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.

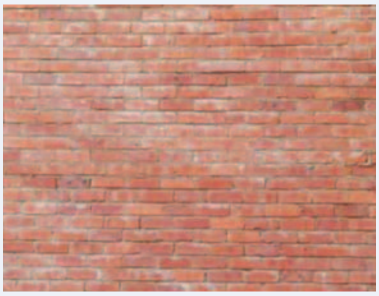
2.2. CHOICE OF EXTERNAL WALL SYSTEM

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

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.

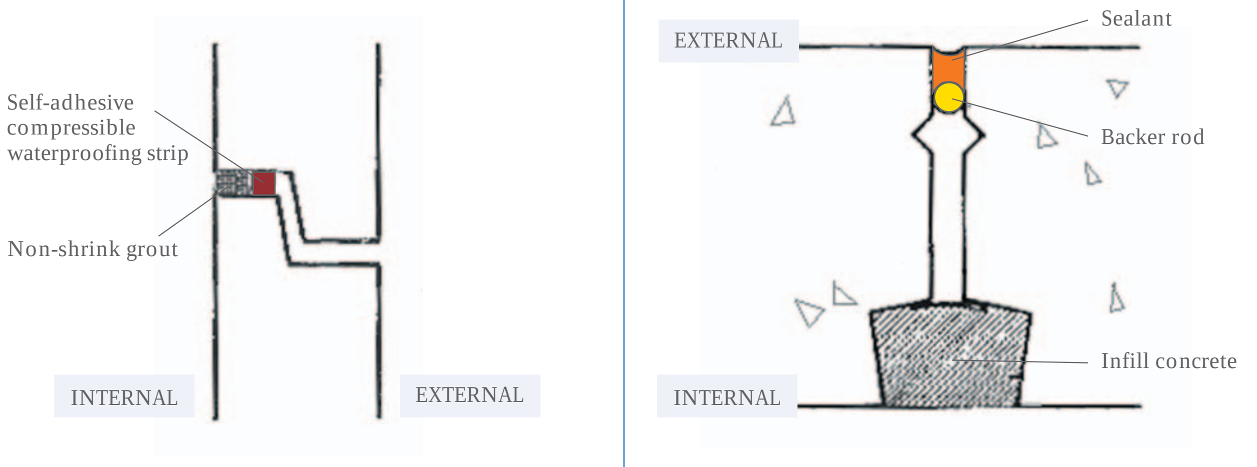
Hence, the use of precast concrete walls is strongly recommended for external wall construction.

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)

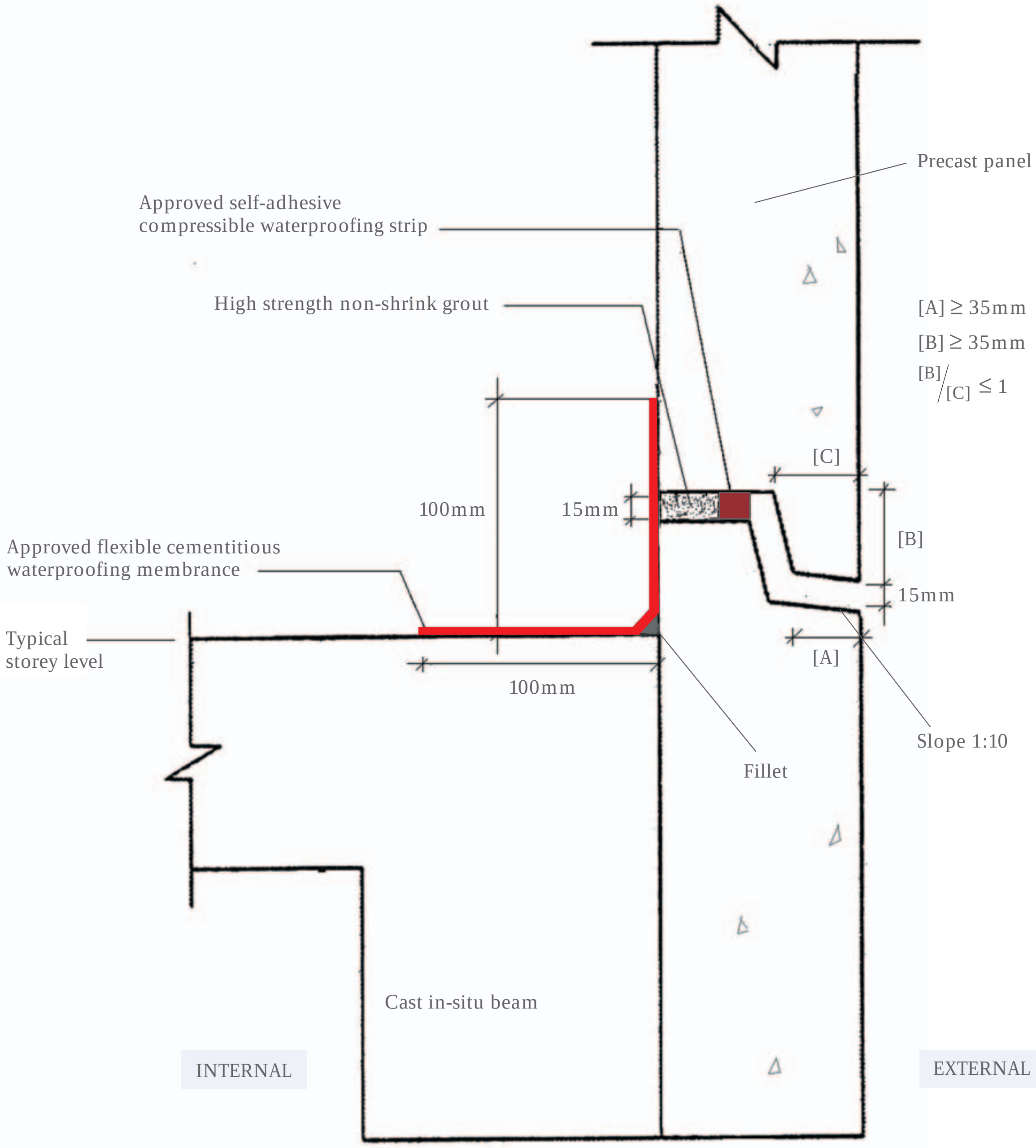
Two-stage vertical joint (Plan view)

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.

