12

Building Mortars

12.1 INTRODUCTION

Building mortars are mixtures used for the jointing of bricks, stones, blocks, etc. Mortar may be defined as a paste (capable of setting and hardening) obtained by adding water to a mixture of fine aggregates such as sand and binding material, e.g., clay, gypsum, lime or cement or their combinations. The pyramids of Egypt have been built with clay-gypsum, gypsum-lime and lime mortars. Indians have used lime mortar for monumental structures such as Taj Mahal and forts. In the years that followed, if was found that burning limestone with clayey substance produced hydraulic lime of high water-resistant properties. Lime with a still higher content of clay led to the manufacture of Roman cement. In 1824 Portland cement appeared; today it is considered to be the strongest binding material for making mortar.

The mortar composition is designed by the volume or weight of material in 1 m^3 of mortar or by the relative amount of materials with the amount of binding material taken as unity. For simple mortars composed of one kind of binding material and containing no mineral admixtures (e.g., cement mortar), the composition will be designated, say 1:4, i.e., one part (by weight or volume) of binding material (cement) and 4 parts of sand. Combined mortar composed of two binding materials or combined mineral admixtures are identified by three figures, e.g., 1:0.4:5 (cement: clay: sand). Some of the important uses of mortars are as follows:

1. In brick and stone masonry—it is used in the vertical joints and is spread over each layer to give bed and a binding medium for successive layers of masonry.

2. In plastering and pointing—to cover exposed walls and joints to protect against weathering besides better appearance.
3. As matrix in concrete.

12.2 CLASSIFICATION

Mortars are classified on the basis of their bulk density, kind of binding material, applications and ,physical and mechanical properties.

On the Basis of Bulk Density

Type of Mortar	Bulk Density (kg/m^3)	Aggregate
Heavy weight	>1500	Heavy quartz or sand
Light weight	<1500	Light porous sand from pumice, tuffa, slags, etc.

On the Basis of Binding Material

The governing factors in deciding a particular type of mortar for a specific structure depends upon the desired strength of masonry, resistance to penetration of rain water, immediate and long term appearance, hardening temperature, expected working conditions of the building and cost.

For most practical purposes a building mortar will fall in one of the following classes:

Cement Mortars are prepared from Portland cement or its varieties, sand and water.

Lime Mortars are mixture of air hardening lime or hydraulic lime, sand and water.

Gypsum Mortars are prepared from gypsums or anhydride binding materials.

Mud Mortars are prepared from clay nodules and are used in construction of houses for poor and temporary construction works.

Composite Mortars may be surkhi-motar (surkhi, lime and water), lime-surkhi-sand mortar, cement-lime mortar and cement-clay mortar.

On the Basis of Application

Brick Laying Motars are intended for brick work.

Finishing Mortars are intendend for architectural or ornamental parts , application of decorative layers on walls and panels.

Special Mortars are intended for acoustics, X-ray shielding, plugging concrete at oil fields, etc.

On the Basis of Physical and Mechanical Properties

The basis of this classification is the strength of concrete which underlies the durability of concrete. Building mortars are subdivided into nine grades on the basis of compressive strength from 0.4 to 30.0N/mm^2.

12.3 CHARACTERISTICS OF GOOD MORTAR

The chief properties of hardened mortar are strength, development of good bond with building units, resistance to weathering and those of green mortar mixes are mobility, placability and water retention. In addition, the mortar should be cheap and durable and should not affect the durability of building units in contact. The joints made with mortar should not develop cracks.

Strength

The strength of masonry depends upon both the mortar and the building unit (brick, stone or block). A very strong mortar with weak building units will be of little use. It is also important to consider whether full strength is required within a short time. In cold weather, when the strength of lime or cement mixes develops slowly, this is likely to affect the choice of mix. Strong cement mortars are most likely to lead to shrinkage cracks, and should, therefore be avoided except where high strength is an essential requirement. On the other hand the use of much weaker mortar say, 1:10 cement mortar is not satisfactory since reduction in cement content leads to less workability, less cohesion and will produce porous joints of low frost resistance. Strength of hardened mortar depends on the activity of binding materials, the water-cement ratio, consumption of binding material and the quality of sand. It has been found that:

1. The density and strength of mortars made of the same class of aggregate decrease as the proportion of fine aggregate is increased.
2. It requires about twice as much cement to produce a mortar of given strength when fine sand is used as it does with coarse sand.
3. When the percentage of mixing water is increased beyond that required to form a placeable mix, the density and strength of mortar reduces. The proportionate effect is greatest at the early ages.
4. Even small percentage of mica if present considerably lowers the tensile strength and adversely affects the compressive strength.
5. There is a loss of compressive strength by the replacement of less than 25 per cent of cement by hydrated lime.
6. Cement lime mortars are helpful in autogenous healing of cracks.

