Successful plastering

1. Introduction

Sand-cement plaster is used extensively in building work as a decorative or protective coating to concrete and masonry walls and concrete ceilings.

The aim of this publication is to provide the technical information needed for successful plastering. It is intended for architects, building contractors, building inspectors, and anyone in need of guidance to achieve a satisfactory standard of work.

Aspects dealt with include selection of materials, mix proportions, surface preparation, and correct plaster application.

This publication deals with conventional architectural applications of plaster. Special applications such as squash courts and swimming pools are outside its scope.

2. Requirements

Plaster has important requirements in the fresh and hardened states.

In the fresh state plaster must be workable, cohesive, and plastic, and have good water retention. The properties of fresh plaster depend on the materials used, especially the sand, and on mix proportions.

In the hardened state, plaster must be: strong enough to hold paint and withstand local impact and abrasion; free of unsightly cracking; well bonded to the substrate; have an acceptable surface texture; and have acceptable surface accuracy (with reference to a plane or curved surface). The properties of hardened plaster depend on the properties of the fresh plaster, the substrate, and on workmanship.

The following sections give information that should make it possible to meet these requirements.

3. Selecting materials

As discussed in section 2, the properties of plaster in both fresh and hardened states depend to a large extent on the properties of the materials used. This section gives guidance on selecting materials.

3.1 Cement

All cement sold in South Africa must meet the requirements of SANS 50197 for Common cement or SANS 50413 for Masonry cement and the National Regulator for Compulsory Standards (NRCS) requirements as detailed in NRCS VC9085. Bags should be clearly marked with the strength grade, notation indicating composition and a Letter of Authority (LOA) number issued by the NRCS. An LOA is issued for each cement type from each source. To verify valid LOA numbers contact the NRCS on 012 428 5199 or www.nrcs.org.za.

CEM I and CEM II A cements are used in plaster with good results. CEM II B-V or W cements are recommended for plaster exposed to damp conditions during service (e.g. plastered plinths below damp proof course level and freestanding walls) to reduce the risk of efflorescence.

Masonry cements may be used in accordance with the requirements in SANS 2001-EM1.

Cements with slow early strength development should be used only if protection of the plaster on the substrate (against sun and wind resulting in evaporation of moisture from the surface) will be adequate to minimize early cracking before the plaster has developed sufficient tensile strength. It is recommended that users consult cement manufacturers for advice when considering highly extended cements.

The choice of cement should be based on the properties of the sand to be used in the plaster, see sections 3.2 and 3.3.

3.2 Sand

Sand is by far the major constituent of plaster and has a significant influence on its performance and material cost. In South Africa, natural sands, i.e. pit, river and dune sands, are almost invariably used. An important requirement is that sand should be free of organic matter such as roots, seeds, twigs, and humus. This is an absolutely essential requirement in the case of white or pigmented plasters.

If a sand includes lumps that are not easily broken between the fingers, it is not ideal for use in plaster; if such a sand is to be used, then such lumps should be removed by sieving.

Crusher sands are not generally suitable for use in plaster due to their angular particle shape. However, crusher sands have been used successfully in rich mixes for special applications such as plastering of squash court walls and pipe linings. Limestone or marble crusher sands are commonly used, with white cement, for plastering swimming pool shells.

"Karoo" sands, which contain a high proportion of disc-shaped dark-coloured particles, should not be used for plastering. This is because they exhibit excessive swelling and shrinkage on wetting and drying respectively. This causes excessive shrinkage cracking in the hardened plaster.

The use of ash as aggregate is also not recommended unless the ash has been thoroughly tested and proven to be sound.

Important physical properties of sands are:

- Clay content
- Grading
- Maximum particle size
- Particle shape

SANS 1090, the standard covering sand for plaster and mortar, gives limits for certain properties of sands but these should be regarded as no more than a guide. It has been found that sands meeting this standard do not necessarily produce satisfactory plaster; conversely sands that do not meet this standard may produce acceptable mixes.

Clay content

Only a small proportion of clay can be tolerated in sand used in plaster. Clay normally causes a high water requirement and high drying shrinkage.