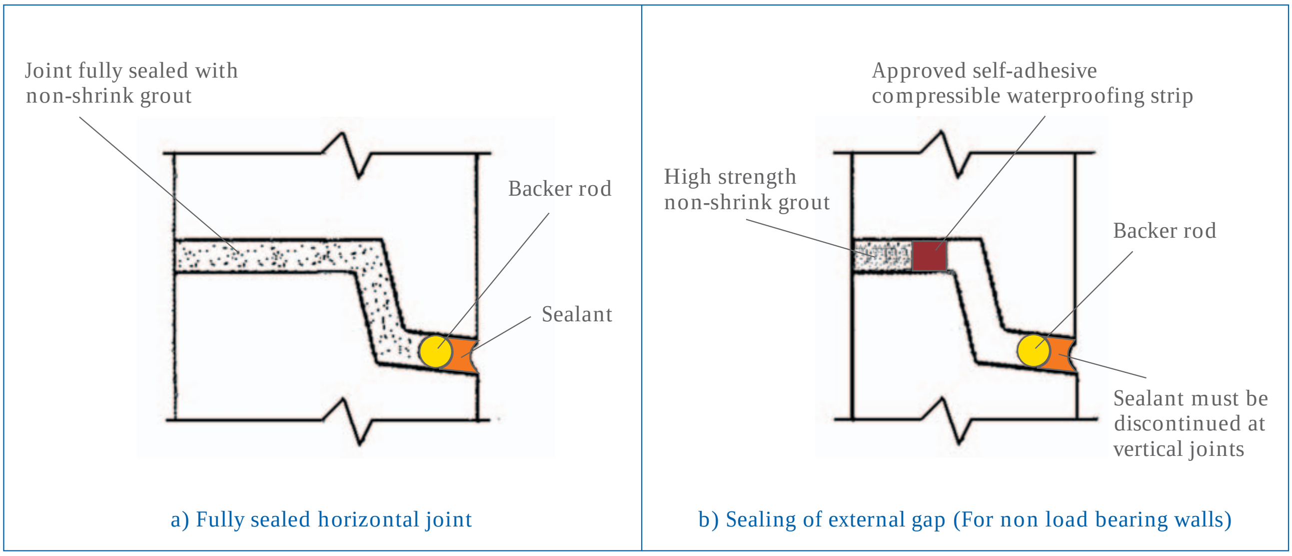
Figure 2.3: Typical sectional view of horizontal joggled joint (for non load-bearing walls)



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



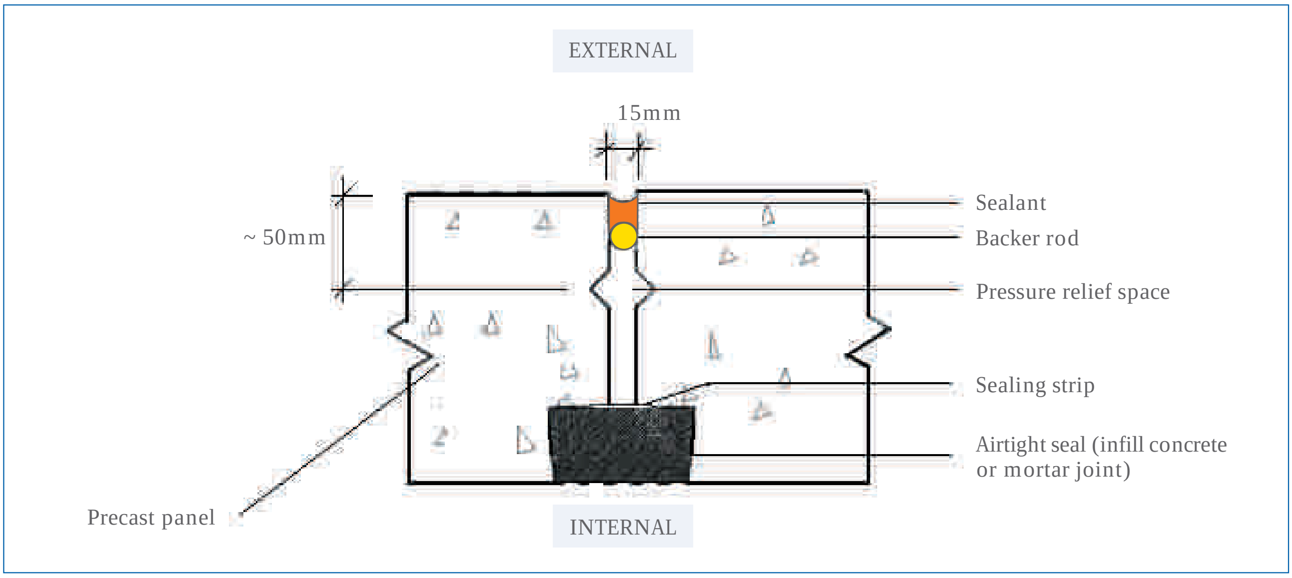
a) Fully sealed horizontal joint

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

2.3.2 VERTICAL JOINTS

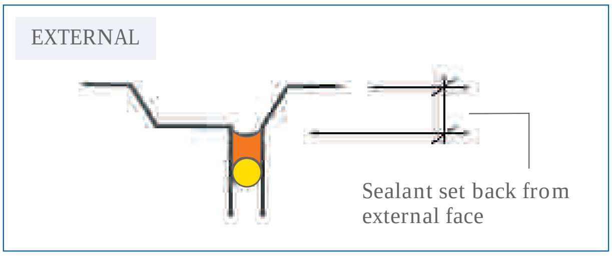
The two-stage joint detailing is recommended for vertical joints as it provides various water-resistant barriers. These include a sealant at the outer wall face, a pressure relief space to avoid rain driven penetration, and an infilled concrete/mortar joint with a sealing strip at the inner wall face. 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)

