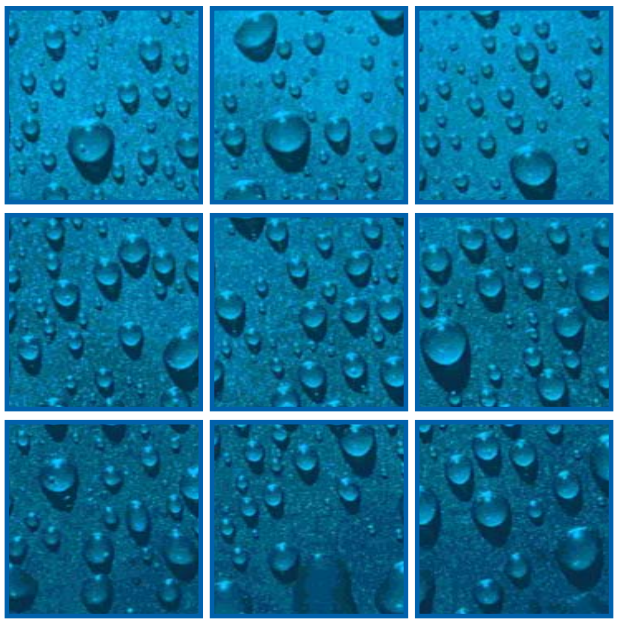
Waterproofing for External Wall

GOOD INDUSTRY PRACTICES



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Foreword

The Building and Construction Authority (BCA) has been promoting the use of Construction Quality Assessment System or CONQUAS 21 as the de facto national yardstick for measuring the workmanship quality of building projects. To meet the rising expectations of homeowners, the Quality Mark (QM) Scheme was launched in July 2002 to promote a higher consistency in workmanship standards for residential developments.

Besides setting standards and assessing the level of workmanship through CONQUAS 21 and QM Schemes, BCA is developing a series of publications called CONQUAS 21 Good Industry Practices Guides to share with the industry good work practices adopted by practitioners and contractors who consistently deliver high quality work.

This "Good Industry Practices – Waterproofing for External Wall" is part of the CONQUAS 21 Enhancement Series on Good Industry Practices. Waterproofing for external walls is one of the more problematic areas in building work. This guide provides simple and practical tips to assist designers in designing external walls with good waterproofing performance and contractors in achieving high quality workmanship. Photographs and graphical representations are used extensively in the guide to provide easy reference and better illustration.

It must, however, be pointed out that this guide only serves to illustrate some of the good practices designers and contractors have adopted while designing and installing external walls. This guide is not meant to be a text book on how external walls must be designed and installed. We gratefully acknowledge the contributions of these practitioners and trust that the industry will find this publication useful in its pursuit of quality excellence.

Lam Siew Wah
Deputy Chief Executive Officer
Industry Development
Building and Construction Authority

Acknowledgement

"Good Industry Practices –Waterproofing for External Wall" was developed with inputs from architects, main contractors, precasters, waterproofing suppliers and members from the various professional associations.

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Fermold Pte Ltd
Excel Precast Pte Ltd
Eastern Pretech Pte Ltd

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1. Introduction

In a survey conducted by BCA in year 2003 involving about 10,000 private residential units, water seepage through external walls was found to be a common defect faced by homeowners. The survey findings also showed that the use of single layer brickwall is the most common cause of water seepage through external walls. Almost 90% of the water seepage occurred through cracks in the plastered brickwalls. In general, water seepage through external walls occurred within the first five years of building completion.

Water seepage through the external walls is unacceptable to the occupants. The problem is further compounded by Singapore's high humidity and abundant rainfall throughout the year. High wind speeds experienced by high-rise buildings also increase the likelihood of water seepage. Building envelopes must, therefore, be adequately designed and constructed to prevent ingress of water.

There are various external wall systems used in the local industry, including precast concrete walls, cast in-situ reinforced concrete walls, brickwalls, curtain walls, cladding walls, concrete block walls, etc.

Due to volume constraint, this publication focuses on precast concrete walls, cast in-situ reinforced concrete walls and plastered brickwalls. It provides industry good practices to help achieve durable and effective waterproofing of the building envelope.

2. Design of External Walls

2.1. GENERAL

The ingress of rainwater impinging on external walls usually occurs though joints and cracks in the walls. To a lesser extent, seepage through absorption and permeation may also occur depending on the material and thickness of the walls.

Watertightness of external walls is usually achieved by using suitable materials, providing adequate wall thickness, designing proper construction details, as well as providing surface rendering and finishes which serve as barrier against water ingress. Where external walls are exposed to severe weather conditions, more extensive surface waterproofing should be employed.

This chapter focuses on the design aspects of precast concrete walls and plastered brickwalls.

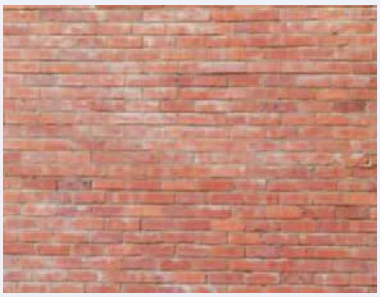
2.2. CHOICE OF EXTERNAL WALL SYSTEM

The common types of external walls include cast in-situ reinforced concrete (RC) walls, precast concrete walls and masonry brickwalls.

Figure 2.1: Common types of external wall system

Reinforced Concrete (RC) Wall

Precast Concrete Wall



Masonry Brickwall

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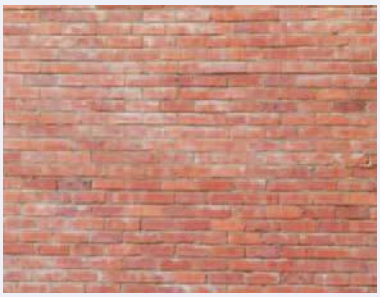


Masonry Brickwall

Water seepage usually occurs through the fabric of building elements or through the gaps between these elements. For effective watertightness, the wall system should be constructed with impervious material and with minimal joints. Large precast concrete panels and cast in-situ RC construction with low water cement ratio, in general, have better watertightness performance than brickwalls, which have extensive joints between layers of bricks. In addition, precast walls have many other benefits over cast in-situ concrete walls and brickwalls, such as better quality, higher buildability and better durability.

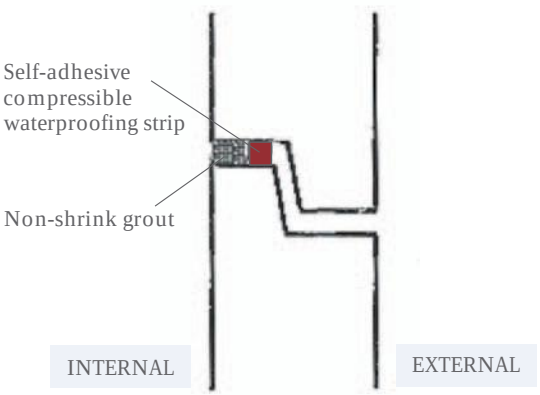
Hence, the use of precast concrete walls is strongly recommended for external wall construction.

2.3. EXTERNAL PRECAST WALLS

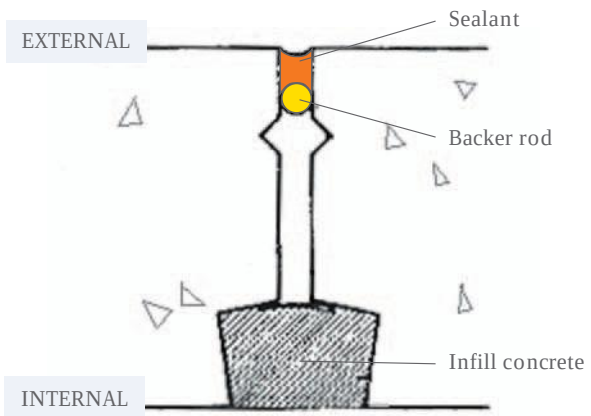
Precast joints are the weakest links in ensuring watertightness of the external precast concrete walls. These include joints between precast concrete elements, between precast and cast in-situ elements, as well as between precast elements and window/door frames or other fittings. Joint detailing and the use of suitable sealant should, hence, be carefully considered during the design stage. Joints with complicated profiles are difficult to seal and this may affect the watertightness of the building envelope.

There are two types of joint detailing employed for precast concrete walls, namely the one-stage joint and two-stage joint. One-stage joint is a simple butt joint with sealant applied against a backer rod at the external face of the wall. One-stage joint offers only a single line of defence against water seepage. Pressure drop may occur across the one-stage joint and water may seep through micro cracks or hairline cracks. Two-stage joint (Figure 2.2), on the other hand, provides two defence lines against water ingress. Experience has shown that two stage joints give better watertightness performance than one-stage joints.

Figure 2.2: Two-stage joint detailing



Two-stage horizontal joint (Sectional view)



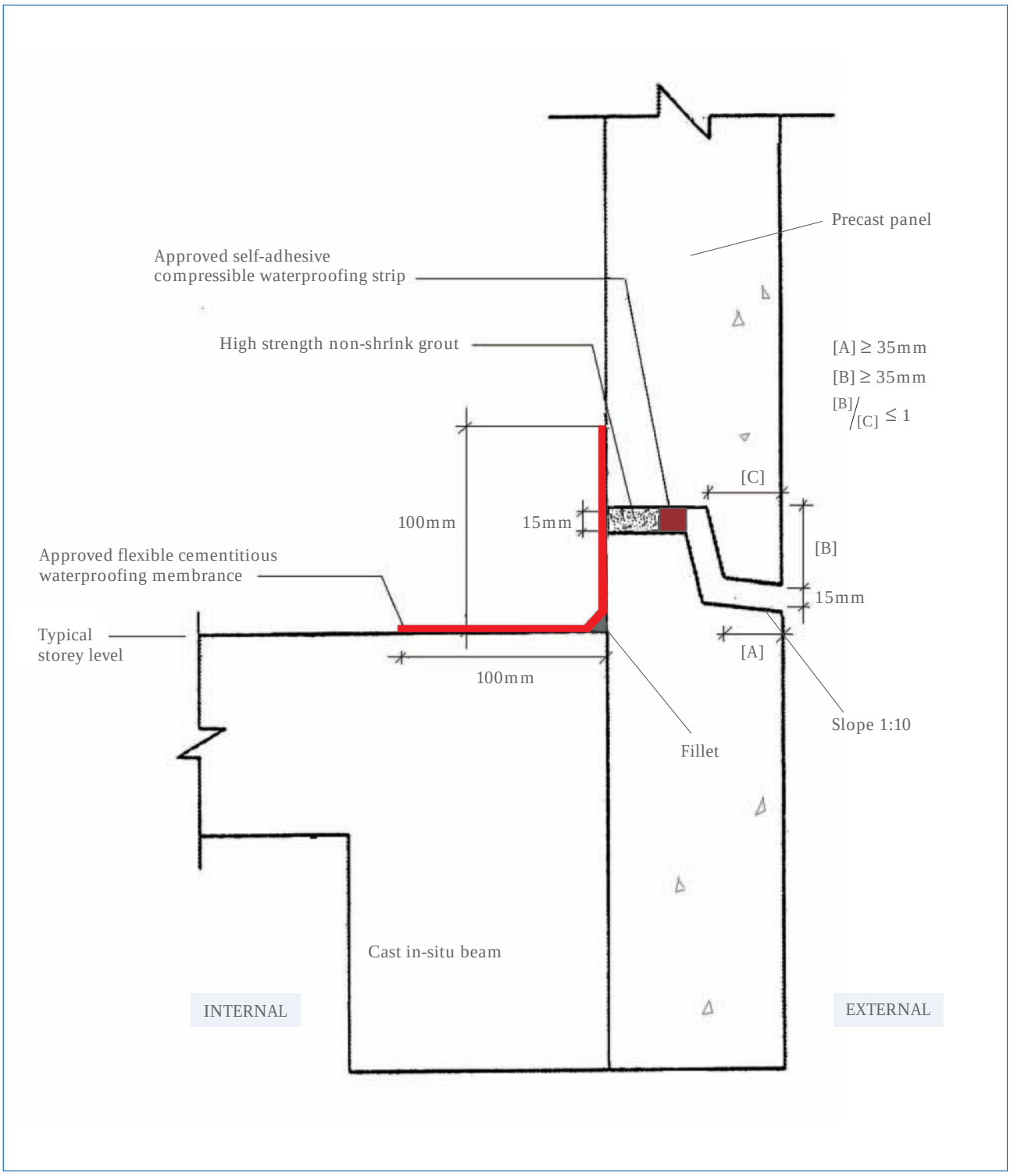
Two-stage vertical joint (Plan view)

2.3.1 HORIZONTAL JOINTS

For horizontal joints of precast walls, joggled joints (as shown in Figure 2.3) provide better watertightness performance than the butt joints. The matching upstand and downstand profile of the joggled joint prevents inflow of water through the building envelope. The height of the upstand and downstand is dependent on the exposure conditions, wall thickness and type of precast wall (load-bearing or non load-bearing). It generally ranges from 35mm for mild exposure to 100mm for severe exposure condition.

Figure 2.3 shows the typical details for a horizontal joggled joint. The joint is sealed with high strength non-shrink grout and an approved self-adhesive compressible waterproofing strip. In addition, an approved flexible cementitious waterproofing membrane may be used at the inner corner of the intersection between the wall panel and beam/slab for enhanced watertightness performance.

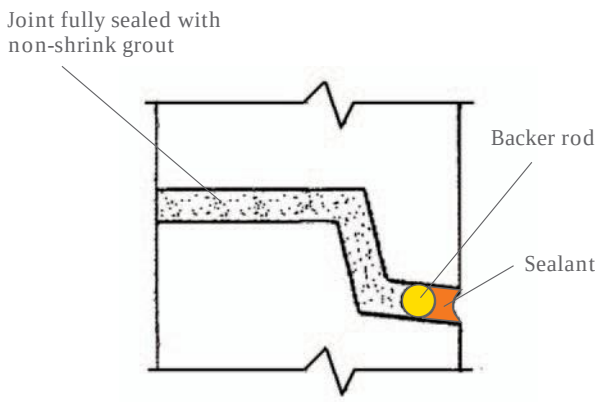
Figure 2.3: Typical sectional view of horizontal joggled joint (for non load-bearing walls)



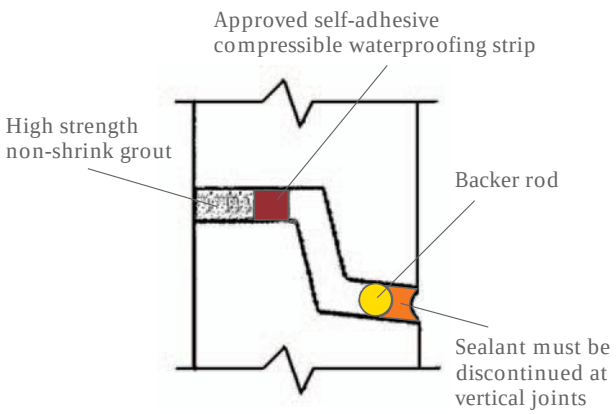
The gap at the external wall face is usually not sealed to allow incident water in the joint to drain off. If this gap is also to be sealed (eg. for aesthetic reasons), the joint can be fully sealed using non-shrink grout, with a backer rod and an appropriate sealant installed at the exterior end of the joint (Figure 2.4a). Alternatively, the joint can be sealed with non-shrink grout at the interior end with a sealant installed at the exterior end of the joint. For such sealing system, the sealant must be discontinued at regular intervals (at intersections with the vertical joints) to drain off incident water that has managed to seep into the gap (Figure 2.4b).

For load bearing walls, the entire horizontal joint must be sealed, for example, with non-shrink grout (Figure 2.4a).