Sands with high clay content may generally be recognized as follows:

- The fraction that passes a 0,075-mm sieve* can, after being moistened, be rolled into a thread about 3 mm or less in diameter.

- Plaster mixes made with such sands:
  - Are very "fatty" and tend to cling to a trowel.
  - Have a high water requirement.

Specialist advice should be sought if there is any doubt about the content and type of clay in a sand.

Grading

Ideally, the sand should have a continuous grading, from dust up to the largest particles. The fractions passing the 0,150-mm and 0,075-mm sieves* ("fines") are important because they significantly influence the water requirement, workability and water retentivity of the mix.

*Such sieves are expensive and normally found only in laboratories. For a field test, place a few handfuls of dry sand in the foot of a nylon stocking and tie it closed. Shake the sand and collect the dust in a bowl.

Increasing these fractions results in increased water requirement (with consequent lower strength and higher shrinkage), but improved workability and water retentivity. The optimum fines content is therefore a compromise between these properties.

For plasters, a sand lacking in fines may be used with hydrated builder's lime, mortar plasticiser, or masonry cement, or it may be blended with a fine filler sand.

Sand with a good grading, see Table 1, is likely to be suitable for use with CEM I or CEM II A cements without the addition of builder's lime or other products.

A sand with excessive fines may be improved by washing or by blending with a suitable coarser sand. The coarser sand could be a crusher sand provided that the resulting plaster is suitable for the application, and it gives acceptable results.

The SANS 1090 grading requirements for plaster sand are shown in Table 1.

Table 1: SANS 1090:2009 grading requirements for plaster sand

Sieve size mm	Percentage passing sieve by mass
4,75 mm	100
2,36 mm	90 - 100
1,18 mm	70 - 100
600 µm	40 - 90
300 µm	5 - 65
150 µm	5 - 20

Note: Some coarser material may be acceptable, or desirable, for textured decorative work.

Maximum particle size

For conventional smooth plaster, all the sand should pass through a sieve with 2,36-mm openings. For coarsely textured decorative work, the corresponding sieve size is 4,75 mm.

Oversize particles (and lumps) should be removed by sieving.

Particle shape

Ideally, for good workability, the particle shape should be nicely rounded and the particle surface texture should be smooth. The particle shape of natural sands tends to be rounded due to weathering whereas that of crusher sands tends to be angular or flaky. Some river sands, however, contain newly weathered particles with a rough surface texture and angular particle shape. These particles are normally in the coarser fraction of the sand and should be screened out.

Assessing the suitability of a sand for plastering
A sand may be assessed by doing both of the following:

- Comparing grading and maximum particle size, and – if necessary – apparent clay content, with the recommendations given.

- Making a mix to assess water requirement and workability.

Mix assessment may be done as follows:
(i) Mix 2,5 kg of cement and 12,5 kg of sand to a uniform colour on a non-absorbent surface.
(ii) Add water slowly while mixing until the mix reaches a consistence suitable for plaster.
(iii) If 2,5 ℓ of water is needed, the sand is of good quality. If 3 ℓ is needed, the sand is of average quality. If 3,75 ℓ is needed, the quality of the sand is poor; and if more water than that is required, the quality is very poor. Only "Good" sands are suitable for use in all plaster work. "Average" sands may be used for interior plaster. "Poor" and "Very poor" sands are not recommended and should be avoided.
(iv) Assess the workability of the mix (at plastering consistence) as follows:

Make up a mixture of sand, cement and water, and lime or admixture were appropriate, to the required proportions. Add the water slowly and mix until the consistence is considered satisfactory.

Using a plasterers trowel place some of the mix, about 100 mm thick and 200 mm diameter, on a flat non-absorbent surface. Holding the blade horizontal, try to force the trowel down towards the surface. If plasticity is good, the mix will extrude easily around the perimeter of the blade and it will be possible to push it almost on to the surface.

Place some of the mix on a bricklaying trowel, tap the trowel a few times to compact the mix then turn it upside down. The mix should cling to the trowel but should fall off if it is shaken.

