COVER THE EARTH:
Plasters for Soilblock Buildings

Development Alternatives
NEW DELHI
COVER THE EARTH:

Plasters for Soilblock Buildings

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INTRODUCTION

Earth, while being an excellent building material vis-a-vis cost, availability, structural strength and insulation, is extremely vulnerable to attack by water and termites. Particularly in developing countries, earth construction has vast potential in mitigating the acute housing shortage faced by the rural and urban poor. However, in the tropical and semi-tropical climates of developing countries, soilblock buildings are vulnerable to both rain erosion and termite infestation. Numerous traditional methods have been used to overcome such disadvantages of earth as a building material; other techniques have been proposed and are currently being applied by such groups as CntERRE (France), the Central Building Research Institute (India), Grupo Talpuy (Peru), ASTRA (India) and others.

Among the methods of preventing erosion and of protecting earth structures from water and termites are stabilizing the walls, providing damp-proof coursing (dpc), roof overhang, clay wailing tiles and plastering. Stabilization may be achieved through densification of soil by compaction in a mechanical ram and/or addition of binding agents such as lime or cement. Damp-proof coursing atop the plinth protects walls from ground level attack by preventing the seepage of moisture through the foundation with a water resistant layer containing a bituminous agent. Further, the dpc often contains an anti-termite compound such as the brand name Aldrin. Roof overhang reduces exposure of the walls to rainfall. Fired clay wailing tiles, fixed to the external wall surface, protect the soilblocks from rain and wind.

Among, the most effective form of protecting exposed earth surfaces, plastering essentially protects the external walls from rain and humidity, from rats, mice and termites, and provides decoration to the building (Stulz, 1981). Plasters are most often, cheaper than wall stabilization, since they are only surface treatments. They are at once more interesting and complex than other wall protection systems, owing to the vast range of materials and techniques with the potential for application. Finally, plastering allows full creativity in determining texture and color.
STATEMENT OF THE PROBLEM

We are concerned here primarily with protecting earth walls, and to some extent roofing systems, from damage during rain and from airborne moisture. Several types of attack may lead to weakening of the walls as illustrated in Figure I.

(a) gravity feed through crack (b) wicking through porous medium

Figure I: Moisture Attack to Walls

(c) wind and pressure differential (d) poor drip detail through faulty joint

Figure I: Moisture Attack to Walls

FUNCTIONS OF PLASTER

The external wall system, including plaster, may be considered a single element of an entire structure. Rich (1977) enumerates various characteristics of external walls, the four primary functions being:

1) appearance,
2) structural strength,
3) weather barrier, and
4) durability.

Plaster coating of walls, evidently, serves the first of these functions directly, by providing the external surface of the wall. Particularly for soilblock walls subject to rainfall, the plaster enhances structural strength, in that the wet compressive strength of soilblocks is negligible. We are concerned here primarily with designing plasters to perform the latter two functions of wall systems—weatherability and durability.
FACTORs INFLUENCING PLASTER PERFORMANCE

The performance and efficiency of plasters is a function of a number of interrelated factors. The most significant performance indicators are erosion resistance, bond strength, (im)permeability and impact resistance. These may be evaluated against cost per unit area, percentage labour component and percentage local economy component with a view to minimising the first and maximising the latter two. A weighted composite performance index can be prepared when adequate data on the performance indicators becomes available. The detailed impact of each is presented below:

Erosion Resistance

In designing adequate protection for a building, we must consider the vagaries of local weather in order to ascertain the severity of rainfall to which it will be subjected during its life. The erosion of a particular material by rain is the combined effect of the erosivity of rain and the erodibility of the material (refer to Glossary). We shall investigate the process of rain erosion by considering first the patterns of local precipitation based on meteorological records, and second the characteristics of plasters that can readily be determined in the laboratory.

Though two locations may record the same total annual precipitation, the rates at which rain falls at both are likely to differ. One may be subject to gently falling rain prolonged over a period of time, while the other occasionally receives heavy, driving rain as during cloudbursts. Of the two, the latter will have a greater erosion problem due to higher intensity (mm precipitation/hour). For two reasons, intensity appears to be the most appropriate index of the erosivity of rain: it is related to other parameters of rainfall that come to play in the process of erosion (to be discussed subsequently); and records of intensity are often kept in meteorological archives or are easily determined, with a reasonable degree of accuracy, from local daily precipitation data recorded with simple equipment.

Two parameters that affect erosivity and are related to intensity are drop size and drop velocity. The percentage of rain falling as large drops (greater than 3 mm diameter) increases with increasing intensity. However, the scatter of drop size is still considerable. A convenient definition is the median volume drop diameter, d(50), or the diameter such that half the volumetric precipitation occurs as drops with larger diameters and half with smaller. At intensities up to 115 mm/hour, d(50) increases to 3 mm, and decreases thereafter.

Drop velocity, related to wind resistance and mass, increases as drop diameter increases. Large drops (about 5 mm diameter) can have a still air velocity of 9 m/s. Added to this is the effect of high wind velocity. The velocity vector resulting from vertical free fall and the horizontal component caused by wind can reach a magnitude of 11 m/s.
The significance of drop diameter (giving drop mass) and drop velocity lies in the energy of impact or the kinetic energy of the raindrop:

\[ KE = \frac{1}{2}(m)(V^2). \]

Large drops result in high values of impact energy on two counts: drop mass increases as a cubic function of diameter, and for large drops with high terminal velocities, energy increases with velocity squared. As plaster particles are loosened by the energy of impact, the most severe erosion occurs at high intensities when the proportion of large drops with high velocities is at a maximum. 30-minute intensities (i.e., that rate of precipitation in mm/hour during the 30 minute period with the maximum rainfall) of 100-115 mm/hour are highly erosive. The critical 30-minute intensity between highly erosive and severely erosive storms appears to be 115 mm/hour.

Based on the rainfall figures and charts presented in Appendix I, the intensity-recurrence interval relation for New Delhi was computed as:

\[ i(30) = \frac{57.54}{t(R)^{0.1915}} \]

\[ i(30) = \text{the 30-minute intensity (mm/hr)}, \]
\[ t(R) = \text{the recurrence interval (years)}. \]

This implies that, severely erosive storms are likely to occur on a statistical average of once in 38 years and highly erosive storms once every 18 years.

The impact of rainfall intensity on plaster performance can only be measured over long periods of time. Short term simulation tests as the spray erosion test can only serve as a means of comparing various plaster types, and hence as an aid to designers. A empirical link has to be built up between these short term tests, rainfall intensity and long term plaster durability.
Wall-to-Plaster Bond

We require plasters that exhibit good bonding to earth surfaces. Note that the wall-to-plaster bond should exhibit the same shear properties as the soilblock wall itself, or the entire plaster coat may slip and fall. Increased bond strength requires either higher concentrations of binder or significantly higher levels of labor input in wall preparation and hence, entails higher cost.