Figure 2.4: Typical sectional view of horizontal joggled joint



a) Fully sealed horizontal joint

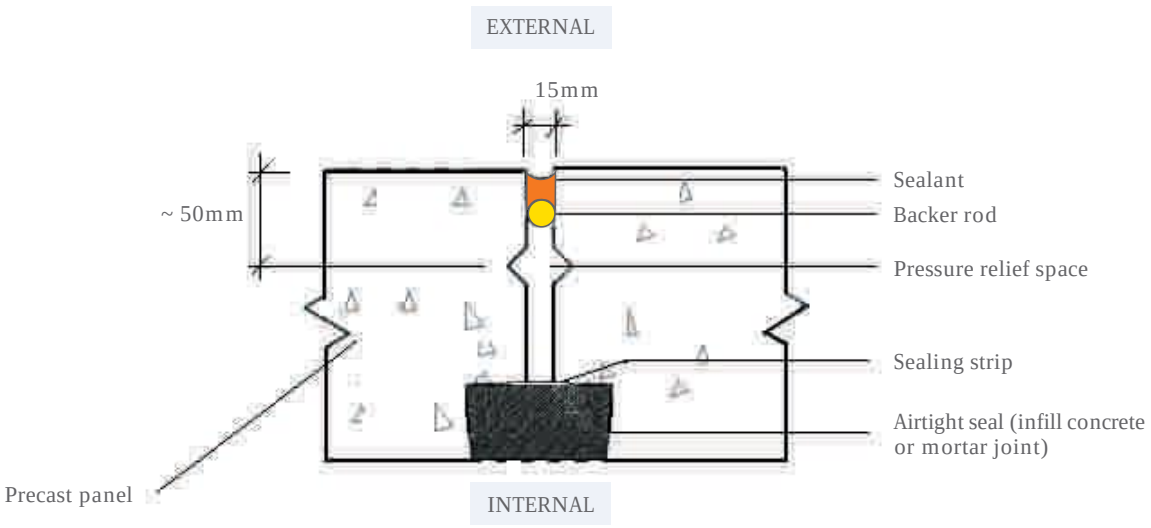


b) Sealing of external gap (For non load bearing walls)

2.3.2 VERTICAL JOINTS

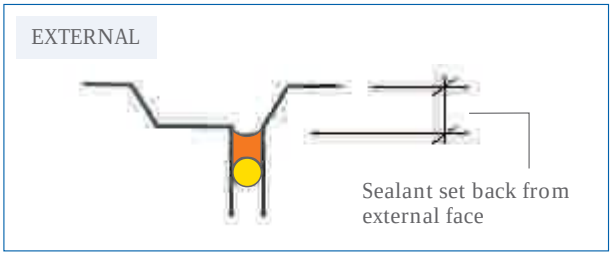
The two-stage joint detailing is recommended for vertical joints as it provides various water-resistant barriers. These include a sealant at the outer wall face, a pressure relief space to avoid rain driven penetration, and an infilled concrete/mortar joint with a sealing strip at the inner wall face. The seal at the external face should be discontinued at intersections with the horizontal joints to allow draining of incident water.

Figure 2.5: Vertical joint sealed with sealant and infill concrete/mortar joint, with pressure relief space (plan view)



For better protection of the sealant from rain, wind and UV light, the sealant may be set back from the external face of the wall as shown in Figure 2.6. This helps to minimise deterioration of the sealant.

Figure 2.6: Setting back of sealant from the external face of the panel (plan view)



According to CP 81:1999, the grooves that create the pressure relief space should comply with the following minimum requirements:

a) Width = 15mm
b) Depth = 5mm; and
c) Sharp edges.

The grooves that create the pressure relief space should be located as shown in Figure 2.8 below, with the grooves sloped at an angle not more than 10° from the vertical axis.

Figure 2.7: Dimensions of pressure relief space (plan view)

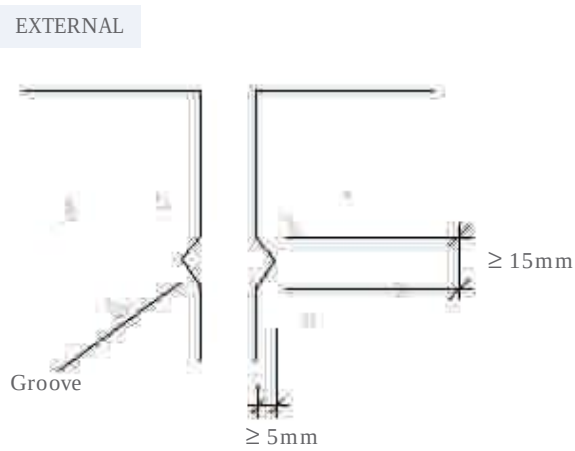
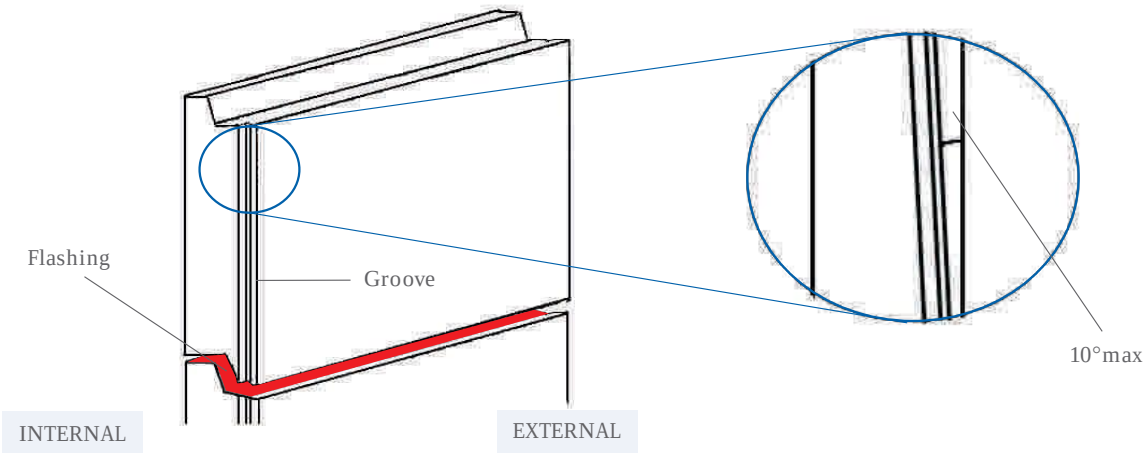


Figure 2.8: Typical details of a pressure relief space



If a sealing strip is to be used with the infill concrete/mortar joint at the inner wall face as shown in Figure 2.5, its width should be equal to the joint gap plus sufficient overlap (approximately 60mm) on each side of the joint. The sealing strip should be made of an elastic material, or alternatively, some slack in the sealing strip should be provided so that it does not tear under repeated stresses at the joint area. A suitable gasket can also be used in place of the sealing strip to create an airtight seal at the inner wall face.

Having an abutting cast in-situ concrete column or stiffener behind the joint can further enhance watertightness of the joint. This type of joint is known as the 'wet' or cast in-situ joint connection, and is effective in preventing water seepage through the precast joints. Examples of wet joints are shown in Figure 2.9 to 2.11.

Figure 2.9: Typical vertical joint with cast in-situ stiffener (plan view)

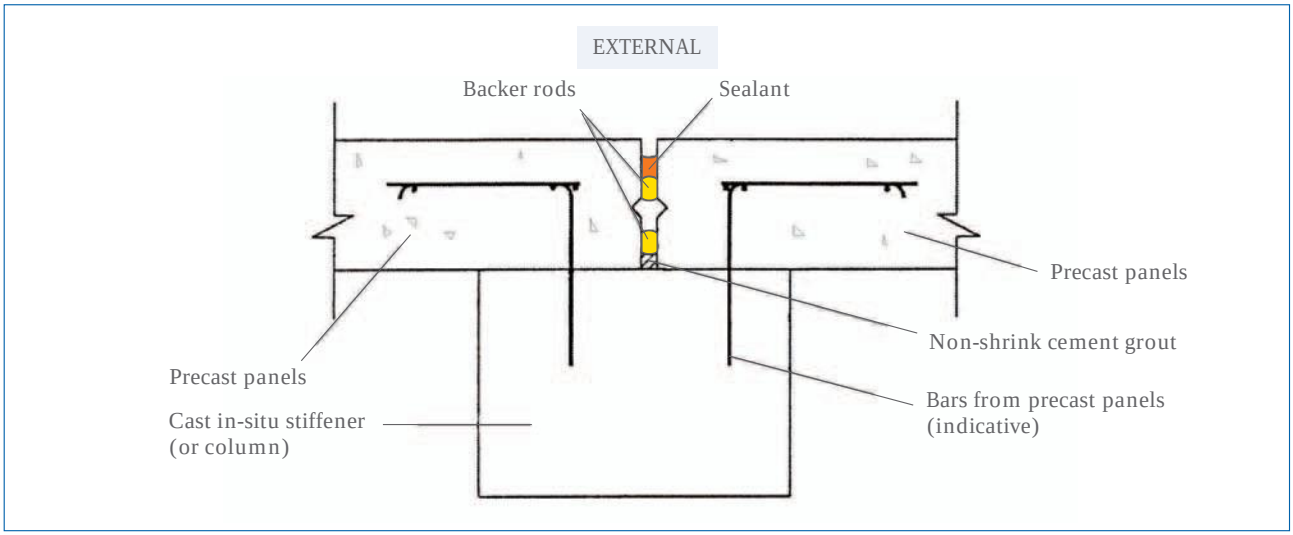


Figure 2.10: Typical details for wet joint between precast panels (plan view)

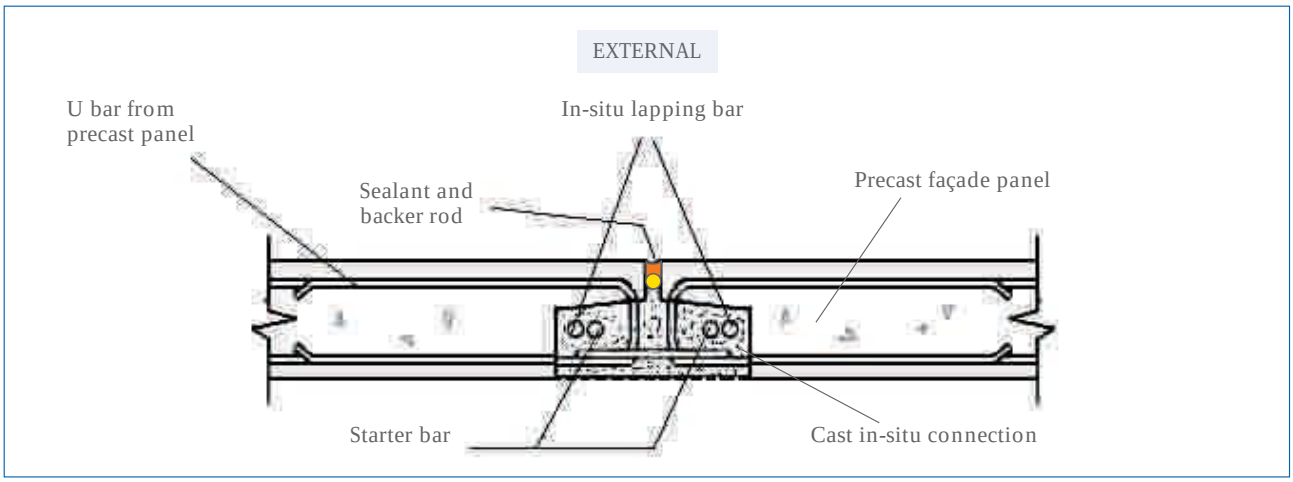
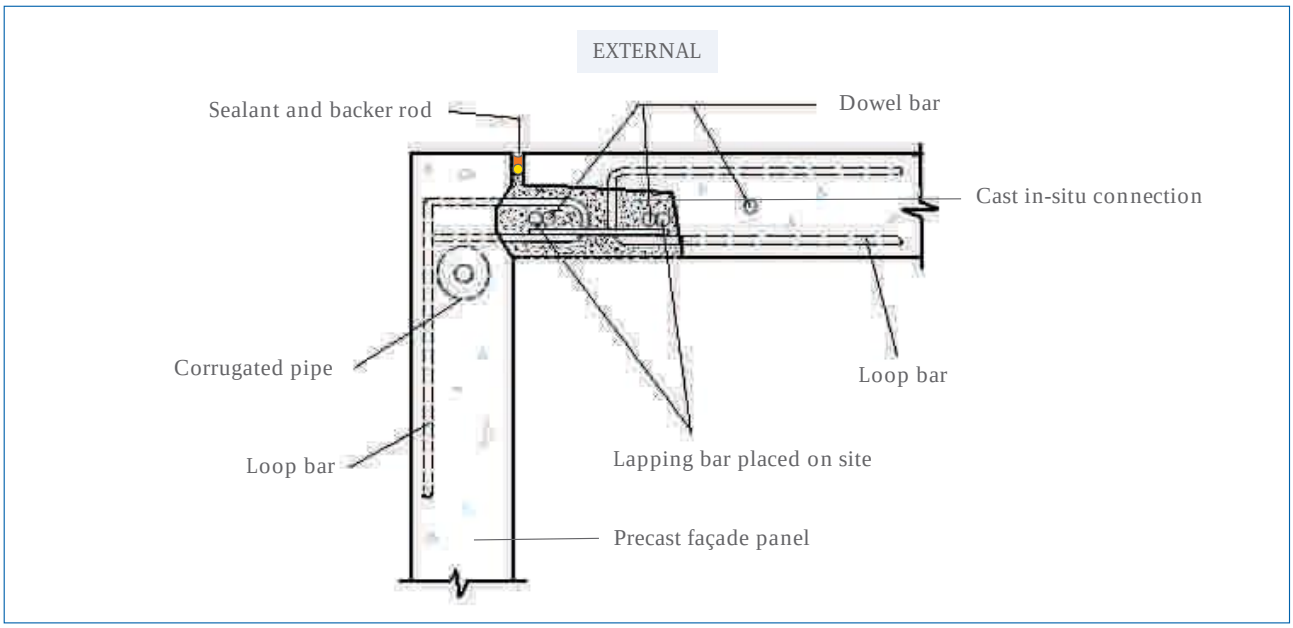


Figure 2.11: Typical details for corner joint between precast panels (plan view)

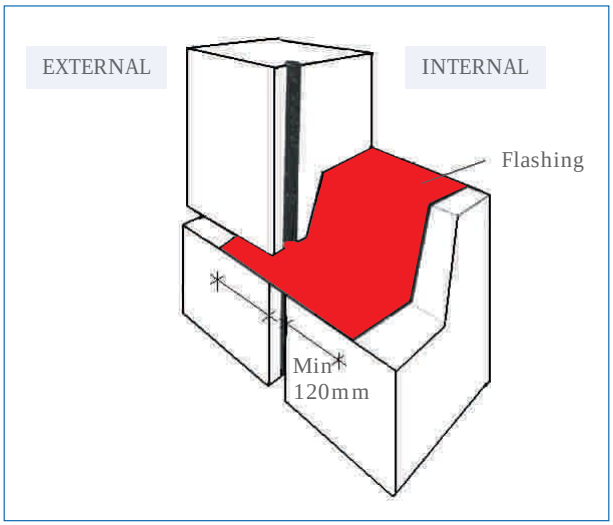


*Note: Rebar details shown in Figure 2.9 to 2.11 are only indicative.
Actual rebar detailing must be provided in structural design and drawings.

2.3.3 INTERSECTIONS OF HORIZONTAL AND VERTICAL JOINTS

Intersections of the horizontal and vertical joints should be detailed to contain any incident water within the individual floor levels. To achieve this, a flashing could be installed over a width of at least 120mm on either side of the vertical joint as shown in Figure 2.12.

Figure 2.12: Intersection of horizontal and vertical joints



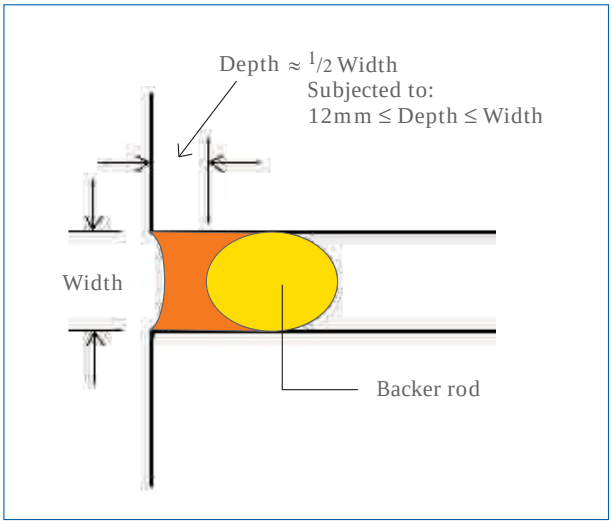
2.3.4 JOINT WIDTH AND DEPTH

Joints between precast wall panels should have adequate width to accommodate anticipated movements of the panels, and to ensure the joint sealant performs within its design capabilities. When the joint gaps are too narrow, adjacent elements may come into contact and be subject to undesired loading, distortion and cracks. A good practice is to provide a joint gap of 12mm – 20mm to ensure proper application of sealants.