The finishability of a plaster can be assessed by floating the surface of some of the mix with a plasterer's trowel. The surface should not tear if the finishability is good.

3.3 Additives for plaster
A number of additives are used in the manufacture of sand-cement mixes. These include:
- Hydrated builder's lime
- Mortar admixtures, most commonly plasticisers
- Bonding aids
- Pigments

Hydrated builder's lime
In South Africa both calcitic lime, $Ca(OH)_2$, and dolomitic lime $Ca(Mg)(OH)_2$, are available depending on location. Builder's lime must comply with SANS 523 (type A2P) and is used to improve workability, plasticity, and water retentivity of mortars and plasters. Up to one bag (25 kg or 40 litres measured loose) may be used per bag of common cement.

The quantity added depends largely on the fines content of the sand. Builder's lime should not be used with masonry cement.

Lime tends to increase the water requirement of the plaster and hence reduce the compressive strength slightly, however the improved workability and water retention result in better bond and lower permeability.

As a rule, lime is more expensive than cement in South Africa. South African limes are non-hydraulic and cannot be used to replace cement in the mix.

Chemical admixtures
Chemical admixtures are sometimes used in plaster mixes to improve workability and water retentivity. They should comply with SANS 50934. The use of all admixtures must be properly controlled in order to avoid adverse consequences.

The most commonly used admixtures are so-called "mortar plasticisers" which are in fact air-entraining agents. On no account should they be used with masonry cements.

Bonding aids
Bonding aids (or bonding liquids) are often used in plaster mixes, and in spatterdash for bonding plasters to their substrates. These must be used strictly in accordance with manufacturer's instructions.

They can be very effective in improving bond but only if the substrate has been properly prepared. By no means are they a substitute for a good surface preparation and workmanship. They also impart good workability to the mix but overdosing can lead to low strength.

Pigments
Pigments are used to impart colour to plaster. Pigments should comply with BS EN 12878 or an equivalent standard.

Pigments must be alkali-tolerant and, if the plaster will be exposed to sunlight, ultraviolet-resistant and should not increase the water requirement of the mix unduly. Pigments for use with portland cements are available in powder and liquid forms in a variety of colours, and are normally inorganic metallic oxides.

Caution should be exercised when using carbon black as a pigment. Experience has shown that some grades leach from the cement matrix over time.

For any given combination of cement and sand, the dosage depends on the pigment colour and the desired final colour of the plaster. Each pigment has a saturation dosage above which the colour of the mix remains the same. Dosages in excess of the saturation dosage waste pigment and can weaken the mix by increasing the water requirement.

For uniform colour, the pigment should be thoroughly mixed with the cement prior to mixing with the sand. Machine mixing is preferable, if not essential.

Variegated colour effects are also possible by partially mixing one or more additional pigments into the mix.

Note that both the sand and cement colour can have a distinct effect on the final colour, as can the amount of mixing water added and it is therefore important, particularly for pigmented plasters, that both the sand and cement are obtained from one consistent source prior to commencing work, and that the batch quantities are carefully controlled.

As already mentioned, an absolutely essential requirement in the case of white or pigmented plasters is that the sand is free of organic matter in the form of roots, twigs, humus, seeds and plant resins as these can cause localized retardation, staining, and pop-outs.

On a practical note, a very important aspect to consider when specifying pigmented plasters is that it is impossible to patch them without the patch being visible. This means that all plumbing, electrical, and other fixtures must be installed and tested prior to plastering.

3.4 Water for plaster

The water used should be fit for drinking.

Important Notes

1. Gypsum-based plaster should never be mixed with a plaster made with portland cement. This is because gypsum is a sulphate compound which attacks portland cement paste especially in damp conditions. This attack causes swelling, softening, and disintegration of the plaster.

2. Builder's lime and air-entraining agents should not be used with masonry cement.

4. Mix proportions

Mix proportions for conventional plaster are shown in Table 2.

Preferred mix proportions for plaster that will be moist during service, e.g. below damp proof course, are 50 kg of common cement, preferably CEM II B-V or W, with 2 wheelbarrows (130 litres) of suitable plaster sand; these proportions should reduce the risk of damp problems if the plaster is mixed thoroughly and applied correctly.

