BRITISH STANDARD

BS 8297:2000

Incorporating Corrigenda Nos. 1 and 2

Code of practice for

Design and installation of non-loadbearing precast concrete cladding

ICS 91.060.10

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee B/209, General building codes, to subcommittee B/209/22, Concrete cladding, upon which the following bodies were represented:

Construction Confederation
Chartered Institute of Building
Department of the Environment, Transport and the Regions
National Council of Building Material Producers
National House Building Council
Royal Institute of British Architects
Royal Institution of Chartered Surveyors

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Association of Consulting Engineers
British Precast Concrete Federation
Building Research Establishment
Construction Fixings Association
District Surveyors Association
Institution of Civil Engineers
Institution of Structural Engineers

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11064 Corrigendum No. 1	September 2000	Amends Figure 2
13018 Corrigendum No. 2	December 2000	Amends Figure 2

Contents

Foreword

This British Standard has been prepared under the direction of Technical Committee B/209, General building codes. It supersedes BS 8297:1995 which is withdrawn.

This new edition of BS 8297 has been updated and restructured to include additional advice on the design and installation of fixings, thickness of concrete cover to reinforcement and wind loading. Limit state design values based on the mechanical properties of austenitic stainless steel have replaced the permissible stress method used in earlier editions and a new abbreviated method of determining the design wind loading of low rise buildings has been added.

Assessed capability. Users of this British Standard are advised to consider the desirability of assessment and registration of a supplier's quality systems against the appropriate part of BS EN ISO 9000 by a third-party certification body.

Enquiries as to the availability of third-party certification schemes will be forwarded by BSI to the Association of Certification Bodies. If a third-party certification scheme does not already exist, users should consider approaching an appropriate body from the list of Association members.

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Annexes A, C and D are normative. Annex B is informative.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

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Introduction

With framed structures, where the loads are carried by the frame and not by the external walling, the materials or combinations of materials used to cover the structural framework are referred to as the cladding. The generally accepted difference between cladding and curtain walling is the relationship between the enclosing materials and their framing. In a cladding system the framework is normally covered by the units and weatherproofing is achieved by gasketry or similar methods. In curtain walling the structural framework which supports the infill panels or glazing may be exposed, with the skin of the structure fitted into it.

Cladding is required to carry its own weight and resist peak gust wind loading. It needs to provide weather protection and thermal performance, provide fire resistance and may need to be resistant to internal or external explosion or bomb damage. Its construction will need to allow for the dimensional tolerances of construction and movement of the building structure during its lifetime. Strength, long life and versatility are the inherent characteristics of precast concrete cladding.

Because precast cladding is almost inevitably a bespoke product, specially made for each project, the manufacturing process is non-repetitive and does not lend itself to automation. The weight and size of units can also be critical. Involving the manufacturer at the design stage can therefore often lead to more efficient production and optimization of the fixing system.

1 Scope

This British Standard gives recommendations and guidance for the design, manufacture, transport and installation of non-loadbearing precast concrete cladding in the form of:

a) units supported by and fixed to a structural frame or wall;

b) units used as permanent formwork in part or in whole.

It includes recommendations on the precautions which have to be taken to provide for permanent and temporary movements of the structure due to shrinkage and elastic deformation under load, to enable the cladding to perform its function satisfactorily. It gives the minimum standards needed and the materials and methods of fixings most frequently used. It applies to new buildings but many provisions may be applicable to alterations or refurbishment of existing buildings.

Guidance is given on the manufacture of units, their surface finish and methods of test. The procedure for structural design given in this standard is based on limit state design. An abbreviated method of determination of design wind loadings for low rise buildings is given in annex A.

This standard does not provide recommendations relevant to loadbearing cladding, units incorporating glass reinforced cement, or the design of the supporting structure to which the cladding is attached.

2 Normative references

The following documents contain provisions that, through reference in this text, constitute provisions of this British Standard. For dated references, subsequent amendments to, or revision of, any of these publications do not apply. For updated references, the latest edition of the publication referred to applies.

BS 12:1991, *Specification for Portland cement.*

BS 146:1991, *Specification for Portland blast furnace cement.*

BS 648:1964, *Schedule of weights of building materials.*

BS 882:1992, *Specification for aggregates from natural sources for concrete.*

BS 1014:1975, *Specification for pigments for Portland cement and Portland cement products.*

BS 1178:1982, *Specification for milled lead sheet for building purposes.*

BS 1881-5:1970, *Testing concrete — Part 5: Methods of testing hardened concrete for other than strength.*

BS 3148:1980, *Methods of test for water for making concrete (including notes on the suitability of the water).*

BS 3797:1990, *Specification for lightweight aggregates for masonry units and structural concrete.*

BS 3892-1:1993, *Pulverized fuel-ash — Part 1: Specification for pulverized fuel-ash for use as a cementitious component in structural concrete.*

BS 4027:1996, *Specification for sulfate-resisting Portland cement.*

BS 4246:1996, *Specification for high slag blast furnace cement.*

BS 4449:1988, *Specification for carbon steel bars for the reinforcement of concrete.*

BS 4482:1985, *Specification for cold reduced steel wire for the reinforcement of concrete.*

BS 4483:1985, *Specification for steel fabric for the reinforcement of concrete.*

BS 5075-1:1982, *Concrete admixtures — Part 1: Specification for accelerating admixtures, retarding admixtures and water reducing admixtures.*

BS 5075-2:1982, *Concrete admixture — Part 2: Specification for air-entraining admixtures.*

BS 5075-3:1985, *Concrete admixtures — Part 3: Specification for superplasticizing admixtures.*

BS 5080-1:1993, *Structural fixings in concrete and masonry — Part 1: Method of test for tensile loading.*

BS 5080-2:1986, *Structural fixings in concrete and masonry — Part 2: Method for determination of resistance to loading in shear.*

BS 5139:1991, *Method of specifying general purpose polypropylene and propylene copolymer materials for moulding and extrusion.*

BS 5328-1:1991, *Concrete — Part 1: Guide to specifying concrete*

BS 5328-2:1991, *Concrete — Part 2: Methods for specifying concrete mixes.*

BS 5368-1:1976, *Methods of testing windows — Part 1: Air permeability test.*

BS 5368-2:1980, *Methods of testing windows — Part 2: Watertightness test under static pressure.*

BS 5368-3:1978, *Methods of testing windows — Part 3: Wind resistance tests.*

BS 5628-3:1985, *Code of practice for use of masonry — Part 3: Materials and components, design and workmanship.*

BS 6093:1993, *Code of practice for design of joints and jointing in building construction.*

BS 6100 (all parts), *Glossary of building and civil engineering terms.*

BS 6180:1999, *Barriers in and about buildings — Code of practice.*

BS 6213:1982, *Guide to selection of constructional sealants.*

BS 6375-2:1987, *Performance of windows — Part 2: Specification for operation and strength characteristics.*