Shear failure, or the slipping of the plaster from the wall, is a function of the void ratio of the wall and plaster materials, the confining stresses at the wall-to-plaster bond, and the rate of loading, although the latter is negligible in a fixed plaster. For the purposes of this discussion we assume first that failure occurs along the vertical plane, and second, somewhat tenuously, that shear and tensile stresses observe a linear relationship.

Shear stress is a function, not only of the confining stresses, but of cohesion as well. Surface tensile stresses in plasters are due either to temperature-induced shrinkage or to eccentrically loaded plasters. Cohesion is a result of material properties on either side of the wall-to-plaster bond.

Ideally, the external wall element of the final building, including soilblock, mortar, and plaster, should have shear properties as indicate in Figure III. Here, the abscissa represents distance from a point just inside the soilblock wall, while the ordinate represents shear stress.

![Graph](image)

(a) Good Bond

(b) Poor Bond

Figure III: Shear Stress vs. Horizontal Distance Through the Plaster From a Point Just Inside the Wall
Impact Resistance

Durability of the plaster coat depends in part on its ability to withstand impact. During the course of its life, the plaster will be bumped, scraped, scratched and generally abused by humans and animals alike. High plaster density and the use of several coats are the essential means of ensuring resistance to impact. Surface finishes with low coefficients of friction are more resistant to abrasion than rough plaster surfaces. While material properties are important in providing durability (see Appendix II for tests to determine impact resistance), methods of application, including densification, multiple coats, and surface finishing, are critical in achieving durable plasters. Refer to the sections under "Application and Curing" for detailed discussions of such techniques.

SOME GENERAL CONSIDERATIONS

Prior to investigating basic plaster types, individual mixes, and their costs, a discussion of plastering techniques is in order. These are particularly applicable to earth structures of rammed earth, adobe, and wattle and daub, though buildings of pressed soilblocks and mud mortar will also require surface protection. The designer and builder should take into account the patterns of building use and conditions prevailing on site. Do eaves protect the walls? Can domestic animals damage the building? Does use of other forms of surface protection, such as roof overhang or walling tiles, obviate the application of plaster? These and other questions will affect the choice of surface protection to be used while still leaving room for innovation.
APPLICATION AND CURING

As important as the quality of materials used in plastering is the method of preparation, application and curing. Small samples, as those for testing, are generally better prepared. The sand is well sieved, and binder and water thoroughly mixed. Crucial to the protection provided by plaster is the quality of workmanship in detailing edges, corners and plaster joints. On a larger scale, such quality control is more difficult. Certain steps should therefore be taken to ensure durability, good bonding and detailing—principally the application of multiple coats, wall preparation and rounding of edges.

Single or Multiple Coats?

In many cases a single coat of plaster is adequate, though double or triple coats will provide additional protection and reduce maintenance costs. For buildings in areas of high rainfall intensity and high total precipitation, particularly in monsoon regions, a double coat may obviate yearly maintenance. Higher capital investment during construction will reduce maintenance costs during the life of the building.

Material costs for single and double coats of mud-straw plaster are Rs. 0.75/sq.m and Rs. 1.25/sq.m; and labor costs are Rs. 3.00/sq.m and Rs. 5.50/sq.m, respectively. Maintenance costs for a single coat are Rs. 0.65 incurred annually, while for double coats, Rs. 0.75 incurred biannually. Consequently, a double coat will result in lower overall costs after the tenth year. However, in countries with labor costs higher than in India, the advantage of a double coat may be realized earlier, as maintenance of plasters is particularly labor-intensive.

For buildings whose occupants do their own maintenance—most earth buildings in India are plastered and kept up by women—a single coat is standard practice. However, more durable plasters involving multiple coats would reduce the burden on women of shelter maintenance. However, with prevailing social customs, this would merely allot women more time for other drudgery work, not necessarily promoting income-generating activities, education, or family health.
Wall Preparation

It is recommended that all horizontal mortar joints be raked to a depth of 1 cm. These 'keys' provide greater surface area for the wall-to-plaster bond and allow direct load transfer of the plaster's self weight as opposed to simple adhesion between two vertical surfaces. Refer to Figure IV.

![Figure IV: Keys Strengthen the Wall-to-Plaster Bond](image)

The wall should be thoroughly cleaned with a wire-brush to loosen all grit and dust which result in poor bonding.

At least 24 hours prior to plaster application, a wash may be applied, of a mix of the binding agent and water. For example, for lime plasters, the wall is doused with a 1:7 (lime:water) wash the evening prior to plastering. Care must be taken that the wash is just thin enough that all the binder is absorbed by the wall. Free binder in the form of powder on the dried wall will reduce bond strength. The absorption of the wash, in effect, stabilizes the surface of the wall, disallowing shear failure of the mudbrick surface just behind the wall-to-plaster bond.

The effect of wetting the wall just prior to application is a slower drying plaster which will not crack as readily. For this reason, plaster should be applied in the morning or evening when the wall is cool. Plaster applied in the morning may crack from shrinkage combined with tensile failure when the wall expands on heating up in the afternoon sun. 'Craze,' or hairline surface cracks can be sealed by tamping with the rounded end of the trowel handle, or a rounded hammer head.

Curing

Curing of cement and lime-based plasters is essential. At least twice daily, the entire plastered area should be wet thoroughly. This should continue for not less than seven days for lime-based plasters and 28 days for cement based plasters.
Detailing

Detailing at edges and corners should be done by plastering in a continuous application over the edge or corner. That is, the plaster should not be brought up to the edge from both sides before completing the detail. Edges should be rounded slightly to avoid cracking during drying.

Wherever possible, an entire wall surface should be completed from top to bottom in one session. Joining plastered surfaces, as from one day's work to the next, should always be done on a plane surface, never at an edge. Vertical joints are less problematic than horizontal joints in that water seepage is most pronounced through a poorly finished horizontal joint. Should horizontal joints be required, the upper surface should be tucked over the lower surface to protect it from gravity flow of rain through the joint to the wall underneath, as shown in Figure V.

![Figure V: Properly Detailed Horizontal Plaster Joint](image)

Detailing of plaster on roofs, eaves, window sills, dpc and other similar elements saves considerable maintenance time and cost. Drip detailing is extremely important in keeping water away from the walls below. Wire mesh with openings no larger than 20 mm, fixed to the base plaster coat or directly to the wall, roof, etc. with 25 mm nails spaced every 10 to 15 cm, aids in bonding. Large vertical surfaces will need to be notched at appropriate intervals to contain shrinkage cracks, this also holds for plaster finishes on mud roofs.