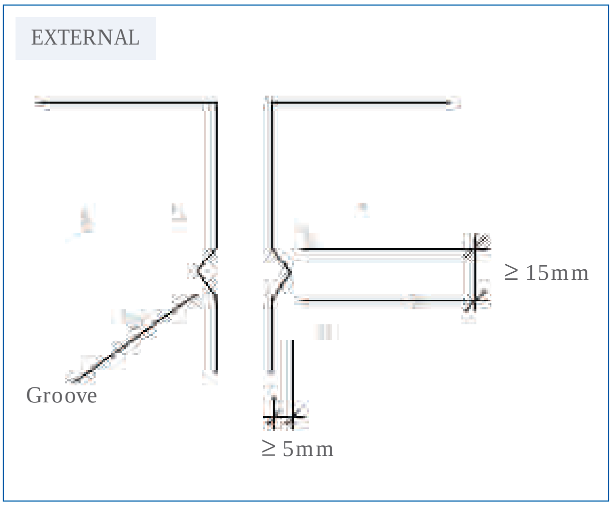
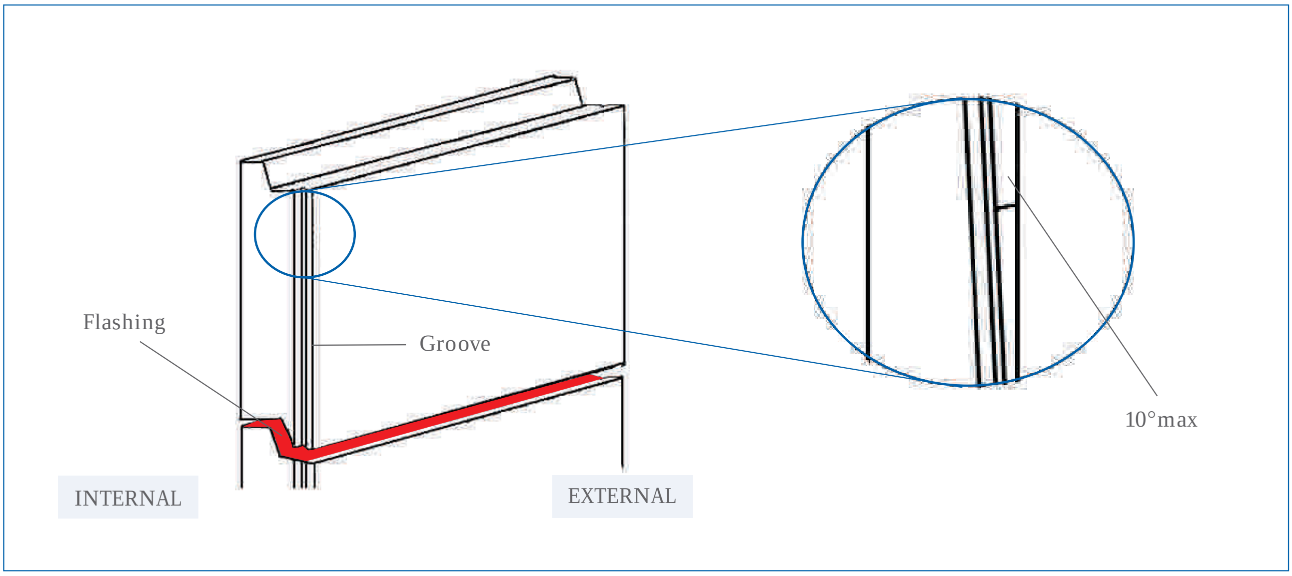


Figure 2.8: Typical details of a pressure relief space



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)

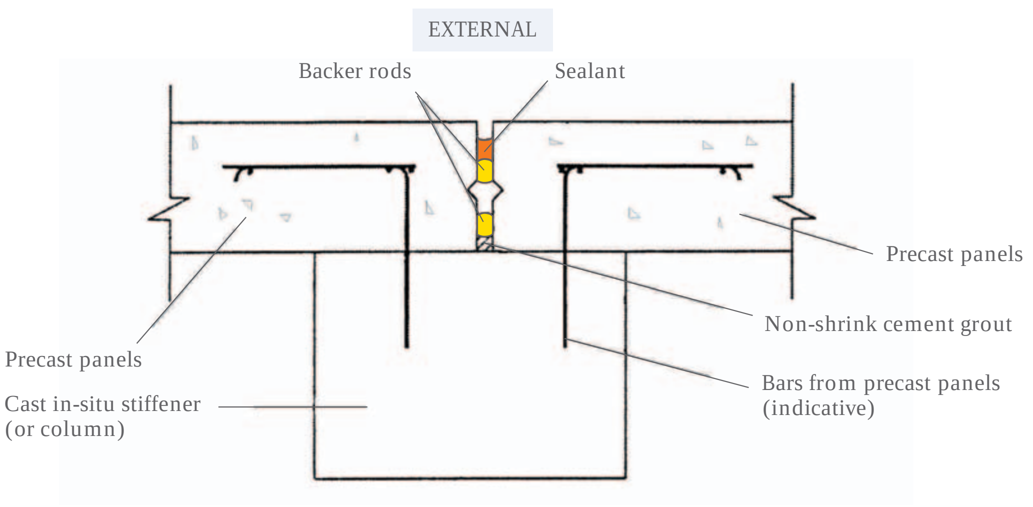


Figure 2.10: Typical details for wet joint between precast panels (plan view)

