Bureau of Indian Standards (1991): SP 20: Handbook on Masonry Design and Construction. New Delhi.

1.4 **Mortar**

1.4.1 ***General***

Mortar is an intimate mixture with water of a binder such as cement or lime and some inert material such as sand, crushed stone, in the form of a smooth paste. In masonry, mortar has an important role to play and that is to bind the units together into one mass, in order that masonry may effectively perform its functions. Various types of mortars in common use are: mud mortar, lime mortar, cement mortar, cement-lime mortar and lime-pozzolana mixture mortar. Composition, properties and methods of preparation of various types of mortars are as follows.

1.4.2 ***Materials for Mortars***

Materials used for making mortars are a) binder, such as clay, lime, cement; b) inert materials such as sand, crushed stone; c) pozzolana such as fly ash, burnt clay/surkhi; d) lime-pozzolana mixture and e) plasticizers.

1.4.3 ***Properties of Mortars***

Properties of mortars which are sought for use in masonry are: workability, water retentivity, rate of stiffening, strength, resistance to rain penetration and durability. These properties have been discussed below explaining their effect on masonry. Choice of masonry mortar is governed by several considerations such as type of masonry unit and its properties, degree of exposure to weather and environments, strength requirements, etc.

1.4.3.1 ***Workability***

Workability enables it to be spread and applied to masonry unit with ease. It also facilitates proper filling of joints in masonry. A good mortar would hang from the trowel and will flow down readily when lightly jerked. This property of mortar depends on properties of various ingredients used for making mortar and on the method of mixing adopted. As a general rule, a mud mortar prepared from fine clay soil has better workability than one prepared from sandy soil and a lime mortar has a better workability than cement mortar….

1.4.4 ***Preparation of Mortars***

1.4.4.1 ***Mud mortar***

Soil for mud mortar should have clay or silt content 60 to 70 percent and sand content 40 to 30 percent. It should be free from vegetation, organic matter, gravel, coarse sand and should not contain excessive quantities of soluble salts. Selected soil should be placed in regular stacks of about 30 cm height, with raised edges. Size of stack should be regulated so that mortar obtained is adequate to meet a day's requirement. Enough water should then be added so as to soak the entire soil. After 12 to 24 hours, it should be worked up with a 'phowrah' and trodded over with bare feet so as to form a thick paste, adding more water if necessary and removing all clods, stones, roots, etc. If during course of use, the mortar becomes stiff due to loss of moisture by evaporation, more water should be added and the mortar retempered.

If use of soil containing excessive soluble salts is unavoidable, salts should be leached out from the soil, by adding sufficient water daily to the soil stack, once or twice, for about a week and letting the water drain out from the sides of the stack. If soul containing excessive salts is used in mud mortar without leaching, the mortar will not have much binding quality.

1.4.4.2 *Lime mortar*

Slaking of lime-There are basically two methods of slaking of quicklime at site, namely, 'tank slaking' and 'platform slaking'. In the latter method, there are some variations depending on type of lime, that is hydraulic, non-hydraulic, dolomitic or kankar. These methods have been described below:

1) ***Tank slaking -*** This method of slaking is adopted in case of semi-hydraulic and non-hydraulic calcium lime. It is not suitable for slaking hydraulic, dolomitic and kankar lime because, firstly, these limes, being slow in slaking, do not slake properly by this method and secondly, hydraulic and kankar limes lose their strength rapidly due to excess of moisture. In case of semi-hydraulic and non-hydraulic calcium lime, this method has the advantage over the other method of slaking, namely platform slaking, that hydrated lime obtained is in the form of putty, free from any impurities and unhydrated particles, and mortar made from lime in putty form has good workability.

For this method of slaking, there should be preferably two tanks of suitable sizes, the first one at a raised level of 40 to 50 cm depth, so that its contents could flow by gravity to the second tank of 75 to 80 cm depth, at a lower level. The upper tank is filled with water up to about 25 cm depth and quicklime broken to small lumps of 5 to 10 cm size is added to the tank to cover the entire bottom of the tank **up to about half the depth of water.** Care should be taken to ensure that no part of lime is exposed above water. As soon as quicklime comes in contact with water, it begins to slake with evolution of heat and rise of temperature. Pace of feeding of quicklime to tank is so adjusted that **near-boiling temperature is maintained**. Contents of the tank are constantly hoed and stirred to promote slaking. After the

slaking has apparently ceased, hoeing and stirring is continued for sometime more to ensure complete and thorough slaking.

