with bitumen or waterproofing asphalt mastic. By the impregnating material and composition of the covering layer-asphalt reinforced mats are subdivided into common and high heat-resistant grades. Reinforced mats are manufactured 3.0-10.0 m long, up to 1 m wide and 4-6 mm thick. These are used for glued-on waterproofing jobs and for sealing expansion joints.

Some of the other applications of bitumen and asphalt are in the manufacture of piece waterproofing items such as waterproofing asphalt slabs, waterproofing stone and prefabricated concrete items.

Waterproofing asphalt slabs are manufactured by covering pre-impregnated fibreglass or metal mesh by a hot-process waterproofing mastic or sand asphalt concrete mastic or by press mouldinghot-process waterproofing asphalt mastic or sand asphalt concrete mastic or by press moulding hot-process waterproofing asphalt mastic or sand asphalt concrete mixture. Slabs are either reinforced or non-reinforced. Non-reinforced slabs are made 80-100 cm long, 50-60 cm wide and 1-2 cm thick, where as reinforced slabs are 100-120 cm long, 75-120 cm wide and 2-4 cm thick. These are used for glued-on waterproofing work and filling of deformation joint. They may be employed during the cold season.

Waterproofing stones are manufactured by impregnating artificial or natural porous materials (brick, concrete, tuff, opoka, chalk, limestone etc.) with bitumen or coal tar products to a depth of 10-15 mm. Stones should be waterproof. They are employed for making waterproof brickwork and lining with the use of cement and asphalt mortars.

Prefabricated waterproofing reinforced concrete items are manufactured by impregnating prefabricated reinforced concrete elements (piles, slabs, sections of pipes, tubings, etc.) with organic binders to a depth of 10-15 mm. These items are used for anticorrosion waterproofing ofinstallations exposed to simultaneous action of impact loads and mineralized water.

1.12. PAINTS AND VARNISHES

Table 1.12.1. Constituents of paint

Constituent	*Characteristics*
(*i*) Base	Iron oxide, titanium oxide, Lithophone, antimony white, zinc oxide, sublimed blue, red lead, sublimed white lead, lead sulphate, white lead
(*ii*) Vehicle	Material mixed with paint to help its spreading over. Oils used are ; Linseed oil, Nut oil, Poppy oil, Rosin oil, soya bean oil, China wood oil
(*iii*) Colouring matter	Red : Indian red, Venetian red, Burnt sienna Tuscan red, English vermillion, Cinnabar Black : Charcoal black, Bone black, Lamp black, Carbon black, Graphite Yellow : Chrome, Ochre, Zinc yellow Blue : Cobalt, Ultramarine, Prussian. Green : Verdigris, Chrome

Contd...

Constituent	*Characteristics*
(*iv*) Thinner	It provides additional workability. Turpentine, naphtha, and spirit.
(*v*) Drier	Added to hasten the process of drying. Commonly used driers are ; Red lead, Zinc sulphate, Massicot, Lithrage
(*vi*) Adulterant	Added to increase bulk of the paint. Silica, Magnesium silicate, Calcium Carbonate Barium sulphate

1.12.2. Painting new wooden surface. Before painting new wooden surface timber should be :

(I) *Seasoned* and

(II) *Preparing the surface :* Surface to be treated should be dried. Joining nails should be pushed below the surface of timber. Timber containing dead knots should not be used for painting. Other knots should be treated by application of two coats of ground red lead or by hot lime or by applying two coats of varnish.

1.12.3. Painting iron and steel work

- Clean the surface and free the same from rust and scales.
- Apply first coat using red lead or lead oxide.
- Apply subsequent coats when the previous coat has dried.

1.12.4. Covering Capacity of Paints. The covering capacity of paints depend upon their composition, surface to be covered etc. Still for a rough guideline, following may be taken as a general guide.

Type of paint	*Covering power in sq / metre / litre lead priming paint*
(*a*) On wood	9—11
(*b*) On metal	9—13
Other paints	
Glass paint	9—13
Enamel	9—13
Varnish first coat	11—13
Second coat	13—18
Water based paints and distempers	6—8

Paint holding properties of certain important timbers and recommended priming system is shown in Table 1.12.2.

Table 1.12.2

Wood	*Best primer*	*Paint holding properties*
Chir	Aluminium primer or pink primer.	Poor
Deodar	White lead/aluminium	Poor
Yaman	White lead primer	Intermediate
Mango	Pink/white lead	Intermediate
Sal	Pink/white lead	Intermediate
Shesham	White lead/pink primer	Good
Teak	White lead/pink primer	Good

1.12.5. Varnish. The use of varnish is limited to superior quality of timber whose fibre and timber give better appearance.

