must be deeply and well keyed to take every subsequent layer.

New work can be added on to a wall as soon as the wall below has dried enough to enable it to take the weight of the new work without distortion.

C6.3
Cob is placed on the wall until the wet cob will not stand further work being placed upon it without the faces bulging outwards. This can be as soon as overnight.

An overlapping pattern is necessary to ensure there are no vertical discontinuities where shrinkage could accumulate, resulting in a wide vertical crack.

The height of each layer of cob varies depending on wall thickness and mix stiffness, but is generally between 200 mm and 300 mm per day.

It is important to ensure good bonding around corners and at intersections, where longer cobs can be moulded at once to help maintain good bonding.

A recommended method for keying is to form holes 40 mm to 50 mm deep and 30 mm to 40 mm diameter in the top surface at 100 mm centres.

The cob can be moulded true to finished line as work progresses or alternatively, once firmed up, the face of the cob wall can be trued up by cutting back.

Depending on the thickness of the wall and the weather, curing takes from 1 week to several months, usually at least 4 weeks.

Excessive exposure to wind or sun can accelerate surface drying and cause cracking.

6.4 Construction joints and cold joints

Before new work is added, the previous cob is to be wetted down.

If the previous layer has dried, then a layer of clay slip shall be worked into the wetted surface of the old work before adding the new.

6.5 Services and reinforcing

Cob is placed around vertical reinforcement and electrical conduits as the wall is built up.

Horizontal reinforcement is to be placed on cob that is soft enough to embed the reinforcing as the layers continue upwards, and is laid by pressing the reinforcing into a cob layer at least 50 mm thick with more cob laid above it and worked in that same day.

C6.5
Tests have shown that it is important for good bonding to embed reinforcing within the body of new work and not be placed directly between old and new work.

6.6 Shrinkage

Vertical settlement due to cob shrinkage shall be provided for when laying up the wall against fixed items such as posts. When fixing ties between cob work and items such as posts or joinery frames, all cob work below tie level shall first be allowed to harden.

Fittings, frames, and vertical reinforcement embedded in the wall shall be detailed to allow for shrinkage to ensure that the shrinkage can occur unrestrained.

C6.6
If vertical shrinkage is restrained by other parts of the structure, then cracking due to 'hanging up' is likely to result.

6.7 Control joints

Control joints are not required (see 2.14.1)

C6.7
Horizontal shrinkage is controlled by the aggregates. Micro-cracking is controlled by the fibres in the mix and these prevent the aggregation of shrinkage into vertical cracks. Shrinkage can occur at posts and other fixed items, especially at the end of a section of wall. This shrinkage needs to be allowed for in the design.

6.8 Finishing

Low-density cob, with a density from 800 kg/m^3 to 1400 kg/m^3 shall be coated with hydrated lime plaster externally and earth plaster internally in accordance with section 8. Heavy cob walls may be plastered with either an earth or lime plaster in accordance with section 8.

C6.8
Cob can be shuttered to shape vertical faces, but if end stops are used the material at the vertical joints needs to be well worked and keyed to endure horizontal continuity.

7 REQUIREMENTS ADDITIONAL TO SECTION 2 FOR POURED EARTH AND IN-SITU ADOBE

C7 General

These methods include 5% to 15% Portland cement in the mixes to reduce shrinkage and to enhance the strength and durability of the walls.

If Portland cement is not used in the mix then these methods should be regarded as a form of boxed cob, and the cob section used.

Hydrated lime or quicklime may sometimes be used also to help with stabilisation with some soils, or to limit shrinkage. Its use is subject to SED.

Poured earth

Formwork is set up to mould panels of such a size as to not be adversely affected by shrinkage. In some cases large panels are made, while in other cases smaller blocks are cast upon which subsequent courses are moulded. Walls have been poured either in one unit or in a series of formwork lifts. Current practice usually involves setting up of a number of moulds in a castellated pattern and the casting of a series of single bricks with gaps between them. The sections are then allowed to set and shrink. Material is then cast to fill the gaps, or subsequent courses are made in such a way so that the vertical gaps between sections in the preceding lower course are filled. A number of proprietary moulding systems are available.

In-situ adobe

In-situ adobe is a technique closely allied to poured earth, except in-situ adobe uses a stiff cement-stabilised material placed into an adobe-brick-sized temporary mould smaller than the boxing units often used for poured earth panels, to contain the material as it is first placed upon the wall. The mould is removed immediately leaving the brick surface to be worked up into a monolithic wall with the desired surface finish as it stiffens and hardens. Some mixtures are stiff enough to be placed by hand in a manner similar to cob without a mould.