Joint depth is also an important factor as failures often occur because the sealant depth is either too thick (cohesion failure, unable to stretch sufficiently) or too thin (adhesion failure, insufficient bonding to sides of substrates) to function as intended.

The depth of sealant depends on the type and conditions of service. Elasto-plastic sealants are usually applied such that the depth is half the width for maximum movement accommodation and elastic sealants perform best in thin sections. CP 81:1999 recommends that for joints of more than 12mm width, the sealant depth should be half the width but not less than 12mm, and not exceeding the width of joint (see Figure 2.13).

Figure 2.13: Typical sealant joint detailing for joints of more than 12mm width



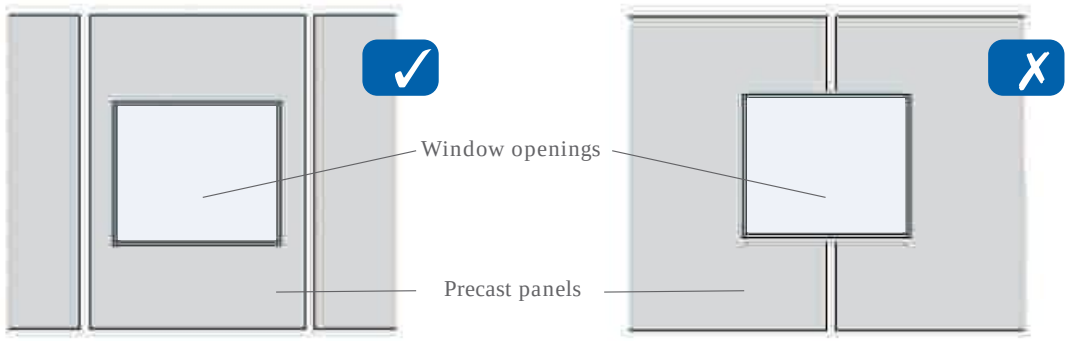
2.3.5 OTHER CONSIDERATIONS

Window openings should be located within a single precast panel. Window openings formed across adjacent panels may lead to water seepage into the window head.

The use of integrated precast components, such as façade with beam, air con ledge, bay window, planter box, etc, can offer better watertightness performance as there are fewer construction joints.

Ease of maintenance and repair should also be considered at the design stage. Sealants may need regular inspection, repair and replacement. Proper access should be taken into consideration. For instance, the positioning of services or other features in front of the joints will make future access difficult.

Figure 2.14: Location of window openings



Window frame located within a single panel

Window frame across adjacent panels

Figure 2.15: Examples of integrated precast components

Façade and beam

Façade and air con ledge

Façade and bay window

2.4 EXTERNAL MASONRY BRICKWALLS

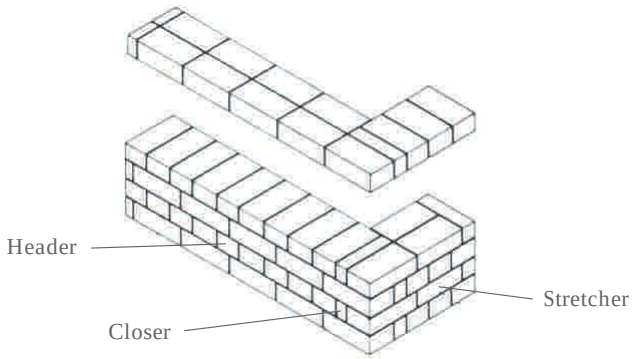
In general, external brickwalls have inferior watertightness performance than precast concrete walls and cast in-situ RC walls. The quality of the erected brickwalls is highly workmanship-dependent.

Due to its inferior watertightness performance, brickworks are not encouraged for use in the construction of external walls. Where the Designer decides to use external brickwalls for the project, the following good practices on designs of external brickwalls should be adopted to achieve the required watertightness performance.

2.4.1 WALL THICKNESS

Half-brick thick walls have inferior waterproofing performance compared to full-brick thick walls. Hence, where brickworks are used for external wall construction, full-brick thick walls with English bond instead of half-brick thick walls with Stretcher bond should be adopted.

Figure 2.16: Full-brick thick brickwall with English Bond



2.4.2 COMPOSITION OF MORTAR JOINTS

Cement mortar joints are relatively more porous and are, hence, more susceptible to water seepage than the brick units. The type of mortar bedding selected can have a considerable effect on its bonding strength and workability, which in turn affects the watertightness of the joints.

2.4.3 PROVISION OF SURFACE FINISHES

Rendered brickwalls give better rain resistance than fair-faced brickwalls. It is, however, essential to select the appropriate mix ratio, thickness and number of coats to minimise cracks in the rendering.

Figure 2.17: Applying rendering to an external brickwall

2.4.4 PROVISION OF CONCRETE KERBS

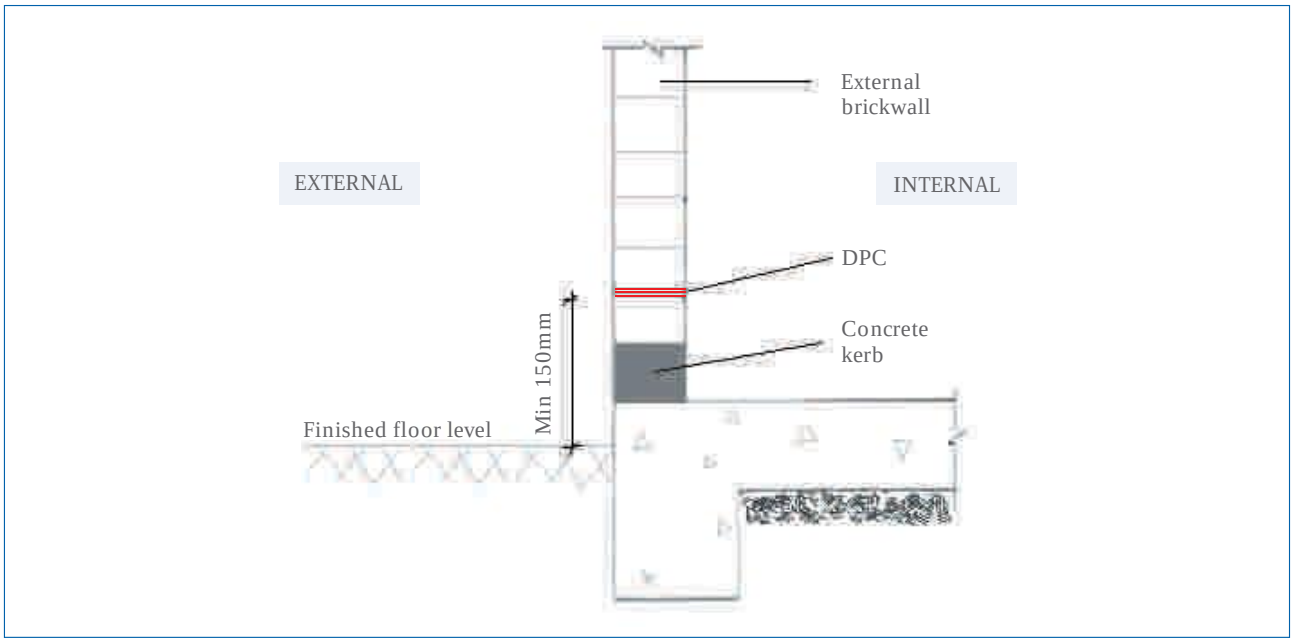
Concrete kerbs of at least 100mm height should be provided for external brickwalls to enhance their watertightness. As a good practice, these kerbs should be provided at every storey. This is especially important where there is a RC recess or a RC ledge at the beam/ floor level.

Figure 2.18: Concrete kerb at the base of brickwall

2.4.5 DAMP-PROOF COURSE (DPC)

Ground water can penetrate the building fabric, rising vertically through capillary action. Damp-proof course (DPC) should be provided in masonry walls to guard against such ground moisture. To protect against rainwater bouncing off the ground and splashing onto the wall, the DPC should be installed at a minimum 150mm height above the surrounding finished floor level.

Figure 2.19: Installation of DPC



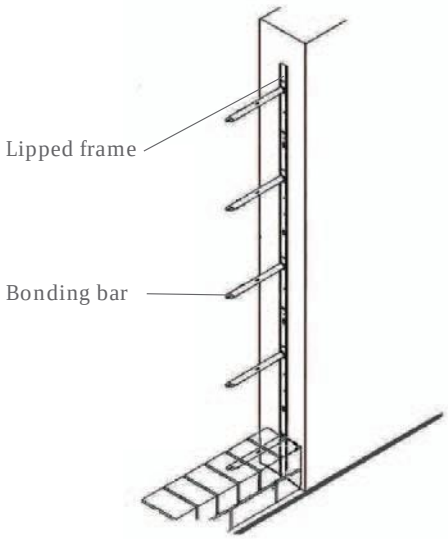
2.4.6 JOINTS BETWEEN DISSIMILAR MATERIALS

Where the brickwall abuts a concrete member, bonding bars should be provided at the joints to minimise cracks at these locations. These bonding bars should be secured to the concrete member. Alternatively, these bars could be cast together with the concrete member.

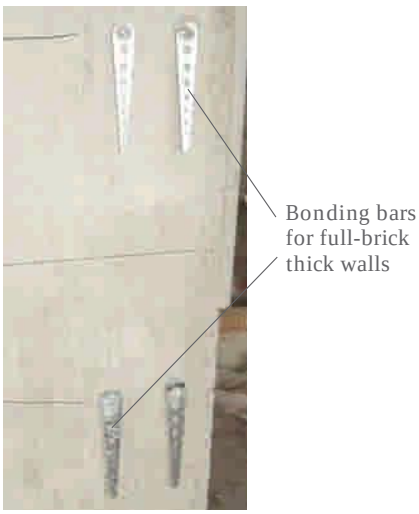
Some bonding bar systems come with a lipped frame that is fastened to the concrete member. The lipped frame allows greater flexibility in positioning the bonding bars to facilitate brick-laying. The bonding bars should be of minimum 200mm length and installed at every 4th course of the brickwalls.

A layer of mesh reinforcement should be provided at the interfaces between dissimilar materials, for example between brick and concrete members. The mesh reinforcement helps to distribute stress and prevent plaster crack at these locations.

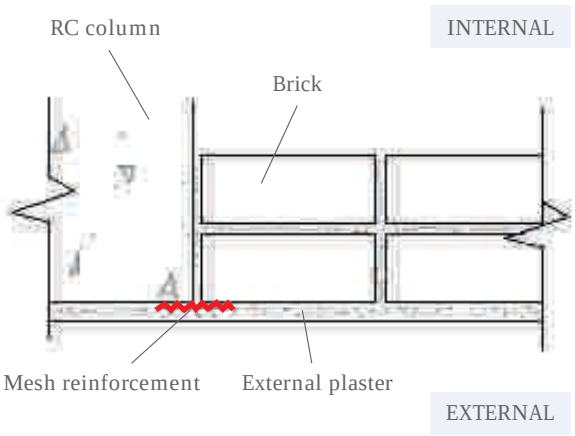
Figure 2.20: Joints between brick and RC members



Bonding bars with lipped frame system



Bonding bar system without a lipped frame



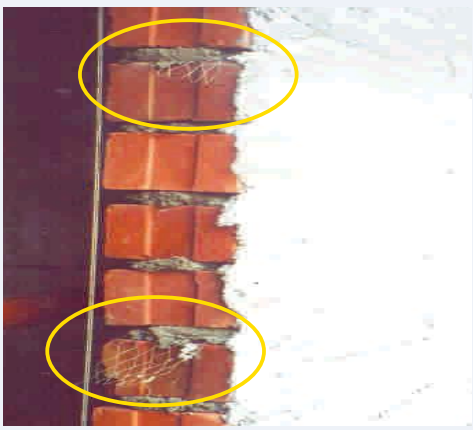
Mesh reinforcement at interface
between brickwall and RC column (plan view)

Mesh reinforcement at interface
between brickwall and RC column

2.4.7 MESH REINFORCEMENT IN MORTAR JOINTS

To provide additional resistance to stresses, vibration and thermal movement, mesh reinforcement should be embedded in the mortar joints between courses of brickwork. The mesh reinforcement should be laid over the 1st or 2nd course and at every subsequent 4th course of brickwork. There should be minimum 150mm lapping where different sections of mesh reinforcement overlap.

Figure 2.21: Mesh reinforcement embedded at every 4th course



2.4.8 STIFFENERS AND MOVEMENT JOINTS

Vertical and horizontal stiffeners should be provided for big panels of brickwork. Consult the structural Engineer for details of the stiffeners. Where brickwalls abut the stiffeners, steel bonding ties should be provided at every 4th course.

Figure 2.22: Example of a vertical RC stiffener for walls

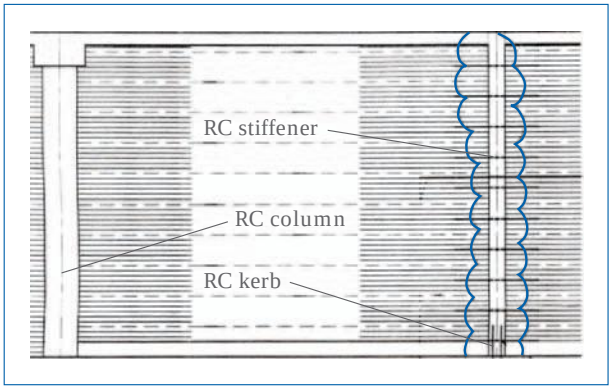
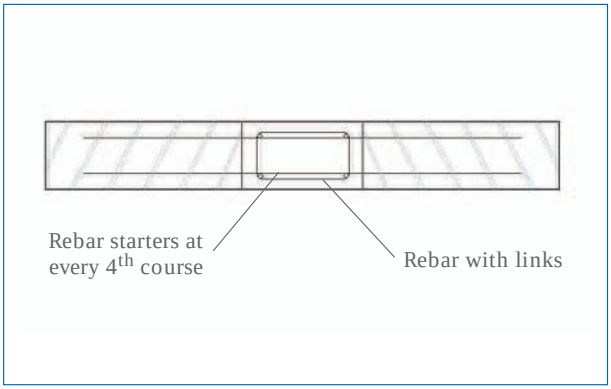
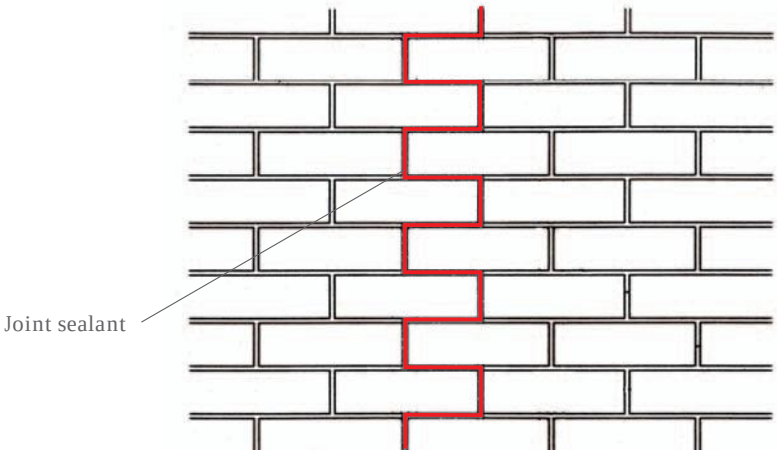


Figure 2.23: Typical stiffener details



Vertical movement joints of about 12mm width should be provided in brickwork at maximum 6m intervals. Joints should be filled with a suitable material, such as polyethylene strip or urethane sealant.

Figure 2.24: Vertical movement joints



2.5 OTHER DESIGN CONSIDERATIONS

2.5.1 EXTERNAL BUILDING FEATURES

External features such as bay windows, air conditioning ledges and planter boxes are increasingly being used in building projects. For such features, the following provisions should be considered:

- overhangs protruding minimum 300mm out of the building envelope help to shield the external walls (especially brickwalls) from direct rainfall;
- overhangs also help to shield wall openings (such as window openings or M&E openings) from direct rainfall;
- adequate fall along protruding features to avoid accumulation of stagnant water at the corner joints; and
- drips provided at the underside of external features to prevent water flow towards the external walls.