Table 1.12.3. (*a*) Commonly used paints

Trade name	*Composition*	*Characteristics*
All paint	Finely ground Al particles mixed in oil or spirit	Gives good shining appearance. Suitable for oil tank, gas tank and water tank
Cement paint	Cement mixed in paint	On brick or cement surface
Cellulose paint	Cellulose sheet, photo film or nitro cotton	Used in aeroplanes
Coal tar	Coal tar	Heated coal tar is used as protective coat for iron, steel or timber
Enamel	Zinc oxide is ground nicely and mixed with water	Costly but very durable

Table 1.12.3. (*b*) Commonly used varnish

Trade name	*Composition*	*Characteristics*
Copal varnish	Copal dissolved in linseed oil	High quality varnish
Oil varnish	Shellac	Available ready made
Spirit varnish	Resin dissolved in spirit	Provides good glossy surface
Distemper	Made by boiling chalk with red or yellow ochre, red soil etc. along with glue. Used in place of white or colour wash	Suitable for interior surfaces

1.13. MISCELLANEOUS DATA TABLES

Table 1.13.1. Characteristics of various materials

Nomenclature	*Characteristics*
1. Mica	A natural material, available in thickness of upto 0.006 mm. The white variety is largely used for electric insulation.
2. Bakelite	This resinous material was invented by Dr. Bakel and it is obtained in liquid form by heating phenol and formaldehyde in equal amounts. Solidifies on cooling. Various uses are ; Ceiling material, interior decorator, bearings for pumps, electric insulator.
3. Ebonite	Prepared from vulcanising rubber to which large % of sulphur is added and the mixture is heated. Extensively used as handles for electric equipment. It takes good polish.
4. Rubber	Obtained in liquid form from rubber trees. Extensively grown in India. The process of mixing sulphur with rubber is known as vulcanising. Synthetic rubber is prepared from acetylene gas and a number of patented types are available. Extensively used in building industry and tyres.
5. Graphite	Non crystalline form of carbon. Falls under the following categories : (*i*) *Non-crystalline type*. Used in paint industry as it is not affected by acid or alkali. (*ii*) *Flake type* Found in nature and is used in making fireproof material such as crucible. (*iii*) *Artificial type*. Obtained by heating non-crystalline type in electric furnace. Used for making electrodes.

Table 1.13.2. Classification of bricks based on compressive strength as per IS code

Class	*Average compressive strength not less than (N/mm^2)*
350	35.0
300	30.0
250	25.0
200	20.0
175	17.5
150	15.0
125	12.5
100	10.0
75	7.5
50	5.0
35	3.5

Notes: (*i*) The burnt clay bricks having compressive strength more than 40 N/mm^2 are known as heavy duty bricks and are used for heavy duty structures such as bridges, foundations for industrial buildings, multistory buildings, etc.
(*ii*) Each class of bricks as specified above is further divided into sub classes *A* and *B* based on tolerances and shape. Subclass-*A* bricks should have smooth rectangular faces with sharp corners and uniform colour. Subclass-*B* bricks may have slightly distorted and round edges.

	Subclass-A		*Subclass-B*	
	Dimension, cm	*Tolerance, mm*	*Dimension, cm*	*Tolerance, mm*
Length	380	± 12	380	± 30
Width	180	± 6	180	± 15
Height				
(*i*) 9 cm	180	± 6	180	± 15
(*ii*) 4 cm	80	± 3	80	± 6

Note: Water absorption of bricks above class 125 should be less than 15%.

Table 1.13.3. Performance requirements of acid-resistant bricks

Sl.No.	*Characteristic*	*Requirements*	
		Class I Bricks	*Class II Bricks*
(*i*)	Water absorption, percent, max	2	4
(*ii*)	Flexural strength, kgf/cm^2, min	100	70
(*iii*)	Compressive strengtn, kgf/cm^2, min	700	500

Contd...

Sl. No.	*Characteristic*	*Requirements*	
		Class I Bricks	*Class II Bricks*
(*iv*)	Resistance to acid	Loss in weight shall not exceed 1.5 percent	Loss in weight shall not exceed 4.0 percent
(*v*)	Resistance to wear (optional)	Average wear shall not exceed 2 mm	

Table 1.13.4. Classes of sand lime bricks

Class	*Average Compressive Strength kgf/cm²(N/mm²)*	
	Not less than	*Less than*
75	75 (7.5)	100 (10)
100	100 (10)	150 (15)
150	150 (15)	200 (20)
200	200 (20)	–

Table 1.13.5. Maximum drying shrinkage of sand lime bricks

Class	*Drying Shrinkage (Percent of Wet Length)*
75	0.025
100	0.025
150	0.035
200	–