Workmanship

Good masons always throw the plaster mix forcefully against the wall. Not only does this reduce wastage of fallen mix, but it compacts the plaster and expels entrained air, resulting in a denser, less permeable coat, with a better wall-to-plaster bond. This is of particular importance for base coats whose primary function is to protect the wall from moisture. Surface coats, applied for finish, require less compaction. In fact, a semi-porous surface is often desirable, particularly over lime base plaster. First, it allows the base plaster to 'breathe,' aiding durability, for lime plasters must absorb atmospheric carbon dioxide, and moisture. Second, from an aesthetic point of view, a rough finish may be quite appealing.
PLASTERS

Historical records of building techniques show that a wide range of organic binders have been used by various civilizations. Predominant among these materials are oils and glues extracted from plant and animal products. However, other binding agents have been used with some degree of success: human and animal hair, blood, egg whites, and sugar. European builders of the Middle Ages used beer, malt, and urine to improve durability.

Masons in medieval Indian added urad-ki-dal (lentils) to their lime mortars and plasters. However, due to the rise in cost over the centuries of most vegetable and animal products, such plasters are too expensive today. For example, urad costs Rs. 9/kg, jaggery Rs. 3/kg, animal glue Rs. 14/kg, to name a few, while lime costs Rs. 0.75/kg, cement Rs. 1.50/kg, and gypsum Rs. 2/kg. As additives to synthetic binders, these organic binding agents are used sparingly, though the advantages that such admixtures offer have not been adequately documented. There appears to be scope for experimentation with other organic binders where local production and supply exceed demand. For instance, babul-ka-gond (gum arabic) is produced in large quantities in localities of Gujarat and Rajasthan and could be incorporated into local craft.

The use of organic binders today has considerable potential, but depends on local availability of materials and masons experienced with their use. Standardization of such plasters is problematic due to the variable quality of binding agents.

The following discussion of plaster mixes for earth structures is broken down into four types: mud-straw, lime, cement, and gypsum. Obviously there is considerable overlap, for instance lime-cement plasters; but cost is a distinguishing feature among the four. While mud-straw, and to some extent lime-based plasters, can be considered low-cost, cement and gypsum plasters require high initial investment. Temporary structures may require little maintenance, yet it may be cost-effective to clad a permanent structure with a lime-cement plaster, for example.
Mud-Straw Plaster

Satisfactory use of mud plaster, also called 'dagga,' with various amounts of straw and animal dung, has been reported from Egypt, the Sudan, Peru, the United States, and India. Making use of locally available materials, these plasters are the cheapest and easiest to apply, though they require considerable preparation and maintenance.

A large pit is dug and filled partially with soil of the following composition: clay, 20-25%; silt, peat, loam, 30-40%; and sand, 40-45%. Sandy soil may be improved by adding sediment from local ponds. It should be noted that the soil mix used for soilblock making has similar composition and is well-suited to mud-straw plaster.

Rice straw (cut to 5 cm length) or wheat straw (2 cm, to speed the decomposition) is added to the soil. The amount may vary from 35 to a maximum of 70 kg of straw per cubic meter of soil, depending on local materials and the durability required. A suitable rule-of-thumb is to use 50 kg of straw per cubic meter of soil. One cubic meter of soil will produce sufficient plaster to cover 100 square meters of surface at 7 mm thickness. For two coats of 10 mm each, approximately three cubic meters are required to cover the same area.

Water is poured into the pit and thoroughly mixed in with the soil and straw by foot or by shovel at least twice daily until the straw decomposes. Water must be added periodically and the pit will emit the smell of rotting vegetable matter. In hot weather, decomposition may take only five to seven days, while in winter it may take two weeks or longer.

As discussed above in "Wall Preparation," the wall is doused before applying the plaster. The plaster is mixed to the required consistency for application by hand or by trowel. The uneven finish achieved by hand-plastering can be overcome by a final leaping.

Surface cracking of the plaster may result from a dry or hot wall underneath or too little sand in the soil. Minor cracks are repaired and a smooth surface is imparted by a thin coat of dung wash, or gobri, applied by hand. This leaping is prepared from 20-30 kg of fresh dung per 100 square meters of surface, mixed with water to such consistency that a thin layer may be applied without the leaping running down the wall. The consistency of the mix may be stiffened by adding soil, though not more than the original quantity of dung.
Waterproofing mud plasters against attack by torrential rains involves the addition of bituminous compounds including tar from oil-bearing plants, soaps and sulphonated oils. Hot cottonseed tar applied to mud plaster has been found to provide satisfactory protection. The tar must be heated so as to allow application on the wall in a thin coat using a coarse brush. Solutions of animal glue achieve similar results; however, the dried coat is somewhat water soluble, and will eventually erode. Additionally, glue made from animal bones may be taboo. Alternately, a 'cutback' of bitumen and kerosene may be applied to the surface. All such surface coatings, however, impart their own color, usually a dirty brown or black, to the wall. In addition to looking unsightly, such surfaces, being non-absorbent, do not take whitewash or surface decoration well. Consequently, cutback may be added directly to the plaster mix and/or leaping prior to application on the wall.

Cutback is prepared by adding hot bitumen to kerosene (never vice versa, to ensure adequate mixing and prevent fire) at 5:1 (bitumen to kerosene by weight). 64 kg of the prepared cutback is added to the plaster per cubic meter of soil (Central Building Research Institute, 1984). For surface coating only, the cutback must be thinner, requiring 1:1 or even 1/2:1 (bitumen to kerosene by weight).
Lime Plaster

Plasters made of lime and pozzolanic materials have good cementitious properties, have a high strength to cost ratio, and set quickly enough to allow application of additional plaster coats. All well-prepared lime plasters have excellent workability. However, lime-sand plasters made of pit sand or river sand are susceptible to erosion and result in a chalky finish, even when well cured.

Lime is available in a variety of qualities, from fine hydraulic lime to kankar (rock) lime. The Indian Standards Institute has specified six classes of lime (IS:712-1984), which apparently none of the material suppliers in the country follow!

Of the six, (Class C) fatlime appears to be most widely available. Because it bonds particularly well with pozzolanic substances, its use in low-cost plasters is recommended.

While fly-ash and coal-ash have certain pozzolanic properties, they are available only at thermal power stations and railway yards. The most common and widely used pozzolana throughout the Indian subcontinent is surkhi, or crushed fired brick. Generally a dull red to orange in color, surkhi results in a dried lime-surkhi plaster of pinkish hue. Additionally, an exceedingly smooth surface can be achieved by applying a thin lime-surkhi wash which is repeatedly gone over by a wet mason’s float.

Preparation of lime for masonry and plastering is an art, despite tests to check consistency and workability. Techniques vary with the quality and age of the lime, the desired properties and the surface to which the plaster is applied. Satisfactory results have been achieved with dried, sieved, hydrated fatlime and surkhi. Water should be added to the dry mix at least 24 hours prior to plastering to allow larger lime particles to rehydrate.