Figure 2.25: External brickwall with overhang

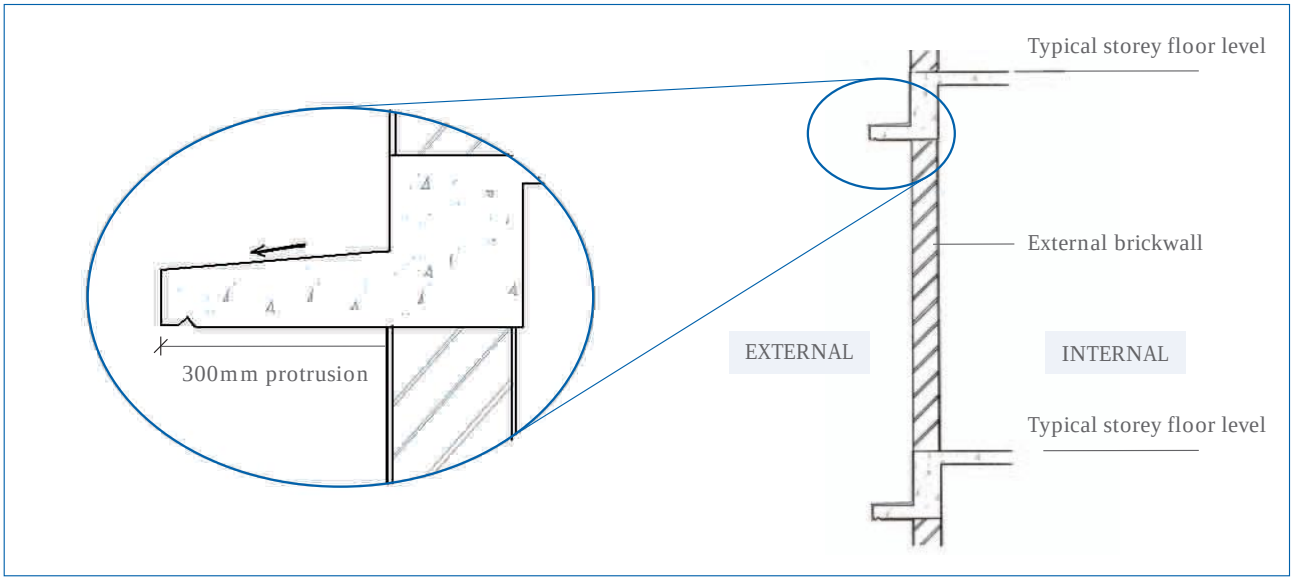
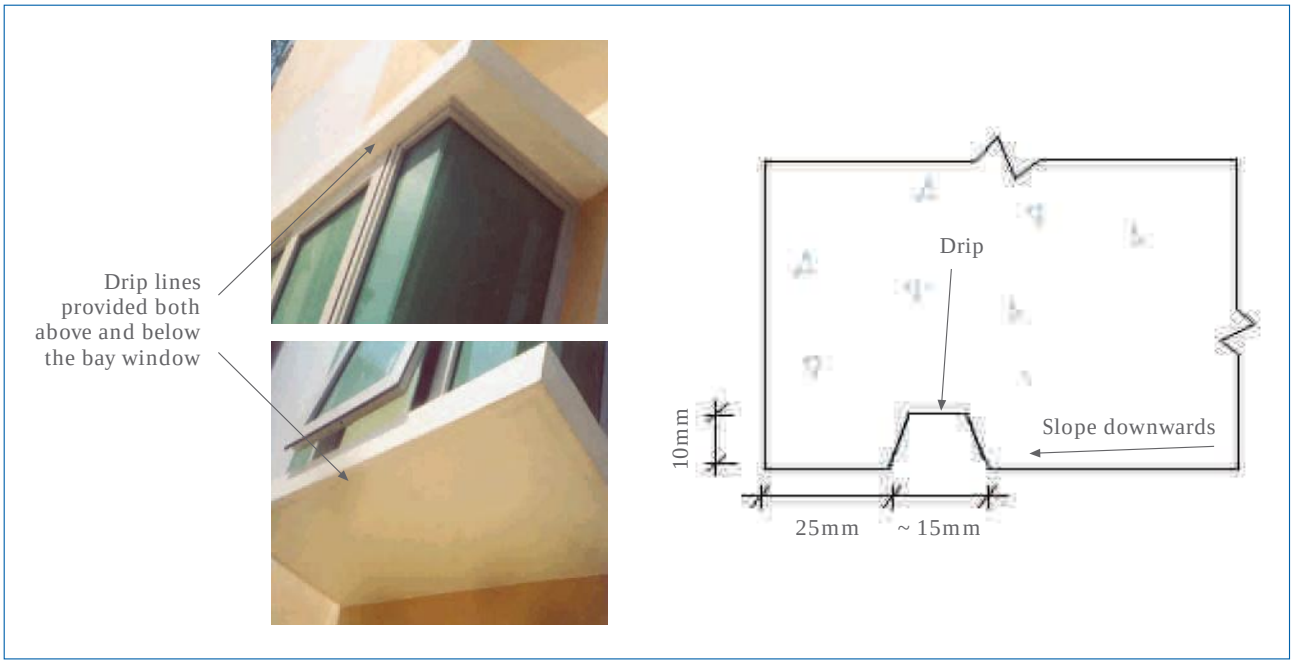


Figure 2.26: Provision of overhang

Figure 2.27: Provision of drip at underside of external features

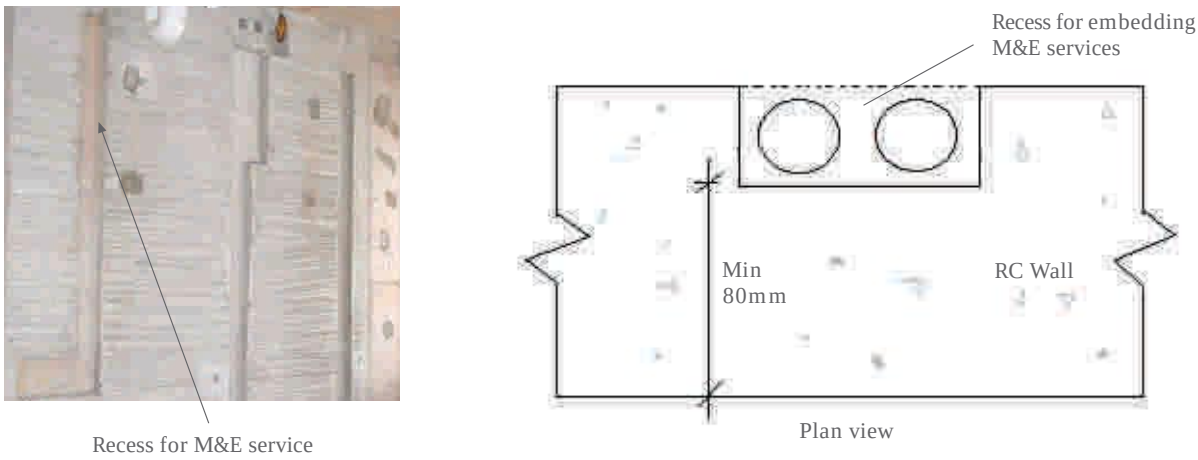


2.5.2 M&E SERVICES

Chasing of external walls for embedding M&E services reduces the effective thickness of the walls and weakens the physical barrier against water ingress. Designers should avoid running M&E services along external walls, especially external brickwalls.

For RC walls, recess for embedding M&E services should be provided during the concrete casting stage. Hacking of walls should be avoided. The effective thickness of RC walls should be maintained at a minimum of 80mm.

Figure 2.28: Recess provided in RC wall during concrete casting



Services that penetrate the external walls should be housed within trunking boxes. All gaps between the trunking boxes and the external walls must be completely sealed to ensure watertightness at these penetrations. The penetration points should, where possible, be situated below an overhang element, as shown in Figure 2.26.

Figure 2.29: M&E services that penetrate the external walls

Housing M&E services in trunking box (View from inside)

Housing M&E services in trunking box (View from outside)

2.5.3 WATERPROOFING APPLICATION ALONG PERIMETER WALLS AND PLANTERS

A layer of waterproofing membrane should be applied to the perimeter walls with an upturn of minimum 300mm along the external walls, as shown in Figure 2.30. For external walls with surrounding planters (eg. environment decks), the required upturn of 300mm should be measured from the finished soil level.

For external walls designed with surrounding concrete planter box, it is a good practice to apply waterproofing membrane over the entire interior of the planter box, as shown in Figure 2.31.

Figure 2.30: Waterproofing application along perimeter walls and planters

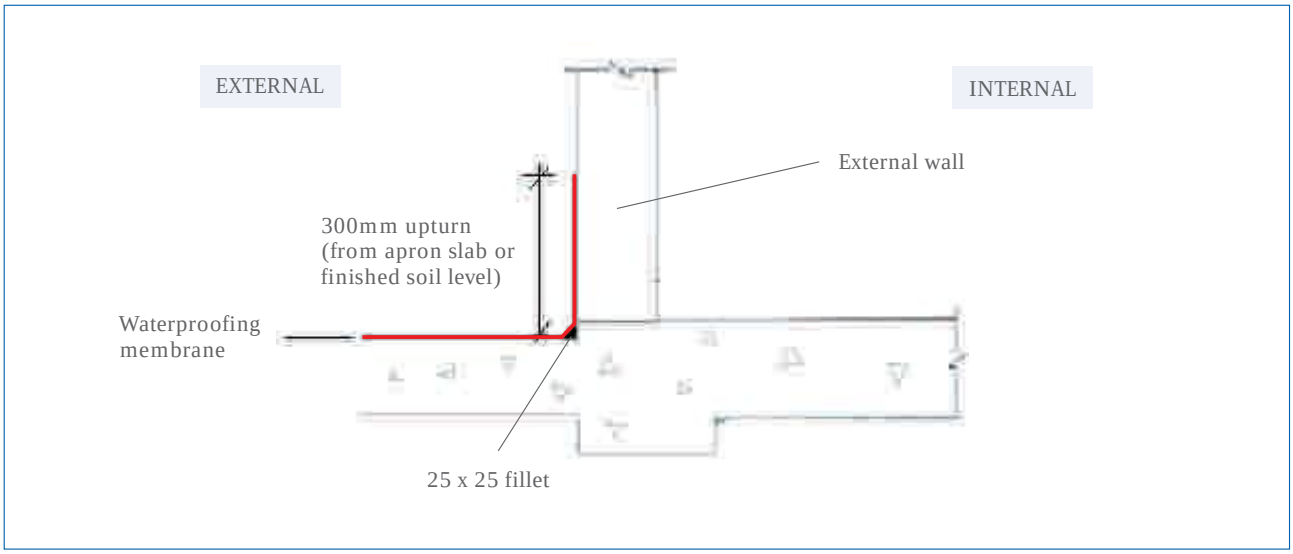
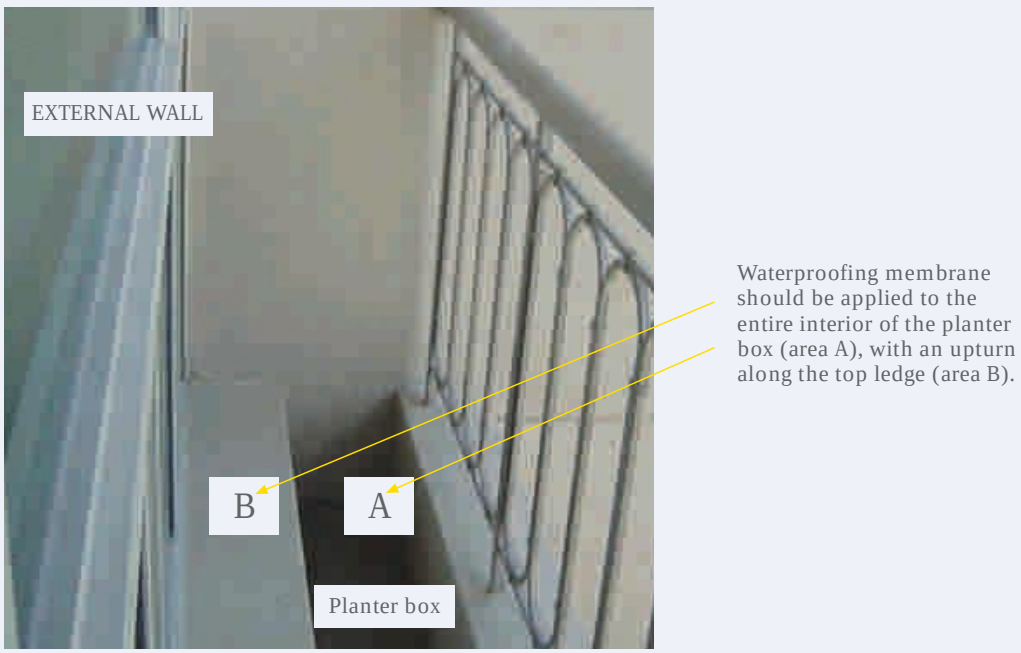


Figure 2.31: Planter box



3. Material Selection

3.1. CONCRETE CONSTITUENTS

The constituent materials of concrete should satisfy the durability, structural performance and safety requirements, taking into consideration the environment to which it will be subjected.

The common types of cement used in concreting include:

- Ordinary Portland Cement (OPC, complying with SS 26);
- Sulphate-resisting Portland Cement (SRPC, complying with BS 4027);
- Low heat Portland Cement (LHPC, complying with BS 1370), etc.

The exposure conditions of the concrete and whether there are other special requirements, should be considered in the selection of the cement type. For example, concrete made with Portland cement is not recommended for use in acidic conditions.

Aggregates can be grouped into fine, coarse and lightweight categories. For most common types of works, aggregates of 20mm size are suitable. For thin concrete sections with closely spaced reinforcement or thin cover, aggregates of maximum 10mm nominal size are used.

Admixtures such as superplasticisers, water-reducing agents, accelerators, etc. (complying to SS 320) may be added to serve its intended use. Admixtures selected should not impair the concrete durability or increase the corrosion of reinforcement.

Steel reinforcement may consist of steel bars, welded wire fabric, or wires. For normal reinforced concrete, the common types of reinforcement bars (complying with SS 2: 1999) used are Grade 250 mild steel bars, Grade 460 high tensile bars in ribbed profile and Grade 485 welded mesh reinforcement.

Grades for reinforced concrete normally range from C30 to C50. These grades indicate the compressive strength of concrete after 28 days of curing. Refer to SS 289: Part 1: 2000 for the selection of concrete under various exposure conditions.

3.2. SEALANT AND BACKER RODS

Sealants are used to seal the joints between precast elements. The selected sealant must be able to bond firmly to the concrete and accommodate panel movements without splitting, tearing or loss of adhesion. It must also be resistant to ultra-violet (UV) light and other weathering effects.

In general, joints that are subject to frequent and rapid movement require an elastic sealant. Joints in massive components with high thermal inertia, on the other hand, may be satisfactorily sealed with an elastoplastic, plastoelastic or a plastic sealant.

Table 3.1 below compares the advantages and disadvantages of some common sealants used.

Table 3.1: Comparison of common sealants

Sealant Type	Advantages	Disadvantages
Polysulphide	• Good UV resistance • Horizontal applications • Immersion applications	• Low recovery rates • Low-movement capability • Primers required
Polyurethane	• Good elongation capability • Excellent recovery rates • Horizontal applications	• Moisture sensitive • Not paintable • Require some priming
Silicone	• High-movement capability • Excellent adhesion • Excellent recovery rates	• No submersion applications • Possible staining

Source: “Construction Waterproofing Handbook” by Michael T. Kubal, 1999.