With in-situ earth building all the shrinkage takes place in the wall. Each course is required to bond to previous layers, and severe shrinkage will act against this, as well as causing destructive or disfiguring cracks.

The success of these methods of construction relies heavily upon selecting a soil mix that virtually eliminates the shrinkage that is inherent with these methods.

These techniques rely on there being just enough clay in the mix to provide initial moulding of the material before cement hydration occurs, while containing high volumes of aggregates to limit shrinkage. The use of cement with limited moisture in a stiff mix also helps reduce shrinkage. The effects of shrinkage are also overcome by limiting the size of cast units.

Minor shrinkage cracks, if they should occur, can be packed or sealed with more mix or surface coatings if there is no risk of loss of structural or weathering integrity.

7.1 Material and mixes

7.1.1 Soil

Soils for poured earth should be soaked for at least 12 hours before moulding and the cement added just before final mixing and placement.

C7.1.1
With some soils the mix can be worked up from dry to give acceptable results.

7.1.2

Clay lumps larger than 12 mm shall be excluded from the mix. The maximum particle size for aggregates shall be 25 mm diameter.

C7.1.2
Test panels or previous experience with the proposed soil mix which demonstrates the suitability of particles larger than 25 mm can be satisfactory but are outside the scope of this standard.

Exclusion of larger particles is usually done by sieving but can also be done by pulverising. The presence of large lumps of unmixed clay on the surface of a wall can make the maintenance of a consistent surface finish or the application of renders particularly difficult.

While no specific range of particle sizes is proscribed, materials with a well-graded range of particle sizes will generally be found to be stronger and less porous.

Some successful in-situ adobe mixes have used two-thirds sand.

7.1.3 Moisture content

The moisture content of an earth mix for poured earth and in-situ adobe is critical to help control for shrinkage, and should therefore be limited to the minimum amount necessary for workability.

C7.1.3
Typically with these types of cement stabilised mixes, around 50% of the shrinkage takes place within the first 48 hours and 90% within 2 weeks.

7.1.4 Fresh mix containing cement

All of a mix shall be placed and moulded within 45 minutes of the cement first coming in contact with water or damp earth except as provided for in 7.1.5.

7.1.5 Stale mix containing cement

Stale mix, being that which is older than 45 minutes from initial wetting, may not be used neat in a wall but may be used as up to 30% of the proportion of material in a new fresh mix. A fresh mix may comprise up to 30% stale mix and 70% fresh provided that fresh cement is added to this new mix as if there was no cement in the stale mix. All properties of the wall made with this mix containing part stale and part fresh shall fully conform in all regards to this standard as if there were no stale mix present.

C7.1.5
The use of mixes comprising part stale mix can be of different colour and if the wall is not to be coated, the use of stale mixes may not be suitable for aesthetic reasons.

There is no upper limit on the age of stale mixes that may be used, as long as conformance with this standard is not compromised.

7.2 Method of construction

7.2.1 Moulds

Earth mixes shall be placed into the moulds. While being placed, it shall be vibrated, rodded, tamped, or worked to create a homogenous wall free of voids, and to ensure that all reinforcing is well encapsulated and with the earth material. Vibrators must be used with extreme care to ensure that there is no segregation of particles within the mix.

The top surface shall be screeded flat while the mould is still in place and then roughened to a minimum 5 mm amplitude, or otherwise left very well keyed before the material is fully hardened to enhance the bond with subsequent courses.

C7.2.1
The earth material is likely to be too stiff for vibrators to be effective but, if used, extreme care needs to be taken to ensure that there is no segregation of particles within the mix.

7.2.2 Previous work

The surface of previous work shall be thoroughly wetted immediately prior to placing of subsequent work.

7.2.3 Height in a day

The maximum height of wall that shall be added in a day is 450 mm.

C7.2.3
Wetting prevents premature drying at the joint and improves bond strength.

7.3 Curing and drying

7.3.1 Drying

All work shall be moist-cured by spraying with either a concrete curing agent, by being covered with plastic film, or by covering with fabric kept damp for a minimum of 7 days before being allowed to dry.

C7.3.1
Shelter the wall to limit excessive exposure to direct sun or strong wind that can cause uneven drying and consequential cracking.

7.3.2 Work containing cement

All work containing Portland cement shall be moist-cured by being covered with fabric, which shall be kept damp for a minimum of 7 days before being allowed to dry.