Quicklime is often prepared by hydrating a known quantity of lime with sufficient water. The resulting putty may be added directly to the dry bulk material just prior to plastering. Care must be taken to ensure the correct volumetric proportion on mixing. Finally, the quicklime must not be so thin as to result in a thin plaster mix.

Lime plasters must be cured for at least seven days before finishing or adding a second coat. Strength depends on hydration and absorption of atmospheric carbon dioxide. Generally, lime plasters reach full strength after decades, even centuries. Structures built by the Romans have been found to contain lime mortars that are still not fully hydrated!
Cement Plaster

Cement is more effective per unit volume as a binding agent than lime. Typically, the bulk material to cement ratio is double that of bulk to lime. The resulting plaster is both harder and more brittle. Additionally, as cement binds well with large particles, as in pit sand, the final plaster is more porous than a lime-surkhi plaster, for instance.

Neither are cement plasters as workable as lime plasters. Consequently, it is common to add lime to a cement plaster to improve workability. However, cement-based plasters set quickly, reaching maximum strength earlier than lime plasters, provide a strong, clean finish, and are resistant to abrasion.

Bonding of cement plasters on soilblock walls is weak. Providing a cement wash on a raked wall prior to application of cement plaster will improve bonding. Due to the brittle character of cement plasters, cracking will be a problem if plastering is carried out in the summer. Plastering in the evening with adequate curing on the following days produces the best results.

Gypsum Plaster

Between cement and lime-based plasters vis-a-vis hardness, gypsum plasters are water absorbent. For this reason they are perhaps the most ill-suited of the plasters discussed in this report to application on earth walls.

Gypsum sets quickly, necessitating the use of retarders. This drawback and the cost of bulk gypsum as compared even to cement and lime preclude its use for low-cost buildings.
PLASTER COSTING

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (g/cc)</th>
<th>Bulk Cost (Rs./100 kg)</th>
<th>Unit Cost (Rs./kg)</th>
<th>Energy of Production (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat Straw</td>
<td>na</td>
<td>90/100 kg</td>
<td>0.90</td>
<td>na</td>
</tr>
<tr>
<td>Cow Dung</td>
<td>na</td>
<td>10/100 kg</td>
<td>0.10</td>
<td>na</td>
</tr>
<tr>
<td>Bitumen</td>
<td>na</td>
<td>40/13 kg</td>
<td>3.25</td>
<td>na</td>
</tr>
<tr>
<td>Coarse Sand (Badarpur)</td>
<td>1.38</td>
<td>140/cum.</td>
<td>0.10</td>
<td>200</td>
</tr>
<tr>
<td>Burnt Clay Poz- zolana (Surkhi)</td>
<td>1.32</td>
<td>120/cum.</td>
<td>0.10</td>
<td>1300</td>
</tr>
<tr>
<td>Lime</td>
<td>0.62</td>
<td>80/100 kg</td>
<td>0.86</td>
<td>6320</td>
</tr>
<tr>
<td>Gypsum</td>
<td>na</td>
<td>50/25 kg</td>
<td>2.00</td>
<td>1510</td>
</tr>
<tr>
<td>Animal Glue</td>
<td>na</td>
<td>14/ kg</td>
<td>14.00</td>
<td>na</td>
</tr>
<tr>
<td>Gum Arabic</td>
<td>na</td>
<td>100/ kg</td>
<td>100.00</td>
<td>na</td>
</tr>
</tbody>
</table>

* Note: Unit costs were computed from bulk costs (1987), and densities, assuming losses.


TABLE II: DRY MIX WEIGHT

<table>
<thead>
<tr>
<th>Plaster Thickness (mm)</th>
<th>Dry Mix Weight* (kg/sq.meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mud-Straw</td>
</tr>
<tr>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>15</td>
<td>21</td>
</tr>
</tbody>
</table>

* Note: For mud-straw plasters with 40 kg straw/cu.meter of earth; lime plasters 1:3 - 1:4 with surkhi; and lime-cement plasters 1:1:8 - 1:1:12. These figures are based on field trials and ref. Khanna, 1982.
### TABLE III: LABOR COSTS

<table>
<thead>
<tr>
<th>Plaster Thickness (mm)</th>
<th>Mud-Straw</th>
<th>Lime</th>
<th>Lime-Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>3.00</td>
<td>7.00</td>
<td>7.30</td>
</tr>
<tr>
<td>12</td>
<td>3.20</td>
<td>7.10</td>
<td>8.25</td>
</tr>
<tr>
<td>15</td>
<td>3.50</td>
<td>9.20</td>
<td>9.20</td>
</tr>
<tr>
<td>Double (10 + 10)</td>
<td>5.80</td>
<td>14.40</td>
<td>14.80</td>
</tr>
</tbody>
</table>

*Note: Assuming mason’s wage of Rs. 45/day, laborer’s of Rs. 22.50/day. Values based on field trials and consultation with Patel Schedule of Building Works, (January 1987).*

### TABLE IV: PROJECTED COST MATRIX

<table>
<thead>
<tr>
<th>Plaster Mix</th>
<th>Material (a), Labor (b), and Total Cost (c), (Rs./sq.meter applied)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plaster Mix</td>
</tr>
<tr>
<td>40kg straw/cu.meter</td>
<td>a) 3.90</td>
</tr>
<tr>
<td>earth with 64kg cutback</td>
<td>b) 3.00</td>
</tr>
<tr>
<td>(5 bitumen: 1 kerosene).</td>
<td>c) 6.90</td>
</tr>
<tr>
<td>Base 1:6 (lime:surkhi)</td>
<td>a) 9.65</td>
</tr>
<tr>
<td>Surface 1:2:8 (cement: lime:Radarpur sand)</td>
<td>NA</td>
</tr>
</tbody>
</table>