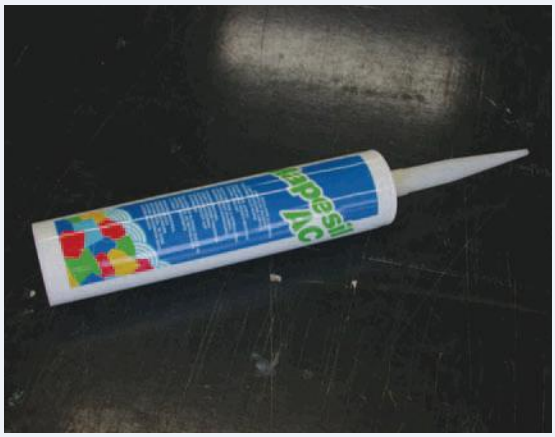
The backer rod is of major importance in joint design and installation. It is inserted into sealant joints to provide three critical functions:

- Allows applicators to control and monitor the depth of sealant application;
- Prevents three-sided adhesion of the sealants to reduce stress on sealant material; and
- Forms the hourglass shape necessary for proper joint design.

Primers could be used with some sealants to ensure good bonding between the sealant and concrete element.

Consult the manufacturer to ensure that the sealant, primer and backing materials are compatible.

Figure 3.1: Sealants and backer rods



Sealant for gun application

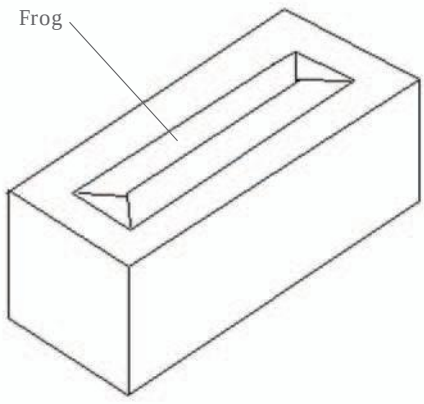
Cross-link, compressible,
closed-cell polyethylene backer rods

3.3 CLAY BRICKS

Bricks may be made from burnt clay or concrete. Clay bricks are more commonly used in the local industry than concrete bricks. Bricks used for external walls should be solid, or with a frog. They should possess a minimum compressive strength of 35MN/m^2 (for load-bearing walls) or 20MN/m^2 (for non load-bearing walls). Hollow bricks should not be used for external walls.

Figure 3.2: Solid bricks

Solid brick without frog



Solid brick with frog

Moisture expansion in bricks may cause cracks to develop in the mortar joints or plaster. These cracks are potential paths for water seepage. In accordance with SS 103:1974, the average water absorption of common bricks should be laboratory tested to be not more than 25% by mass after immersion in cold water for 24 hours. A lower water absorption rate (eg. 15% - 20%) should be specified if the walls are exposed to more severe weather conditions or subject to frequent impingement of rainwater.

3.4 CEMENT MORTAR

Cement mortar used for brickwork bedding or for plastering should possess the following desired characteristics:

- high water retentivity;
- high plasticity;
- good adhesion;
- low shrinkage during and after hardening; and
- high durability.

Selection of appropriate mortar mix for plastering would depend on the characteristics of the substrate and exposure conditions. In accordance with CP 82:1999, sand used for external plastering should not contain silt content in excess of 5% in mass in order to reduce shrinkage. A well-graded sand will improve the cohesiveness of the wet mix.

Masonry or ordinary Portland cement may be used:

Type of cement used in mortar mix	Descriptions
Masonry cement	• Addition of air-entraining agents tends to improve the water retentivity and workability of the mix by generating minute air bubbles in the mix
Ordinary Portland cement	• Plasticiser is normally required to enhance its water retentivity, plasticity, workability and adhesion • Plasticiser to comply with BS 4887 and used in accordance with manufacturer's specifications

Figure 3.3: Example of a prepacked mortar mix

Figure 3.4: Example of a waterproofing admixture

Accelerators, retarders or other admixtures should not be used without the prior review and approval by the Designer.

In general, mortar proportions of cement-sand mix for bedding of brickwall and external rendering should be between 1:3 to 1:5. A lower cement ratio is usually used for bedding of non load-bearing brickwalls. For better performance, pre-packed mortar mixes are recommended.

Waterproofing additives may be added to block or line pores inside the concrete or masonry mortar in order to stop water passage.

Fortifying latexes, also known as bonding agents, such as SBR or acrylic-based latex, can be added to mortar mixes to enhance their water resistance, adhesion to substrate, and cohesion to resist cracking. Alternatively, some of these bonding agents can be applied directly to wall substrates before plastering (for such application, manufacturers' instructions should be followed strictly since latexes, if left to dry on the surface, may cause delamination of the plaster).

The bonding agents can also be used in the patching of form tie holes.

3.5 DAMP-PROOF COURSE

The DPC materials used in brickwalls fall into three groups:

a) flexible materials such as bitumen DPC (according to BS 6398), bitumen/sheet metal composites, polyethylene, bitumen polymer, pitch polymer and sheet metal;

b) semi-rigid materials, such as mastic asphalt; and

c) rigid materials, for example, dense bricks, bedded in cement mortar.

The selected DPC material should comply with BS 6398.

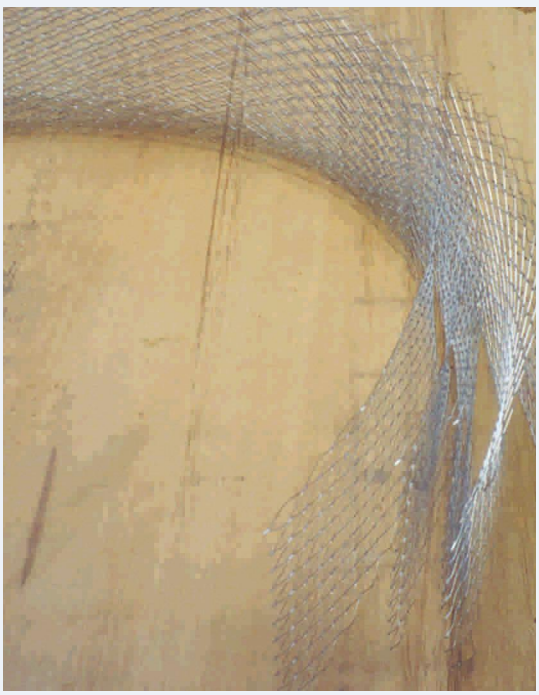
3.6 BONDING BAR SYSTEMS, REINFORCEMENT AND LINTELS

Bonding bar systems should be hot-dipped galvanised to the following requirements:

a) Bonding bars - minimum average coating mass of 460g per m^2 or equivalent thickness of 64 microns in accordance with BS EN 1461.

b) Lipped frame - minimum average coating mass on individual points to be 410g per m^2 or equivalent thickness of 57 microns in accordance with BS EN 1461.

Figure 3.5: Metal lathing



Metal lathing (wire mesh) reinforcement should be hot-dip galvanised, fabricated from 1.6mm wire 6mm square mesh. For reinforcement to be embedded within the brick mortar bedding, the width of the mesh should be 12mm less than wall thickness.

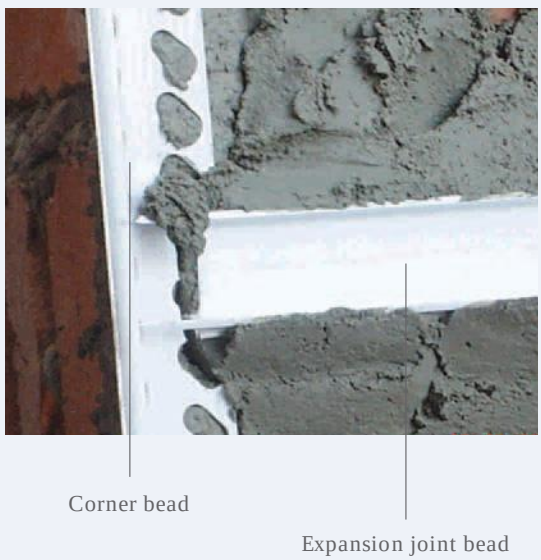
There are two types of lintels: conventional concrete lintels or steel lintels. Steel lintels are lighter than conventional concrete lintels and may have designs that provide better key to plastering.

3.7 BEADS USED IN EXTERNAL PLASTERING

Beads used in external plastering can be of PVC material or galvanised steel. Where galvanised steel beads are used, ensure that they conform to the following:

Corner beads	• Galvanised steel (450g) to BS 1369 • Nominal sizes to be 5mm bead with 62mm minimum expanded metal wings (subject to manufacturer's recommendations).
Expansion joint beads	• Rust proof galvanised steel with adjustable opening subject to manufacturer's recommendations

Figure 3.6: Corner beads and expansion joint beads



4. Delivery, Handling & Storage

In general, all materials should be delivered, stored and handled in a manner that protects them from damage, moisture, dirt and intrusion of foreign materials. Ordering and delivery of materials should be planned according to the work progress to minimise storage on site, where there are higher possibilities of damages and deterioration of materials.

Materials delivered should be checked against the specifications and approved samples. The following are some verification to be carried out on the delivered materials:

Materials	Verification
Precast components	Structural defects, dimensional tolerances, surface finishes and physical damage
Bricks	Type, grade and size
Pre-packed mortar	Type and condition of packaging
Site mix mortar	Quality of sand and silt content
Bonding agent, Waterproofing admixtures, Liquid applied waterproofing materials, and Sealant	Delivered in original packaging, shelf life from date of production and batch reference

4.1 PRECAST COMPONENTS

The following quality control checks should be carried out on the delivered precast components:

- structural defects;
- dimensional tolerances;
- surface finishes; and
- physical damage.

Figure 4.1: Quality control checks for precast elements

Laitance and exposed aggregates

Chipped corners

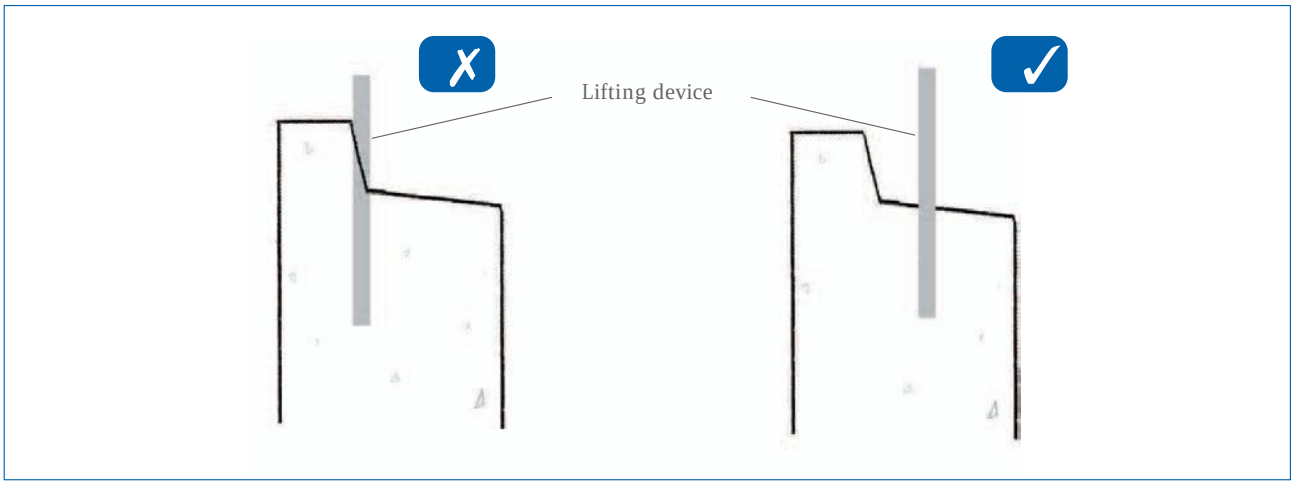
Measurement of dimensions

Inconsistent surface finish

All precast components should be handled in a manner that avoids excessive stresses, damages and cracks to the components, especially during demoulding and handling in site precast yards. Young immature concrete is more prone to cracks, which may cause future watertightness problems.

The location of the lifting device should be situated at the downstand of the joggled profile of panels to prevent excessive stress and cracks around this area (see Figure 4.2).

Figure 4.2: Location of lifting device (Cross-section view)

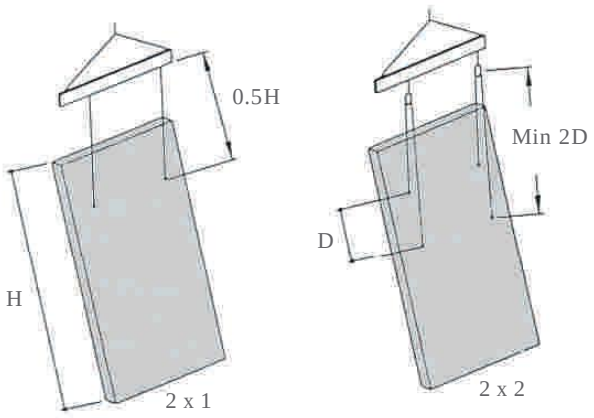


CP 81:1999 recommends that the following be considered when handling precast units on site:

- minimum concrete strength;
- size and weight of precast unit;
- adequacy of reinforcement to resist handling stresses;
- number, size and location of lifting points;
- method of lifting and type of lifting equipment; and
- proper supports and support location.

Rigging system selected should ensure safety and equal load distribution to all lifting points. Two common rigging configurations are the 2 x 1 and 2 x 2 configurations as shown in Figure 4.3.

Figure 4.3: Rigging of precast panels



Common rigging configurations

An example of 2 x 1 rigging

Precast components should be placed on strong and level supports. The supporting points should be positioned such that the precast components are not subject to excessive stress. Stacking should be done in a manner that ensures stability, safety and avoids damage to the components.

Figure 4.4: Precast units stored on ground level

Store on wooden or rubber supports with firm mortar base

Undue stress and damage caused at support location

4.2 BRICKS, CEMENT, SAND AND OTHERS

Proper packaging, delivery, handling and storage of bricks help to prevent breakage, cracking, chipping, spalling and other damages. Bricks should be stored on a flat surface and should avoid direct contact with the ground. They should be placed in a manner that facilitates easy handling and allows adequate air circulation around the bricks.

Figure 4.5: Properly packed and supported brick units

Bricks should not be stacked higher than 2 pallets. They should be hoisted in pallets or transported using a pallet jack. Transportation of bricks using wheelbarrow should be avoided, unless absolutely required, such as in narrow spaces.

Figure 4.6: Transport and storage of brick pallets

Bricks stacked on 3 pallets

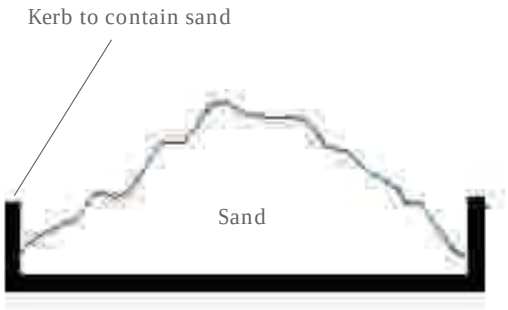
Bricks stacked on 2 pallets

Transporting bricks with a pallet jack

Hoisting bricks in pallets

Aggregates for the mortar mix should be stored with good drainage provision and protected from dirt, intrusion of foreign matter and excessive high temperatures. Sand should be stored in a manner free from contamination by other site materials, for example, by providing a containment with proper base and kerb. A sand pump could be used to transport sand, where needed.

Figure 4.7: Transportation and storage of sand



Provide a good base (eg, plywood or lean concrete) to store sand

Using sand pump to transport sand to required location

Cement and pre-packed mortars should be stored off the ground in a clean and dry area. Materials affected by dampness should be discarded.

Flexible DPC materials should be stored in a dry area, with proper cover and protected from physical damage. In addition, the materials should be handled with care during storage:

a) rolls of DPC should be stored upright on their ends on level surface;

b) rolls of DPC should not be stacked up to more than three packs or beyond 1m high;

c) bitumen and other thermoplastic materials should be kept away from direct heat source; and

d) materials should be stored in a manner that protects them from distortion.

Reinforcement materials should be properly stored and protected from soil, dirt, loose rust scale or other coatings. Bonding agents, waterproofing additives or waterproofing membrane systems should be stored at room temperature and kept away from direct sun.

Figure 4.8: Store materials above the ground

Storage of pre-packed materials

Storage of liquid materials

5. External Wall Construction

5.1. ERECTION OF EXTERNAL PRECAST WALLS

The erection of precast walls generally involves the following steps:

a) moving the precast wall panels from delivery truck or site storage yard to the designated locations for installation;

b) raising the precast panels to the required elevation (and rotating to correct orientation if necessary);

c) fixing the precast panels in position; and

d) casting the wet joints and/or grouting and applying sealant.