BS 6398:1983, *Specification for bitumen damp-proof courses for masonry.*

BS 6399-2:1997, *Design loading for buildings — Part 2: Code of practice for wind loads.*

BS 6399-3:1988, *Design loading for buildings — Part 3: Code of practice for imposed roof loads.*

BS 6515:1984, *Specification for polyethylene damp-proof courses for masonry.*

BS 6588:1996, *Specification for Portland pulverized-fuel ash cements.*

BS 6699:1992, *Specification for ground granulated blast furnace slag for use with Portland Cement.*

BS 6744:1986, *Specification for austenitic stainless steel bars for the reinforcement of concrete.*

BS 7475:1991, *Specification for fusion welding of austenitic stainless steels.*

BS 7583:1996, *Specification for Portland limestone cement*

BS 7619:1993, *Specification for extruded cellular unplasticized PVC (PVC-UE) profiles.*

BS 8110-1:1997, *Structural use of concrete — Part 1: Code of practice for design and construction.*

BS 8200:1985, *Code of practice for design of non-loadbearing external vertical enclosures of buildings.*

BS 8221-1:2000, *Code of practice for cleaning and surface repair of buildings — Part 1: Cleaning of natural stone, brick, terracotta and concrete.*

BS 8221-2:2000, *Code of practice for cleaning and surface repair of buildings — Part 2: Surface repair of natural stone, brick and terracotta.*

BS EN 485-2:1995, *Aluminium and aluminium alloys — Sheet, strip and plate — Part 2: Mechanical properties.*

BS EN 573-4:1995, *Aluminium and aluminium alloys — Chemical composition and form of wrought products — Part 4: Forms of products.*

BS EN ISO 3506-1:1998, *Mechanical properties of corrosion resistant stainless steel fasteners — Part 1: Bolts, screws and studs*

BS EN ISO 3506-2:1998, *Mechanical properties of corrosion resistant stainless steel fasteners — Part 2: Nuts.*

BS EN 10027-2:1992, *Designation systems for steel — Part 2: Steel numbers.*

BS EN 10088-2:1995, *Stainless steels — Part 2: Technical delivery conditions for sheet, plate and strip for general purposes.*

BS EN 10088-3:1995, *Stainless steels — Part 3: Technical delivery conditions for semi-finished products, bars, rods and sections for general purposes.*

BS EN ISO 1873-1:1995, *Plastics — Polypropylene (PP) moulding and extrusion materials — Part 1: Designation system and basis for specifications.*

BS ISO 1163-1:1995, *Plastics — Unplasticized poly(vinyl chloride) (PVC-U) moulding and extrusion materials — Part 1: Designation system and basis for specifications.*

BS ISO 11600:1993, *Building construction — Sealants — Classification and requirements.*

3 Terms and definitions

For the purposes of this British Standard the terms and definitions given in BS 6100 (some of which are replicated below for convenience) and the following apply.

3.1

bimetallic corrosion

corrosion caused by contact between dissimilar metals in the presence of an electrolyte, such as water

3.2

cavity barrier

construction provided to close a concealed space against penetration of smoke or flame, or provided to restrict the movement of smoke or flame within such a space

3.3

cladding[1)]

form of building covering that supports only its own weight and environmental forces that may act upon it

3.4

composite unit

cladding unit having a facing of materials other than concrete

3.5 fixings

3.5.1

fixing

device used to connect, support or restrain one or more cladding units to the main structure

NOTE This may comprise of several components including a bolt, threaded stud, anchor, bracket, etc.

3.5.2

anchor

component part of a fixing which may be cast-in, or post installed into the structure, or the unit

3.5.3

loadbearing fixing

device used to support the dead weight of one or more cladding units and to transfer this load to the structure, which may also be used to restrain the unit

3.5.4

location fixing[1)]

temporary device whose sole purpose is to assist in the alignment of the cladding units

3.5.5

restraint fixing[1)]

device designed to tie cladding units to the structure, or to one another, to resist horizontal forces

3.6 joints

3.6.1

compression joint[1)]

gap between adjacent units, designed to accommodate partial closure resulting from vertical shortening of the structure, relative to the cladding

3.6.2

filled joint

gap not required to accommodate movement between adjacent units, which has been filled with a jointing product

3.6.3

movement joint[1)]

gap that permits movement between adjacent units

NOTE Also commonly known as an expansion joint.

3.6.4

open joint[1)]

unfilled gap between adjacent units or between a unit and the structure

NOTE A baffle strip may be located in vertical open joints.

3.7 joint materials

3.7.1

back-up material

material inserted in a joint which limits the depth of the sealant applied and which determines the back profile of the sealant

3.7.2

baffle[1)]

flexible preformed section designed to be fitted in grooves between the adjacent units to minimize direct entry of rain into an open joint

3.7.3

gasket[1)]

flexible, generally elastic, preformed material that constitutes a seal when compressed, and which resists the passage of water and air

3.7.4

sealant[1)]

material applied in an unformed state to a joint, which seals it by adhering to appropriate surfaces within the joint

4 Materials and components

4.1 Customer requirements

4.1.1 ***General***

The specifier should provide the cladding designer with either:

a) a performance specification; or

b) a prescriptive specification.

4.1.2 ***Performance specification***

The specifier should provide the designer with basic information concerning the building to which the cladding will be attached (see annex B). Additional information should include the following:

a) surface colour and appearance;

b) required insulation properties;

c) maximum size and weight of cladding units;

d) deflection criteria;

e) design life;

f) fixing locations;

g) sound attenuation criteria;

h) solar radiation criteria;

i) loading criteria.

[1)] Definition differs from that given in BS 6100.

4.1.3 ***Prescriptive specification***

Alternatively, the specifier/manufacturer should provide the designer with all relevant details of the cladding, including:

a) dimensions of units;

b) concrete mix specifications;

c) reinforcement details and schedules;

d) surface finish requirements;

e) insulation details;

f) fixing details;

g) tolerances;

h) details of any "built-in" components.

4.2 Specifications for materials and components

4.2.1 ***General***

Recommendations for materials and components that are covered by British Standard specifications are included in this section. For materials not covered, evidence of their satisfactory performance and suitability for use in particular conditions should be obtained and carefully assessed. For certain materials and components, guidance is available from product conformity certification.