Lime in slurry form is then run down, through a sieve of IS designation 2.36 mm, to the lower tank, where it is allowed to mature and thicken so as to form putty. **Period of maturing should be 1 to 2 days** in case of semi-hydraulic lime and not less than **3 days in case of non-hydraulic lime.**

In case, a continuous supply of lime putty is desired, there should be two low- level tanks, to be used alternatively. On small jobs, the lower tank could be dispensed with and slaking of lime and its maturing to form putty could be carried out in one tank.

Lime, putty should not be allowed to dry before use, and when kept in storage, it should be completely covered with a layer of water. Putty of non-hydraulic lime could be kept in storage **up to 2 weeks, without any risk of deterioration** in quality but putty of semi-hydraulic lime should be used within 1 or 2 days.

2) platform slaking of semi-hydraulic and non-hydraulic calcium limes – Quicklime is broken to about 5 to 10 cm size and is spread in a 15cm thick layer on a water-tight masonry platform.

Water is then sprinkled over it intermittently, overall quantity of water used being approximately **60 percent by weight of the quantity of quicklime**. It is necessary to regulate the quantity of water carefully through experience, so that after slaking, hydrated lime is in the form of dry powder. If excess water is used, hydrated lime will not be in dry powder form and if less water is used, slaking will not be complete. To ensure thorough and complete slaking, lime should be, at intervals, hoed and turned over adding more water if necessary. When slaking activity has apparently ceased, the slaking process should be allowed to continue by itself for a further period of one or two days. Slaked lime should then be screened through a sieve of IS designation 3.35 mm and hydrated lime kept stored in a compact heap, suitably covered with a tarpaulin or a layer of dry bricks to protect it from wind, dust and rain. It is desirable to use lime after slaking as soon as possible but within 7 days, since it deteriorates in quality due to contact with air.

3) *Platform slaking of hydraulic lime.*

Hydraulic lime slakes rather slowly and, therefore, before slaking the lumps should be broken to pieces of size 5cm and below. In fact, if lime is very refractory, it should be ground to a coarse powder so as to ensure good slaking. Quicklime should be heaped on a water-tight masonry platform and water to the extent of about 30 litres per quintal sprinkled over the heap and mixed with lime so that all

lumps or pieces of quickline get thoroughly wetted. The heap should then be covered all over with a layer of measured quantity of sand 5 to 8 cm thick in order to conserve heat of hydration and the heap left undisturbed for 36 hours. After this, lime along with sand should be screened through a sieve of IS designation 6.3 mm; When using this hydrated time, quantity of sand used for covering the heap should be taken into account while proportioning lime and sand. This lime should be stored in a compact heap and protected from moisture and rain. It should be used as soon as possible within 7 days. If limestone has been burnt at high temperatures, it cannot be properly slaked at site, and pressure slaking in an autoclave becomes necessary.

4) *Platform slaking of dolomitic lime*. Slaking procedure of this lime is similar to that of hydraulic lime. However, the quantity of water used should be 40 litres per quintal and the heap should be left undisturbed for 2 to 3 days. Thereafter, it should be screened. stored and proportioned just like hydraulic lime. In case of this lime also, pressure slaking is needed when limestone has been burnt at high temperature.

5) *Slaking of Kankar lime*. Since kankar lime contains a large proportion of impurities, it is very slow in slaking. This lime has, therefore, to be ground to a coarse powder before slaking. Procedure for slaking of this lime is similar to that of hydraulic lime. However, no sand should be added as cover during slaking and the quicklime after wetting and turning over, should be left in the form of a compact heap for 2 to 3 days for slacking.