Figure 5.1: Erection of a precast wall

1. Remove precast wall from delivery truck

2. Raise the precast wall to required height and orientation

3. Position compressible waterproofing strip at joint

4. Apply non-shrink grout

5. Lower precast wall into position

6. Adjust position of precast wall

7. Install strutting

8. Verify plumb (and adjust if necessary)

9. Remove excess grout infill after precast wall is erected

5.1.1 CASTING OF WET JOINTS

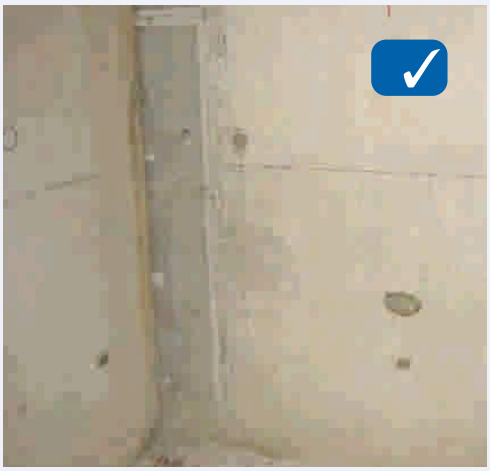
The use of wet joints is essential in minimising water seepage through the joint areas.

Figure 5.2: Casting of wet joint connections

1. Prepare continuity bars of wet joints

2. Set up formwork for casting

Figure 5.3: Wet joints



Good example of a wet joint

Bad example of a wet joint

5.1.2 SEALING OF JOINTS

Precast wall panels should be erected within the allowable construction tolerances, with emphasis placed on the gap size at the joints. This is important to facilitate proper installation of backer rod and application of sealant to ensure effective watertightness at these locations.

Concrete surfaces at the joint should be sound, smooth, clean and free from all mortar dust or other contaminants that may affect the adhesion of sealant to the surfaces. Some sealants may require a primer to improve the adhesion. In such cases, manufacturer's advice should be sought to ensure compatibility of the sealant and primer. As shown in Figure 5.4, poor surface preparation, resulting in loose particles and contaminants trapped in the sealant can lead to premature failure of the sealant system.

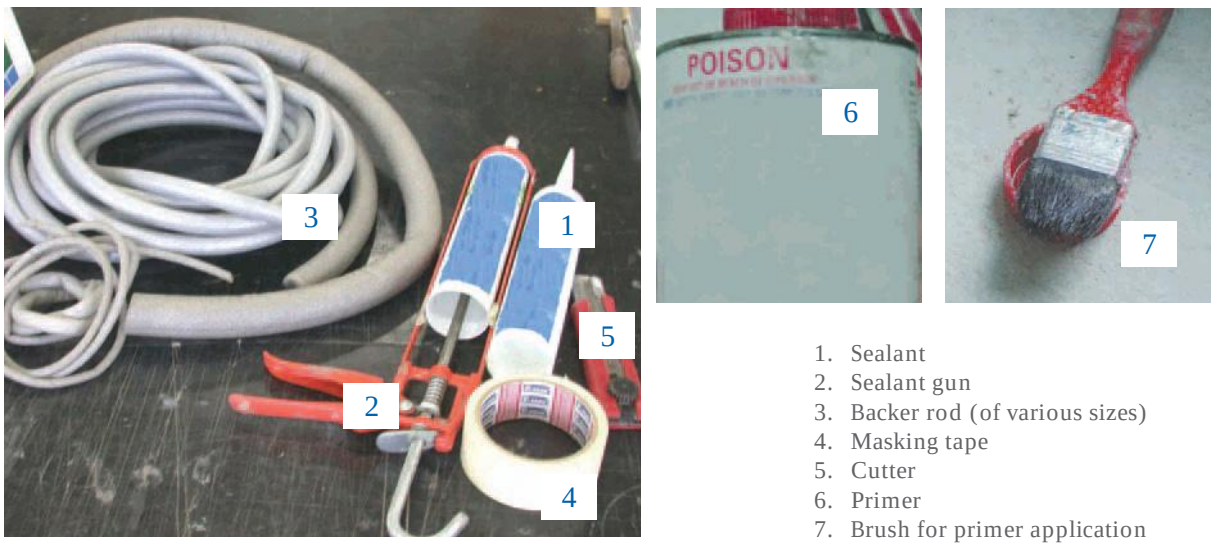
Figure 5.4: Premature failure of sealant due to contaminants

Where form release agents, form oils, or other surface coatings had been used, it is recommended that the joint surfaces be treated with a light sandblast, scarification or other approved methods in accordance with the manufacturer's advice to improve the adhesion of the sealant.

For effective sealing, the sealant should be extruded against a firm backing, such as a suitable backer rod, so that it is forced against the sides of the joint during application. The applied sealant should not adhere to the backing material because the induced restraint and resultant stresses from three-sided adhesion could lead to premature failure of the sealant system. A bond breaker such as polyethylene film could also be used, in place of a backer rod to prevent three-sided adhesion.

The applied sealant should be tooled to achieve a slightly concaved surface that is smooth, free of ridges, wrinkles, sags, air pockets and embedded impurities.

Figure 5.5: Tools for sealant application



1. Sealant
2. Sealant gun
3. Backer rod (of various sizes)
4. Masking tape
5. Cutter
6. Primer
7. Brush for primer application

5.2 CAST IN-SITU REINFORCED CONCRETE WALLS

Cast in-situ reinforced concrete (RC) walls are generally watertight, unless cracks are formed in the walls or at the joints between different elements. Cracks may be formed as a result of poor concrete quality, poor workmanship and/or unfavourable environmental factors.

To ensure watertightness at the joints between RC-RC members, the following preparatory work should be carried out before subsequent pour of concrete:

a) roughen the joint surface while the concrete is still green (eg. using a wire brush);

b) remove laitance at the joint surface;

c) rectify honeycombed areas with pressure grouting using approved material; and

d) apply a thin slurry coat of bonding agent at the joint surface, where watertightness is critical.

It is important to achieve the required alignment and verticality during casting so that there is minimal rectification work. The following should be observed:

a) formwork should be in good condition;

b) proper bracing and strutting; and

c) thorough checks on plumb and alignment before casting.

Form tie holes on external walls should be properly sealed to ensure watertightness of the building envelope. The following good practices should be adopted:

a) wall plugs of resilient material (non-biodegradable) and of appropriate sizes should be inserted into the form tie sleeve holes;

b) surrounding concrete surfaces should be cleaned to remove all loose particles and dampened;

c) a slurry coat of bonding agent, cement and water (refer to manufacturer's instructions on the mix ratio) should be applied to the dampened surface; and

d) non-shrink grout should be used to seal the holes. The slurry coat should still be fresh at time of application of mortar.

Figure 5.6: Joint surface roughened to improve bonding at RC-RC joint

Figure 5.7: Patching of form tie holes

1. Remove plastic cone

2. Insert wall plug into sleeve

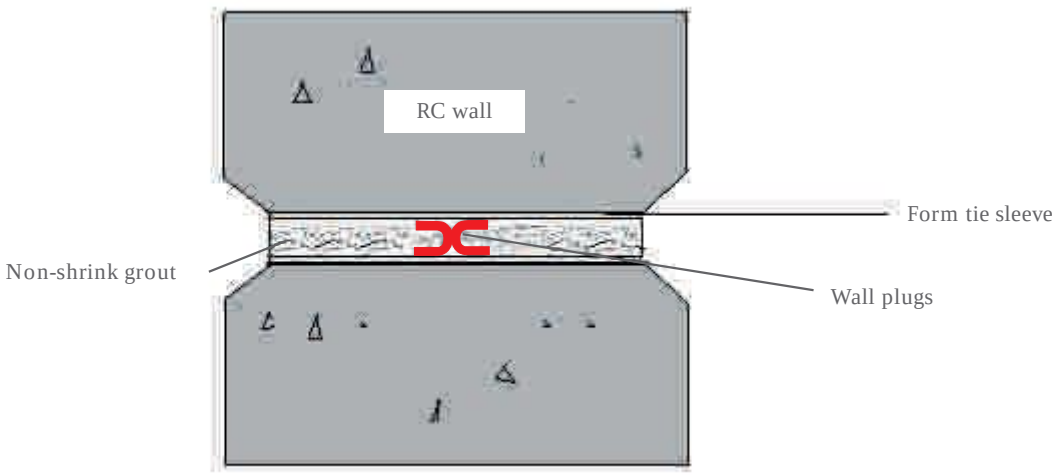
3. Clean concrete surface

4. Apply slurry of bonding agent, cement water

5. Mix non-shrink grout

6. Press grout mix into recess and finish by removing excess grout from concrete surface

Figure 5.8: Form tie sleeve hole (sectional view)



5.3 BRICKLAYING

5.3.1 GENERAL

Quality workmanship in bricklaying is essential in ensuring watertightness of brickwalls.

There should be proper co-ordination between external brickwork and other works. Setting out of all works, including openings, sills and lintels, should be coordinated. A copy of the approved brickwall setting out drawings could be displayed at appropriate location for easy reference.

There should be adequate scaffolding provided to enable workers to work from the outer side of external walls to achieve a high standard of laying and pointing works.

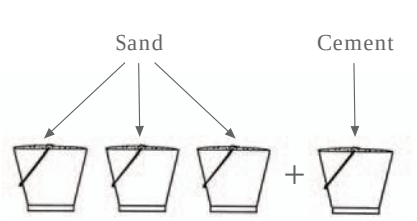
5.3.2 BATCHING, MIXING AND USE OF MORTAR

For enhanced performance, pre-packed mortar mix is recommended.

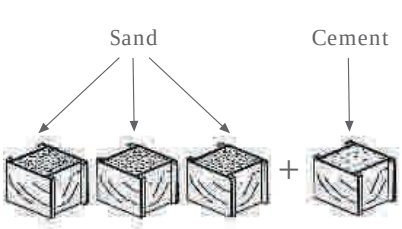
For site batching of mortar mix, standard size containers should be used to ensure correct proportion of materials. The use of shovels to gauge the amount of materials cannot be relied upon to give consistent performance. Additives should only be used upon the Designer's permission, and with the advice from the manufacturer. Machine mixing is recommended to achieve a thorough blend of mortar.

Wide variations in the mixing time should be avoided. Insufficient mixing may result in non-uniformity, poor workability and low water retention of the mortar. Excessive mixing, on the other hand, may adversely affect the strength and bonding of mortar due to air entrainment. It is a good practice to regulate the quantity of mortar being mixed, so that the mortar can be used up within the working time.

Figure 5.9: Measuring materials for mortar mix



Example of using bucket batching for a 1:3 mix



Example of using gauge box batching for a 1:3 mix

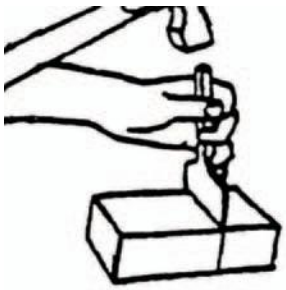
Gauging by shovels cannot be relied upon to give consistent mortar mix

5.3.3 CUTTING OF BRICKS

Proper setting out of the brickwork helps to reduce unnecessary cutting of brick units. Where cutting of brick units is needed, it is recommended that appropriate cutting machine be used to produce clean-cut edges. Alternatively, bricks could be cut using a bolster and a hammer. However, this method tends to produce less satisfactory results.

Figure 5.10: Cutting of bricks

Machine cut



Cutting with a bolster and hammer

5.3.4 LAYING OF BRICKS

Brick units are generally porous and absorb moisture from the mortar during laying. This affects the adhesion between the brick units and the mortar. It is, hence, a good practice to dampen the brick units before laying, and to lay the mortar beds in shorter lengths to reduce rapid loss of water from the mortar through evaporation before the next course is being laid.

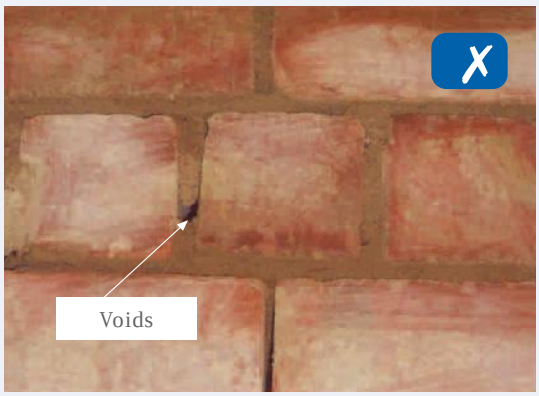
In addition, the top surface of the brick walls where the previous laying stopped, and the surfaces of abutting concrete slab/ beam/ column/ kerb should also be well wetted before commencement of laying. The bricks, however, should not be overly wetted (do not soak the bricks in water), as this may result in excessive efflorescence and staining of the brickwalls.

Brick units should be laid in full mortar bed with full head joints. Frogged bricks should be laid with the frog side facing up. The frogs should be completely filled with mortar to ensure no presence of voids between the bricks.

Watertightness would be adversely affected if voids are present in the cement mortar. Bricks should be laid in full and consistent mortar bed (Figure 5.10). The practice of furrowing the bed joints and buttering only the outer edges of the units should be avoided. As cement mortar joints are usually less watertight than the masonry units, average thickness of the mortar joints should not be thicker than 10mm.

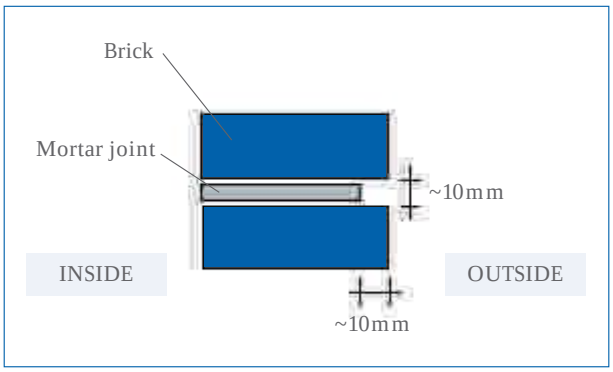
Figure 5.11: Mortar joints

Brickwork without voids



Brickwork with voids

Figure 5.12: Raking of external mortar joints for plastered brickwalls



The joints should be raked out to a depth of about 10mm while the mortar is still green to form an adequate key for plaster (Figure 5.12).

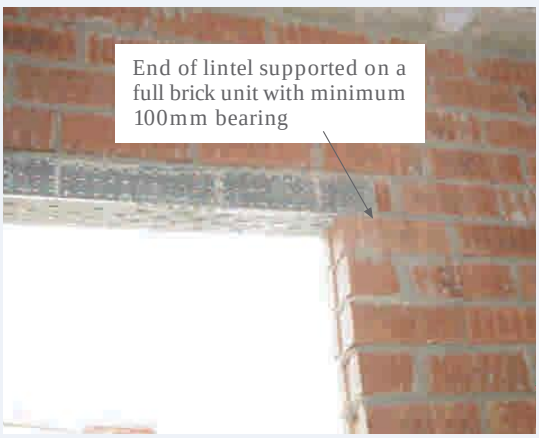
As the brickwall is being erected, embed bonding bars and mesh reinforcement (exmet) in the mortar joints at every 4th course of brickwork. Where 2 pieces of reinforcement are joined, an overlapping of minimum 150mm should be provided. Lintels should be installed for doors and windows opening.

Figure 5.13: Installing bonding bars, brick reinforcement and lintels

Bonding bars fixed to a concrete column

Bonding bars embedded at every 4th course of brickwork

Mesh reinforcement embedded at every 4th course and tucked into the next course



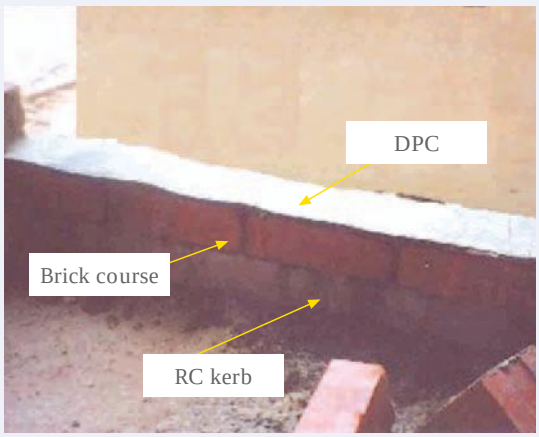
Steel lintel installed at window opening

5.3.5 INSTALLATION OF DAMP-PROOF COURSE (DPC)

DPCs should be laid on a smooth bed of fresh cement mortar. Care should be taken to ensure that the DPCs are not damaged, torn or punctured during the process of bricklaying. There should be minimum 150mm lapping at any joint between two sections of DPC.