Resistance to Penetration of rain

The mortar for plastering should protect the masonry joints and units by forming an impermeable sheet. A satisfactory bond between the building units, mortar and plaster should be ensured.

Mobility and Placeability

The term mobility is used to indicate the consistency of mortar. The placeability is the ease with which the mortar mix can be applied with a minimum cost in a thin and uniform layer on the surface. Depending on its composition a mortar may have a consistency ranging from stiff to fluid. Mortars for masonry, finishes and other works are made sufficiently mobile. The mobility of mortar mix determines its placability. Mortars prepared from Portland cement alone are frequently deficient in cement paste, stiff and non-placeable and often plasticizers are added.

Water Retention

It is characterized by the ability of mortar not to stratify during transportation and to retain adequate humidity in a thin layer spread over a porous bed. A mortar mix of low water retention will show the defects after hardening. Mortar may lose so much water that the amount left may be insufficient for its hardening and required strength. Mineral and organic plasticizing agents may be added to enhance water retention.

12.4 FUNCTIONS OF INGREDIENTS

Cement, lime and clay used as binding materials impart adhesive power and strength.

Sand is an adultrant, but increases the crushing strength of mortar and reduces shrinkage. When used in lime mortar, it assists the hardening of fat lime by allowing air to penetrate providing carbon dioxide for carbonisation.

Surkhi is used for economy and for furnishing hydraulic properties to lime mortar.

Flyash and cinders are used in lime mortar as fine aggregate in place of surkhi.

Molasses or gur is mixed with fat lime mortar; solubility of lime is increased and it readily crystallises. Consequently the mortar solidifies easily. One part of molasses is used with 80 parts by weight of water used for mixing the fat lime.

Water in mortar lubricates the surfaces of aggregate, spreads the binding material uniformly so that it can fill the pores in the fine aggregate and cause hydration of cement and hydraulic lime. The pH value of water used should not be less than 6.

12.5 CEMENT MORTAR

Cement mortar can be prepared by mixing cement, sand and water in desired proportions. Portland cement and blast furnace slag cement form excellent mortars for walls built with bricks, stones and large blocks. Puzzolana Portland cement and sulphate-resisting cement form mortar which are used for constructions exposed to aggressive and waste waters. Cement mortars are used for plastering, rendering smooth finishes and damp proof courses.

The mix proportions of cement mortar are given in Table 12.1.

Table 12.1 Mix Proportions

S.No.	*Type of Work*		*Cement*	*Sand*
1.	Masonry		1	4-5
2.	Plastering	(a) Interior	1	4
		(b) Exterior	1	5-6
3.	Pointing		1	1-3
4.	Reinforced brick work		1	3
5.	Foundation		1	3-4

Preparation Small quantities of mortar are mixed manually; mechanical mixers may be used for large quantities.

For *manual mixing*, sand is sieved, cleaned with water to remove dirt and dust and dried. This dry sand is laid uniformly, on a pucca platform, over which cement is uniformly spread. The whole mass is then thoroughly mixed with spades till it becomes uniform in colour. A depression is then made in the middle of the mix and required quantity of water is added. The dry mix from the sides is moved and placed on the edges of the depression formed till the water is completely absorbed by the mix. The wet mix is then worked with spades to give a uniform consistency to the mortar.

For *mechanical mixing* the calculated quantity of cement, sand and water are fed into the cylindrical container of the mixer. A rotar with blades, inside the container, rotates and thoroughly mixes the ingredients. A typical Turbulent mixer is shown in Fig.12.1.

Precautions Cement mortar should be of uniform and workable consistency. It should be consumed within 30 minutes from the instant of adding water to the mix. The bricks, stones and blocks should be fully saturated in water before laying. The masonry and plastered or pointed surface should be kept completely wet by sprinkling water for at least 7 days.

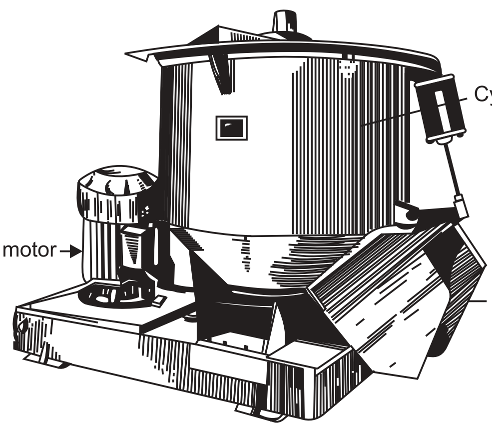

Fig. 12.1 Turbulent Mortar Mixer

Effect of Alkali Waters and Sea Water on Cement Motar Neat cement paste may disintegrate by the combined chemical and mechanical action of waters containing salts. The sulphates and chlorides are chemically active and remove lime from the cement. The carbonate of soda alone or in sloution with sodium chloride or sodium sulphate withdraws silica. Under the conditions of alternate wetting and drying this process is accelerated. Crystals of large sizes are formed and expansive forces are produced which disintegrate the neat cement paste. This effect is less pronounced in lean mortars.