4.2.2 ***Materials for pre-cast concrete***

4.2.2.1 *Cement*

Cement should conform to the relevant British Standard as follows.

a) Ordinary and rapid-hardening Portland cement	BS 12
b) Sulfate-resisting cement	BS 4027

Other cements conforming to the following standards may be used, but as concrete made with these cements may have different properties they should only be used after their suitability has been demonstrated. Guidance is given in BS 8110-1.

c) Portland blast furnace cement	BS 146
d) Portland pulverized-fuel ash (PFA) cement	BS 6588

Combinations manufactured in the concrete mixer from Portland cement and ground granulated blast furnace slag (GGBS) or PFA should conform to the relevant standards.

e) Ordinary Portland cement with GGBS conforming to BS 6699	BS 146 BS 4246
f) Ordinary Portland cement with PFA conforming to BS 3892-1	BS 6588
g) Portland limestone cement	BS 7583

4.2.2.2 *Aggregates*

Aggregates should conform to the relevant British Standard as follows.

a) Aggregates from natural sources	BS 882
b) Lightweight aggregates	BS 3797

4.2.2.3 *Additions*

Where the following materials are used, they should conform to the relevant British Standard as follows.

a) Ground granulated blast furnace slag	BS 6699
b) Pulverized-fuel ash	BS 3892-1

4.2.2.4 *Admixtures*

Admixtures should conform to the relevant British Standard as follows.

a) Accelerating admixtures	BS 5075-1
b) Retarding admixtures	BS 5075-1
c) Water reducing admixtures	BS 5075-1
d) Air entraining admixtures	BS 5075-2
e) Superplasticizing admixtures	BS 5075-3

NOTE Other admixtures may be used if their suitability can be demonstrated.

4.2.2.5 *Pigments*

Pigments should conform to BS 1014.

4.2.2.6 *Water*

Water should be clean and free from materials deleterious to concrete.

NOTE Tests for water for concrete-making are given in BS 3148.

4.2.2.7 *Facing materials*

Where composite construction is envisaged, care should be taken to ensure the materials are compatible in service (see **5.10.3**).

4.2.2.8 *Water resisting admixtures*

Aluminium stearate waterproofers may be incorporated into concrete to reduce the permeability depending on mix design.

Stearate waterproofers are also available as admixtures for mortars and the manufacturer's instructions for use should be followed.

4.3 Steel

4.3.1 ***Carbon steel reinforcement***

Steel reinforcement for concrete should conform to BS 4449, BS 4482 and BS 4483, as appropriate.

4.3.2 ***Stainless steel reinforcement***

Stainless steel reinforcement for concrete should conform to BS 6744.

4.3.3 *Austenitic stainless steel fixings*

4.3.3.1 *General*

Austenitic stainless steel should conform to the following standards.

a) Stainless steel sheet strip and plate	BS EN 10088-2
b) Stainless steel rod and bar	BS EN 10088-3

Austenitic stainless steel for restraint and loadbearing fixings should conform to the grades and uses given in Table 1.

Guidance on the design of stainless steel fixings is given in **7.3**. Further guidance is given in *Design of stainless steel fixings and ancillary components* [1] and ENV 1993-1-4.

4.3.3.2 *Cast-in sockets*

Cast-in sockets should conform to the grades of austenitic stainless steel and their uses given in Table 1.

NOTE Because cast-in sockets perform a critical role in the support of cladding, it is recommended that 100 % inspection of steel grade, size, thread cutting/alignment and cross-pin security/centrality be carried out.

Guidance on the mechanical properties of austenitic stainless steel components is given in **7.3.4**.

4.3.3.3 *Bolts and nuts*

Bolts and nuts should be of austenitic stainless steel conforming to BS EN ISO 3506-1 and -2. Grades of bolts and nuts are identified as:

A1, which generally equates to 1.4303;

A2, which generally equates to 1.4301;

A4, which generally equates to 1.4401.

NOTE Grade A1 is more prone to corrosion than A2.

4.3.3.4 *Welding*

Welding of austenitic stainless steel components should conform to the requirements of BS 7475 and should only be undertaken where the necessary facilities, expert knowledge and skills are available.

Procedures for testing welds should be agreed at the design and specification stage. Scale and discolouration resulting from welding, hot working and heat-treatment should be removed from components using appropriate cleaning methods.

NOTE If scale is not removed, premature rust and staining of the surface is likely to occur; corrosion attack may commence and a shorter serviceable life may result.

4.4 Materials for jointing and pointing

4.4.1 *Mortars*

Guidance on the types of mortar for different claddings is given in BS 5628-3.

4.4.2 *Sealants*

Sealants for use on a concrete (or mortar) substrate should conform to type F requirements of BS ISO 11600 and should be selected using the guidelines found in BS 6213 and BS 6093. Sealants which have proven performance and durability in similar structures should be the preferred choice.

NOTE The expected service life of a sealant may exceed 20 years, (depending on correct installation and environmental conditions). Regular inspection is recommended; after 5 years initially, and annually thereafter.

4.4.3 *Back-up materials*

Back-up material should be made of polyethylene closed cell foam, polyurethane closed cell foam or butyl rubber closed cell foam. They can be obtained as sheet material which is cut to the required width or as square, rectangular or circular section strips. All are intended to be installed in the joint under a degree of compression and the section selected will be governed by the joint sizes. Back-up materials should be compatible with the selected sealant.

4.4.4 *Gaskets*

Non-cellular gaskets should be made of chloroprene, butyl, chlorobutyl or ethylene propylene rubbers. Cellular gaskets should be made of natural chloroprene, butyl, ethylene propylene, styrene-butadiene or isoprene rubbers.

NOTE Guidance on materials is given in BS 6093 and BS 4255-1.

Gaskets may be of various sections, but tubular, fir cone and cellular gaskets are the most satisfactory. Gaskets should be durable and take up movements and tolerances (see Table 11).

Table 1 — Recommended grades of austenitic stainless steel used for fixings

Grade[a]	Formerly known as	Application
1.4301	304 S15 and 304 S16	For general fixings.
1.4305	303 S31	If significant machining is required (i.e. for cast-in sockets and some bolts). It is not suitable for welding or working on site.
1.4307	304 S11	For hot working or welding.
1.4401	316 S31	For enhanced resistance to pitting corrosion (e.g. for use on coastal sites).
1.4404	316 S11	For hot working or welding for use on coastal sites
1.4541	321 S31	For stabilized welding if subsequent heat treatment is not desired

[a] The designation system used in BS EN 10088 for stainless steel is defined in BS EN 10027-2.

4.4.5 *Baffles*

Baffles should be preformed sections made of polychloroprene or similar material.

4.5 Materials for flashings, weatherings and cavity trays

Flashings, weatherings and cavity trays should conform to the relevant British Standard and the recommendations given in Table 2.

Only durable materials which do not stain light coloured materials should be used.

NOTE Copper and copper alloys should not be used for flashings and weatherings.

4.6 Coating agents

Water repellents are not recommended for impervious surfaces or for surfaces consisting mainly of impervious materials such as those commonly used in exposed aggregate concrete.

Where coatings are used they should be applied to surfaces prior to handover and not to individual components; to avoid inadvertent treatment of bedding surfaces which could affect mortar or sealant bonding. It is also important to ensure that the faces of mortar joints are treated.

Silane treatments can be used on permeable concrete subject to suppliers' recommendations.

5 Design of cladding units

5.1 General

External concrete cladding used as a non-loadbearing enclosure has functional requirements similar to other materials and reference should be made to BS 8200, *Precast concrete cladding* [2], *Aspects of cladding* [3] and other publications which provide a systematic framework for the design of non-loadbearing external walls.