*Note: Patel estimates that the total labor charge per square meter for finishing mouldings, conices, arches, drip details, etc. is Rs. 17.50 for single coat and Rs. 29.00 for double coats.*
<table>
<thead>
<tr>
<th>Procedure</th>
<th>Cost (Rs.)</th>
<th>Area (sq. meter)</th>
<th>Unit Cost (Rs./sq. meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raking and brushing</td>
<td>22.50</td>
<td>26</td>
<td>0.90</td>
</tr>
<tr>
<td>-2 laborers cover 26 sq. meters in 4 hours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lime wash (1 lime: 7 water)</td>
<td>0.86</td>
<td>12</td>
<td>0.07</td>
</tr>
<tr>
<td>-15 minute's labor</td>
<td>0.70</td>
<td>12</td>
<td>0.06</td>
</tr>
<tr>
<td>Base plaster (12 mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>47 kg lime</td>
<td>40.00</td>
<td>9</td>
<td>4.44</td>
</tr>
<tr>
<td>244 kg surkhi</td>
<td>24.40</td>
<td>9</td>
<td>2.70</td>
</tr>
<tr>
<td>-labor: 6 mason-hours</td>
<td>33.75</td>
<td>9</td>
<td>3.75</td>
</tr>
<tr>
<td>- labor-hours</td>
<td>25.30</td>
<td>9</td>
<td>2.81</td>
</tr>
<tr>
<td>Curing for 7 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-labor: 14 labor-days</td>
<td>315.00</td>
<td>800</td>
<td>0.40</td>
</tr>
<tr>
<td>Surface plaster (10 mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 kg cement</td>
<td>57.60</td>
<td>15</td>
<td>3.84</td>
</tr>
<tr>
<td>40 kg lime</td>
<td>32.00</td>
<td>15</td>
<td>2.13</td>
</tr>
<tr>
<td>0.23 cum Badarpur sand</td>
<td>31.00</td>
<td>15</td>
<td>2.07</td>
</tr>
<tr>
<td>1/2kg color</td>
<td>1.50</td>
<td>15</td>
<td>0.10</td>
</tr>
<tr>
<td>-labor: 1 mason-day</td>
<td>45.00</td>
<td>15</td>
<td>3.00</td>
</tr>
<tr>
<td>- labor-hours</td>
<td>33.75</td>
<td>15</td>
<td>2.25</td>
</tr>
<tr>
<td>Curing for 14 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-labor: 28 labor days</td>
<td>630.00</td>
<td>800</td>
<td>0.79</td>
</tr>
<tr>
<td>Total Material</td>
<td>16.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Labor</td>
<td>13.21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Note: The material component is 66% more than estimated; labor is 9% less.
CONCLUSION AND ANALYSIS OF PLASTER TEST RESULTS

Lime-surfki and combination lime-cement-sand plasters emerged as the most erosion resistant and efficient plasters (refer appendix I) under the tests conducted. Lime surfki plasters, however, are cheaper than combination plasters.

Lime-coarse sand plasters have slightly more erodability than lime-surfki plasters and are more permeable. Cement plasters were not found to be efficient for earth walls because the wall-plaster bond is very weak. These plasters do not fail but crack and break away from the wall surface. Cement based plasters are generally more expensive than lime plasters in lime abundant areas. Cement plasters may, however, be the only alternative in areas where lime is not available or is more expensive. Cement plasters with fine sands have better bonding properties than those with coarse sands and are more permeable.

Double coat plasters are very effective with low erodability, permeability and high bond strength. These plasters are (because of the additional material and labour involved) more than twice the cost of single coat plasters.

A table showing a comparative ranking of plasters is presented below:

<table>
<thead>
<tr>
<th>Plaster type</th>
<th>Plaster Mix</th>
<th>Erodability</th>
<th>Wall plaster bond</th>
<th>Impact resistance</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime-Surfki</td>
<td>1:4</td>
<td>Very low</td>
<td>Good</td>
<td>Good</td>
<td>Low</td>
</tr>
<tr>
<td>Lime-Surfki</td>
<td>1:6</td>
<td>Very low</td>
<td>Good</td>
<td>Good</td>
<td>Low</td>
</tr>
<tr>
<td>Lime-coarse sand</td>
<td>1:3</td>
<td>Very low</td>
<td>Good</td>
<td>Good</td>
<td>Low</td>
</tr>
<tr>
<td>Lime-Cement Coarse sand</td>
<td>1:1:8</td>
<td>Very low</td>
<td>Good</td>
<td>Good</td>
<td>Medium</td>
</tr>
<tr>
<td>Lime-coarse sand</td>
<td>1:4</td>
<td>Low</td>
<td>Good</td>
<td>Good</td>
<td>Low</td>
</tr>
<tr>
<td>Cement-fine sand</td>
<td>1:3</td>
<td>Low</td>
<td>Weak</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Cement-fine sand</td>
<td>1:4</td>
<td>Medium</td>
<td>Weak</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Cement-coarse sand</td>
<td>1:4</td>
<td>Medium</td>
<td>Very weak</td>
<td>Very low</td>
<td>High</td>
</tr>
</tbody>
</table>

Note: All plasters are a minimum of 10 mm thick.
APPENDIX I: PLASTER TESTING

Below is outlined a test to determine erodability of plasters that will aid the designer in selecting the most appropriate plaster type. All tests are not applicable to all plasters. For example, it was found that the spray test gave results of questionable utility for cement based plasters—the samples simply did not erode. Care should be taken to mix and apply samples of plaster for testing under similar conditions as expected on site.

SPRAY TEST
(Modified from K.S. Jagadish et. al)

While rainfall and the actual conditions under which erosive precipitation occur are extremely difficult to model, the spray test is a useful simulation of the process of erosion by rain. Though the quantitative data extracted from spray testing plaster samples is dependent not only on material properties, but also on techniques of application and curing conditions, the test provides an excellent means of assessing the relative advantages and disadvantages of the various samples tested.

Apparatus

a) Centrifugal pump (one horsepower [0.746 kW], >20 m head).
b) Shower head of the following fabrication:

- inlet diameter: 15 mm
- outlet diameter: 90 mm
- cone length: 130 mm
- hole spacing: 5 mm (on rectilinear grid)
- hole diameter: 1 mm
- total number of holes: 312
- density of holes: 4/sq.cm

c) Pressure gauge (>2.0 kg/sq.cm)
d) Tank and stand as shown:

FIGURE VI: SPRAY TEST APPARATUS
Method

1) Construct 50x30x10 cm wall samples of un/stabilized, compressed soil blocks with un/stabilized mud mortar, allowing the fabricated samples to dry in the sun at least a week. Place the samples off the ground to prevent termite attack.

[Note that plaster mixes must be prepared in advance if required. For example, mud-straw plaster must ferment prior to application. However, cement plasters should be applied before setting takes place].

2) One day before the actual application, prepare the samples by raking the horizontal mortar joints and brushing the wall sample clean of grit.

3) With the tools required for good masonry work (trowel, float, etc.), apply the plaster onto a slightly wetted sample surface. Be sure that the plaster covers the entire 50x30 cm front face, as well as the sides and top. Take care to wrap the plaster all the way around to the rear face and provide a drip detail along the bottom edge of the front face as shown.

![Diagram of wall sample detailing](image)

(a) Cross Section  (b) Rear View

FIGURE VII: WALL SAMPLE DETAILING

The drip detail will reduce the effect of water running off the front face and subsequently being absorbed between the wall and plaster.

4) Record the date of plaster application, time of day, weather conditions, sun or shade dried, and thickness of plaster. Qualitatively, note such parameters as surface moisture, and adhesion of the unfinished mix to the wall.