Effect of Oil and Acids on Cement Mortar Well-cured cement mortars are not affected by oils. Lean mortars may develop less strength after 7 days when partially immersed in oil than when moist-cured for a month prior to immersion. The mortar surfaces soaked with oil show a marked reduction in abrasive resistance. When mineral oils are incorporated in the mixing water they retard the set of cement and reduce strength.

Animal and vegetable oils attack the lime compounds in the cement and form lime soap causing disintegration. Therefore, only mineral oils should be used for lubricating moulds.

For pH value less than 7 water removes the lime from cement in proportion to the decrease in the pH number and consequently the strength is reduced.

Effect of Sugar on Cement Mortar Up to 0.15 per cent of sugar added to cement delays the setting time and destroys the early strength. However, when added up to 2 per cent, it increases the strength at an age of 2 to 3 months. The action of sugar is attributed to the formation of a soluble calcium saccharate ($C_{12}H_{22}O_{11}.CaO + 2H_2O$)

Effect of Low and High Temperatures on Cement Mortar The rate of setting of cement falls for temperature falling below 4.5°C. When the temperature falls below freezing the particles of cement in unset cement paste separate by the expansion of water. Alterations in freezing and thawing before set break the bond between cement particles and consequently there is loss of power. If binding cement freezes before setting but thaws without refreezing, it achieves half the normal strength under proper curing.

Considerable chemical activity is noticed in neat cement paste when setting at–18°C. At such low temperatures neat cement paste gains strength at a very slow rate but develops a high proportion of its normal value after several years. Cement paste hardening at room temperatures attains higher strength than when allowed to harden for a like period after exposure to freezing temperatures.

Effect of Premixing and Retempering Cement Mortar Only half of the cement grains are hydrated by water in ordinary cement paste. The powder obtained by crushing and grinding neat cement briquettes has cementitious properties, and briquettes made after a second regrinding possess a low strength. The strength is found to reduce in proportion to the increase in water-cement ratio caused by retempering.

12.6 LIME MORTAR

Lime mortar is made by mixing lime, sand and water. Lime used for mortar may be fat lime (quick or hydrated lime) or hydraulic lime. *Fat lime* has high calcium oxide content. Its hardening depends on loss of water and absorption of carbon dioxide from the atmosphere and possible recrystallisation in due course. *Hydraulic lime* contains silica, alumina and iron oxide in small quantities. When mixed with water it forms putty or mortar having the property of setting and hardening under water.

Slaked fat lime is used to prepare mortar for plastering, while hydraulic lime is used for masonry construction and are most suitable for construction of chimneys and lightly loaded superstructure of buildings. The mix proportions of lime mortar for various types of works are given in Table 12.2.

Table 12.2 Mix Proportions

S.No.	*Type of lime*	*Lime*	*Sand*	*Fineness modulus of sand*	*Type of work*
1.	Fat Lime	1-2	2-3	2-3	Plastering
		1.5	2-3	2-3	Pointing
2.	Hydraulic	2-3	1.5-2.5	1.5-2.5	Masonry

Notes: **1. Sand in lime mortar is an adulterant, and reduces its shrinkage. Lime mortar becomes porous allowing air to penetrate and helps the mortar in hardening.**

2. Lime mortar is not suitable for water-logged areas and damp situations.

Lime mortars have plasticity and placability, good cohesion with other surfacings and little shrinkage. They harden and develop strength very slowly continuously gaining strength over long period. Fat lime mortars do not set but stiffen only as water is lost by absorption (by masonry units) and evaporation. The gain in strength is a very slow reaction of lime with carbon dioxide absorbed from air.

Preparation

Manual Mixing Lime and sand in required quantities are placed on an impervious floor or in a tank (Fig. 12. 2). The constituents are thoroughly mixed dry by turning them up and down with spades. Water is added and mixing is done again with spades till mortar of uniform colour and consistency is obtained.

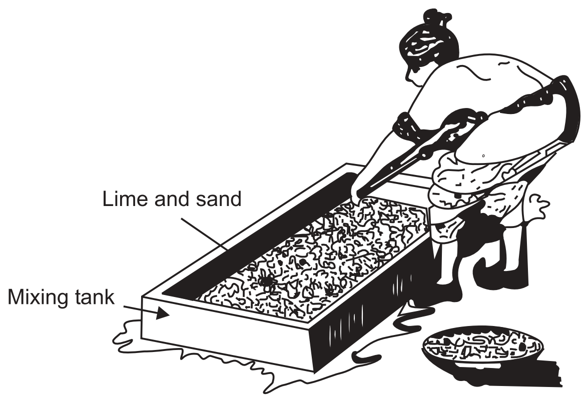

Fig. 12.2 Manual Mixing

Mill Mixing Mills used for preparing lime mortars in undeveloped countries may be a *chakki or ghanni* run by bullocks (Fig. 12.3) while a pan mill (Fig. 12.4) is used in developed countries. In the case of ghanni the required quantity of ingredients in the form of putty is put in the trench and grinding for 100 to 200 revolutions is carried out by moving stone roller. The operation takes about 2 to 3 hours for each batch of mix; the time required in a Pan mill is much less.