5. Surface preparation

This section deals with the preparation of the surface to which the plaster is applied, i.e. the substrate.

Aspects discussed are substrate properties; techniques of surface preparation; and methods of preparing different types of surface.

5.1 Surface properties required for successful plastering

The surface to be plastered should be accurately positioned overall and zones should not deviate excessively from a plane (or curved) surface. Ideally, the substrate should be rough; absorbent to a limited extent; strong and clean, i.e. free from any film, such as dust, oil, or paint, which could impair bond between plaster and substrate.

Plaster thickness should be as recommended (see section 6.3) and as uniform as possible. The more accurate the substrate the easier it is to meet these requirements.

Roughness improves adhesion by providing a positive "key" for plaster to grip. Absorption removes the water film, between substrate and plaster, which would tend to weaken adhesion. Excessive absorption will however dry out the plaster (see Absorption in section 5.2). The strength of the substrate material should be greater than, or equal to, that of the hardened plaster.

Before any plastering commences, all chases should be completed and all electrical and plumbing conduits, boxes, etc. should be fixed in position.

Table 2: Prescribed mix proportions for plaster (adapted from SANS 2001-EM1:2007)

Type	Common cement kg	Lime kg	Masonry cement MC 22,5X or MC 12,5X kg	Masonry cement MC 12,5 kg	Sand, loose damp volume, ℓ	Sand, standard wheelbarrows
External plaster	**50**	**0-25**	**-**	**-**	**150**	**2,5**
	-	**-**	**50**	**-**	**130**	**2**
Internal plaster	**50**	**0-25**	**-**	**-**	**200**	**3**
	-	**-**	**50**	**-**	**150**	**2,5**
	-	**-**	**-**	**50**	**100**	**1,5**

Table 3: Mix proportions for plaster for soft burnt clay brickwork and other weak substrates[4] (see Section 6.4)

Description	Using common cement		Using masonry cement		
	Cement[1] kg	Hydrated builder's lime[2] kg	Sand, measured loose and damp litres	Masonry cement[3] kg	Sand, measured loose and damp litres
Mix C Plaster applied to a very weak substrate, e.g. poorly burnt clay brick	50	0 - 50	300	50	200

1. Complying with SANS 50197-1 strength classes 32,5 and 42,5 only.
2. A 25 kg bag of lime has a nominal volume of 40 litres.
3. Complying with SANS 50413-1; strength class 22,5X.
4. Not suitable for mud-brick walls or adobe construction.

5.2 Techniques of preparing surfaces

Accuracy

In a new work, surface preparation starts with accurate setting out and construction of walls and soffits.

The aim should be to provide a surface that can be plastered to the required lines and levels by applying a coat (or coats) of uniform thickness. Excessively thick plaster, or plaster of uneven thickness should not be relied on to hide inaccurate work.

Where zones of the substrate surface deviate from the required plane (or curved) surface by more than about 10 mm, the first option is to remove high areas by hacking or cutting. If this is not practicable, apply undercoats to low areas in such a way that the final coat is of uniform thickness (see section 6.3).

In cases where overall thickness exceeds the recommendations given in section 6.3, it is advisable (and safer) to mechanically anchor the plaster to the substrate, e.g. with stainless steel studs. This is also recommended when plastering dense non-absorbent substrates.

Strength

For new work, masonry units strong enough to survive handling and transport prior to being built in should be strong enough to hold plaster. Similarly, in situ concrete should have ample strength.

In some cases, it is necessary to plaster existing walls of soft clay brick. Methods of plastering such surfaces are discussed later (see sections 5.3 and 6.4).

Roughness

Background surfaces should ideally be at least as rough as coarse sandpaper or rough-sawn timber.