The DPC laid should cover the entire width of the bricks. After laying the DPC, a fresh layer of mortar should be laid over the DPC as soon as possible, followed by the next course of brick. This creates good adhesion between the brick units, mortar and DPC.

Figure 5.14: Laying damp-proof course (DPC)



1. Lay DPC on fresh mortar bed

2. Lay fresh mortar over DPC

3. Lay at least one more course of brick over DPC

4. Damp-proof course laid with good adhesion

5.3.6 OTHER GOOD PRACTICES

As described in Section 2.4.3, a layer of metal lathing (mesh reinforcement) should be provided at the following locations to minimise the development of cracks:

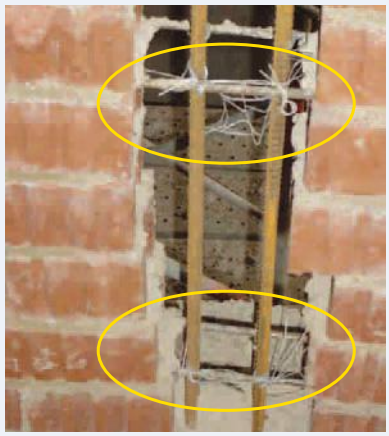
- interfaces between brick and RC elements;
- around door frames;
- around steel lintels; and
- around openings for electrical services.

Figure 5.15: Installing mesh reinforcement

Reinforcement installed around door frame

Reinforcement installed around lintel

Reinforcement installed around openings for electrical services



Reinforcement bars installed at every 4th course of brickwork for RC stiffeners

M&E services that penetrate the external walls should be housed in trunking boxes, with the surrounding gaps properly sealed to prevent any leakage, as illustrated in Figure 5.16 below.

Figure 5.16: Encasing M&E services in trunking boxes

1. Routing of pipes in the trunking box

2. Patching surrounding gaps using cement mortar

3. Connecting the trunking and finishing with paint

5.3.7 COMPLETING WORKS FOR BRICKLAYING

Mortar infill should be properly compacted between the last course of brickwork and the beam/ slab soffit. For better compactness, the use of a hand pump is recommended. Joints should be checked after excess mortar is removed from the brick face to ensure that the joints are properly filled. Any voids should be filled with grout. Where grout is used, avoid excessive water in the mix which may cause segregation and undue shrinkage.

Figure 5.17: Inject mortar between last course of brickwork and beam soffit

Gap between top course of brickwork and beam soffit

Hand pump for injection of mortar

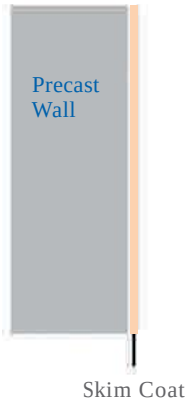
Use hand pump to fill gap with grout

Completed grouting work

5.4 EXTERNAL PLASTERING AND SKIM COAT

Typical cross sectional details of finishes for external wall are shown below:

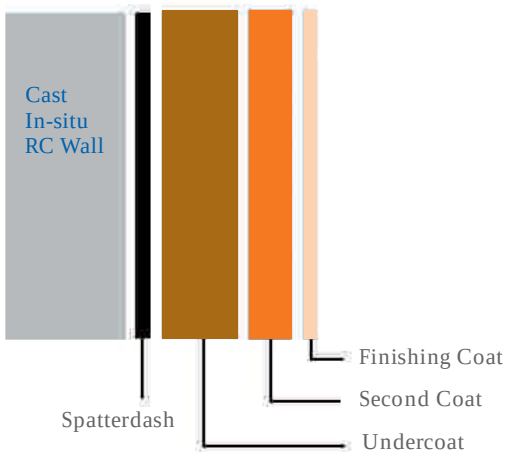
Figure 5.18: Typical cross sectional details of external finishes



Typical cross section of a precast wall (or a cast in-situ RC wall) requiring skim coat only

External finishes for precast walls consisting:

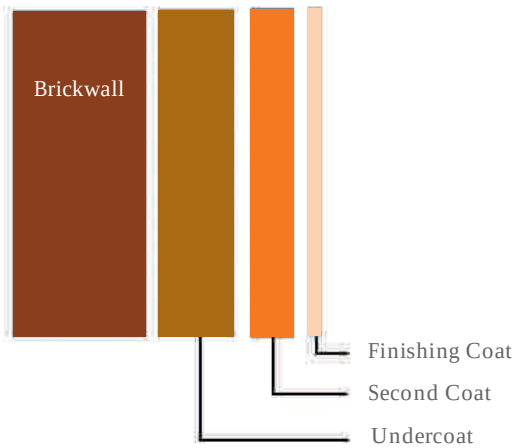
1. a thin layer of skim coat to fill out minor voids/ surface imperfections.



Typical cross section of a cast in-situ RC wall requiring plastering

External finishes for cast in-situ reinforced concrete (RC) walls consisting:

1. a spatterdash coat for better keying of the subsequent rendering coats;
2. an undercoat (scratched);
3. a second coat; and
4. a finishing coat.



Typical cross section of a plastered brickwall

External finishes for brickwalls consisting:

1. an undercoat (scratched);
2. a second coat; and
3. a finishing coat.

Figure 5.18 shows that external wall construction with precast walls involve the least work for external finishes. The process is, hence, less workmanship-dependent and more efficient.

5.4.1 PREPARATORY WORK

There should be proper co-ordination between external finishing works and works of other trades.

Gaps between the external walls and window/ door openings should be fully grouted with waterproofing mortar before the commencement of finishing work.

Figure 5.19: Sealing gap between window frame and external wall

Using hand pump to fill gap between frame and wall with waterproofing mortar before plastering

Gunning sealant into groove line after plastering is completed

External RC members with poor alignment and plumb, poor construction joint, honeycombed and badly formed surfaces should be rectified accordingly. All protrusions, fins, imperfections and blemishes should be removed from the RC surfaces.

Cleaning

All brick, concrete and other surfaces should be cleaned of dust, dirt, debris, grease, form release agents (for concrete surfaces), laitance and any other detrimental materials that may affect the bonding of plaster or skim coat.

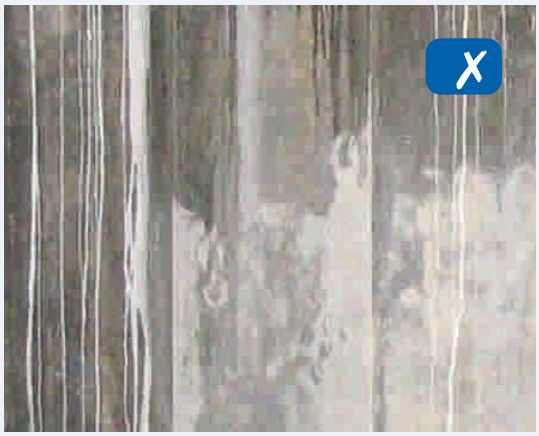
Active biological growth, such as algae, fungus and mould, should be removed as they may result in the formation of poorly laminated finishes, creating undesirable cavities or even cracks, thereby reducing the watertightness of the finishing coats. Appropriate cleaning solution can be used for this purpose.

Figure 5.20: General cleaning prior to application of finishes

Cleaning prior to application of finishes

Use of high pressure water jet

Figure 5.21: Use of appropriate cleaning solutions prior to application of finishes



Presence of form oils with efflorescence

Application of cleaning solution to remove residual form release agents on concrete surfaces

Treatment At Joints Between Dissimilar Materials

A layer of approved waterproofing compound should be applied at locations where there are potential risks of water seepage, for example, at brick-RC joints or around embedded M&E services.

A layer of render should be applied over the joint area prior to the application of the waterproofing membrane. The width of the applied waterproofing compound should be minimum 200mm (i.e. 100mm on each side of the joint). Once the waterproofing membrane has cured sufficiently, install a layer of metal lathing over the waterproofing membrane to prevent cracks at these interfaces.

Figure 5.22: Treatment at joints between dissimilar materials

1. Apply render to brick-RC joints

2. Apply waterproofing membrane

3. Install metal lath at brick-RC joints

Waterproofing Application along Perimeter Walls and Planters

There should be proper surface preparation before application of waterproofing membrane to the surrounding perimeter walls and planters as discussed in section 2.5.3. Refer to manufacturer's instructions on the surface preparation required, as well as coverage and number of coats to be applied. The membrane should be applied with a minimum 300mm upturn along the external wall (Figure 2.30 in Chapter 2).

Figure 5.23: Apply waterproofing membrane to perimeter walls with 300mm upturn

Application of Spatterdash Coat

For cast in-situ RC walls that require plastering, proper bonding and keying are important in ensuring good adhesion of the plaster to the RC substrate. The substrate surfaces should be dampened before commencing application of spatterdash coat. A spatterdash coat of 3-5mm thick should be applied to give effective keying action. For better performance, a thin layer of bonding agent can be applied on the RC surfaces before the application of the spatterdash coat. The application of the spatterdash coat should commence when the bonding agent is still damp.

Figure 5.24: Spatterdash coat on RC surfaces for better bonding with plaster

5.4.2 APPLICATION OF PLASTER

Plastering can substantially increase the rain resistance of external walls. However, cracks in the plaster may develop over time and reduce the level of protection against rain. Cracks in the plaster are usually caused by shrinkage of the plaster and/ or inadequate bonding between the plaster and the substrate.

For better performance, pre-packed plaster mixes are recommended. Approved waterproofing compound or bonding agent could be added to the plaster mix to improve its waterproofing ability.

Brick surfaces should be moistened prior to application of the undercoat to obtain good adhesion and prevent excessive absorption of water from the undercoat by the brickworks. Plastering on brick surfaces is usually applied in two coats (excluding the finishing coat). The thickness may vary depending on the evenness of the wall surface. Usually, the undercoat is between 8-10mm thick (scratched), and the second coat is 6-10mm thick. Some pre-packed plastering mortars may allow thinner layers of application. For such cases, refer to specifications of the manufacturer. The total thickness allowed for the plaster (including all coats) should generally be limited to 25mm.

For plastered RC surfaces, the thickness of plaster should be between 5-18mm. If the structural works are constructed with good alignment and surface condition, a thinner coat of plaster or skimming may be applied.

Each plaster coat should be sufficiently cured by mist spraying before applying the subsequent coat. Rapid drying of the plaster should be avoided to achieve better shrinkage control.

Where applicable, all plastering works should be terminated at groove lines, casing beads, corners, openings, or other acceptable intersection of surfaces to achieve a better finishing without any visible lines at the terminating plaster. To reduce the risks of water seepage at the joints between two adjacent groove lines, a suitable sealant should be applied to these joints, including the turning corners of the groove line after plastering.

Figure 5.25: Terminating plastering works at groove lines

All defective plaster, including hairline cracks, pits, blisters, and other defects, should be rectified. When carrying out rectification works, a suitable bonding agent should be applied to the existing plaster edges or surfaces where the new plaster will be applied over.

5.4.3 APPLICATION OF SKIM COAT

The surface of RC members (including precast walls) should be constructed to good alignment and plumb so that plastering is not required. Where there are minor surface unevenness or blemishes, the RC surfaces could be skim coated with approved skimming materials. In such cases, the skimming can be applied in two coats, steel trowelled until a smooth and uniform surface is achieved. As a general guide, thickness of skim coat to RC walls should not exceed 5mm.

Skim coats should be cured for 48 hours by fog spraying to prevent rapid drying. For the first 12 hours, a very light fog spraying is recommended.

Figure 5.26: Application of skim coat

1. Prepare skimming tools

2. Scoop skimming mortar onto plastering hawk

3. Apply skim coat onto prepared RC surface, trowel until smooth and uniform

5.4.4 APPLICATION OF SEALER

Subsequent to the completion of plastering works or skim coating, it is recommended to apply a water repelling sealer, either film forming or impregnating in nature, over the external wall before commencing painting works. In particular, water-based impregnating sealers can form a hydrophobic zone which protects the substrate against water ingress. Prior to application of the sealer, the receiving surface should be dry, clean and free from dust, dirt, grease and any loose foreign matter. Refer to manufacturer's instructions on the selection and usage of the sealer.

Figure 5.27: Application of sealer prior to painting works

6. Testing

6.1. WATERTIGHTNESS TESTS

External Wall Panels

To verify the watertightness performance of the completed external walls, field watertightness test could be carried out on minimum 10% of the external walls. The conduct of field watertightness test is especially critical for external brickwalls where waterproofing performance is highly workmanship-dependent.

For conduct of the watertightness test, water should be sprayed on the wall surface at a distance of 1800 – 2000 mm from the wall, with the nozzle fixed at an inclined angle of 30 degree to the external wall. 300 litres of water should be delivered to the test wall panel for 2 hours.

The test wall panel is considered to have passed the test if no dampness or seepage appears on the internal surface of the wall panel or the adjacent areas during the test and within half an hour after the completion of test.

Joints Between External Wall and Window Frame

Field tests should be conducted to verify the watertightness performance of the joints between the external wall and window frame.

The following parameters are used in the CONQUAS 21 field watertightness test:

Water intensity	: 300mm/hr : 1 litre/min/m of joint
Wind Pressure	: 240 Pa
Nozzle inclination	: 90° to wall
Distance of nozzle from wall	: 200mm
Sample	: 1 sample = 2m length of joint
Spray duration	: 10mins

Figure 6.1: Conduct of field watertightness test for joints between external wall and window frame

No sign of seepage should be detected throughout the test.

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Figure 5.27: Application of sealer prior to painting works

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Spray duration	: 10mins

Figure 6.1: Conduct of field watertightness test for joints between external wall and window frame

No sign of seepage should be detected throughout the test.

6.2 TESTS FOR RENDERED SURFACES

The following tests could be conducted after the completion of external finishing work:

6.2.1 TAP TEST

Tap all wall surfaces after installation of final coat to identify any hollow areas. All hollow areas should be remedied accordingly.

Figure 6.2: Tap test to detect hollow areas

6.2.2 ADHESION TEST

Conduct pull-out tests on plaster applied to concrete surfaces within 21-28 days after plastering. For each test, 5 spots are to be randomly selected. Details of the adhesion test are as follows:

- Size of test sample:
  - 75mm x 75mm

- Passing criteria:
  - Average tensile pull out strength of the five spots ≥ 0.40 N/mm^2; and
  - Individual pull-out strength of each sample ≥ 0.30 N/mm^2.