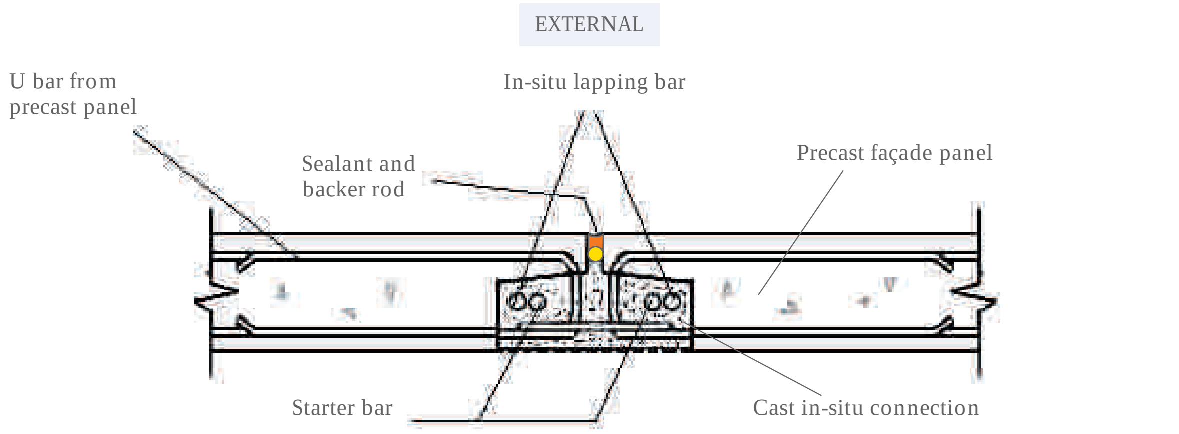
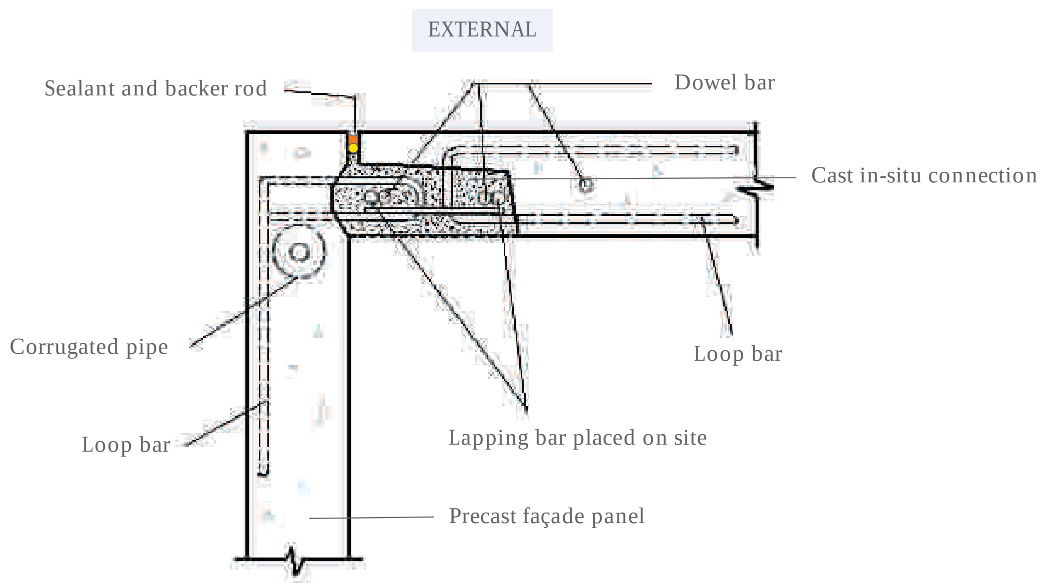


Figure 2.11: Typical details for corner joint between precast panels (plan view)



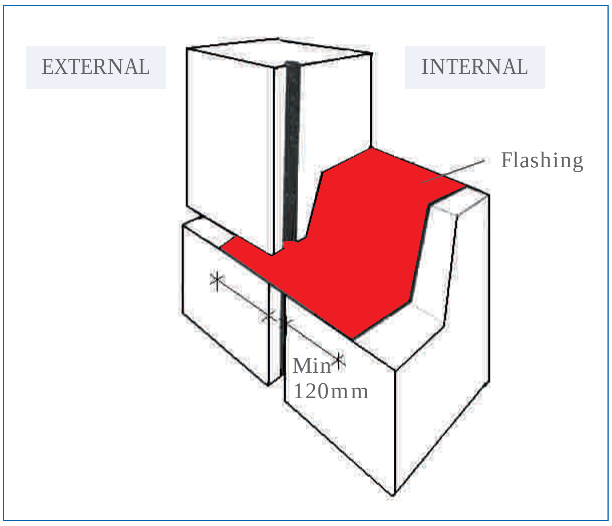
*Note: Rebar details shown in Figure 2.9 to 2.11 are only indicative.
Actual rebar detailing must be provided in structural design and drawings.