Alternatively the process of slaking and wet grinding to form mortar could be combined and carried out in mortar mill as in 1:4.4.2(e)(6).

c) Use of hydrated lime in mortar. When semi-hydraulic and non-hydraulic limes have been supplied at site in hydrated form or these have been slaked on a platform at site, it is desirable to soak lime in water for some time before use, so as to ensure proper workabilitv of mortar. Soaking should be for a minimum period of 16 hours in case of non-hydraulic lime and for 8 to 12 hours fat semi-hydraulic lime. Hydraulic lime should not be soaked before use since this lime starts setting on getting wet and thus loses strength if presoaked. If lime mortar has been prepared from dry hydrated, non- hydraulic and semi-hydraulic limes, its workability can be improved by keeping it in storage for 16 to 24 hours in case of non- hydraulic lime and 8 to 12 hours in case of semi-hydraulic lime. In case however, some pozzolana has been used in the mix, the mortar should be used as soon as possible within 4 hours.

d) ***Proportioning of mix*** - For preparation of lime mortar, lime, in the form of dry hydrate or putty, and fine aggregate (sand and pozzolana) are proportioned by volume. Though density of lime putty varies with its age, getting denser as it ages,

for all practical purposes, volume of putty is taken to be same as that of dry hydrated lime. In case of sand, it is its dry volume that is to be taken for proportioning and therefore due to allowance has to be made for its bulkage, in case the sand is moist. When lime supplied is in the form quicklime for estimating roughly, lime requirement, it may be assured that one quintal of quicklime will yield 5 standard sized bags (0.035 m3) of dry hydrated lime, after making allowance for residue and wastage. When lime used in non-hydraulic, it is necessary that at least half the volume of fine aggregate is a pozzolanic material namely, cinder, fly ash or burnt clay. Even in case of semi-hydraulic lime it is desirable to use pozzolona to the extent of at least one third of the volume of fine aggregate, so as to get better strength. Though it is not essential to use pozzolana in a mix of hydraulic lime mortar, there is no technical disadvantage in doing so if it results in saving in cost.

e) Mixing and grinding

1) Mixing can be done either manually in a masonry trough or in a mechanical mixer. The latter method gives much better result and is preferable. For all important jobs, mixing should therefore be done in a mechanical mixer.

2) When mixing is done manually, if lime is in dry powder form, lime and sand or lime and pozzolana and then sand should be first mixed dry. Water should then be added and wet mixing continued for some time more so as to ensure thorough and uniform mixing. When lime is in putty form, some water may be added right in the beginning, since otherwise, because of sticky nature of putty, mixing is difficult. Alternatively, lime putty and water may be first mixed in the trough to form a thin paste and then sand/pozzolana added and further mixing carried out.

3) When a mechanical mixer is used, all ingredients may be added at one time and mixing carried out for at least 5 minutes.

4) In lime mortar optimum result is obtained by grinding the mortar in a mortar mill, after dry or wet mixing of ingredients, manually or mechanically. The mortar mill could be either animal drawn or mechanically powered. The ingredients after mixing are fed into the mortar mill and grinding done, continuously raking the stuff to ensure uniform grinding, and adding more water as and when necessary. Grinding should be continued till all particles of fine aggregate are fully coated with lime and mortar is of uniform colour all through. In an animal drawn mortar mill, grinding should generally be done for 120 to 180 revolutions (2 to 3 hours) depending on nature of lime and aggregate used and quality of mortar desired. In case of mechanically powered mortar mill, grinding, should generally be done for

at least 15 minutes.

5).—When using hydraulic lime, sometimes, as a short cut, unslaked lime in the form of small lumps or coarse powder, is fed directly into the mortar mili along with requisite quantity of fine aggregate and wet grinding is started. Thus, process of slaking, mixing and grinding take place simultaneously. Drawback of this method is that some unburnt stone also gets crushed and incorporated into the mortar mix and as a result, strength obtained from this mortar is somewhat less. It is, therefore, desirable to first slake the hydraulic lime and screen the same so as to remove unburnt stone before mixing and grinding.