Figure 6.3: Test for plaster surface

1. Mount test plate onto plaster

2. Conduct pull-out test

3. Test area to be patched back

Appendix A

Sample of Inspection and Test Plan (ITP)

Project: _____

Scope of Work: Installation of External Precast Walls

S/No	Activity	Responsibility	Inspection Method	Requirement Reference	Acceptance Criteria	Stage/Frequency	Records
1	SUBMISSION						
1.1	Submit shop drawings and associated calculations, method statements, material samples for approval	MC/ADO	Review	Specifications	Conform to specifications	Prior to start work	Approved submissions
1.2	Submit design mix of concrete and constituent materials for approval	MC/ADO	Review	Specifications	Conform to specifications	Prior to start work	Approved submissions
2	INCOMING MATERIALS INSPECTION						
2.1	Carry out inspection of precast wall panels (good condition, lifting points, connections)	MC/ADO	Visual	Section 4	Conform to specifications	Each delivery	Delivery docket
2.2	Carry out inspection of grouting materials and prepacked skimming mortar (confirm type and quantity)	MC/ADO	Visual	Section 3 and 4	As per approved samples	Each delivery	Delivery docket
3	PRE-ERECTION						
3.1	Setting out	MC/ADO	Visual	Drawings	Conform to drawings	For each location	Checklist
3.2	Temporary supports	MC	Visual	Specifications/ Method statement	Conform to specifications/ method statement	For each location	Checklist
3.3	Joints and connections (surface condition, starter bars, shim plate level, waterproofing strip, etc)	MC	Visual/Measure	Specifications/ Method statement	Conform to specifications/ method statement	For each location	Checklist
4	INSTALLATION						
4.1	Connection details/ interface requirements/ joint seals (including waterproofing treatment eg, backer rod, sealant, waterproofing strip, grouting)	MC/ADO	Visual	Specifications/ Method statement	Conform to specifications/ method statement	For each location	Checklist
4.2	Installed panel verticality, level and alignment	MC/ADO	Visual/Measure	Specifications	Conform to specifications	For each location	Checklist
4.3	Wet joints exposed surface	MC	Visual	Section 5	Conform to specifications	For each location	Checklist

Prepared by _____ Verified by _____ Approved by _____

Date _____ Date _____ Date _____

LEGEND MC – Main contractor/ Installer ADO – Architect/ Designer/ Owner

Sample of Inspection and Test Plan (cont'd)

Project: _____

Scope of Work: Installation of External Precast Walls

S/No	Activity	Responsibility	Inspection Method	Requirement Reference	Acceptance Criteria	Stage/Frequency	Records
5	PREPARATION FOR SKIMMING						
5.1	Hand over precast works to finishing works, including clearance from other trades	MC	Visual	Section 5	Conform to specifications	For each location	Checklist
5.2	Check preparation of substrate to receive finishing, including M&E services	MC/ADO	Visual	Section 5	Conform to specifications/ method statement	For each location	Checklist
6	APPLICATION OF SKIM COAT						
6.1	Skimming mortar mixing	MC/ADO	Visual	Section 5	Conform to specifications/ method statement	In process	Checklist
6.2	Check application of skim coat (finished surface for evenness, squareness and plumb). All rectification works should be completed before painting works.	MC/ADO	Visual	Section 5	Conform to specifications/ method statement	For each location	Checklist
7	FINAL INSPECTION						
7.1	Check for any cracks on finished surface	MC/ADO	Visual	Specifications	Conform to specifications	Per location	Checklist
7.2	Carry out watertightness test on - External wall panels - Joints between external wall and window frame	MC/ADO	Visual	Section 6	- No dampness - No leakage	As per required	Test records

Prepared by _____ Verified by _____ Approved by _____

Date _____ Date _____ Date _____

LEGEND MC – Main contractor/ Installer ADO – Architect/ Designer/ Owner

Sample of Inspection and Test Plan (ITP)

Project: _____

Scope of Work: External Cast In-Situ Reinforced Concrete Walls

S/No	Activity	Responsibility	Inspection Method	Requirement Reference	Acceptance Criteria	Stage/Frequency	Records
1	**SUBMISSION**						
1.1	Submit design mix of concrete and constituent materials for approval	MC/ADO	Review	Specifications	Conform to specifications	Prior to start work	Approved submission
1.2	Submit shop drawings and method statements for approval	MC/ADO	Review	Specifications	Conform to specifications	Prior to start work	Approved submission
2	**INCOMING MATERIALS INSPECTION**						
2.1	Carry out inspection of rebar	MC/ADO	Visual	Mill Certs	Mill Certs	Each delivery	Delivery docket
2.2	Carry out inspection of grouting materials for form tie holes and joint repair	MC/ADO	Visual	Specifications	As per approved samples	Each delivery	Delivery docket
2.3	Carry out concrete receiving inspection (check slump & concrete cube sampling)	MC	Visual/Measure	Approved design mix	Conform to specifications	Each truck load	Delivery docket
2.4	Carry out inspection of prepacked mortar mixes for finishing works (confirm type and quantity). - For on-site mixing of cement/sand, inspect plastering sand (silt content), cement and admixtures	MC/ADO	Visual/Measure	Section 3 and 4	As per approved samples Silt content of plastering sand ≤ 5% by mass	Each delivery One sample per delivery	Delivery docket and Test records
3	**PREPARATION AND CONCRETING**						
3.1	Carry out inspection prior to closing formwork	MC/ADO	Visual	Drawings	Conform to drawings	For each casting area	Checklist
3.2	Monitor concrete placement (confirm that vibration, spread, discharge rate complies with specs, monitor delivery interval, waste & cumulative quantity)	MC	Visual	Specifications/ Method statement	Conform to specifications/ method statement	Every casting	Checklist
4	**INSPECTION OF CAST IN-SITU CONCRETE WALL**						
4.1	Post-pour inspection (formwork stripping, finished concrete surface, verticality, concrete curing)	MC	Visual	Drawings	Specifications/ Method statement	After casting/ Every storey	Checklist
4.2	Concrete strength (analysis of cube test results)	MC/ADO	Visual	Drawings	Specifications	After casting/ Every storey	Test records
4.3	Seal form tie holes and repair joints/cracks	MC	Visual	Drawings	Method statement	Prior to wall finishing	Checklist

Prepared by _____ Verified by _____ Approved by _____

Date _____ Date _____ Date _____

LEGEND MC – Main contractor/ Contractor ADO – Architect/ Designer/ Owner

Sample of Inspection and Test Plan (cont'd)

Project:_____

Scope of Work: External Cast In-Situ Reinforced Concrete Walls

S/No	Activity	Responsibility	Inspection Method	Requirement Reference	Acceptance Criteria	Stage/Frequency	Records
5	**PREPARATION FOR FINISHING WORKS**						
5.1	Hand over RC works to finishing works - Check verticality/horizontality of off-form RC surface and decide thickness of plaster/skim coat - Check clearance from other trades	MC/ADO	Visual/ Measure	Section 5	Conform to specifications/drawings	Per location	Checklist
5.2	Check preparation of substrate to receive finishing - If plastering is required, check application of spatterdash coat, setting out and level packs, angle beads, groove line, etc	MC/ADO	Visual	Section 5	Conform to specifications/ method statement	Per location	Checklist
6	**FINISHING WORKS (IN-PROCESS INSPECTION)**						
6.1	Cement mortar mixing	MC/ADO	Visual	Section 5	Conform to specifications/ method statement	In process	Checklist
6.2	Check application of skim coat (or plastering, if required). For plastering, check undercoat (scratched and sufficiently cured), second and final coat. Inspect finished surface for evenness, squareness, plumb and hollowness (for plastered surface). All rectification works should be completed before painting works.	MC/ADO	Visual	Section 5	Conform to specifications/ method statement	Per location	Checklist
7	**FINAL INSPECTION**						
7.1	Check for any cracks on finished surface	MC/ADO	Visual	Section 5	Conform to specifications	Per location	Checklist
7.2	For plastered surfaces, carry out pull-out test on completed plasterwork and check for hollowness	MC/ADO	Measure	Section 6	Conform to specifications	As per required	Test records
7.3	Carry out watertightness test on - External wall panels - Joints between external wall and window frame	MC/ADO	Visual	Section 6	- No dampness - No leakage	As per required	Test records

Prepared by _____ Verified by _____ Approved by _____

Date _____ Date _____ Date _____

LEGEND MC – Main contractor/ Contractor ADO – Architect/ Designer/ Owner

Sample of Inspection and Test Plan (ITP)

Project:_____

Scope of Work: External Brickwalls

S/No	Activity	Responsibility	Inspection Method	Requirement Reference	Acceptance Criteria	Stage/Frequency	Records
1	**SUBMISSION**						
1.1	Submit material samples, shop drawings, method statements for approval	MC/ADO	Review	Specifications/ drawings	Conform to specifications/drawings	Prior to start work/ each sample	Approved submissions
2	**INCOMING MATERIALS INSPECTION**						
2.1	Carry out inspection of brick, sand & cement for brickwork (confirm grade, type & quantity)	MC	Visual	Section 4	As per approved sample	Each delivery	Delivery dockets
2.2	Carry out inspection of jointing materials (bonding bars, lintels, etc) and damp-proof materials	MC	Visual	Section 4	As per approved sample	Each delivery	Delivery dockets
2.3	Carry out inspection of prepacked mortar mixes for plastering (confirm type and quantity) - For on-site mixing of cement/sand, inspect plastering sand (silt content), cement and admixtures	MC/ADO	Visual/ Measure	Section 3 and 4	As per approved sample Silt content of plastering sand ≤ 5% by mass	Each delivery One sample per delivery	Delivery dockets and Test Register
3	**PREPARATION AND INSTALLATION**						
3.1	Structural clearance and setting out	MC/ADO	Visual	Section 5	Conform to shop drawings	Per unit/ Prior to start work	Checklist
3.2	Cement mortar mixing	MC/ADO	Visual	Section 5	Conform to method statement	In process	Checklist
3.3	Check completed 1st course brickwall	MC/ADO	Visual	Section 5	Conform to shop drawings/ method statement	Per unit	Checklist
3.4	Build remaining brickwalls to $^{1}/_{2}$ height and then full height	MC/ADO	Visual	Section 5	Conform to shop drawings/ method statement	Per unit	Checklist
4	**INSPECTION OF BRICKWORK**						
4.1	Carry out inspection of completed brickwork - proper packing up of all gaps above last course of bricks - Opening for door/window/other services	MC/ADO	Visual	Section 5	Conform to shop drawings	Per unit	Checklist

Prepared by _____ Verified by _____ Approved by _____

Date _____ Date _____ Date _____

LEGEND MC – Main contractor/ Contractor ADO – Architect/ Designer/ Owner

Sample of Inspection and Test Plan (cont'd)

Project:_____

Scope of Work: External Brickwalls

S/No	Activity	Responsibility	Inspection Method	Requirement Reference	Acceptance Criteria	Stage/Frequency	Records
5	PREPARATION FOR PLASTERING WORK						
5.1	Hand over areas from brickworks to plastering works including clearance from other trades	MC	Visual	Section 5	Conform to specifications/drawings	Per location	Checklist
5.2	Check preparation of brick substrate to receive plastering. Check setting out and level packs, angle beads, metal lath, groove line, movement joints, etc	MC/ADO	Visual	Section 5	Conform to specifications/method statement	Per location	Checklist
6	PLASTERING WORKS (IN-PROCESS INSPECTION)						
6.1	Cement mortar mixing	MC/ADO	Visual	Section 5	Conform to specifications/method statement	In process	Checklist
6.2	Check application of undercoat (scratched and sufficiently cured), second and final coat. Inspect finished surface for evenness, squareness, plumb and hollowness. All rectification works should be completed before painting works.	MC/ADO	Visual	Section 5	Conform to specifications/method statement	Per location	Checklist
7	FINAL INSPECTION						
7.1	Check for any cracks on finished surface	MC/ADO	Visual	Section 5	Conform to specifications	Per location	Checklist
7.2	Carry out pull-out test on completed plasterwork and check for hollowness	MC/ADO	Measure	Section 6	Conform to specifications	As per required	Test records
7.3	Carry out watertightness test on - External wall panels - Joints between external wall and window frame	MC/ADO	Visual	Section 6	- No dampness - No leakage	As per required	Test records

Prepared by _____ Verified by _____ Approved by _____

Date _____ Date _____ Date _____

LEGEND MC – Main contractor/ Contractor ADO – Architect/ Designer/ Owner

Appendix B

Sample Checklist for Installation of External Precast Walls

Project: _____

Location: _____

Checklist	Inspection			Remarks
	Date	Result ✓/✗	Signature	
RECEIVING INSPECTION				
Dimensions (within tolerance)				
Overall conditions - No chipped/ cracked sections - Flatness - Cleanliness				
Lifting points/inserts (position, physical condition)				
Sleeve system/connections - Starter bars (length, size, spacing) - Loop and lapping bars (length, size) - Corrugated sleeve (position, cleanliness)				
M&E services present, if any (position, physical condition)				
CHECKS PRIOR TO HOISTING				
Gridline position (setting out lines and level)				
Temporary supports (adequate propping bracing)				
Surface condition of joint (cleanliness from dust, debris)				
Starter bars from lower floor (number, spacing, size, length)				
Shim plate level				
Backer Rod / Waterproofing strip position				
Standby grout materials				
INSTALLATION OF PRECAST WALLS				
Connection details (including proper grouting at horizontal joints)				
Interface requirements/ loop bars/continuity bars/backer rod/formwork				
Verticality of installed panel				
Alignment between panels				
Level of installed panel				
Joint and seal				
Wet joints exposed surface				
PREPARATION FOR SKIMMING				
Clearance from precast works (including other related trades)				
Wash surface thoroughly with high pressure water jet				
Check cleanliness and dampening of substrate				
APPLICATION OF SKIM COAT				
Mixing of skimming mortar (mixing proportion, use of mechanical mixer, consistency of mix)				
Application of skim coat (thickness, evenness, curing)				
FINAL INSPECTION				
Surface condition/evenness				
No visible cracks or damages				
Watertightness Test (no leakage or dampness) - External wall panels - Joints between external wall and window frame				

Sample Checklist for Construction of External Cast In-Situ Reinforced Concrete Walls

Project: _____

Location: _____

Checklist		Inspection			Remarks
		Date	Result ✓/✗	Signature	
PREPARATION					
Setting out / level					
FORMWORK	Formwork condition				
	Dimension				
	Alignment and plumb				
	Bracing and strutting				
	Service opening, etc				
	Construction joint				
REBAR	No. of rebars				
	Rebar size (diameter)				
	Rebar cover				
	Position and spacing				
	Anchorage / lap length				
	Links / stirrups / starter bars				
	Rebar condition				
M&E SERVICES	Installation				
	Secured properly				
	Bent properly				
	No visual damage				
Check quality of concrete before placing e.g. water-cement ratio, slump test, etc.					
CONCRETING STAGE					
Concrete placing (ensure thorough compaction)					
INSPECTION (FINISHED CONCRETE)					
Dimension					
Alignment / plumb / level					
Exposed surface					
Concrete joints					
Sealing of form tie holes					
PREPARATION FOR FINISHING WORK					
Clearance from RC works (including rectification of RC alignment, brickworks and other related trades)					
Wash surface thoroughly with high pressure water jet					
FINISHING WORKS (IN-PROCESS)					
Application of skim coat					
For plastered RC walls, check: - setting out - application of spatterdash coat - reinforcement lathing (where applicable) - application and thickness of undercoat (compactness and scratched), second and final coat, including proper surface preparation and adequate curing for every coat					

Sample Checklist for Construction of External Cast In-Situ Reinforced Concrete Walls (cont'd)

Project: _____

Location: _____

Checklist	Inspection			Remarks
	Date	Result ✓/✗	Signature	
FINAL INSPECTION OF FINISHING				
Plumb				
Straightness of corners/joints				
Surface condition/evenness				
No visible cracks or damages				
No hollowness and good adhesion of plaster on RC walls				
Watertightness Test (no leakage or dampness) - External wall panels - Joints between external wall and window frame				

Sample Checklist for Construction of Plastered Brickwalls

Project: _____

Location: _____

Checklist	Inspection			Remarks
	Date	Result ✓/✗	Signature	
PREPARATION				
Condition of brick units (no physical damage)				
RC surface receiving bricks				
Moisten bricks				
Structural clearance and set reference lines				
Mixing of bedding mortar and mixing proportion				
FIRST COURSE				
Type of bricks				
Type of bond				
Wall thickness				
Brick joint width				
First course setting out				
Provision of stiffener				
ERECTION OF BRICKWALL				
Damp-proof course (if any)				
Bonding bars				
Reinforcement lathing				
Joint width				
Lintels				
Laid in two operations in half heights				
Gap between top course of brickwork and beam soffit properly grouted				
INSPECTION OF COMPLETED BRICKWORK				
Surface and edge are plain and vertical				
No cracked and chipped bricks				
Joints properly filled with mortar				
PREPARATION FOR PLASTERING WORK				
Clearance from brickwork and other related trades				
Wash surface by high pressure water jet (loose particles, organic growth etc, removed thoroughly)				
Check: - setting out / level pack - cleanliness and dampening of substrate - Angle beads, groove line, etc - reinforcement lathing (where applicable)				
PLASTERING WORK (IN-PROCESS)				
Plastering mortar (Mixing proportion, use of mechanical mixer, consistency of mix)				
Application and thickness of undercoat (compactness and scratched), second and final coat, including proper surface preparation and adequate curing for every coat				

Sample Checklist for Construction of Plastered Brickwalls (cont'd)

Project: _____

Location: _____

Checklist	Inspection			Remarks
	Date	Result ✓/✗	Signature	
FINAL INSPECTION				
Plumb				
Straightness of corners/joints				
Surface condition/eveness				
No visible cracks or damages				
No hollowness				
Good Adhesion				
Watertightness Test (no leakage or dampness) - External wall panels - Joints between external wall and window frame				

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'Waterproofing of Reinforced Concrete Buildings', 1999

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