In the case of projects involving the extensive use of cladding and fixings, it is recommended that a structural engineer sets down the functional requirements governing the principles of its design, its means of support and restraint and the maximum movement of the cladding for which allowance is to be made, together with the anticipated movement characteristics of the building frame, including calculations of the anticipated shortening and how this is to be accommodated in the cladding.

On such projects it is further recommended that a technical specification dealing with all aspects of the supply and/or fixing of the cladding should be prepared in consultation with a structural engineer and that this should include definitions of the nature of any special tests required to be carried out on the cladding in advance of the work.

Maximum economy will be achieved when the number of panel types is minimized. A "type" of unit should be identical in all respects on front, back and edges.

Allowance should be made in the design of the cladding for the expected deviations of the supporting construction (see **5.9**).

5.2 Structural design

5.2.1 *General*

The structural design should conform to the recommendations given in BS 8110-1.

The characteristic dead load of the units, their facings, if any, and any attached components should be calculated from the unit weights given in BS 648.

Table 2 — Materials for flashings, weatherings and cavity trays

Material	British Standard	Grade	Minimum thickness mm
Aluminium alloy	BS EN 485-2 and BS EN 573-4	EN AW-3103	0.6
Aluminium and aluminium alloys	BS EN 485-2	EN AW-1050A, EN AW-1080A EN AW-1200	
Bitumen[a]	BS 6398		
Lead[b]	BS 1178:1982		1.8 (code 4)
Polyethylene	BS 6515:1984		0.46
Polypropylene	BS 5139 and BS EN ISO 1873-1		2.00
PVC-U	BS 7619 and BS ISO 1163-1		
Stainless steel	BS EN 10088-2		0.9

[a] Bitumen-based materials should not be used in positions where run-off can occur onto light coloured materials.

[b] The initial white carbonate run-off from lead flashings, which may stain adjacent units, can be avoided by a smear coat of patination oil after fixing.

5.2.2 ***Wind loading***

Gust peak wind loading on buildings and components should be determined by the method described in BS 6399-2. For low rise buildings up to 15 m in overall height, the abbreviated method for determining the design wind loading described in annex A may be used.

NOTE Although the wind loading determined by this method may not be identical from that derived from BS 6399-2, it should be sufficiently accurate to be used for most low rise buildings.

5.2.3 ***Imposed loading***

There will usually be no imposed loads on cladding units, but upward facing units forming surfaces with a slope of less than 60° with the horizontal should be designed for snow loading and imposed loading in accordance with BS 6399-3.

For units acting as permanent formwork, the pressure of the wet concrete should generally be assumed to be the hydrostatic pressure of a liquid with density of 2 400 kg/m^3.

Where the attachment of the cladding unit to the frame is by means of nibs or corbels, cast monolithic with the units, or by means of metal brackets, rigidly connected to the units, the support reactions should be assumed to act at a distance from the edge of the bearing area on the frame, equal to the depth of that bearing area, unless special provisions are made which will ensure that edge bearing will not occur, in which case the distance may be assumed to be two-thirds of the depth of the bearing (see Figure 1).

Stresses during lifting from the moulds and subsequent handling should be checked to ensure cracking does not occur (which, although it may not be noticed at the time, may result in lack of durability later). This calculation should be based on the unfactored tensile strength of concrete at the time of lifting and take account of factors such as “mould drag” and “crane snatch”, which may significantly increase the load.

When demoulding, a factor of 2 should be applied to the weight of the unit. During subsequent handling a factor of only 1.5 need be applied to the weight of the unit to allow for the dynamic effect of “crane snatch”.

5.3 Thickness of concrete cover to reinforcement

5.3.1 ***Exposure conditions***

The thickness of concrete cover to all normal carbon steel reinforcement should be in accordance with the requirements of BS 8110-1. For the purposes of this, the following classification of exposure conditions should be used.

a) Mild – Internal faces completely within the “dry” envelope.

b) Moderate – Faces within a cavity or subject to condensation.

c) Severe – Faces exposed to severe rain, alternate wetting, drying or occasional freezing, or severe condensation.

Very severe, most extreme, abrasive and other onerous or special situations should be assessed individually.

An additional 10 mm of cover to reinforcement should be provided in exposed non- vertical faces which may be subjected to severe wetting/freezing e.g. cornices, parapets, copings etc. It is also important to ensure that full cover is maintained at false joints and architectural features, which may otherwise reduce the cover locally.

Where a precast concrete panel is faced with natural stone or similar materials having a thickness greater than 25 mm, cover may be reduced by 10 mm, providing the cover from the rear of the facing material is not less than 20 mm.

Where stainless steel reinforcement is used, the thickness of cover may be reduced to 20 mm for severely exposed faces and to 15 mm for mild and moderately exposed faces.

Zinc coating (galvanizing) may provide some initial extra protection to carbon steel reinforcement, but should not be used as a means of reducing the thickness of the concrete cover.

Epoxy-resin and similar resin powder coatings on reinforcement may be used, with reference being made to specialist literature with regard to covers and detailing.

Where reinforcement bars are coated prior to cutting and bending, the cut ends and any damage to the coating caused during the bending process, should be coated with a compatible, durable, rust-inhibiting compound prior to concreting.

In all cases, cover should never be less than the nominal aggregate size, nor less than that required for the purpose of fire resistance.

For lightweight concrete, air-entrained concrete or aggregate sizes greater than 20 mm, reference should be made to BS 8110-1.

5.3.2 ***Concrete mixes and strengths***

In order to provide adequate durability, any concrete that provides cover to reinforcement should conform to the requirements of BS 8110-1.

Where different mixes are to be used for facing and backing, the mix or mixes providing the structural strength of the unit should satisfy the requirements of BS 8110-1 and should be specified in accordance with BS 5328-1 and BS 5328-2.

Guidance on measures to minimize risk of Alkali-silica reaction in concrete are given in Concrete Society Report TR 30: *ASR — Minimising the risk to concrete* [4].

5.3.3 ***Surface absorption***

Initial surface absorption tests, if required, should be carried out on units produced in the same way as those for the production run. Tests should conform to the requirements of BS 1881-5.

The initial absorption for each sample should be not more than the following:

a) 10 minute test = 0.50 ml/m^2·s;

b) 1 hour test = 0.20 ml/m^2·s.

5.4 Fire resisting wall units

If units have to form fire-resisting walls (compartment walls) their thicknesses should be not less than those recommended in BS 8110-1.

5.5 Support conditions and bending moments

5.5.1 *General*

Account should be taken of the support conditions, provided by the fixings, when calculating forces and bending moments in units.

Where support and/or tie-back fixing is by means of discrete corbels, brackets or shims, point supports should be assumed and the units should be designed against wind loads as flat-slabs (see BS 8110-1).

Effective bearings should conform to recommendations given in BS 8110-1.

For concrete corbels, the local bending moments produced by the eccentricity of the vertical reactions being transmitted to individual corbels or brackets, may be assumed to be distributed over an effective width equal to the width of the corbel, plus twice the effective structural thickness.