6) ***Kankar lime -*** Mortar from kankar lime is made by grinding slaked lime in a mortar mill. Proportion of sand to be added to the mix is determined after testing lime for its calcium oxide content. When calcium-oxide content is close to the minimum limit of 25 percent, no sand is added to the mix. When lime is of very good quality, lime and sand are mixed in the proportion of 1 : 1.

Alternatively, mortar from kankar lime should be prepared directly from quicklime by first dry grinding quicklime in the mortar mill and then wet grinding the same, with or without addition of sand. The process of wet grinding should be continued for a minimum period of three hours to ensure thorough slaking. In this process, slaking and grinding take place simultaneously. The result, however, is not so satisfactory as that obtained by the former method.

7) In case of small and less important jobs, it is generally not feasible to arrange a mechanical mixer for mixing and a mortar mill for grinding of mortar. In such a case, wet mixing should, be continued in the mortar trough manually, for a period of at least 15 minutes so that all particles of fine aggregate get thoroughly coated with lime and mortar is of uniform colour all over. Workability and strength of such a mortar however, is not so good as that of mortar prepared by proper grinding.

Storage of mortar - As a general rule, all mortars should be used as soon as possible after preparation and mortar should not be allowed to get stiff before use. Mortars prepared from non-hydraulic and semi- hydraulic limes should be used on the same day and left-over' mortar of previous day should be discarded. As an exception to this general rule, lime mortar prepared from dry hydrated lime without any presoaking should be kept stored in a covered heap before use as in 1.4.3.1, in order to improve its workability. In case of mortar prepared from hydraulic lime, it should be used within 4 hours, as otherwise, it may partly set before use.

g) Use of ***pozzolana in lime mortar -*** Mortar prepared from non-hydraulic lime and sand does not have much strength and is thus not suitable for masonry work, except for very light loads and temporary structures. Such a mortar depends, for its

setting or hardening action on carbonation which takes place very slowly and that also mainly at the surface. Use of coarse angular sand and thorough grinding for such a mortar, however, do help to promote carbonation to some extent and that way, there is some improvement in strength. Where semi- hydraulic and hydraulic limes are not available and use of non-hydraulic lime for masonry is unavoidable, strength of mortar is improved by substituting sand wholly or partly with some pozzolanic material such as fly ash, or burnt clay. Alternatively in place of lime one of the standard lime-pozzolana mixtures, which are marketed as standardized materials (Refer IS 4098 : 1967) should be made use of as dealt with in 1.4.4.5.

1.4.4.4 *Cement-lime mortar*

There are three methods of making cement-lime mortar as given below. These methods are described in order of their preference. On large and important jobs, method one should be normally adopted. Method three should adopted only for small and unimportant jobs. Only that much quantity of mortar should be prepared at a time, as can be consumed in 2 hours.

4) *Method One* - Lime mortar with lime and sand in specified proportion for whole day's requirement should first be prepared from lime putty and sand by mixing in a mechanical mixer and then grinding it in a mortar mill. This mortar called "coarse stuff' is kept aside as stock and prevented from drying out. Coarse stuff and cement should then be taken in suitable proportions in batches and mixed, along with additional water in a mechanical mixer for a minimum of 3 minutes so as to obtain mortar of desired consistency and uniform colour. When ratio of lime to cement in the mix is 1 or less than 1, main function of lime in the mix is to act as a plasticiser and grinding for preparation of coarse stuff may be dispensed with.

For proportioning, volume of coarse stuff is taken to be equal to that of sand in the mix. Thus for preparing cement-lime mortar 1 cement: 2 lime: 9 sand, coarse stuff of proportion 1: 4 ½ is prepared and cement and coarse stuff are mixed in the proportion of 1:2. If on the same day, different mixes of composite mortar namely 1:1:6, I:2:9 and 1:3:12 are needed, coarse stuff of standard proportion I:3 is prepared and additional sand is added where required at the time of mixing to cement and coarse stuff so as to obtain any desired mix. For example, when 1:1:6 mortar is to be prepared with this stock, cement, coarse stuff and sand are mixed together in the proportion 1:1:3. Similarly, for obtaining 1:2:9 and 1:3:12 mortars, cement, coarse stuff and sand in the proportion 1:2:3 and I:3:3 are mixed.When only a small quantity of mortar is needed, mixing of mortar could be done manually on a platform or in a trough.

b) *Method Two* - In this method, cement and sand are taken in specified proportions and are mixed together dry in a mixer. Lime putty in specified

proportion along with requisite quantity of water are then added and further mixing done till mortar of uniform colour is obtained.