Table 1.13.6. Physical Properties of Limestone Slabs

Sl.No.	*Characteristics*	*Requirements*
(*i*)	Water absorption	0.15 percent by weight
(*ii*)	Transverse strength	70 kgf/cm^2
(*iii*)	Durability	Shall not develop signs of spalling, disintegration of cracks

Table 1.13.7. Physical Properties of Marble, Slabs, Tiles and Blocks

Sl. No.	*Characteristics*	*Requirement*
(*i*)	Moisture absorption after 24 hours immersion in cold water	0.4 percent by weight, max
(*ii*)	Hardness (Mhos Scale)	3 min
(*iii*)	Specific gravity	2.5 min

Table 1.13.8. Properties of Granite

Sl.No.	*Property*	*Values*
1	Compressive strength	100 N/mm^2
2	Specific Gravity	2.6
3	Water Absorption	$\ngtr$ 0.5

Table 1.13.9. Physical Properties of Sandstone Slabs

Sl. No.	*Characteristic*	*Requirement*
(*i*)	Water absorption	Not more than 2.5 percent by mass
(*ii*)	Transverse strength	Not less than 7 N/mm^2 (70 kgf/cm^2)
(*iii*)	Resistance to wear	Not greater than 2 mm on the average and 2.5 mm for any individual specimen
(*v*)	Durability	Shall not develop sign of spalling, disintegration of cracks

Table 1.13.10. Water Absorption of stones by Volume

Sl.No.	*Type*	*Water absorption not greater than*
1.	Sandstone	10
2.	Limestone	10
3.	Granite	0.5
4.	Trap	6
5.	Shale	10
6.	Gneiss	1
7.	Slate	1
8.	Quartzite	3

Table 1.13.11. Limits on Coarse Aggregates for Mass Concrete

Class and Size	*IS Sieve Designation*	*Percentage Passing*
Very large, 160-80 mm	160 mm	90—100
	80 mm	0—10
Large, 80-40 mm	80 mm	90—100
	40 mm	0—10
Medium, 40-20 mm	40 mm	90—100
	20 mm	0—10
Small, 20-4.75 mm	20 mm	90—100
	4.75 mm	0—10
	2.36 mm	0—2

Table 1.13.12. Limits on Fine Aggregates - Grading in Zones I to IV

IS Sieve Designation	Percentage Passing for			
	Grading	*Grading*	*Grading*	*Grading*
	Zone I	*Zone II*	*Zone III*	*Zone IV*
10 mm	100	100	100	100
4.75 mm	90—100	90—100	90—100	95—100
2.36 mm	60—95	75—100	85—100	95—100
1.18 mm	30—70	55—90	75—100	90—100
600 micron	15—34	35—59	60—79	80—100
300 micron	5—20	8—30	12—40	15—50
150 micron	0—10	0—10	0—10	0—15

Table 1.13.13. Limits on All-in-Aggregates

IS Sieve Designation	*Percentage Passing for All-in-Aggregate of Nominal Size*	
	40 mm	20 mm
80 mm	100	—
40 mm	95—100	100
20 mm	45—75	95—100
4.75 mm	25—45	30—50
600 micron	8—30	10—35
150 micron	0—6	0—6

Table 1.13.14. Standard Sand For Testing of Cement

Sl. No.	*Sand*	*Percentage*
1.	Passing through 2 mm IS Sieve	100
2.	Retained on 90-micron IS Sieve	100
3.	Particle size greater than 1 mm	33.33
4.	Particle size smaller than 1 mm and greater than 500 microns	33.33
5.	Particle size below 500 microns	33.33

Table 1.13.15. Chemical Composition of Portland Cement

Oxide	*Function*	*Composition (%)*
CaO	Controls strength and soundness. Its deficiency reduces strength and setting time.	60—65
SiO_2	Gives strength. Excess of it causes slow setting.	17—25
Al_2O_3	Responsible for quick setting, if in excess, it lowers the strength.	3—8
Fe_2O_3	Gives colour and helps in fusion of different ingredients.	0.5—6
MgO	Imparts colour and hardness. If in excess, it causes cracks in mortar and concrete.	0.5—4
$Na_2O + K_2O$	These are residues, and if in excess it causes efflorescence and cracking.	0.5—1.3
TiO_2		0.1—0.4
P_2O_5		0.1—0.2
SO_3	Makes cement sound.	1-2

Notes: (*i*) The rate of setting of cement paste is controlled by regulating the ratio $SiO_2(Al_2O_3 + Fe_2O_3)$

(*ii*) Where development of much heat of hydration is undesirable, the silica content is increased to about 21 per cent, and the alumina and iron oxide contents are limited to 6 per cent each.

(*iii*) Resistance to the action of sulphate waters is increased by raising further the silica content to 24 per cent and reducing the alumina and iron contents to 4 per cent each.