For bolted-on metal brackets, the effective width should be taken as twice the effective thickness plus the width between centres of bolts attaching one bracket (if two or more bolts spaced horizontally are used).

If units are top hung, the reinforcement should be designed to resist the tensile force from their own weight as well as the bending moments. Account should be taken of the concentration of such tensile forces at discrete corbels.

Account should be taken of the support conditions during lifting and handling, where they differ from those applying when lifting into final position (e.g. lifting at discrete points; with final support on a continuous nib). When designing elements for use during lifting, dynamic load factors should be applied, appropriate to the type of crane. These are in addition to load factors relating to static design.

5.5.2 *Corbel and nib detail*

Corbel reinforcement should conform to the requirements of BS 8110-1.

Individual corbels should be reinforced with horizontal loops of bars which should envelop any dowels providing horizontal restraint; the ends of the bars forming the loops should be anchored near the face remote from the corbels. The bars forming the loops should be designed to resist the moment in the corbel due to the weight of the unit. The reaction should be assumed to act, at the extremity of the corbel distance from the edge of the slab, equal to the depth of the bearing on the slab (see Figure 1).

Corbel reinforcement should be designed in accordance with the recommendations in BS 8110-1. Where:

1) Av > d, the corbel should be designed as a short cantilever, with lever arm (La) taken from the line of action of the load (V) to the line of the panel reinforcement;

2) Av < d, the corbel should be designed as a strut and tie [see Figures 1a) and 1b)].

NOTE 1 The line of action of the load (V) should be the most severe case possible, such as, the edge of the corbel, the bottom of any chamfer, or the outer edge of discrete shims.

NOTE 2 The vertical reinforcement in the panel should take account of local increases in tension and bending at supports, using the "effective width" shown in Figures 1a) and 1b).

Where temporary discrete bearing packs are used (by the erector) to support full load, the stresses in the supporting nib should be checked.

Continuous supporting nibs should have a continuous horizontal bar running between any dowels or dowel holes and the edge of the slab. This bar should be held by vertical loop reinforcement anchored near the front face of the unit. The loop reinforcement should be designed for the moment due to the own weight, assuming that the reaction acts at a distance from the edge of the slab equal to the bearing on the slab.

Alternatively, continuous nibs may be reinforced with horizontal loops which should envelop any dowels and dowel holes as for individual corbels.

When metal brackets are attached to the units by anchors, either cast-in sockets or post-drilled anchors, care should be taken to avoid edge failure. The edge distance parameters of the fixings should be checked as part of the selection process and edge reinforcement should be provided around the sockets to prevent cone failure around the fixings.

NOTE If substitution of previously specified cast-in sockets by post-drilled fixings is considered, the edge distance parameters should be carefully checked.

5.5.3 *Supporting beams and slab edges*

Beams or slab edges supporting cladding units should be designed assuming that the reactions from the weight of the cladding units act at the front face of the beam or slab edge.

Continuous horizontal bars should be provided between dowel holes or bolt sockets and the edge of the slab and should be tied back with loops into the slab. Alternatively, the edge of the slab may be reinforced with horizontal loops which should envelop any dowels and dowel holes.

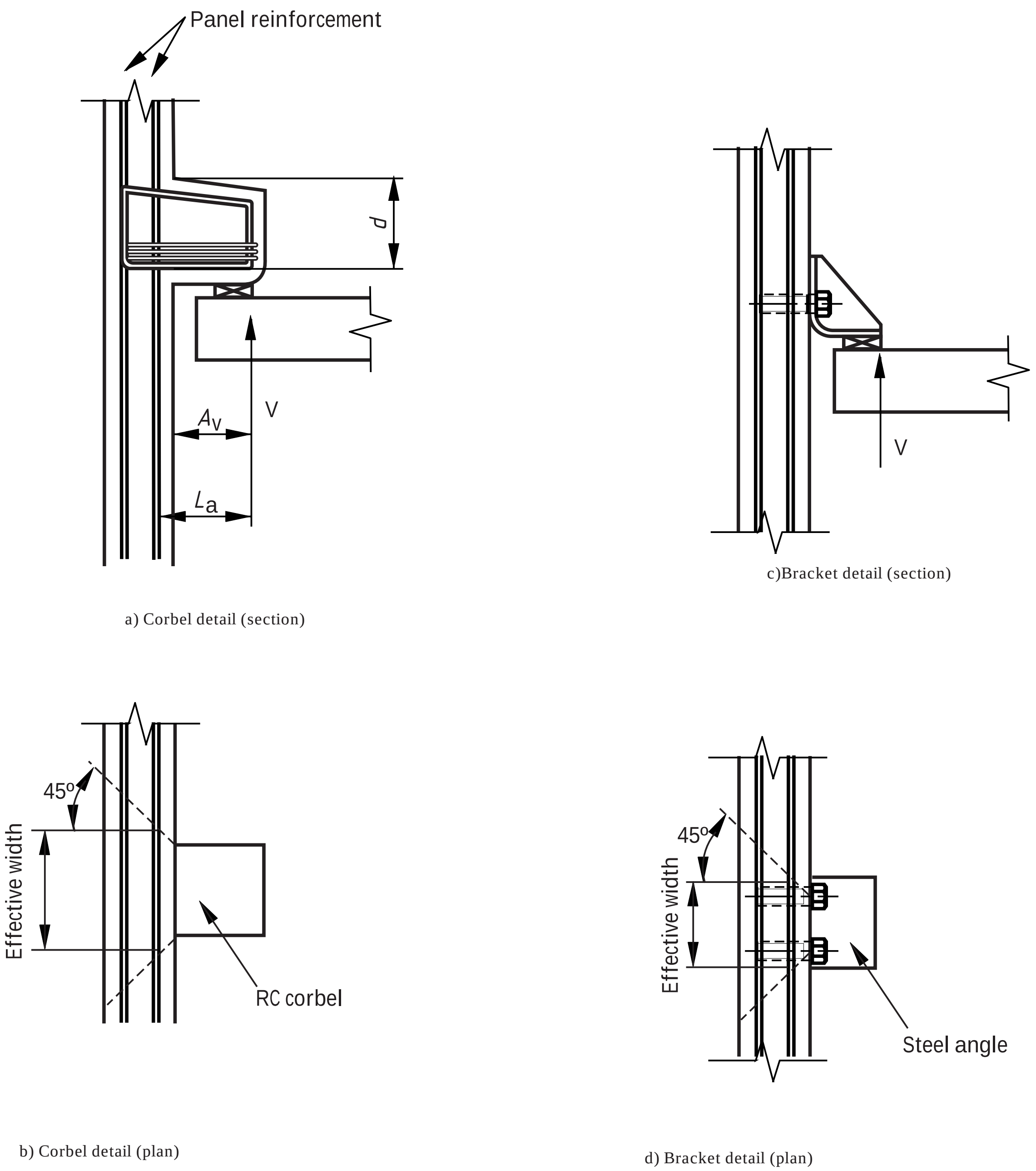


Figure 1 — Assumptions for design of units and corbels/brackets

5.6 Sizes of units including thickness

5.6.1 *General*

The sizes of units should be considered in relation to their weight and likely method of handling. Most concrete cladding units will require mechanical handling.