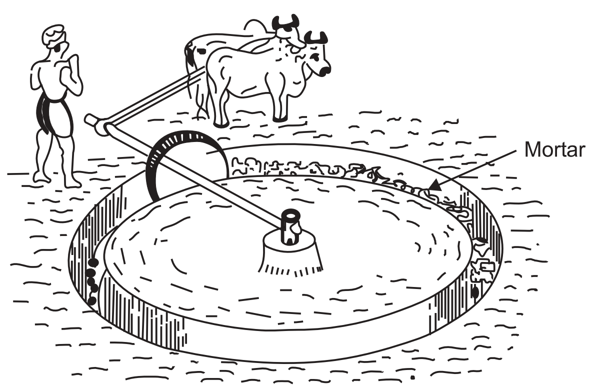

Fig. 12.3 Bullock Driven Mortar Mill (Ghanni)

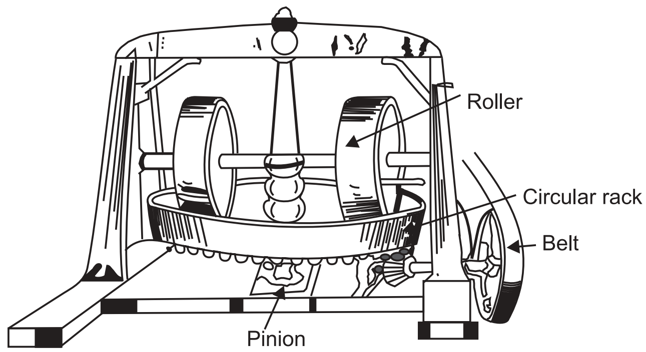

Fig. 12.4 Power Driven Mortor Mill (Pan Mill)

Precautions Lime mortar or putty should be kept moist till use and in no case its drying is allowed. The mortar made of hydraulic lime should be consumed within one day and that with fat lime within 2-3 days.

12.7 SURKHI MORTAR

It is prepared in the same way as lime mortar, with surkhi replacing sand. Surkhi should be ground to pass through 4.75 mm sieve and about less than 15 per cent through 150 micron sieve. Sand is also mixed sometimes. The mix proportions of surkhi mortar are given in Table 12.3.

Table 12.3 Mix Proportions

S.No	*Type of Mortar*	*Lime*	*Surkhi*	*Sand*	*Type of work*
1.	Surkhi	1	2	-	Masonry and foundation
2.	Lime-surkhi	1	1	1	Masonry and foundation

12.8 LIME-CEMENT MORTAR

Also known as *guarded mortar or gauged mortar* is made by mixing cement and lime. The advantages of lime-cement mortar are increased water retentivity, workability, bonding properties and frost resistance. The mortar gives good and smooth plaster finish and is used in buildings.

Preparation: For low lime content, cement and sand are first mixed dry. Lime putty is dissolved in water and added to the dry mix. The mix is then worked thoroughly with spades till uniform consistency is obtained. For high lime content lime cement mortar is made in the mills; lime and sand are first mixed separately in the form of paste for the entire day's requirement. Then cement is mixed with lime mortar in batches to be consumed in an hours time. The mix proportions of lime-cement mortar are given in Table 12.4.

Table 12.4 Mix Proportions

S.No.	*Location*	*Ratio (by volume)*		
		Cement	*Lime*	*Sand*
1.	Outside wall	1	1	6
		1	2	9
2.	Inside wall	1	2	9
		1	3	12

12.9 MUD MORTAR

They are the cheapest type of mortar prepared with locally available ingredients and are used for masonry works, surfacing floors and plastering wall surfaces in low cost houses. To improve resistance to rain water, the plastered surfaces are sometimes sprayed with bituminous material.

Preparation The top 150 to 200 mm layer of earth is removed and the clay nodules dug from the ground are wetted and allowed to mature for a day or two. Some fibrous material such as cow dung is added which prevents the shrinkage cracks. The ingredients are then kneaded well and mixed thoroughly.