7.3.3 Work containing lime

All work containing hydrated lime shall be moist-cured by being covered with fabric, which shall be kept damp for a minimum of 3 weeks before being allowed to dry.

7.4 Surface coatings

Surface coatings may be used to improve appearance or enhance durability, as allowed for in section 8.

7.5 Formwork

Wall formwork may be manufactured in a wide range of sizes and dimensional proportions, with moulds or formwork shaped to allow for the units to be cast and the moulds removed without damage to the cast unit or adjacent work.

Limiting factors include:

(a) The height and thickness of the walls to be built;

(b) Structural integrity;

(c) The need to maintain bonding at corners;

(d) Excessive horizontal shrinkage with consequent cracking can occur with some soils, and this will be more pronounced the larger the placed or cast unit;

(e) The size and shape of the moulds (if any) to be used. Walls can consist of more than one brick to make up the specified thickness, but it is more common to use single-skin construction;

(f) The wall material can be moulded with holes to provide passage for services. These should generally be of small diameter (less than one-third of the wall thickness). Consideration can be given to drilling cores after initial drying.

7.6 Panel sizes

7.6.1

The maximum height of poured earth or in-situ adobe walls placed in one day shall be 450 mm.

Leave new work at least overnight before placing new work on top of old, once the maximum daily height limit has been reached.

Panel sizes over 450 mm high or more than 900 mm long cast in one piece shall be subject to SED.

C7.6.1

Some commercially available poured-earth boxing systems have a course height of around 300 mm.

Boxing for larger wall panels needs to be left until the wall can support its own weight without slumping or deformation.

The moulds have no top or bottom. In-situ adobe moulds are typically made from sheet metal or thin steel, poured earth moulds are usually stronger boxing. Moulds may have slightly tapering sides to ease the removal of the mould from the contained material.

There are no preferred sizes, although cast units especially in in-situ adobe, should not be longer than around 450 mm. Consistency in cast unit thickness has an influence on the level of successive courses. In a commercial environment the amount of dimensional variation allowed may be nominated.

Unless shrinkage is very tightly controlled, pouring a wall with large panel sizes has generally not been found to be practical.

In practice it has been found that limiting the amount poured in one panel of block to less than 0.2 m^3 is a sensible limit for good performance.

7.6.2 For poured earth

Boxing shall not be removed or the next lift shall not be poured until the fresh wall material, and the wall beneath it, are stiff enough to take the weight of the new work without deformation or damage.

7.6.3 For in-situ adobe

Forms are used to help shape the work and may be removed as soon as the material is placed.

The next lift shall not be placed until the layer beneath it is stiff enough to take the weight of the new work without deformation or damage to the older material.

C7.6.3
There are no preferred sizes, although cast units in in-situ adobe are usually about the same size as common mud bricks, often around 150 mm high with up to 450 mm long cast at one time before the next unit is cast. Maximum height is dictated by the amount of slumping that can be controlled by the stiffness of the mix.

Consistency in cast unit wall dimensions has an influence on the level of successive courses.

In a commercial environment the amount of dimensional variation allowed may be nominated.

7.7 Bonding

The earth mix is required to bond to previous layers and adjoining surfaces shall be well roughened and keyed to improve bond.

Poured earth or in-situ adobe blocks shall be cast in an overlapping bond pattern generally using a half bond where possible, and 100 mm minimum bond otherwise.

Wall sections shall be built up so as to maintain continuity of structure around corners.

Where a wall meets another, every course shall be bonded into the abutting wall.

7.8 Reinforcing for all poured earth or in-situ adobe

7.8.1 Horizontal reinforcing.

See either NZS 4299 section 6 or design details in accordance with NZS 4297 for reinforcing details. Install at a maximum of 450 mm centres vertically for mesh reinforcing in accordance with NZS 4299 clause 6.5 and at maximum 900 mm centres for steel bar reinforcing.

C7.8.1
Install the horizontal reinforcing at 300 mm centres vertically if the construction method allows it.

7.8.2 Steel bar horizontal reinforcing

Either cut a V or U shaped groove approximately 50 mm wide and 50 mm deep to take a horizontal reinforcing bar into the top of the previous work once it is stiff enough to be worked without damage to the remaining wall materials. Ensure the rod is fully embedded in the freshly placed material.

7.8.3 Geogrid reinforcing

Place geogrid in a thin course of poured earth or in-situ adobe mix placed on previous work, with the geogrid embedded well into it before the next course of earth mix is placed on top of it while still wet.