Consideration should be given to the maximum sizes permissible for transport and for manoeuvring units at the place of manufacture and for site installation.

Very large or composite units, particularly where lightweight aggregate concrete has been used, may shrink or warp making their accurate alignment and fixing difficult. This may require greater tolerances in fixings and joints.

Sharp arrises and thin projections should be avoided, particularly in large units as they are easily chipped in handling. Chamfered edges resist damage and mask irregularities of alignment.

5.6.2 *Thickness*

The thickness of units should be designed to resist the loads to be imposed upon them. The minimum thickness should have regard to the size of aggregate used, the presence and type of reinforcement and the cover to the reinforcement. Aggregate of 20 mm maximum size is assumed, in the sizes recommended.

Units of uniform thickness which are not reinforced should be not less than 65 mm in thickness and should not exceed 1 m in either height or width.

NOTE Units 65 mm or less in thickness may present special problems in fabrication and fixing.

Where units have stiffening ribs, the thickness of concrete between the ribs should be not less than 65 mm and if 65 mm thick the clear distance between the ribs vertically and horizontally should not exceed 900 mm.

Where aggregate smaller than 10 mm is used and reinforcement is confined to the ribs, the thickness between the ribs may be reduced to 40 mm provided the clear distance between the ribs vertically and horizontally does not exceed 800 mm. Where aggregate larger than 20 mm is used a greater thickness will be needed.

The thickness of the unit and any stiffening ribs should be adequate to allow the provision of support and restraint fixings as well as handling fixings (see Figures 4, 5, 6 and **8.1**). In particular, holes for dowels, bolts and lifting points should be encompassed by reinforcement to resist rupture, and the reinforcement should have its appropriate cover (see **5.3**).

5.7 Deviation and movement

Designers should make allowance in their design for deviations in the erection of the structure and in the cladding and joints, together with the dimensional changes which are likely to occur and tolerances in manufacture of units.

A clearance should be provided to prevent any trapped moisture transferring between the precast concrete units and the structure, not less than 10 mm wide after all construction tolerances have been accommodated.

It is essential that weep holes are provided at points where any entrapped moisture could accumulate e.g. at cavity trays, and at damp-proof course levels.

Joint widths will normally vary as required to take up the deviations, movement and tolerances. If reasonable evenness of joint width is required it is essential that this is specified and that special consideration is given to the manufacture of the units, especially the end units. Slight deviations in the dimension of one unit are likely to be less noticeable than wide variations in joint width.

NOTE Further guidance on dimensional deviations is given in BS 5606, BS 6093 and BS 6954. BS 6954 approaches tolerances on a statistical basis.

5.8 Dimensional changes

These are quantified in **5.9** but the amount can be reduced by careful control of aggregates, mix water:cement ratio and curing.

If facing and backing materials are different, differential movement should be considered to reduce bowing.

Units may also be susceptible to bowing caused by moisture or thermal gradients. These may be cyclic.

Since a significant part of the total drying shrinkage takes place during the first month after casting, concrete units should be left as long as possible before fixing. It is inadvisable, however, to fix matured units to a frame still subject to substantial shrinkage and/or creep.

Cladding units should be stored so as to allow movement.

The size, thickness and profile of the units should be taken into account when considering dimensional changes.

5.9 Accommodation of dimensional changes

5.9.1 *General*

It is essential that dimensional changes in the parts of the building to which the cladding is applied are taken into account when designing the joints between the units (see **5.9.4** and **5.9.5**). Unless these movements are accommodated, substantial stresses may be imposed on rigidly fixed units which may be sufficient to fracture the projecting horizontal support or the units themselves, break the ties, and cause units to bow out from the main structure. The design of fixings should allow freedom of vertical and lateral movement between structure and unit. Where this is not wholly possible, all forces should be allowed for in the design, including those imposed both by movements of the structure, and by shrinkage, thermal and moisture movements of the unit. The assessment of the magnitude of such forces in combination is very complex and can be estimated only very approximately.

The information given in **5.9.2** to **5.9.5** is of a general nature and is intended to outline the most significant factors affecting movement in various supporting structures and claddings, and to provide typical properties of materials to enable some assessment of movements to be made. More detailed guidance may be found in *Design for movement in buildings* [5] and *Estimation of thermal and moisture movements* [6].

5.9.2 *Thermal movements*

The movements which it is essential to take into account are the relative changes in length and height due to temperature differences between the cladding, and the structure to which the cladding is fixed. The magnitude of the movements is dependent on the following:

a) whether the frame is entirely or partly inside the building envelope;

b) ambient temperature;

c) coefficients of thermal expansion of the various materials;

d) the temperature of the various components when the cladding was fixed.

The coefficient of thermal expansion of typical materials is given in Table 3.

For buildings in the United Kingdom with modern standards of thermal insulation and air conditioning, the temperatures tabulated in Table 4 may be used as a guide to the extremes likely to be experienced.

5.9.3 *Differential settlement*

A common assumption in foundation design is that a differential settlement of 1/500 of the distance between adjacent columns is acceptable. This figure is related to the total load, and the angular beam movement that should be allowed for in the design of the cladding will be less than this figure. The reduction will depend on how much of the total load has been applied to the foundations at the time of cladding fixing and on the nature of the soil, for example clays consolidate at a much slower rate than sands after each load increment.

In many cases the effect of differential settlement will be insignificant but the structural engineer should be consulted.

5.9.4 *Elastic deformation under load*

5.9.4.1 *General*

The three aspects of elastic deformation to be taken into account are column shortening, beam deflection, and wind sway.

5.9.4.2 *Steel-framed buildings*

The significance of column shortening will depend on the height and type of construction and on the sequence of construction.

For a traditional, concrete cased, steel framed building of 6 to 10 storeys, with ordinary reinforced concrete or hollow tile floor slabs which are all complete prior to fixing of the cladding, the subsequent elastic column shortening can be as little as 0.5 mm, and will rarely exceed 1 mm, in a 4 m storey height.

For a 25 to 35 storey office tower with dry fire protection to a high-yield steel frame and composite metal decking floors, constructed so that the fixing of the cladding follows only two or three storeys behind the erection of the frame, the elastic shortening of the columns, after the cladding has been fixed, may be as much as 3 mm to 4 mm for a 4 m storey height.

NOTE BS 5950-1 gives recommended limitations for the deflection of structural members due to unfactored imposed load. For example, for beams carrying plaster or other brittle finish a deflection limit of 1/360 of the span of the beam is recommended.

For the traditional concrete-case steel frame with spans up to 8 m this means that the elastic beam deflection, after the cladding has been fixed, will usually be insignificant.