5) Examine the samples every day, ensuring that lime and cement plasters are curing adequately. Note size and extent of cracking. Record local meteorological data during the application and curing period—particularly maximum and minimum temperatures, humidity and rainfall. This is extremely important in comparing results obtained under other conditions, either in other places or at different times of the year.
6) After the curing period is over, carefully place the sample on the stand. The distance from the plastered front face to the showerhead must be 175 mm. Shield the sample with a metal plate, and activate the pump. By means of the gate valve, stabilize the pressure at 1.0 kg/sq.cm. Remove the plate abruptly and begin timing.

7) Observe the process of erosion, noting the time at which cracking begins and where the cracks are concentrated. As the plaster coat begins to wash away fully, note the size of pieces falling away. Shield the sample and note the time elapsed at the point of total failure of the plaster, that is, the point of disintegration of the plaster coat when the brick surface underneath begins to erode. The degree of total failure will vary considerably from sample to sample even with the same plaster type. Hence it is recommended to spray the sample for a maximum duration of two hours, or to the point of total failure.

8) Take measurements of plaster thickness and the depths of erosion at ten points on the area subjected to spray. A reasonably accurate index of the erodibility of plaster is the rate of erosion, or the average eroded depth per minute.
RAINFALL DURATION FREQUENCY CURVES FOR NEW DELHI

(Based on 20 years' sample, IMD)

Precipitation (mm)

Recurrence Interval (Years)

- 15 minute
- 30 minute
- 45 minute
- 3 hour
- 6 hour
- 12 hour
30-MINUTE INTENSITY RECURRENCE INTERVAL CURVE, NEW DELHI (20 YEARS' RECORD)

Equation of best-fit line:

\[ I(30) = \frac{57.54}{R^{0.1615}} \]
Results of testing

Spray testing of various plaster mixes was undertaken to
develop a durable, low maintenance plaster for protection of
soilblock walls. Although, erosion and failure were largely a
result of spray penetrating the cracks formed during the curing
period, the time taken for total failure has nevertheless been
recorded. However, recording the depth of erosion was
problematic, in that for all lime, cement, and lime-cement
plasters, erosion was negligible. Consequently, "na" ("not
applicable") was recorded under the depth of erosion column.
Perhaps more important are the qualitative results recorded under
the two "Remarks" sections.

All mix ratios are by weight; refer to Table I for densities
to convert to volume ratios.

Note: t is the plaster thickness in mm, T is the time in
minutes for total failure, and D is the average depth of erosion
in mm.

Data
Presented in tabular form on the following pages.

<table>
<thead>
<tr>
<th>Plaster Mix</th>
<th>t (mm)</th>
<th>Remarks</th>
<th>T (min)</th>
<th>D (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mud w/- 7% cement</td>
<td>Cracked by morning.</td>
<td>2</td>
<td>Cracks enlarged immediately, mud wall exposed in 90 sec., followed by total plaster failure.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lime: 9% C sand (1:3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Spray enlarged the cracking along edges not take place in 2 hours due to good bonding.</td>
</tr>
<tr>
<td>Lime: 10% C sand (1:4)</td>
<td></td>
<td></td>
<td>55</td>
<td>Gritty film washed off immediately. Edge, corner cracking pronounced by 35 min, first piece fell off by 53 min, followed by failure at 54 min 48 sec.</td>
<td></td>
</tr>
</tbody>
</table>

* C sand here abbreviates coarse pit sand, or Badarpur sand; and F sand fine river sand, or Yamuna sand.
<table>
<thead>
<tr>
<th>Plaster Mix</th>
<th>Remarks</th>
<th>T</th>
<th>Remarks</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime: C sand (1:6)</td>
<td>7</td>
<td>On damp wall, applied morning, semi-shade dried. Day temps to 42 deg C, rel humidity &lt; 60%. Wet morning and evening for 2 weeks.</td>
<td>38</td>
<td>Surface grit washed off immediately. Cracking on front face developed from edges. Total failure due to front face cracking at 38 min 20 sec. Blocks under intact plaster were wet, indicating high permeability.</td>
</tr>
<tr>
<td>Lime: surkhi* (1:3)</td>
<td>12</td>
<td>On damp wall, applied afternoon, shd dried. Day temps to 44 deg C, rel humidity &lt; 60%. Wet morning and evening for 2 weeks.</td>
<td>120</td>
<td>Lime-surkhi mixes were the mason's choice for durability and workability. A high lime concentration in this mix resulted in crazing, though bonding was excellent.</td>
</tr>
<tr>
<td>Lime: surkhi (1:4)</td>
<td>14</td>
<td>On damp wall, applied afternoon, shd dried. Day temps to 44 deg C, rel humidity &lt; 60%. Wet morning and evening for 2 weeks.</td>
<td>120</td>
<td>No cracking or crazing, some surface grit indicating excess lime not reacted with pozzolana. Soilblocks beneath plaster remained dry. Good bonding.</td>
</tr>
<tr>
<td>Lime: surkhi (1:6)</td>
<td>10</td>
<td>On damp wall, applied afternoon, shd dried. Day temps to 44 deg C, rel humidity &lt; 60%. Wet morning and evening for 2 weeks.</td>
<td>120</td>
<td>No cracking, crazing na or surface grit. 10 mm thickness appears to be sufficient to retard permeation. Good bonding. Warrants further work on techniques of wall preparation.</td>
</tr>
<tr>
<td>Lime: C sand: surkhi (1:1:4)</td>
<td>9</td>
<td>On damp wall, applied morning. Semi-shade dried. Day temps to 42 deg C, rel humidity &lt; 60%. Wet morning and evening for 2 weeks.</td>
<td>95</td>
<td>A variation on lime- na surkhi plaster. The sand decreased the workability, and apparently caused edge cracking. Failure at 94 min 33 sec.</td>
</tr>
</tbody>
</table>