Note: **Sometimes clay is added to cement mortar to increase its workability. The grain composition and the water retaining ability of mortar also increases. However, cement-clay proportion should not exceed 1:1. These mortars show high frost resistance and better strength than cement-sand mortar.**

12.10 SPECIAL MORTARS

Some of the mortars intended for use under special circumstances are as follows:

Mortars for Filling Joints between Prefabricated Reinforced Concrete Components are prepared with Portland cement and quartz sand with a mobility of 70 to 80 mm. The grade of the mortar should be same as that of the concrete and in no case less than M-10.

Cement-sand and cement paste injection mortars intended for filling grooves inside prestressed concrete components should have a grade not less than M-40 grade or more is preferred. Sulphite-alcohol vinasse or naphetene soap is added in amounts up to 0.2 per cent of the weight of cement to reduce viscosity.

Packing Mortars used for packing oil wells these mortars may be of cement-sand, cement-loam and cement-sand-loam. Slag Portland cement, puzzolana and sulphate resisting cements are used for aggressive water and packing Portland cement when water pressure is expected. These mortars should have high homogeneity, water resistance, predetermined setting time, adequate water yield under pressure and ability to form soil water-proof plugs in cracks and voids of rocks. Cement-sand-loam mortar with 5 per cent calcium chloride is especially suitable for tunnelling.

Damp-proofing Mortars are prepared using high grade sulphate-resisting Portland cement or sulphate-resisting puzzolana cement as binding material and quartz sand or sand from crushed solid rock. An approximate composition of the mortar is 1:2.5 or 1:3.5. Water proof seams and joints are made from damp-proofing mortars prepared with expanding cement.

Sound-absorbing Mortars are prepared with Portland cement, slag cement, lime or gypsum as binding material, caustic magnesite and single-size fraction sand (3.5 mm) from light weight porous materials such as pumice, cinders, ceramsite, etc. They have a bulk density of 600-1200 kg/m^3 and used as sound absorbing plaster to reduce the noise level.

Fire-shielding Motars are used for setting refractory bricks in the furnace linings where the temperature is too high for ordinary mortars. Aluminous cements and finely powdered fire bricks in the ratio 1:2 give excellent fire resisting mortars. Its trade name is Accoset 50.

X-ray Shielding Mortars Heavy mortars of bulk density over 2200 kg/m^3 are required for plastering walls and ceilings of X-ray cabinets. The binding materials are Portland cement and slag cement, and the aggregates are from heavy rocks in the form of sand (up to 1.25 mm) and dust. Admixtures containing light weight elements (hydrogen, lithium, cadmium) are added to enhance the protective properties.

12.11 SELECTION OF MORTAR

The particular type of mortar to be used for construction works are given in Table 12.5.

Table 12.5 Selection of Mortars

No.	*Nature of work*	*Type of mortar*	*Proportions*
1.	Construction work in water logged areas and exposed positions	Cement or lime mortar lime being eminently hydraulic lime	1:3
2.	Damp-proof courses and cement concrete roads	Cement mortar	1:2
3.	General R.C.C. work such as lintels, columns, slabs, stairs, etc.	Cement mortar, the concrete mix being 1:2:4.	1:3
4.	Internal walls and surfaces of less importance	Lime cinder mortar. Sand is replaced by ashes or cinder,	1:3
5.	Mortar for laying fire-bricks	Fire-resisting mortar	1 part of aluminous cement to 2 part of finely crushed powder of fire-bricks.
6.	Partition walls and parapet walls	Cement mortar Lime mortar prop. 1:1. Lime should be moderately hydraulic lime.	1:3
7.	Plaster work	Cement mortar Lime mortar	1:3 to 1:4 1:2.
8.	Pointing work	Cement mortar	1:1 to 1:2
9.	Reinforced brickwork	Cement mortar	1:3
10.	Stone masonry with best varieties of stones	Lime mortar Lime being eminently hydraulic lime.	1:2
11.	Stone masonry with ordinary stones, brickwork, foundations, etc.	Lime mortar Cement mortar Lime should be eminently hydraulic lime or moderately hydraulic lime.	1:2 1:6.
12.	Thin joints in brickwork	Lime mortar Lime being fat lime.	1:3

12.12 TESTING

The motars are tested for their quality by the crushing strength, soundness, and initial and final setting time tests as discussed in Sec.5.9. The crushing strength of some of the mortars is given in Table 12.6.

Table 12.6 Permissible Strength of Brick Masonry

S.No.	Type of Mortar	Mix portion	Permissible strength (N/mm^2)
1.	Cement	1:3	0.75
2.	Cement	1:6	0.45
3.	Lime	1:3	0:45
4.	Cement-lime	1:1:6 or 1:1:9	0.50

Besides the strength tests of mortar, another test, the permeability test of mortars is of utmost importance from durability consideration. The principal objective in permeability testing is to find the water tightness of the concrete. However, such tests often have little direct relation to the imperviousness of the structure due to presence of cracks and joints. On the other hand, the test is useful in determining the corrosive effect of percolating water which leach out the free lime and gradually attack the lime in the tribalism silicate. It can also be used to measure the relative efficiencies of cements and their rates of hydration. Following is the IS code, method of detraining permeability of mortars and concretes.