For dry-clad beams greater movements can be anticipated and should be allowed for.

For the purpose of calculating deflections, Young's modulus for steel can be taken as $E = 2.1 \times 10^5$ N/mm^2 and for any concrete casing a value of $E = 2.1 \times 10^4$ N/mm^2 may be used, together with the moment of inertia of the uncracked rectangular section.

5.9.4.3 *Concrete-framed buildings*

The elastic deformation of components of a structure to which cladding is attached should be taken into account. Elastic compression of columns may not often be important, but elastic deflection of beams and floor edges may be important, particularly when spans are large. The average modulus of elasticity of concrete of compressive strength between 20 N/mm^2 and 40 N/mm^2 is 28 kN/mm^2.

Further information may be found in BS 8110-2.

Calculations for deflections of long slender beams and cantilevers in particular should take into account the effects of shrinkage and creep as well as of elastic strain.

5.9.5 *Drying shrinkage, creep and moisture movement of concrete*

The degree of movement to be accommodated due to creep and irreversible shrinkage of the structure can be very much reduced if the erection of the cladding units is delayed as long as possible after the striking of the formwork to the main structure. Wherever possible, cladding should not be applied until the basic structure of the building is complete. Such procedure permits the plumbness of the frame or structure to be checked, inaccuracies determined and any remedial measures to be carried out to the face of the structure so as to ensure that the cladding can be fixed satisfactorily. Rigidly fixed cladding units should not be erected before striking the formwork and temporary supports of the main structure.

Table 3 — Coefficients of thermal expansion of buildings materials

Material		Coefficient of thermal expansion $10^{-6}\ K^{-1}$
a) Steel (and any concrete casing to steel members)		12
b) Concrete	Dense gravel aggregate	10 to 14
	Crushed rock (except limestone)	10 to 13
	Limestone aggregate	7 to 8
	Lightweight aggregate	8 to 12
c) Masonry	Concrete brickwork and blockwork	
	Dense aggregate	6 to 12
	Lightweight aggregate (autoclaved)	8 to 12
	Aerated (autoclaved)	8
d) Calcium silicate brickwork		8 to 14
e) Clay or shale brickwork or blockwork		5 to 8
f) Natural stone	Limestone	3 to 10
	Sandstone	7 to 12
	Granite	8 to 10
	Slate	6 to 12
	Marble	3 to 15
	Quartzite	9 to 12

Table 4 — Extreme temperatures of UK structures

Condition		Temperature °C	
		Winter	Summer
a) Ambient temperature	(in the shade)	−10	25
b) External	Cladding — light colour	−20	50
	Cladding — dark colour	−20	65
c) Free-standing structures or fully exposed structural members	Concrete — light colour	−20	45
	Concrete — dark colour	−20	60
	Metal — light colour	−25	50
	Metal — dark colour	−25	65
d) Internal	Normal use	10	30
	Empty — out of use	−5	35

The actual shrinkage of concrete members depends on the water content of the mix, relative humidity, thickness of section and percentage of reinforcement. Typically the long term shrinkage value for structural concrete may be taken as 0.03 %; higher values may be more appropriate for concrete made with lightweight aggregate. Certain dense aggregates can exhibit higher shrinkage characteristics but these are not commonly used. Further guidance is given in BS 8110-2 and *Shrinkage of natural aggregates in concrete* [7].

Under normal climatic conditions in the United Kingdom the rate of shrinkage (expressed as a percentage of its potential) may be assumed to be as shown in Table 5.

Table 5 — Rate of shrinkage of concrete (as a percentage of its potential)

Effective thickness[a] of element	Period			
	14 days	28 days	3 months	1 year
100	15 %	25 %	35 %	70 %
150	10 %	15 %	30 %	50 %
300	<10 %	10 %	20 %	40 %

[a] The effective thickness is the ratio of twice the volume of the concrete divided by the exposed surface area.

In addition, concrete exposed to outdoor climate may exhibit seasonal, cyclic movement of ±0.4 times its long term drying shrinkage. However, cladding the concrete frame can significantly reduce its seasonal movement.

The creep of the main structure will cause permanent shortening of columns and deflection of beams. The magnitude of the creep is dependent on the stress in the concrete, the ambient relative humidity, and the age of the concrete when loaded. It can be assumed that about 40 %, 60 % and 80 % of the final creep develops during the first month, 6 months and 30 months under load respectively, when concrete is exposed to conditions of constant relative humidity. Further guidance is given in BS 8110-2.

Reversible moisture movement is roughly equivalent to two-thirds of the initial drying shrinkage.

5.9.6 *Masonry structures*

The physical properties of masonry materials are so varied that it is not possible to offer specific information in this standard, therefore reference should be made to the main code for walling, BS 5628-3.

5.10 Other factors affecting design

5.10.1 *Atmospheric pollution*

The possibility of units becoming dirty as a result of atmospheric pollution in any particular locality should be ascertained by examination of other buildings in the district, and by noting the factors which have determined the degree of disfigurement.

5.10.2 *Frost action*

Good quality concrete itself is seldom affected by frost but the same is not true of some facing materials which may be incorporated in the concrete. Specifiers should satisfy themselves that such materials are not affected by frost.

5.10.3 *Staining*

To avoid the possibility of the face of the cladding becoming stained by the corrosion of metals, non-staining materials such as stainless steel or silicon aluminium bronze should be used. The provision of lightning conductors should be detailed to obviate staining or damage to the cladding.

Certain timbers and timber based products contain water soluble extractives and some exterior wood finishes are susceptible to chalking, which can cause discolouration. Advice on the selection of timber species and finishes should be sought from the relevant trade associations.

Staining can occur with some sealants and reference should be made to the manufacturer stating the nature of the unit and its facing. Care should also be used with the application of sealant primers, some of which can discolour with time if misplaced on the face of the building.

5.10.4 *Weathering and water run-off*

Finishes vary considerably in their weathering characteristics and designers should be aware of the likely changes in colour and texture of either in the design of the cladding or in the selection of the mix for the units. Possible changes in the colour of the jointing materials should also be taken into account.

The changes in appearance of the facade of a building exposed to the weather are mainly influenced by the aspect and locations of the buildings, the design of the cladding, particularly in relation to the run-off of rainwater, the degree of atmospheric pollution (see **5.10.1**) and the effect of frost action (see **5.10.2**).

It is recommended that water should not be able to drain from limestone, reconstructed stone or concrete on to sandstone or other porous material.

In whatever way the cladding is constructed and jointed, it should be anticipated that some rain penetration and/or condensation may occur within the cavity between the cladding and the inner leaf or back-up wall. Such cavities should therefore have adequate provision for drainage and for damp-proofing over openings.

The use of applied weatherproof compounds is not recommended as they may trap water within the unit (see **4.6**).

Whilst uneven washing of cladding is unavoidable, the pattern should be controlled by the design of projections.

NOTE The run-off from new concrete can etch glass.