Surface roughness can be achieved in one of the following ways:

- Using formwork with a rough surface, e.g. sawn timber, for substrate concrete
- Stripping formwork early and wire brushing concrete
- Hacking
- Abrasive blasting (e.g. sand blasting)
- Raking out mortar joints in masonry substrates to provide a key. A depth of about 10 mm is normally adequate.
- Applying a spatterdash layer

Spatterdash is a mixture of one part of cement (preferably CEMI or CEM IIA) to one and a half parts of coarse sand with enough water for a sluggishly pourable consistence. A polymer emulsion should be substituted for part of the mixing water (usually a quarter to a third, but in accordance with the manufacturer's instructions). The mixture is flicked on to the substrate as an initial coating to provide a key on dense or smooth substrates that have poor suction. The spatterdash should cover the substrate surface completely and form a rough texture with nodules about 5 mm high.

Spatterdash must **not** be allowed to dry out for at least three days. (If a polymer emulsion is included in the mix, then curing should be in accordance with the manufacturer's instructions).It should be tested for adhesion and strength by probing with a screwdriver or knife before plaster is applied to it.

Cleanliness

Surfaces must be free of loose material, such as dust, and films that can interfere with bonding, such as curing compounds. Substrate surfaces may be cleaned by:

- Water jetting
- Blowing with (oil-free) compressed air
- Vacuum cleaning
- Brushing

Solvents should not be used to remove films formed by curing compounds. (Such films must be removed by mechanical means.)

Absorption

First, assess absorptiveness by throwing about a cupful of water against the surface.

The surface will fall into one of three categories:

I No water is absorbed.
II Some water is absorbed but most runs off.
III Most of the water is absorbed.

Category **I** surfaces, which would include hard-burnt clay face bricks, glazed bricks and very dense high-strength concrete, should be prepared by applying a spatterdash coat that includes a polymer emulsion. Such surfaces must not be pre-wetted.

Category **II** surfaces should not require any treatment to control suction.

Category **III** surfaces should be wetted thoroughly for at least one hour and then allowed to become saturated surface dry before the plaster is applied.

5.3 Preparation of various types of substrate Monolithic concrete
Concrete is normally placed in situ but may be precast.

Provide a rough surface by using rough-textured formwork, early stripping of formwork and wire brushing the concrete, hacking or abrasive blasting. (If none of these is practicable, apply a spatterdash coat after ensuring that the surface is clean).

Ensure that no form-release oil is left on the surface to be plastered. Clean down by water jetting or vacuuming. Remove curing compound, if any, by mechanical means. Conventional structural concrete should not require wetting to control suction. Smooth off-shutter high-strength concrete surfaces will require the application of a spatterdash coat.

Concrete masonry
The texture of the masonry units should be sufficiently rough without further treatment. If not, apply a spatterdash coat and / or hack the surface.

If the surface is dusty, clean by brushing, water jetting or vacuuming.

It should not be necessary to control suction of the surface by prewetting, unless the masonry units are very absorbent.

Burnt clay stock brickwork
The texture of the bricks should be sufficiently rough without further treatment. If not, apply a spatterdash coat, hack the surface, or attach the new plaster mechanically with expanded metal lathing.

If the surface is dusty, clean by brushing, water jetting or vacuuming.

Burnt clay stock bricks normally have a very high suction; this can be assessed by wetting the wall (see Absorption in section 5.2). If suction is high, pre-wet the wall and allow it to become saturated surface dry before applying the plaster.

Burnt clay face-brickwork
It is recommended that specialist advice be obtained for each specific case.

Poorly burnt soft clay brickwork
This type of walling may be found in very old buildings, usually when restoration or repairs are being done.

Care should be taken when removing the old plaster so as not to damage the bricks. Protect the wall from rain or running water once the bricks are exposed.

Rake out the joints about 10 mm deep (The mortar is normally very soft.)

Brush down the wall to remove any loosely adhering material.

Lightly dampen the wall and apply a spatterdash coat that incorporates a polymer emulsion to improve adhesion.

6. Application

6.1 Batching
Batching sand by loose volume is satisfactory. Batches based on whole bags of cement are preferable. The size of the batch should, however, be small enough for it to be used up within about two hours.