C7.8.3
If full height wall panels are boxed and poured in one operation, then vertical and horizontal reinforcing bars may be placed inside the wall and tied together before the earth is poured subject to SED.

7.9 Shrinkage

Vertical settlement of poured earth caused by shrinkage shall be considered when detailing around services, or adjoining structure, or reinforcing steel (see 2.3.9).

C7.9
Walls made by this method can shrink vertically as well as horizontally, and allowance should be made when detailing against other materials or structure to ensure that the walls do not 'hang-up' on adjacent walls, joinery elements, or embedded reinforcing.

7.10 Control joints

7.10.1

Vertical control joints to control horizontal shrinkage shall be provided as required by 2.14.

7.10.2

All control joints shall be detailed to resist weather ingress.

7.11 Testing

7.11.1 Samples

Samples for compression testing or flexural tensile strength testing shall be cast into moulds as for adobe.

7.11.2 Frequency and requirements

These shall be tested as required by 2.5 and Table 2.1.

8 SURFACE COATINGS

8.1 General

8.1.1

Surface coatings are not required on many earth wall surfaces, but may be applied to earth walls for a range of aesthetic, amenity, or serviceability reasons.

Although the application of surface coatings may be used to enhance the durability of earth building wall materials, except as provided by 8.2.2, such enhancement is outside the scope of this standard as a means of compliance with the materials and construction requirements of structures designed in accordance with either or both of NZS 4297 and NZS 4299 apart from that allowed by 8.5.2 and 8.5.3.

8.1.2

Surface coatings may be used to enhance the durability of materials that are not excluded by 2.2.2 and 8.2.2 but shall not be used to make unacceptable materials able to be used.

8.1.3

Exterior plaster substrates and plaster systems that lack the minimum weather protection required by NZS 4299 clause 2.7 are outside the scope of this standard.

C8.1.3
Some relatively porous wall materials, such as low-density adobe or cob, are generally plastered for decorative reasons but also to generally improve and maintain serviceability.

Walls with even lower density and more open texture, such as light earth method (LEM) and straw bale, require surface coatings to give adequate serviceability.

Performance of various coating types

Traditional earth, lime, and gypsum based coatings are vapour permeable and generally very compatible with earth surfaces.

Vapour permeable chemical treatments based on silicones, silicates, water and oil based sealers, water resisting agents or paints, or lime-cement based renders can vary widely in their performance on different earths or different earth mixtures and their performance can be unpredictable.

Cement stucco generally has poor vapour permeability and can create moisture problems in an earth wall.

Some chemical or paint treatments that bond well with the surface layers or penetrate beyond the surface can work very well, while others can fail when moisture gets behind them and be sloughed off carrying the whole surface with them. They may vary widely in their performance on different earths or different earth mixtures and their performance can be unpredictable.

Sometimes a coating that performs well on one earthen substrate cannot do so on another.

Some commercially available earth and lime plasters, lime-based paints, or other coatings may carry manufacturers' warranties.

8.1.4

Although plaster coats in practice can contribute to the strength of the walls to which they are applied, no structural properties have been attributed to the plasters described in this section.

8.2 Purposes of surface coatings

8.2.1 Uses

Surface coatings may be used:

(a) To help limit moisture penetration;

(b) To help prevent erosion;

(c) To bind the surface and reduce surface dusting;

(d) For aesthetic or decorative reasons for colouring and for modifying wall surface texture;

(e) To improve general serviceability.

8.2.2 Durability improvement

The durability of a particular earth building material, this may be achieved by either:

(a) Improved weather protection or the erosion index beyond the minimums provided for in NZS 4299 clause 2.7; or

(b) The use of appropriate surface coatings.

8.2.3 Improvement of erodibility index of an earthen substrate by surface coatings

The erodibility index of a material as measured by Appendix K or Appendix L may be improved by a maximum of 1 unit by the application of a surface coating subject to a suitable retesting result.

Any other improvement of the erodibility index or durability of an earth wall by the use of a surface coating is outside the scope of this standard.

Use of any earth wall material as a substrate that fails the wet/dry appraisal test as set out in Appendix J of this standard or fails the erosion tests of Appendix K or Appendix L is outside the scope of this standard whether a surface coating is applied or not.

C8.2.3

The use of surface coatings to improve otherwise unsuitable earthen materials, as can sometimes be required over historical or other surfaces that are at risk of failure in service, is outside the scope of this standard.