design of external walls

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



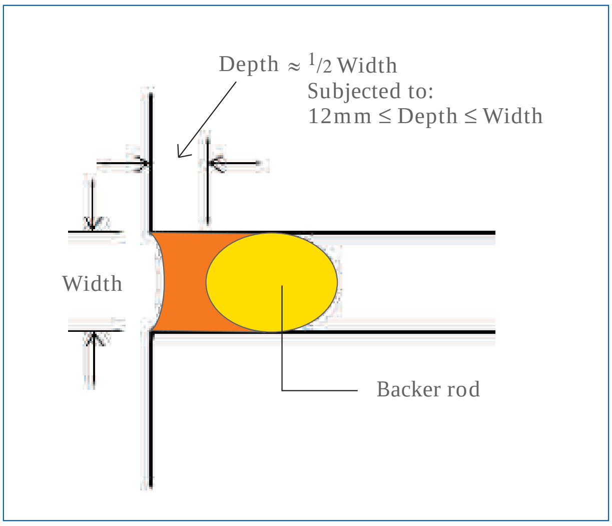
2.3.4 JOINT WIDTH AND DEPTH

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



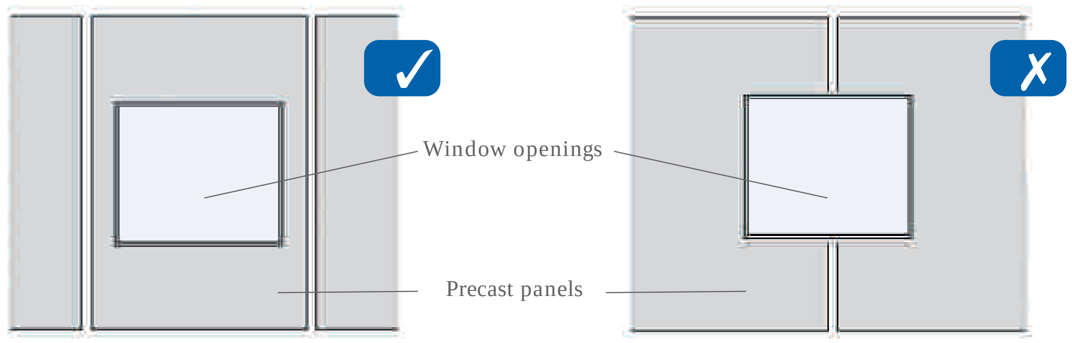
2.3.5 OTHER CONSIDERATIONS

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



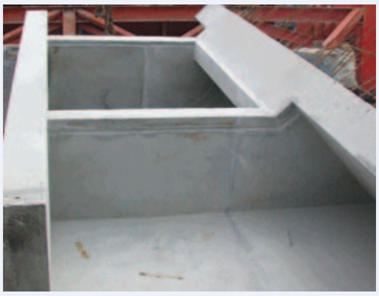
Window frame located within a single panel

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

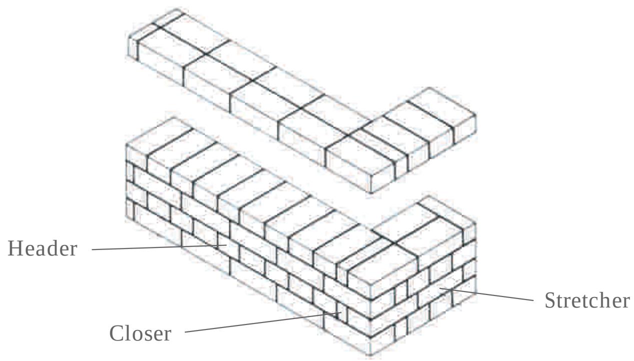
In general, external brickwalls have inferior watertightness performance than precast concrete walls and cast in-situ RC walls. The quality of the erected brickwalls is highly workmanship-dependent.

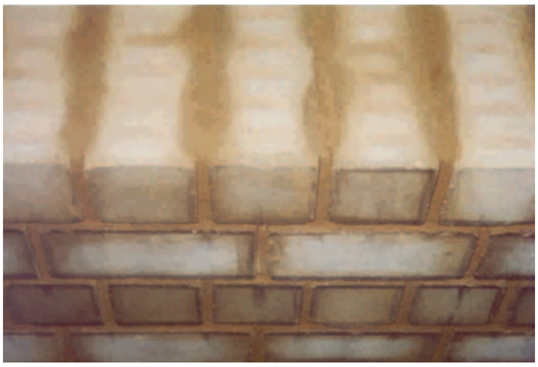
Due to its inferior watertightness performance, brickworks are not encouraged for use in the construction of external walls. Where the Designer decides to use external brickwalls for the project, the following good practices on designs of external brickwalls should be adopted to achieve the required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

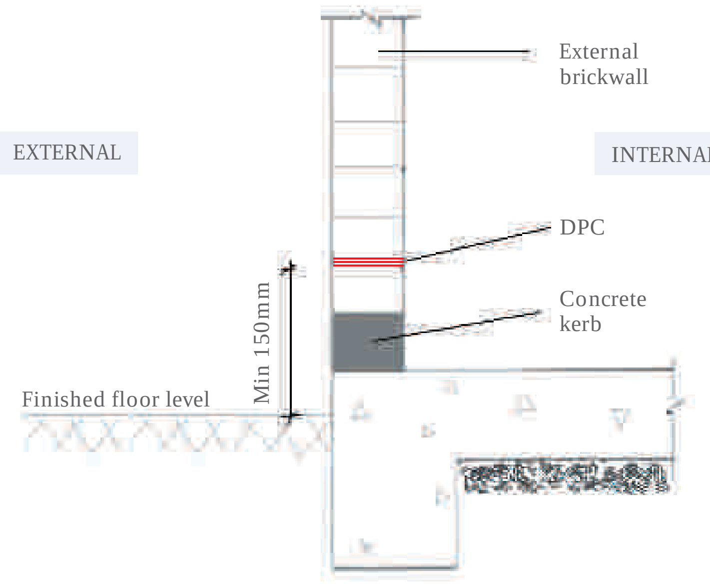
Concrete kerbs of at least 100mm height should be provided for external brickwalls to enhance their watertightness. As a good practice, these kerbs should be provided at every storey. This is especially important where there is a RC recess or a RC ledge at the beam/ floor level.

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



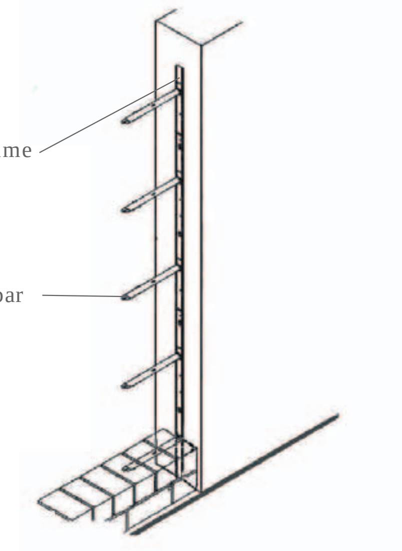
2.4.6 JOINTS BETWEEN DISSIMILAR MATERIALS

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.