Permeability Test

The permeability of cement mortar and concrete specimens, of diameter as given in Table 12.7, are either cast in laboratory or obtained by core cutting of existing structural element is determined to asses the durability of the mortar or concrete used. The mortar or concrete mix is cast in the split moulds of required size. The material is compacted in a manner similar to as proposed during contruction. The mould is struck off level, carefully. The specimen is cured for 28 days. The test is preferably carried out at temperature of 27 ± 2°C. Typical details of the cell and the test arrangement are shown in Fig.12.5.

Table 12.7 Dimension of cell and specimen

Specimen Diameter mm	Dimension of Cell, mm A	B	C
100	115	80	110
150	170	120	160
300	330	260	320

The specimen is thoroughly cleaned with a stiff wire brush to remve all the laitance. The end surfaces are then sand blasted or lightly chiselled. The system is completely filled with water and the desired pressure is applied to the water reservoir and the initial reading of the gauge-glass recorded.

The specimen is subjected to a standard test pressure of $1N/mm^2$, but may be reduced to $0.5N/mm^2$ for relatively more permeable specimens and increased up to $1.5N/mm^2$ for relatively less permeable specimen, from one side. At the same time a clean collection bottle is weighed and placed in position to collect the water percolating through the specimen. The quantity of percolate and the gauge reading is recorded at periodic intervals.

As the steady flow is approached, the two rates tend to become equal and the outflow become maximum and stabilizes. The test is continued for 100 hours after the steady state of