(*iv*) Small percentage of iron oxide renders the highly siliceous raw materials easier to burn. However, if these are in excess, a hard clinker, difficult to ground, is produced. When iron oxide combines with lime and alumina to form C_4AF, it neutralizes some of the undesirable properties contributed by alumina when combined with lime alone. When iron oxide combines with lime alone, it promotes instability.

(*v*) The alkalis accelerate the setting of cement paste.

Table 1.13.16. Minimum Specific Surfaces of Cements

Type of cement	*Specific surface not less than* $10^2 \times mm^2/g$
Ordinary Portland Cement (OPC)	2250
Rapid Hardening Cement (RHC)	3250
Low Heat Cement (LHC)	3250
Porland Puzzolana Cement (PPC)	3000
High Alumina Cement (HAC)	2250
Super Sulphate Cement (SSC)	4000

Table 1.13.17. Minimum Specified Strength of cement in N/mm^2

Type / Days	*1 day*	*3 days*	*7 days*	*28 days*
Ordinary Portland Cement	–	16.0	22.0	31.0
Portland Puzzolana Cement	–	–	22.0	31.0
Low Heat Portland Cement	16.0	27.5	–	–
Rapid Hardening Cement	–	–	22.0	31.0
High Alumina Cement	30.0	35.0	–	–

Table 1.13.18. Classification of Aggregate Based on Unit Weight

Aggregate	*Sp.gr*	*Unit weight (kN/m^3)*	*Examples*
Normal-weight	2.5—2.7	23—26	Sand, gravel, granite, sandstone, limestone
Heavy-weight	2.8—2.9	25—29	Magnetite (Fe_3C_4) Baryte (Ba_3SO_4), scrap iron
Light-weight		12	Dolomite, pumice, cinder, clay

Table 1.13.19. Tolerance Concentration of Impurities in Mixing Water

Sl. No.	*Impurity*	*Tolerable Concentration*
1	Silt and suspended particles	2,000 ppm
2 (*i*)	Carbonates and bicarbonates of Na or K	1,000 ppm
(*ii*)	Bilcarbonates of Mg	400 ppm
3	Chlorides	10,000 ppm
4	Sulphates	20,000 ppm
5	Sulphuric anhydride	3,000 ppm
6	Calcium chloride	2 per cent by weight of cement
7	Sodium sulphide	< 100 ppm
8	Sodium hydorxide	0.5 per cent by weight of cement provided quick set is not induced
9	Dissolved salts	15,000 ppm
10	Organic matter	3,000 ppm
11	pH	6—8
12	Iron salts	40,000 ppm
13	Acids (HCl, H_2SO_4)	10,000 ppm
14	Sugar	500 ppm

Table 1.13.20. Relative Strength of Prisms with Different Height to Depth Ratio

Height/side ratio	0.5	1.0	2.0	3.0	4.0	5.5
Relative strength	1.5	1.0	0.8	0.72	0.68	0.6

Table 1.13.21. Requirements of Lime-pozzolana Mixtures

Sl. No.	*Characteristic*	*Requirements*		
		Type LP40	*Type LP20*	*Type LP7*
(*i*)	Free moisture, percent, max	5	5	5
(*ii*)	Loss on ignition, percent, max	20	20	20
(*iii*)	Fineness, percent, retained on 150-micron IS Sieve	10	10	–
(*iv*)	Setting time (by Vicat apparatus), hours:			
	(*a*) Initial, min	2	2	2
	(*b*) Final, max	24	36	48
(*v*)	Compressive strength: Average compressive strength of not less than 3 mortar cubes of size 50 mm composed of one part of lime-pozzolana mixture and 3 parts of standard sand by volume, kgf/cm^2			
	(*a*) 7 days, min	20	10	3
	(*b*) 28 days, min	40	20	7
(*vi*)	Water retention-flow after suction of mortar composed of one part of lime-pozzolana mixture and 3 parts of standard sand by volume, percent of original flow, min	70	70	70

Table 1.13.22. Chemical Requirements of Lime

Sl. No.	*Type of Test*	*Requirements*							
		Class A	*Class B*		*Class C*		*Class D*		*Class E*
		Hydrated	*Quick*	*Hydrated*	*Quick*	*Hydrated*	*Quick*	*Hydrated*	*Hydrated*
1	Calcium and magnesium oxides, percent, min	60	70	70	85	85	85	85	25
2	Magnesium oxide, percent:								
	max	5	5	5	5	5	–	–	5
	min	–	–	–	–	–	5	5	–
3	Silica, alumina and ferric oxide, percent, min	25	15	15	–	–	–	–	–
4	Unhydrated oxides, percent, max	–	–	–	–	–	8	8	–
5	Insoluble residue in hydrochloric acid less the silica, percent, max	2	3	2	–	–	–	–	–
6	Insoluble matter in sodium carbonate sloution, percent, max	5	5	5	5	5	5	5	5
7	Loss on ignition, percent, max	–	5 for large lump, 7 for lime other than large lump	–	5 for large lump, 7 for lime other than large lump	–	5 for large lump, 7 for lime other than large lump	–	5
8	Carbon dioxide, percent, max	5	5	5	5	5	5	5	–
9	Cementation value								
	min	0.6	0.3	0.3	–	–	–	–	–
	max	–	0.6	0.6	–	–	–	–	–