* C sand here abbreviates coarse pit sand, or Badarpur sand; and F sand fine river sand, or Yamuna sand. Surkhi is crushed fired brick pozzolana; rapas is brick kiln ash.
<table>
<thead>
<tr>
<th>Plaster Mix (mm)</th>
<th>Remarks (Application/Curing)</th>
<th>T (min)</th>
<th>Remarks (Erosion/Failure)</th>
<th>D (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement: 10</td>
<td>On damp wall, applied morning, shade dried. Day temps to 41 deg C, rel humidity &lt; 60%. Wet morning and evening for 1 week.</td>
<td>120</td>
<td>High strength, high cost. No cracking or any sign of failure from spray testing. Bonding was poor, i.e., plaster came off in large slabs.</td>
<td></td>
</tr>
<tr>
<td>C sand (1:3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cement: 11</td>
<td>On damp wall, applied morning, shade dried. Day temps to 41 deg C, rel humidity &lt; 60%. Wet morning and evening for 2 weeks.</td>
<td>120</td>
<td>Same as above. na</td>
<td></td>
</tr>
<tr>
<td>C sand (1:4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cement: 8</td>
<td>On damp wall, applied morning, shade dried. Day temps to 41 deg C, rel humidity &lt; 60%. Wet morning and evening for</td>
<td>120</td>
<td>Same as above. na</td>
<td></td>
</tr>
<tr>
<td>C sand (1:6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* C sand here abbreviates coarse pit sand, or Badarpur sand; and F sand fine river sand, or Yamuna sand. Surkhi is crushed fired brick pozzolana; rapas is brick kiln ash.
<table>
<thead>
<tr>
<th>Plaster Mix</th>
<th>Remarks</th>
<th>T (min)</th>
<th>Remarks</th>
<th>D (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Cement: F sand (1:3)</td>
<td>On damp wall, applied morning, sun dried. Day temps to 41 deg C, rel humidity &lt; 60%. Wet morning and evening for 1 week.</td>
<td>120</td>
<td>Problem encountered with wall samples not representative of field conditions was brittle failure when placing the sample on the stand. Bonding was better than cement-C sand.</td>
<td>na</td>
</tr>
<tr>
<td>11 Cement: F sand (1:4)</td>
<td>On damp wall, applied morning, sun dried. Day temps to 41 deg C, rel humidity &lt; 60%. Wet morning and evening for 1 week.</td>
<td>120</td>
<td>Brittle failure mentioned above occurs for thin coats (≤10 mm?). No cracking, no failure.</td>
<td>na</td>
</tr>
<tr>
<td>8 Cement: F sand (1:6)</td>
<td>On damp wall, applied morning, sun dried. Day temps to 41 deg C, rel humidity &lt; 60%. Wet morning and evening for 1 week.</td>
<td>67</td>
<td>Edge cracking from brittle failure caused pieces to fall off by 65 min, total failure by 67 min 8 sec.</td>
<td>na</td>
</tr>
<tr>
<td>12 Lime: C sand (1:1:6)</td>
<td>On damp wall, applied afternoon, sun dried. Day temps to 42 deg C, rel humidity &lt; 60%. Wet morning and evening for 2 weeks.</td>
<td>96</td>
<td>Edge and corner cracking accentuated within first half hour, though bonding was good so failure at 96 min 8 sec. Low permeability.</td>
<td>na</td>
</tr>
<tr>
<td>11 Lime: C sand (1:1:8)</td>
<td>On damp wall, applied afternoon, sun dried. Day temps to 42 deg C, rel humidity &lt; 60%. Wet morning and evening for 2 weeks.</td>
<td>120</td>
<td>Higher sand proportion than above, hence less cracking. Good bonding, no failure.</td>
<td>na</td>
</tr>
</tbody>
</table>

* C sand here abbreviates coarse pit sand, or Badarpur sand; and F sand fine river sand, or Yamuna sand. Surkhi is crushed fired brick pozzolana; rapas is brick kiln ash.
<table>
<thead>
<tr>
<th>Plaster Mix</th>
<th>Remarks</th>
<th>T (min)</th>
<th>Erosion/Failure</th>
<th>D (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wpc*: 10</td>
<td>On damp wall, applied morning, sides and front cracked by afternoon. Day temps to 41 deg C, rel humidity &lt; 60%. Wet morning and evening for a week.</td>
<td>32</td>
<td>Addition of wpc to reduce permeability. Not necessary as lime-sorkhi itself appears to retard permeation. Wpc upset the lime-pozzolana reaction, resulting in surface cracking.</td>
<td></td>
</tr>
</tbody>
</table>

| Wpc: 9 | On damp wall, applied afternoon. Day temps to 41 deg C, rel humidity < 60%. Wet morning and evening for a week. | 120 | Wpc effective in reducing permeability of cement plaster. As with other cement plasters tested, bonding was poor. |

| Wpc: 12 | On damp wall, applied afternoon. Day temps to 41 deg C, rel humidity < 60%. Wet morning and evening for a week. | 85 | Edge and corner cracking during the curing period became accentuated within the first hour. Total failure at 84 min 45 sec. |

* Wpc here abbreviates water proofing compound, commercially available for addition with cement. C sand here abbreviates coarse pit sand, or Badarpur sand; and F sand fine river sand, or Yamuna sand.
The data tabulated on the previous pages result from spray testing of single plaster coats. Experimentation with double coats was also undertaken; the results are presented below.

<table>
<thead>
<tr>
<th>Plaster Mix</th>
<th>Remarks (Application/Curing)</th>
<th>T (min)</th>
<th>Remarks (Erosion/Failure)</th>
<th>D (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base-lime:  10</td>
<td>On wet wall, base applied evening,</td>
<td>240</td>
<td>Base coat should have been cured adequately prior to application of surface.</td>
<td>na</td>
</tr>
<tr>
<td>surkhi: (1:8)</td>
<td>surface next morning, Semi-shade</td>
<td></td>
<td>Excellent performance vis-a-vis durability and bonding, even after two hours spray, a day to dry and another two hours spray.</td>
<td></td>
</tr>
<tr>
<td>Surface-cement: 8</td>
<td>dried. Day temps to 40 deg C, rel humidity &lt; 60%. Wet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C sand: (1:1:16)</td>
<td>morning and evening for 1 week.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Base-lime:  9 | On wet wall, base applied evening, | 120     | No edge or corner cracking of either coat. After removing the sample from the stand, it was allowed to dry for a day. Bonding of surface to base was poor. No further testing. | na     |
| surkhi: (1:8) | surface next morning, Semi-shade |        | | |
| Surface-cement: 12 | dried. Day temps to 40 deg C, rel humidity < 60%. Wet | | | |
| C sand: (1:8) | morning and evening for 1 week. | | | |

* Glue is animal starch solution, C sand here abbreviates coarse pit sand, or Badarpur sand; and F sand fine river sand, or Yamuna sand. Surkhi is crushed fired brick pozzolana.
APPENDIX II: TESTS FOR STANDARDIZATION OF PLASTERING MATERIALS

Sampling Method for Bulk Materials

The following procedure should be carried out for bulk materials such as sand, lime, earth, and surkhi arriving on site to be used in masonry, plastering, etc.

Apparatus

a) shovel,
b) quartering cone.

Method

1) On opposite sides of the heap, remove and discard 10 cm of surface material from a 30 cm wide strip running vertically down the side of the heap.

2) Take shovelfuls from each strip at equal intervals such that a minimum of three and a maximum of five shovelfuls are placed in a clean receptacle.

3) Mix all the samples taken from both sides thoroughly.

4) Divide the mixed material into four equal piles.

5) Take alternate quarters until the sample size is sufficient for the tests to be carried out.

Test for Grain Size of Coarse Sand (Badarpur)

Badarpur, or pit sand, is a byproduct of quarrying in the vicinity of Delhi. Orange to red in color, it contains angular, hard, silicaceous material. IS:1542-1977, Specification for Sand for Plaster, outlines the following requirement for the particle size composition of coarse sand.