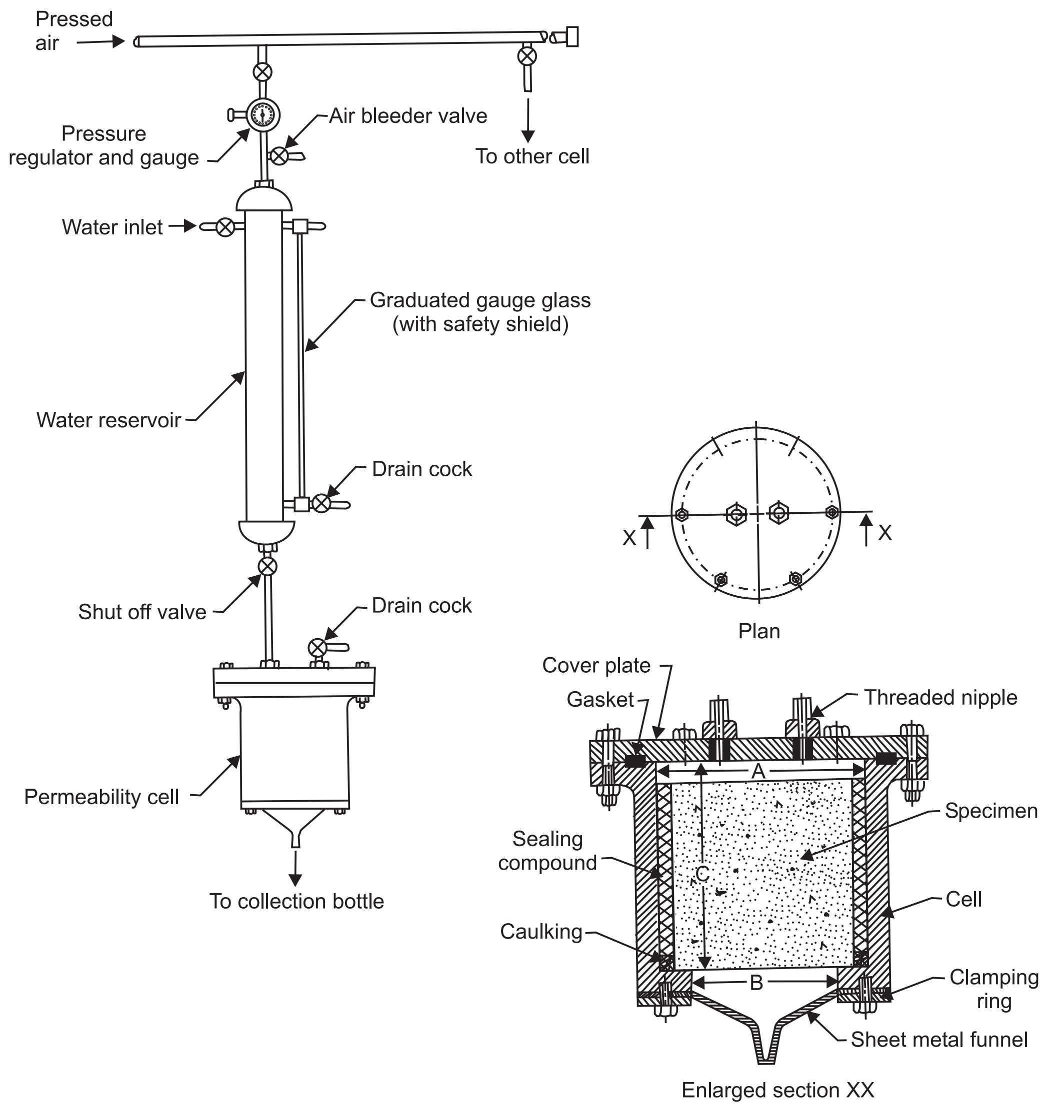

Fig. 12.5 Permeability Test Set-Up (Schematic)

flow has been reached and the out flow is considered as average of all the out flows measured during this period of 100 hours.

The quantity of water percolating through it during a given interval of time is measured and the coefficient of permeability (k) is calculated.

$$k = \frac{Q}{AT(H/L)}$$

where, Q is the quantity of water (ml) percolating over the entire period of the test after the steady state has been reached; A is the area of specimen face in cm^2; T is the time in seconds over which Q is measured; and H/L is the ratio of pressure head to thickness of specimen.

12.13 GROUT

Cement mortar of fluid consistency used to fill the voids and joints in masonry and to repair the cracks is known as grout. Also used to increase the bearing capacity of soil by injection. Grout finds extensive use in dams—to fill the cracks formed after the concrete sets and hardens; spaces between tunnel walls and the surrounding earth—to spread the earth stresses uniformly over the structures and; hollw concrete blocks—to develop bond between steel reinforcement and concrete.

Grout differs from mortar in its fluidity as it is to be poured and not spread into place with trowel. It is essentially composed of cement, fine or coarse sand, water, and a small amount (if any) of grouting admixture . The water-cement ratio should be kept as low as possible to increase the strength and reduce the shrinkage. This may necessitate use of admixtures, e.g., accelerators, retarders, gas forming and workability agents. Accelerators such as calcium chloride or triethanolamine are used to reduce the setting time in situations where plugging effect is desired. When the grout is to be pumped, the retarders or gas forming agents like mucic acid, gypsum are used. Gas forming agents, e.g., aluminium powder is used while grouting in confined areas as under the base of a machine. Workability agents like flyash, bentonite clay, diatomaceous earth, etc. are used as water reducing admixtures.

For wide cracks the grout is poured under pressure or pumped in the cracks. After the crack is filled, pressure is maintained for a few minutes to ensure saticfactory penetration. For finer cracks, chemicals grouts are used. These consist of solution of two or more chemicals forming a gel or precipitate and can be successfully used even in the moist environment. The properties of cement grout are given as follows:

1.	Compressive strength	20-7 N/mm^2
2.	Elastic modulus (compression)	20-30 GPa (IGPa=10^3 N/mm^2)
3.	Tensile strength	1.5-3.5N/mm^2
4.	Flexral strength	2-5N/mm^2
5.	Linear coefficient of thermal expansion	(7-12) × 10^{-6}/ C
6.	Water absorption (7 days)	5-12 %
7.	Development of strength	7-28 days

12.14 GUNITING

The application of mortar or concrete under pneumatic pressure through a cement gun is known as guniting; concrete becomes extremely strong and a high bond is achieved.

The gunite may be defined as mortar comprising cement and sand conveyed through an equipment known as gun. It is pneumatically forced, on a backing surface, through a nozzle where water is added at a high velocity. The mix leaving the nozzle at a high velocity strikes the surface to be repaired or protected. In the process the coarser particles rebound from the surface and leave an excellent bond coat of fine grout in intimate contact with the backing surface. In the process a thin layer of grout builds up and acts like a cushion reducing the percentage rebound in the successive layers. The composition of the material deposited on the backing surface has been found to be different from that of the mix leaving the gun because of more of the coarse materials in the rebound material. Table 12.8 gives the proportions in place for various mixes for optimum nozzle velocity.

Table 12.8 Proportion of Gunite Mixes

Nominal mix placed in the gun *Cement: Sand*	*Mix in place* *Cement: Sand*
1 : 3	1 : 2.0
1 : 3.5	1 : 2.8
1 : 4.0	1 : 3.1
1 : 4.5	1 : 3.3
1 : 5.0	1 : 3.6
1 : 6.0	1 : 4.1

In the application of gunite rebound becomes the most important consideration as it affects the economy. Approximate values of rebound for different working conditions are listed below:

Basements	30%
Vertical walls	40%
Overhead slabs	50%
Beam sides and bottoms	55%
Columns	65%

The impact caused by the jet force compacts the material. A comparatively dry mix is preferred for guniting as the material will support itself without sagging even for vertical and overhead applications. The guniting is done in layers of 40-50 mm. After the first layer is applied and has set initially, all the loose material and laitance is removed by hammer to locate dummy areas resulting from lack of bond or rebound pockets. These pockets are cut and replaced during placing of the next layer. A good well compacted gunite cured for 28 days gives a compressive strength as high as 42 N/mm^2. The average unit weight of gunite is 2300 kg/m^3. Curing is done for seven days.