Table 1.13.23. Physical Requirements of Lime

Sl.No.	Type of Test	*Requirements*							
		Class A	*Class B*		*Class C*		*Class D*		*Class E*
		Hydrated	*Quick*	*Hydrated*	*Quick*	*Hydrated*	*Quick*	*Hydrated*	*Hydrated*
1	Fineness	Shall leave no residue on 2.36-mm IS Sieve, not more than 5 percent on 850 micron IS Sieve and the fraction passing through 850-micron IS Sieve shall leave not more than 10 percent (of this fraction) on 300-micron IS Sieve	—	Shall leave no residue on 2.36-mm IS Sieve, not more than 5 percent on 850-micron IS Sieve and the fraction passing through 850-micron IS Seive shall leave not more than 10 percent (of this fraction) on 300-micron IS Sieve	—	Shall leave no residue on 850-micron IS Sieve, not more than 5 percent on 300-micron IS Sieve and the fraction passing through 300-micron IS Seive shall leave not more than 10 percent (of this fraction) on 212-micron IS Sieve	—	Shall leave no residue on 850-micron IS Sieve, not more than 5 percent on 300-micron IS Sieve and the fraction passing through 300-micron IS Seive shall leave not more than 10 percent (of this fraction) on 212-micron IS Sieve	Shall leave no residue on 2.36-mm IS Sieve, not more than 5 percent on 850-micron IS Sieve and the fraction passing through 850-micron IS Seive shall leave not more than 10 percent (of this fraction) on 300-micron IS Sieve
2	Residue on slaking (on the basis of quick lime taken), Maxmm percent, by weight	—	10 on 850-micron IS Sieve	—	5 on 850-micron IS Sieve, the fraction passing through this Sieve when further passed through 300-micron IS Sieve shall leave residue 5	—	5 on 850-micron IS Sieve, the fraction passing through this Sieve when further passed through 300-micron IS Sieve shall leave residue 5	—	—
3	Setting time	In the putty of standard consistency, initial set shall take place in not less than 2 hours and final set within 48 hours	—	—	—	—	—	—	In the putty of standard consistency, initial set shall take place in not less than 2 hours and final set within 48 hours
4	Compressive strength, Min	17.5 after 28 days shall	however, show an increase over that at 14 days	—	12.5 kgf/cm^2 after 14 days and 17.5 kgf/cm^2 at 28 days shall, however, show an increase over that at 14 days	—	—	—	10.5 *kgf/cm*^{2} after 28 days shall, however,,show and increase over that at 14 days
5	Transverse strength	Modulus of rupture not less than 7.0 kgf/cm^2 at 28 days	—	Modulus of rupture not less than 7.0 kgf/cm^2 at 28 days	—	—	—	—	Modulus of rupture not less than 7.0 kgf/cm^2 at 28 days

Contd...

Sl.No.	*Type of Test*	*Requirements*							
		Class A	*Class B*		*Class C*		*Class D*		*Class E*
		Hydrated	*Quick*	*Hydrated*	*Quick*	*Hydrated*	*Quick*	*Hydrated*	*Hydrated*
6	Workab-ility	—	—	—	Shall require not less than 12 bumps to attain an average spread of 19 cm from an initial spread of 11 cm on the flow table	Shall require not less than 10 bumps to attain an average spread of 19 cm from an initial spread of 11 cm on the flow table	Shall require not less than 12 bumps to attain an average spread of 19 cm from an initial spread of 11 cm on the flow table	Shall require not less than to bumps to attain an average spread of 19 cm from an intial spread of 11 cm on the flow table	—
7	Volume yield	—	—	—	1.7 ml per g or as agreed to be-tween the puchaser and the supplier	—	1.4 ml per g or as agreed to be-tween the pur-chaser and the supplier	—	
8	Soundness	The Le Chatelier moulds shall not exhibit more than 10 mm expansion	—	The Le Chatelier moulds shall not exhibit more than 10 mm ex-pansion	—	—	—	—	The Le Chatelier moulds shall not exhibit more than 10 mm expansion
9	Popping and pitting	—	—	—	—	Shall not exhibit any disintegration popping or pitting on the surface	—	Shall not ex-hibit any disin-tegration popping or pit-ting on the sur-face	—

Table 1.13.24. Physical Requirements of Resin Type Chemical Resistant Mortars

Sl. No.	Particulars	Requirements For Type of Mortar			
		Phenolic Type	Furane Type	Epoxy Type	Polyester Type
(i)	Working time at 27 ± 2°C, min, minutes	20	20	20	20
(ii)	Flexural strength at 7 days, min, kgf/cm^2	75	75	150	150
(iii)	Compressive strength at 7 days, min, kgf/cm^2	350	350	500	500
(iv)	Bond strength, min, kgf/cm^2	10	10	12	12
(v)	Absorption, max, percent by weight	1	1	1	1

Note: — In the test for bond strength the joint shall not fail at or below the value specified.