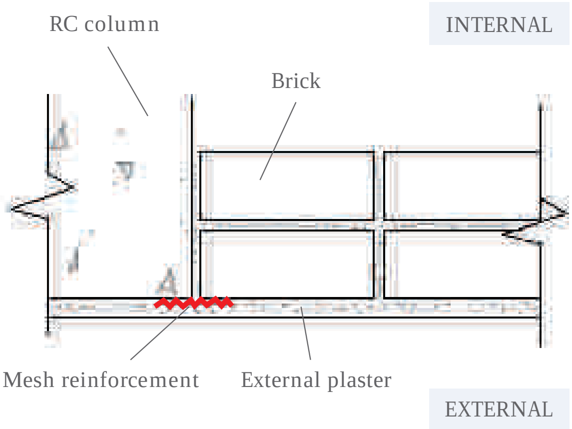
A layer of mesh reinforcement should be provided at the interfaces between dissimilar materials, for example between brick and concrete members. The mesh reinforcement helps to distribute stress and prevent plaster crack at these locations.

Figure 2.20: Joints between brick and RC members



Bonding bars with lipped frame system

Bonding bar system without a lipped frame



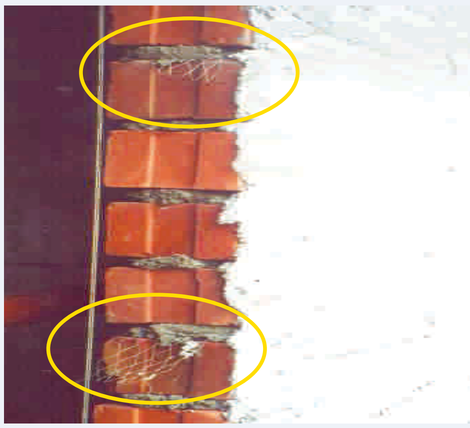
Mesh reinforcement at interface between brickwall and RC column (plan view)

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 4^{th} course of brickwork. There should be minimum 150mm lapping where different sections of mesh reinforcement overlap.

Figure 2.21: Mesh reinforcement embedded at every 4^{th} 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

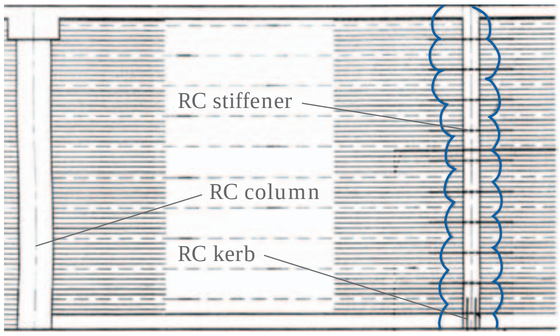
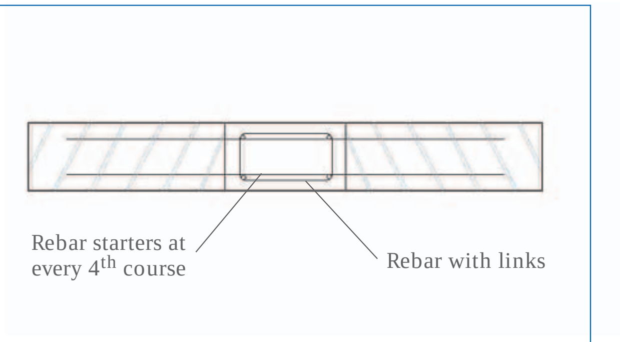
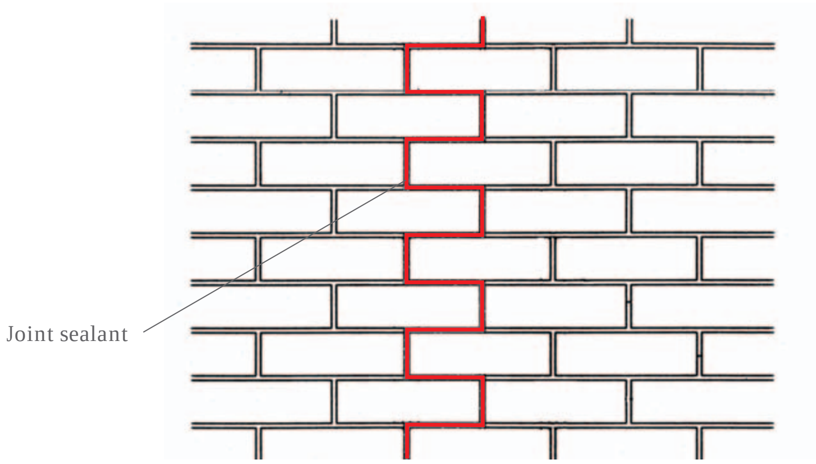