Uses Gunite can be employed for construction of thin section, e.g., folded plates, shells and thin walls; linings for tunnels and swimming pools; repairing of deteriorated concrete damaged by fire, earthquake, chemicals and in hydraulic structures; strengthening buildings, bridges and jetties; stabilizing rocks and earth slopes; protective coatings over prestressing wires and steel pipes and; to furnish rough surface texture form architectural point of view. Pneumatic guniting is also used for refractory castables.

Precautions

1. If the air or water pressure fluctuates a certain amount of a too dry or a too wet mix will be applied leaving a spotty appearance. The water pressure should be kept 0.45-0.675 N/mm^2 higher than air pressure.
2. The backing surface should be thoroughly cleaned. For concrete and masonry surfaces cleaning is followed by wetting and damp drying.
3. The guniting should start from the bottom for walls. The first gunite layer should embed the reinforcement completely. The distance of the nozzle from the backing surface should be 0.6-15m.

4. The nozzle velocity should not be more than 140 m/s. At higher velocities the material particles in the nozzle interfere with rebound material and result in a porous mass of lower strength.
5. The thickness of gunite should not be less than 40 mm for repairing of structures.
6. The rebound material should not be reused.

EXERCISES

1. What is mortar? Briefly describe the various types of mortars.
2. (a) Describe the process of making lime mortar.
   (b) State the functions of sand in mortar.
   (c) What proportions of mortar will you recommend in the following cases:
   1. Lime concrete in foundation, 2. Brick work in foundation.
3. (a) What are the functions of sand, surkhi and water in mortar?
   (b) Under what conditions will you recommend cement mortar over lime mortar for masonry.
   (c) What is the effect of clay in mortar?
4. (a) Describe briefly the method of preparing lime mortar.
   (b) Why are lime mortars ground and why cement mortars are not ground?
   (c) How can mortar be made water proof?
5. What are the different types of mortars used for engineering works?
   State the composition and function of each.
6. (a) What are the advantages of adding surkhi to lime mortar?
   (b) Describe the procedure of preparing cement mortar.
   (c) What are the precautions to be exercised while using mortars?
7. What do you understand by
   (a) Grout (b) Gauged mortar (c) Guniting
8. Give the reasons:
   (a) Why are bricks and stones soaked with water before they are laid in cement mortar?
   (b) Why are molasses used in mortar?
   (c) Why is sand added to mortar?
   (d) Why is puzzolana added to mortar?
   (e) Why is it necessary to cure mortar?
9. Write short notes on:
   (a) Lime mortar (b) Lime-surkhi mortar
10. (a) What are the essential properties of lime mortar?
    (b) How and why the grinding of lime mortar is done?
    (c) State the tests conducted for quality acceptance of mortars.
11. What types of mortars will you recommend under the following situations? Give reasons for your selection. Also write the proportions of the ingredients:
    (a) Masonry in foundation (b) Plastering: interior of a house
    (c) Foundation work
12. Enlist the tests carried out to check the quality of mortars. How is permeability of cement mortar determined?

Objective Type Questions

1. Which of the following mortars is most suitable for construction work in water-logged areas?
   (a) Lime mortar (b) Gauged mortar (c) Cement mortar (d) Mud mortar
2. After addition of cement, the gauged mortar should be used whithin
   (a) 30 minutes (b) 1-2 hours (c) 8-10 hours (d) 24 hours
3. A gauged mortar is obtained by adding which of the following ingredients to cement?
   (a) Sand stone (b) Sand and surkhi (c) Sand and lime (d) Surkhi alone
4. Lime mortar is generally made with
   (a) quick lime (b) fat lime (c) hydraulic lime (d) white lime
5. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I (Cement mortar for different works)	*List-II* (Proportion of cement: sand in mortar)
A. Normal brick work	1. 1:4
B. Plastering work	2. 1:3
C. Grouting the cavernous rocks	3. 1:6
D. Guniting	4. 1:1.5

Codes:

	A	B	C	D		A	B	C	d
(a)	1	2	3	4	(b)	3	1	2	4
(c)	3	1	4	2	(d)	4	3	2	1

6. One of the main demerits in using the lime mortar is that it
   (a) is not durable (b) does not set quickly
   (c) swells (d) is plastic

Answer Table

1. (c) 2. (b) 3. (c) 4. (c) 5. (c) 6. (b)