Table 1.13.25. Physical Requirements of Sulphur Type Chemical Resistant Mortars

Sl.No.	Property	Requirement
(i)	Compressive strength at 48 hours, min, kgf/cm^2	280
(ii)	Tensile strength at 48 hours, min, kgf/cm^2	30
(iii)	Flexural strength at 48 hours, min, kgf/cm^2	70
(iv)	Bond strength at 48 hours, min, kgf/cm^2	10
(v)	Proportion of original strength retained after thermal shock test, min, percent	20
(vi)	Moisture absorption, max, percent	1.0
(vii)	Tendency of aggregate to settle, max, variation from unity	0.6

Table 1.13.26. Mechanical Properties of Mild Steel Wires

Condition	Tensile Strength, MPa	
	Finishes other than Galvanized	Galvanized
Annealed	500 Max	300—550
Soft drawn	550 Max	–
1/4 hard	450—650	–
1/2 hard	600—800	–
Hard	700—950	550—900
1 MPa = 1 N/mm^2 = 1 MN/m^2 = 0.1020 kgf/mm^2		

Table 1.13.27. Physical Properties of Mild Steel Wires

Characteristic	Fe 415	Fe 500
0.2 percent proof stress, min N/mm^2	415.0	500.0
Elongation, percentage, min (on gauge length on 5.65 A, where A is the cross sectional area)	14.5	12.0

Table 1.13.28. Chemical Composition of Mild Steel Wires

Constituent	*Percentage Max*	
	Fe 415	Fe 500
Carbon	0.25	0.30
Sulphur	0.055	0.050
Phosphorus	0.055	0.050

Table 1.13.29. Physical Requirements of High Tensile Steel Bars Used in Prestressed concrete

Sl.No.	*Property*	*Value*
1	Tensile Strength	1000 N/mm^2
2	Proof stress	80—90% of ultimate strength
3	Elongation of rupture	min. 10%
4	Young's Modulus	1.6×10^5 to 2.1×10^5 N/mm^2
5	Relaxation	$\ngtr 50$ N/mm^2 at the end of 1000 hours

Table 1.13.30. Mechanical Properties of Structures Steel (Standard Quality)

Class	*Thickness / Diameter mm*	*Tensile Strength kgf/mm^2*	*Yield Stress min kgf/mm^2*	*Percentage Elongation min*
Plates, flats, angles, tees, beams, channels, etc	Below 6	Bend test only shall be required		
	6 to 20	42—54	26	23
	Over 20 up to 40	42—54	24	23
	Over 40	42—54	23	23
Bars (round, square and hexagonal)	Below 10	Bend test only shall be required		
	10 to 20	42—54	26	23
	Over 20	42—54	24	23

Notes: 1. 1 N/mm^2 = 1 MN/m^2 = 0.102 kgf/mm^2.

2. Provided that the yield stress and elongation requirements are complied with, the upper limit for tensile strength may be raised by 3 kgf/mm^2.
3. If agreed to mutually, the material with thickness below 6 mm may be supplied with tensile property requirements.
4. Weight 7.85 g/cm^3

Table 1.13.31. Chemical Composition of Structural Steel (Standard Quality)

Constituent	*Percent, Max*
Carbon (for thickness/diameter 20 mm and below)	0.23
Carbon (for thickness/diameter over 20 mm)	0.25
Sulphur	0.055
Phosphorus	0.055

Note: When steel is required in copper-bearing quality, the copper content shall be between 0.20 and 0.35 percent.