Figure 2.23: Typical stiffener details



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

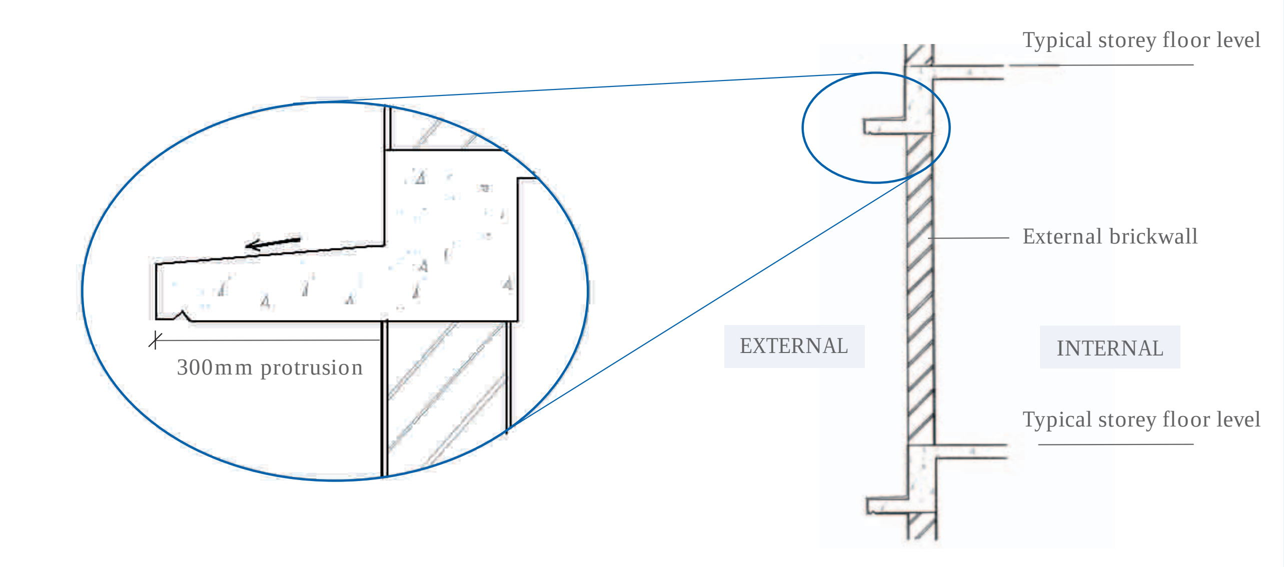
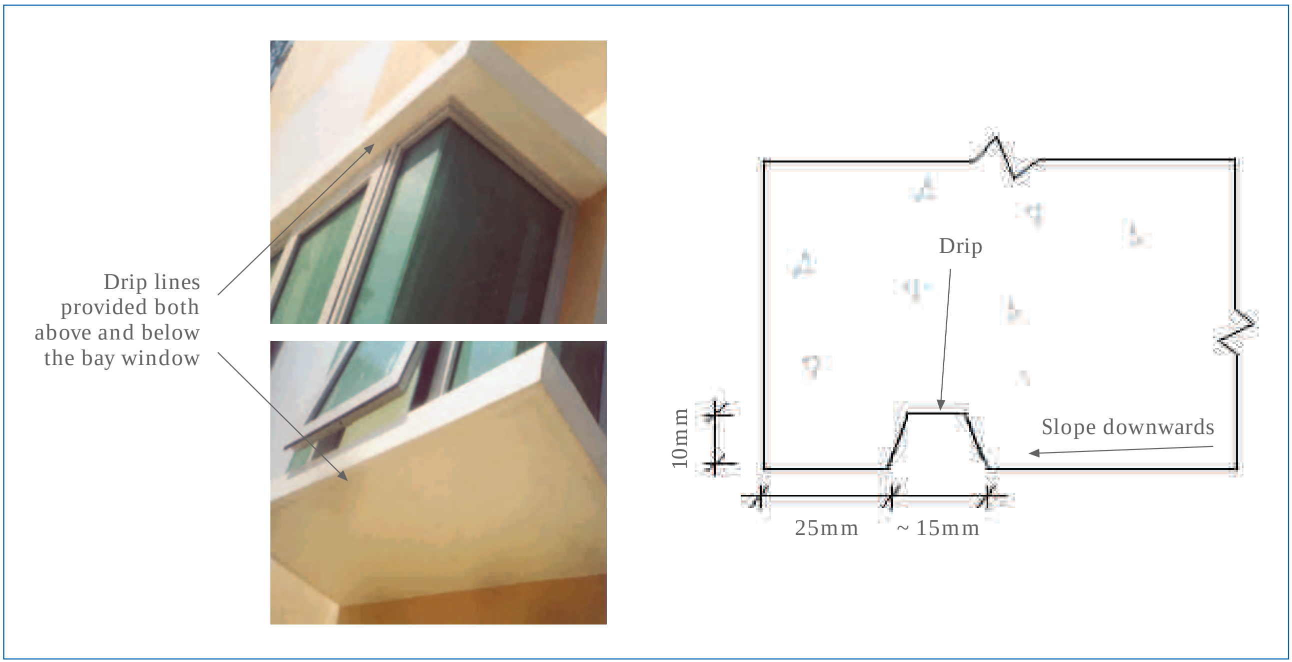