6.2 Mixing
This may be done by machine or by hand. Machine mixing is preferable and highly recommended.

Hand mixing should be done on a smooth concrete floor or steel sheet. First spread out the sand about 100 mm thick. Spread the cement uniformly over the sand. Mix sand and cement until the colour is uniform. Then gradually add water while mixing until the right consistence is reached.

6.3 Plaster thickness
Recommended thicknesses are:

- First undercoat: 8 - 16 mm
- Second undercoat: (if any): 6 - 10 mm
- Finish coat: 5 - 8 mm

If plaster is applied in a single coat, thickness should be 10 - 16 mm. A single coat should not be thicker than 16 mm.

6.4 Applying the plaster
When sequencing building activities, it is highly recommended that the roof is clad before plastering starts. Never work in direct sun. Plastering should be protected from the sun and drying winds. If it is necessary to plaster walls exposed to the sun, especially in hot or windy conditions, then special precautions may be needed to protect the plaster on the wall from sun and wind to reduce the risk of cracks in the plaster.

The plaster should be used up within two hours of being mixed and never be retempered by mixing in additional water.

Ensure that plaster is not continuous across the line of a dampproof course. Plaster should be cut through to the substrate where different substrate materials meet, e.g. masonry and concrete.

The general procedure for applying plaster is as follows:
For accurate work, apply screed strips before the wall is plastered. These are narrow strips of plaster along the perimeter of the wall, or at suitable intervals on the wall, that act as guides for the striker board.

Using a rectangular plasterer's trowel, apply plaster onto the wall or ceiling using heavy pressure to compact the plaster and ensure full contact with the substrate. The plaster should be slightly proud of the intended surface.

Once the plaster starts to stiffen, it should be struck off to a plane (or curved) surface using a light striker board. Material removed in this way should be discarded.

If plaster is to be applied in more than one coat, the undercoat(s) should be scored with roughly parallel lines about 20 mm apart and 5 mm deep. The purpose of scoring is two-fold; to provide a key for the next coat and to distribute cracking so that it is less noticeable.

For the final coat, use a wood float to remove ridges made by the striker board. At the same time fill in any depressions and float flush with the surrounding plaster.

If a very smooth texture is required, a steel trowel may be used on the surface. Very smooth surfaces are, however, not generally recommended because they tend to craze and show imperfections.

Various decorative finishes are also possible. Techniques include brushing, flicking plaster onto the surface and lightly floating, etc.

In the special case of soft burnt clay brickwork, plaster should be applied as follows:
Using **mix C** (see Table 3) with the maximum amount of lime, fill major depressions in the wall and scratch well. If mesh reinforcement or metal lathing is to be used, nail it to the wall using galvanized nails driven through the spatterdash coat and use spacers to keep it away from the wall. Apply the first coat of plaster, again using **mix C** with the maximum amount of lime. This first coat is used to achieve a plane surface. (In some cases, it is necessary to use two coats to achieve this).

It must be well scratched, cured for at least two days and allowed to dry. The scratching, followed by the drying period, distributes shrinkage cracks. Apply the final coat of plaster, using the same **mix C** or preferably a slightly leaner mix. Striking off and finishing are done as described previously.

6.5 Accuracy
SANS 2001-EMI:2007 states that "Where required in terms of the specification data, the permissible deviations in plaster shall not exceed 6 mm under a 2 m straight edge."

7. Specifications
Specifications for plaster work should cover the following aspects: selection of materials, mix proportions, application, finish, and surface tolerances.

8. Conclusion
Provided sufficient attention is paid to the selection of materials, mix proportions, preparation of substrate surfaces and the application of the plaster, the results should be serviceable and aesthetically acceptable.

Note: For more information on plaster defects and their causes, refer to ***Common defects in plasters*** available from The Concrete Institute.

9. Further reading and reference documents
SANS 2001-EM1:2007, **Construction works. Cement plaster**, Pretoria: Standards South Africa, 2007.

SANS 1090:2009, **Aggregates from natural sources – Fine aggregates for plaster and mortar**, Pretoria: Standards South Africa, 2009.

SANS 523:2009, **Limes for use in building**, Pretoria: Standards South Africa, 2009.

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