Table 1.13.32. Mechanical Properties of Structural Steel (High Tensile)

Nominal Thickness Diameter	*Tensile Strength, Min*				*Yield Stress, Min*	
	St 58-HT (*kgf/mm*^{2})		*St 55-HTw* (*kgf/mm*^{2})		*St 58-HT* (*kgf/mm*^{2})	*St 55-HTw* (*kgf/mm*^{2})
Below 6	Bend test only shall be required					
6 to 28	58		–		36	–
Over 28 up to 45	58		–		35	–
Over 45 up to 63	58		–		33	–
6 to 16	–		55		–	36
Over 16 up to 32	–		55		–	35
Over 32 up to 63	–		52		–	34
Over 63	55		50		30	29
Percentage elongation : 20 Percent, min						

Note: Weight 7.85 g/cm^3

Table 1.13.33. Mechanical Porperties of Structural Steel (Ordinary Quality)

Steel Designation	*Product*	*Thickness / Diameter (mm)*	*Tensile Strength* (*kgf/mm*^{2})	*Yield Stress Min* (*kgf/mm*^{2})	*Elongation Percent Min*
Fe 310—0	Plates, angles, flats, tees, beams, etc	Below 6	Bend test only shall be required		
		6 and above	32 to 44	–	26
	Bars	Below 10	Bend test only shall be required		
		10 and above	32 to 44	–	26
Fe 410—0	Plates, flats, angles, tees, channels, beams	Below 6	Bend test only shall be required		
		6 up to 20	42 to 54	26	23
		Over 20 up to 40	42 to 54	24	23
		Over 40	42 to 54	23	23
	Bars	Below 10	Bend test only shall be required		
		10 up to 20	42 to 54	26	23
		Over 20	42 to 54	24	23

Notes: 1 — In/mm^2 = 1 MN/m^2 = 0.102 kgf/m^2

2. Provided that the yield stress and elongation requirements are complied with, the upper limit for tensile strength may be raised by 3 kgf/mm^2.
3. Weight - 7.85 g/cm^3

Table 1.13.34. Requirements For Paving Bitumen

Sl. No	*Characteristic*	*Requirement For Grades*					
		A25	*A35* *S35*	*A45* *S45*	*A65* *S65*	*A90* *S90*	*A200* *S200*
1	Specific gravity at 27°C, min	0.99	0.99	0.99	0.99	0.98	0.97
2	Water, percent by weight, max	0.2	0.2	0.2	0.2	0.2	0.2
3	Flash point, Pensky Martens Closed Type, °C, Min	175	175	175	175	175	175
4	Softening point, °C	55 to 70	55 to 70	45 to 60	45 to 60	35 to 50	30 to 45
5	Penetration, at 25°C 100 g, 5 seconds in 1/100 cm	20 to 30	30 to 40	40 to 50	60 to 70	80 to 100	175 to 225
6	Ductility, at 27°C cm, Min	5	10 (50)	12 (75)	15 (75)	15 (75)	15 (No value given)
7	(*a*) Loss on heating, percent by weight, Max	1	1	1	1	1	2
	(*b*) Penetration of residue [expressed as percentage of item (5)], Min	60	60	60	60	60	60
8	Matter soluble in carbon disulphide, percent by weight, Min	99	99	99	99	99	99

Note: - Wherever two values are given, the values given in bracket shall be applicable to Type S bitumen and other applicable to Type A bitumen. All other values are applicable to both Types A and S bitumen.

Table 1.13.35. Requirements For Coal Tar Pitch

Sl.No.	*Characteristic*	*Requirement For Grades*			
		Soft Pitch	*Soft Medium Pitch*	*Hard Medium Pitch*	*Hard Pitch*
1	Specific gravity at 27°C	1.20 to 1.30	1.22 to 1.32	1.22 to 1.32	1.28 to 1.38
2	Softening point	45 to 55°C	58 to 68°C	70 to 80°C	82 to 92°C
3	Distillate:				
	Percent by weight below 270°C, max	4	4	3	No Test
	Percent by weight below 300°C, max	8	8	4	No Test
4	Matter insoluble in toluene (free carbon), percent by weight, max	25	28	30	35
5	Ash, percent by weight, max	0.5	0.5	0.75	0.8

Table 1.13.36 Requirements For Creosote And Anthracene Oil

Sl. No.	Characteristic	Requirements		
		Creosote Type I	Creosote Type II	Anthracene Oil
1	Specific gravity, 38/38°C	1.03 to 1.10	1.03 to 1.10	1.09 to 1.15
2	Water content, percent by volume, max	2.0	2.0	2.0
3	Matter insoluble in benzene, percent by weight, max	0.50	0.50	0.50
4	Distillation fractions, percent by weight (per 100 g), distilling up to			
	(a) 210°C, max	5	2	–
	(b) 235°C, max	30	10	2
	(c) 315°C, max	75	55	40
	(d) 355°C, min	–	–	45
5	Specific gravity of distillation fractions, 38/38°C, min			
	(a) Fraction between 235 and 315°C	–	–	1.025
	(b) Fraction between 315 and 355°C			1.085