Figure 2.26: Provision of overhang

Figure 2.27: Provision of drip at underside of external features

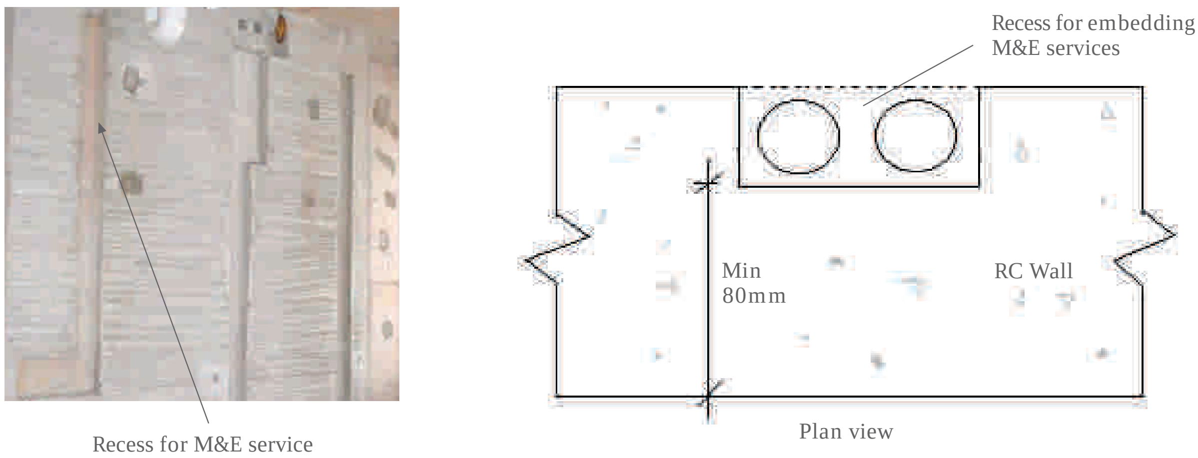


2.5.2 M&E SERVICES

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

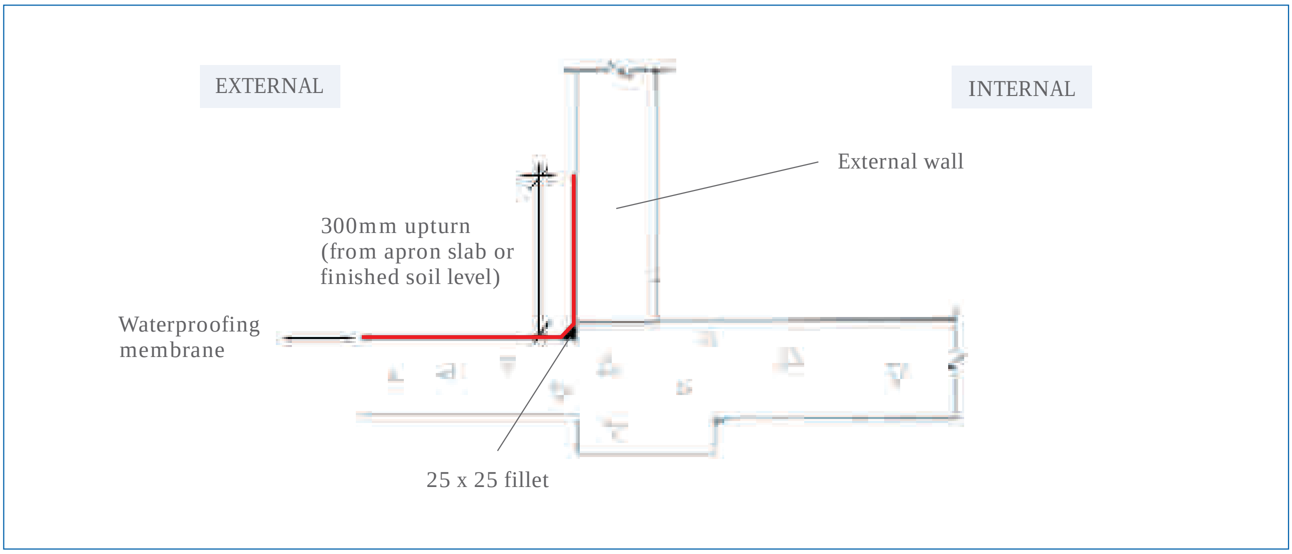
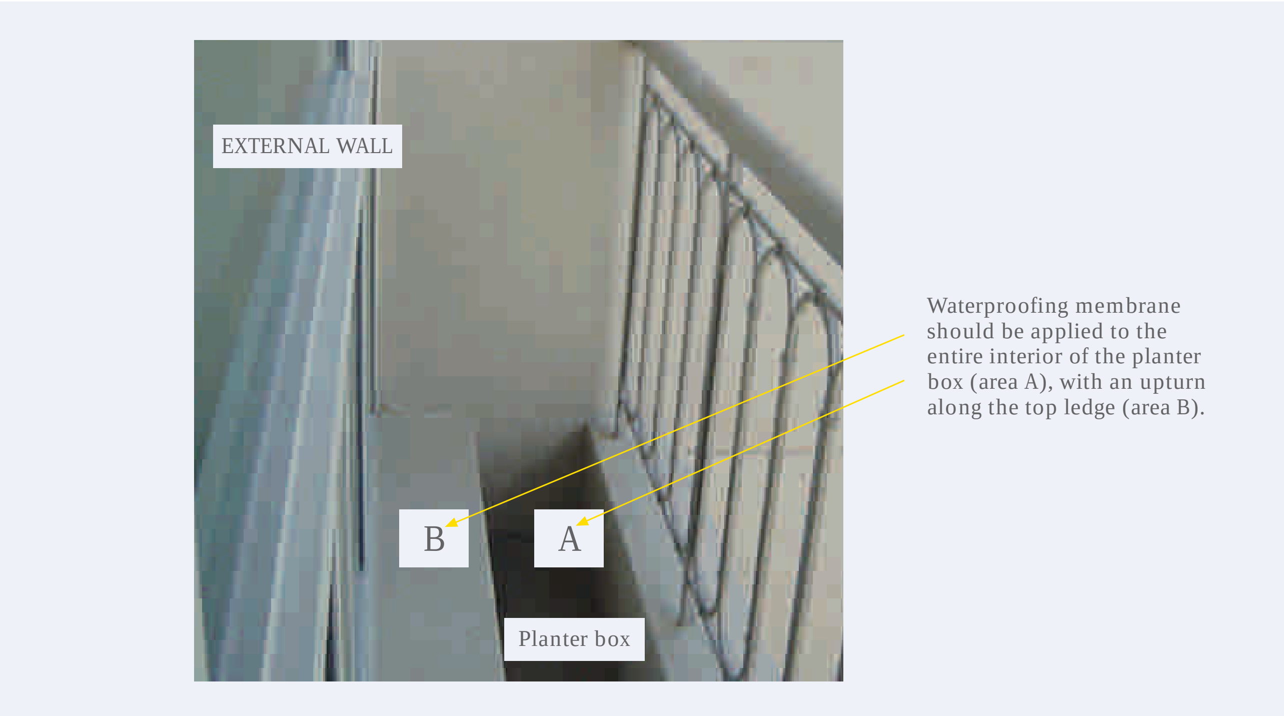


Figure 2.31: Planter box



design of external walls