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percentage Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5 mm</td>
<td>100</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>95-100</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>95-100</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>90-100</td>
</tr>
<tr>
<td>600 microns</td>
<td>80-100</td>
</tr>
<tr>
<td>300 microns</td>
<td>20-65</td>
</tr>
<tr>
<td>150 microns</td>
<td>0-15</td>
</tr>
</tbody>
</table>

Mortar cubes of 1:6 (cement:sand by volume) should have 28-day compressive strength greater than 30 kg/sq.cm.
GRAN SIZE ANALYSES
BADARPUR SAND AND SURKHI

Percentage Passing

Log Sieve Diameter

1.875 2.176 2.477 2.778 3.072 3.378 3.525 3.577

BADARPUR SAND

SUKHI
Field Tests to Determine Lime Types

Due to the variability of lime available from material suppliers, a few simple tests can aid in determining the quality of bulk lime supplied on site. IS:712-1984, Specification for Building Limes, classifies lime as follows:

Class A - hydraulic lime.
Class B - semi-hydraulic lime, used for mortars, lime concrete, base plaster.
Class C - fatlime, used for surface plaster, whitewashing, composite mortars and addition with pozzolanas.
Class D - magnesium/dolomitic, used for surface plaster, whitewashing.
Class E - kankar, for masonry mortars.
Class F - silicacious/dolomitic, for base and surface plasters.

IS:1642-1986, Methods of Field Testing of Building Lime, outlines two simple tests to determine lime class.

1) Mix 5 ml of well-settled lime with 1:1 HCl to a total of 25 ml. Excessive effervescence indicates CaCO3. Allow to stand for 24 hours. Thick gel formation results from Class A; thin gel from B and E; no gel from C, D, and F.

2) Make 50 mm diameter balls of quicklime, allow 6 hours to set. Immerse in water. Disintegration in a few minutes indicates classes C or D, little expansion and numerous cracks indicate B or E, no disintegration indicates A.
GLOSSARY OF TERMS

crazing - hairline cracks on a plaster surface that has dried too quickly.
cutback - mixture of kerosene and bitumen, used for waterproofing walls or plasters.
erodibility - the propensity of a material to erosion by the individual or combined effects of rain and wind.
erosivity - the capability of rainfall to cause erosion of an exposed surface.
keys - raked mortar joints in brickwork that increase the surface area of the wall-to-plaster bond and allow direct load transfer of the plaster itself weight.
leaping - thin surface coating of dung and soil to provide plaster finish.
pozzolana - any material, inherently without cementitious properties, which when combined with lime, forms compounds with cementitious properties.
surkhi - crushed fired brick powder, a pozzolana.

Mason’s Tools

brickhammer - small hammer with one sharp end for evenly breaking bricks (Hindi, vasuli).
float - small, handheld tool to finish the plaster surface (Hindi, guurma)
mason’s line - thin, unbreakable cord to check linearity of wall surfaces (Hindi, sooth).
plumbline/bob - cord and weight used to check vertical alignment (Hindi, saoul).
screed - stiff, true aluminum or wood beam, roughly two meters in length, used for striking off the plaster surface (Hindi, phanti).
square - steel scale with internal and external 90 degree angles (Hindi, guyiya).
trowel - triangular steel spatula used to apply plaster to the exposed wall, and to detail edges, etc. (Hindi, karni).
BIBLIOGRAPHY


Anonymous, "Organic Additives and Admixtures for Plasters."


Central Building Research Institute, Live Better With Mud and Thatch, CBRI, Roorkee, 1984.

Central Public Works Department, Specifications for Works at Delhi, Vol. I, Delhi, 1967.


Handa, C.L., C.L. Dhawan, and D.P. Sondhi, "Soil Cement Blocks as Protection Against Wave Wash and Erosion," Irrigation Research Institute, Amritsar, undated.


Indian Standards Institution (ISI), National Building Code of India, New Delhi, 1983.

ISI, IS:1642-1986, Methods of Field Testing of Building Lime (Second Revision), New Delhi, 1986.

ISI, IS:2542-1978, Methods of Test for Gypsum Plaster, Concrete and Products, Part I: Plaster and Concrete (First Revision), New Delhi, 1979.

ISI, IS:2542-1981, Methods of Test for Gypsum Plaster, Concrete and Products, Part II: Gypsum Products (First Revision), New Delhi, 1981.


ISI, IS:1727-1967, Methods of Test for Pozzolanic Materials (First Revision), New Delhi, 1983.


ISI, IS:2547-1976 (Parts I and II), Specification for Gypsum Building Plaster (First Revision), New Delhi, 1976.


Khanna, P.N., Indian Practical Civil Engineers Handbook, 1982.


Development Alternatives

Development Alternatives is an organisation dedicated to devising and promoting better approaches for the Development of India.

It is a new institution whose aim is to transform the opportunities offered by technology into solid rewards for the people.

Development Alternatives functions as an agent of change, particularly on the problems of the poor of our country and acts as a bridge between what is within their reach and what could be in their grasp.

The Programmes

The programmes of Development Alternatives cover a spectrum of mutually reinforcing activities in areas such as:
- Appropriate Technology
- Environmental Management
- Systems Design

Development Alternatives is a nation-wide network of groups and individuals who believe in the possibility of change for the better and are confident that they can personally and collectively work to bring about such a change.

What sets Development Alternatives apart is:
- Mass distribution of products for villagers through modern management methods
- Small scale entrepreneurship fully backed by a nation-wide organisation
- Self-sustaining, commercial operations directly aimed at social objectives
- High quality science harmonised with traditional knowledge.

Franchised Network

We are a country-wide decentralised organisation operating through a network of franchised units, a pioneering venture to overcome the barriers between modern technology and rural poverty.

Our Network is a chain of units with a common purpose, each adapting to local needs and conditions and sharing information and experience for their mutual benefit.

Our Franchising approach brings individual, autonomous units engaged in production of marketing under the umbrella of a common strategy for standardised products and services. It provides our partner franchisees with a well-defined corporate image and a well-known brand name.

DA is supported by UN agencies and international bodies and has its headquarters in New Delhi.

Our Products

Initially, our technology and services include:
- Improved cookstoves (Chulhas)
- Low cost housing technologies
- Mudblock presses
- Low cost improved hand looms
- Solar Energy systems
- Water and sanitation systems
- Biomass energy systems
- Bicycle trailers
- Paper and board making equipment
- Pottery products
- Energy plantations
- Lamps
- Environmental management systems

How About You?

We need ideas, people, money, goodwill.

Join us in our venture—a new experiment—a new adventure.

Operations

Our product range meets the present needs of people and at the same time opens new paths to more food, water, energy, jobs. Our modern marketing system ensures widespread availability of our products and after sales services.

Our operational system ensures efficient use of natural resources.

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