Table 1.13.37. Requirements of Industrial Bitumen

Sl.No.	Characteristic	Limit For Grade									
		75/15	65/25	75/30	85/25	85/40	90/15	105/20	115/15	135/10	155/6
1	Specific gravity at 27°C	1.00 to 1.05	1.00 to 1.05	1.00 to 1.05	1.00 to 1.05	1.00 to 1.05	1.01 to 1.06	1.01 to 1.06	1.01 to 1.06	1.02 to 1.07	1.02 to 1.07
2	Flash point, Pensky Martens Closed Type, °C, min	200	200	200	200	200	200	200	200	200	200
3	Softening point, °C	65 to 80	55 to 70	70 to 80	80 to 90	80 to 90	85 to 100	95 to 115	110 to 120	130 to 140	150 to 160
4	Penetration, at 25°C, 100 g 5 seconds in 1/100 cm	10 to 20	20 to 30	25 to 35	20 to 30	35 to 45	10 to 20	15 to 25	8 to 20	7 to 12	2 to 10
5	Ductility, at 27°C, in cm, Min	2.5	10	3	3	3	2	2	2	1	0
6	Loss on heating, percent by weight, max	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
7	Matter soluble in carbon disulphide, percent by weight, min	99	99	99	99	99	99	99	99	99	99

Note: Grades- Industrial bitumen either fully blown or semiblown shall be of the following ten grades:

75/15	90/15
65/25	105/20
75/30	115/15
85/25	135/10
85/40	155/6

Note - The two figures given in the grades denote approximate values of softening point and penetration in that order; for example, 85/25 means that industrial bitumen corresponding to this grade has approximately a softening point of 85°C and a penetration of 25.

Table 1.13.38. Weight of Engineering Materials

Alum.	1,696 gm/cum
Aluminium sheets per mm thickness	2.8 kg/cum
Asbestos flat sheets 6 mm thickness	12.21 kg/sqm
Asbestos Corrogated or traford sheets 6 mm thickness	17.09 kg/sqm
Ashes, cinder	740 kg/sqm
Asphalt	2,200 kg/cum
Bitumen	1,040 kg/cum
Brass	8,550 kg/cum
Bel metal	8,720 kg/cum
Bricks clay kiln burt 1st. class	1,760 kg/cum
Ballast (brick)	1,200 kg/cum
Masonry (brick)	1,920 kg/cum
Cement ordinary aluminous	1,440 kg/cum
Chalk	1,938 kg/cum
Stone chips	2,420 kg/cum
Hollow blocks (25 mm thick)	2,563 kg/cum
Clay dry lump	1,040 kg/cum
Copper sheet per mm thickness	8.69 kg/sqm
Fire brick	2,083 kg/cum
Fire clay	2,,243 kg/cum
Glass common	2,530 kg/cum
Lead	11,374 kg/cum
Lead sheet per mm thickness	11 kg/sqm
Leather	897 kg/cum
Lime stone	1,360 kg/cum
Unslaked lime	960 kg/cum
Slaked lime	640 kg/cum
Concrete with brick ballast	1,920 kg/cum
Mortar cement	2,080 kg/cum
Mortar lime	1,760 kg/cum
Mortar gypsum	1,200 kg/cum
Sand dry coarse	1,600 kg/cum
Sand wet coarse	1,900 kg/cum
Sand wet River	2,000 kg/cum
Sand wet River	1,840 kg/cum
Stone	2,515 kg/cum
Shale	2,595 kg/cum

Contd...

Shellac gum	509 kg/cum
Steel cast	7,850 kg/cum
Steel mild	7,850 kg/cum
Steel hard	7,810 kg/cum
Corrogated steel sheets, galvanised :	
16 gauge	16,405 kg/sqm
18 gauge	13,085 kg/sqm
20 gauge	10,204 kg/sqm
22 gauge	8,398 kg/sqm
24 gauge	6,933 kg/sqm
Stone, Basalt	2,850 - 2,960 kg/cum
Stone, Granite	2,640 - 2,800 kg/cum
Stone, Laterite	2,080 - 2,400 kg/cum
Lime stone	2,400 - 2,640 kg/cum
Marble	2,620 kg/cum
Marble chips	1,802 kg/cum
Quartz rock	2,640 kg/cum
Sand stone	2,240 - 2,,400 kg/cum
Slate	2,800 kg/cum
Stone metal or chips	1,600 - 1,920 kg/cum
Snow	0,096 kg/cum
Soap stone	2,643 kg/cum
Rubble stone masonry	2,080 kg/cum
Ashlar stone masonry	2,640 kg/cum
Marble dressed	2,700 kg/cum
Coal Tar	1,121 kg/cum
Pitch	1,281 kg/cum
Terra cota (solid)	2,080 kg/cum
Country tile	63,354 kg/sqm
Timber Hard wood	640 - 960 kg/cum
Timber Light wood	400 - 480 kg/cum
Timber Medium wood	480 - 640 kg/cum
Fresh water	1,000 kg/cum
Sea water	1,025 kg/cum