When lime to be used is in the form of dry hydrated powder, it should be pre-soaked in a trough for about 16 hours in case of non- hydraulic lime and for 8 to 12 hours in case of semi-hydraulic lime, excess of water if any, decanted off from top and putty thus formed in the trough, used for making mortar, as described earlier. If mixing is to be done manually, measured quantities of lime putty and water are mixed together separately in a container and emulsion of lime thus formed (called milk of lime) added to dry mix of cement and sand and further mixing done in a trough or over a platform. Care should be taken to add only that much water as would give mortar of desired consistency.

c) *Method Three* - In this method, cement, hydrated lime and sand in the specified proportion are first mixed dry in a mixer or on a platform and then water added and further mixing done so as to obtain a mix of uniform colour and desired consistency. Wet mixing should be carried out for a minimum period of 3 minutes in case of mechanical mixing and 10 minutes in case of manual mixing. **With this method, workability of resulting mortar is not so good as that obtainable by methods one and two.** This method of mixing should, therefore, be adopted only when methods one and two are not feasible from practical considerations.

1.4.4.5 *Lime-pozzolana mixture mortar*.

This mortar is made by taking lime-pozzolana mixture and sand in specified proportions and mixing the ingredients in the same manner as cement mortar. Mortar made from lime-pozzolana mixture of type LP20 or LP40 as binder, which are hydraulic, should be used within 4 hours of mixing, while mortar made from lime-pozzolana mixture of type LP-7, which is semi-hydraulic should be used within 12 hours….

1.6 Curing

1.6.1 Masonry mortars based on cement, hydraulic and semi-hydraulic lime, and non-hydraulic limes containing pozzolans, depend for their setting/hardening action on hydration, for which it is necessary that water used in mixing should not dry out during the process of hydration. In order to prevent early drying of moisture, all exposed faces of masonry are wetted periodically by sprinkling water over the same. The process of sprinkling water over masonry to prevent drying out is commonly known as “curing”.

1.6.2 Curing of masonry should begin as soon as partial set of mortar has taken

place. This would depend on type of binder used (that is whether cement, hydraulic, semi-hydraulic, or non-hydraulic lime) and the ambient temperature. In hot weather, setting action is rapid, while in cold weather, it is slow. Another factor which governs the time of commencement of curing is the water retentivity of mortar.

Curing of masonry using cement mortar, which has low water retentivity should be commenced early, while curing of masonry using lime mortars, which have high water retentivity, should be commenced a little later. Broadly speaking**, in hot weather, curing of masonry should be commenced within 12 hours in case of cement mortar, 24 hours in case of lime mortars made from hydraulic and semi-hydraulic limes and 36 hours in case mortars made from non-hydraulic lime. In cold weather, curing should be deferred for about 12 hours in each case.**

1.6.3 Curing should be continued up to a minimum period of 7 days from date of laying of masonry. However, in case of masonry using rich cement mortar (1:4 or richer) when strength of masonry is a special consideration, period of curing should be extended to 10 days in dry weather (humidity less than 50 percent).

1.6.4 Frequency of curing during a day depends on ambient temperature and relative humiditv. In hot and dry weather water should be sprinkled 3 times a day that is early morning, mid day and evening; in hot and humid weather or temperate and dry weather, watering should be done twice (morning and evening) and in cold weather, once a day. In case of masonry units having high shrinkage co-efficient, as for example, concrete blocks, sprinkling of water should be done sparingly so that water affects only the surface of the masonry. Excessive watering in this case is likely to cause too much of shrinkage cracking on drying….

1.6.6 In mud masonry, apart from drying of mud mortar and consequent hardening of mortar on this account, there is no other setting action requiring the presence of moisture. Thus, no curing is required in case of this masonry.