5.10.5 *Flashings and weatherings*

5.10.5.1 *Metal*

Sheet metal for flashings and weatherings should be selected after consideration of the conditions of use, exposure and chemical action due to contact with other materials. Aluminium, zinc and their alloys, when in contact with certain other metals in the presence of moisture, may suffer bi-metallic corrosion, and their direct contact with other metals should be avoided.

5.10.5.2 *Non-metallic materials*

Materials other than metals can be used for flashings, though the life of some depends largely upon the extent of direct exposure to the weather. Some materials, such as fibre reinforced bitumen, need to be heat softened to shape, while others, such as polyethylene or bitumen/polyethylene, are held in position by an adhesive selected for the particular material. The choice of any materials for flashings should take these points into consideration at the design stage, bearing in mind the methods of construction of the building.

5.11 Cavity barriers to resist the spread of fire

It is essential to provide cavity barriers to prevent the spread of fire, both horizontally and vertically, in the cavity behind the units and to reduce the effect of fire on the fixings. Horizontal cavity barriers should be located at each storey to prevent the spread of fire from storey to storey. Vertical cavity barriers should abut compartment walls.

Particular care should be taken with the detailing of cavity barriers at fixings and at vertical joints between units in order to avoid gaps in the cavity barriers.

NOTE Experience has shown that serious fires can spread at these points.

Cavity barriers should be composed of non-combustible materials having at least 30 minutes fire resistance. They should be adequately fixed and supported to ensure that they remain effective for the life of the cladding.

Requirements concerning cavity barriers are contained in part B of the Building Regulations [8].

5.12 Signs and attachments to cladding units

Signs and other attachments should not normally be fixed to the cladding units but their fixings should be taken through to the main structure in such a manner as to avoid contact with the units. Where an attachment is made to the unit, the detail should be cleared by checking with the structural engineer and cladding unit manufacturer to ensure that:

a) the cladding panel and its fixings will safely accommodate the additional forces;

b) any fixing holes that require drilling into the unit are positioned so that they do not interfere with any reinforcing bars or mesh.

6 Position and detail of joints

6.1 General

Joints should be designed with appropriate widths and sealant materials, if any, to suit the individual project, in accordance with BS 6093.

Primarily, joints are intended to ensure the weathertightness of the building, allowing for the movement to which they may be subjected, due to structural deflection and thermal or moisture changes.

The majority of joints between cladding units will act as movement joints. They should allow the relative movement between the structure and the cladding to take place without overstressing the cladding units and fixings.

The type of joint and any sealant will be determined by the type, size, thickness and surface finish of the cladding units. Design of joints should be simple, to ease manufacture and installation. They should be capable of accommodating the accumulated tolerances of both the frame and units, whilst maintaining the joint width within their working range.

6.2 Movement joints

The width of a movement joint will depend on the expected amount of movement and the maximum strain that can be accommodated by the sealant. Factors affecting movement will include moisture and temperature. The magnitude of the movement can be estimated by the method outlined in **5.9**.

Where a movement joint (commonly known as an expansion joint) is already incorporated in the design of the supporting structure, to accommodate the movements of the building, it is essential that the movement joint is taken through the cladding including any subsequently applied finish. The amount of movement to be accommodated at these points may be appreciable and the sealant for pointing the joints should be selected accordingly.

The width of the joint should always be greater than the calculated movement. If the joint is to be sealed the width of the joint should be such that the strain capacity of the sealant is not exceeded (see also **6.4**).

A vertical movement joint should be provided between all adjacent panels.

Care should be taken to ensure that adequate movement joints are provided in the cladding to parapets and to copings, since parapets, being open to the weather on two sides, are generally subject to more movement than other parts of a building.

These joints may be designed as “sealed” or “open-drained”. In sealed joints it is essential that all hard obstructive material is removed from the joint before sealant is applied.

6.3 Compression joints

Compression joints are horizontal movement joints which, additionally, should be designed to accommodate the vertical shortening of a frame, in order to prevent a build up of compressive forces being transferred to the cladding or its fixings.

The width of a compression joint should be calculated to allow for maximum column or wall shortening from all causes. It should also allow for compressibility of the jointing or joint caulking and sealing materials which, when fully compressed, may transmit pressure (see **6.4**).

Much of the vertical movement of a reinforced concrete building will have occurred within a month of completing the concrete structural frame. The time at which the compression joints should be sealed will depend upon the detail design of the units and upon the materials used for making the compression joint. The joint should be left open for as long as practicable. Compression of the joint will result in a part of the sealant being extruded on the face of the cladding. This may be reduced if the sealant is tooled concave at the time of its application.

These joints may be designed as "sealed" or "open-drained". In sealed joints it is essential that all hard obstructive material is removed from the joint before sealant is applied.

6.4 Filled and sealed joints

6.4.1 *Filled joints*

Filled joints rely on the use of gap-filling materials, used in accordance with the manufacturer's recommendations.

6.4.2 *Sealed joints*

The dimensions of sealed joints should follow the guidance given in BS 6213 and in the sealant manufacturer's literature. However, it is not considered practical to apply sealants satisfactorily in joints less than 6 mm wide and, for concrete, a minimum joint depth of 10 mm is advised.

NOTE The application of a primer is recommended on concrete, to enhance adhesion and guard against the possibility of staining.

Where sealed joints are required to exclude the weather it is recommended that they should have at least two seals, to reduce maintenance and extend the effective life of the inner seal (see Figure 2). Where double seals are provided the joint width will need to be a minimum of 15 mm.

Where a very porous facing is used, the inner seal should be aligned with the concrete backing, and the joint width may need to be increased significantly. The second seal should be aligned with the interface of any porous facing and backing concrete, if at all possible.

For double protection a secondary seal is sometimes applied at the internal face of the unit. The use of a secondary seal may require access to the back of the unit (see Figure 2).

6.4.3 *Sealant*

General guidance on the choice of sealants is given in BS 6213 and CIRIA Report R178, *Sealant joints in external facades* [9]. However as the subject is complex it is advisable to seek guidance from the sealant manufacturer at an early stage. See also **4.4.2**.

Some sealants can cause staining with particular substrates and specifiers should refer to the sealant manufacturer to confirm the suitability of the selected sealant. On precast concrete cladding staining is unlikely to occur if a sealant is used in conjunction with a recommended primer.

6.4.4 *Back-up materials*

Suitable back-up materials are recommended in **4.4.3**. They should be installed in the joint before application of the sealant, but it is preferred practice to apply any required sealant primer before the back-up material.

Back-up materials perform a number of functions in a joint. They serve to limit the cavity depth, thus ensuring that the sealant fully coats the joint side during application. They ensure that the correct width to depth ratio is obtained and they may also act as a bond breaker.

If the selected sealant bonds to the back-up material this will seriously limit the movement accommodation of the sealant and, in this instance, a bond breaker such as a polyethylene tape should be applied to the back-up material before application of the sealant.

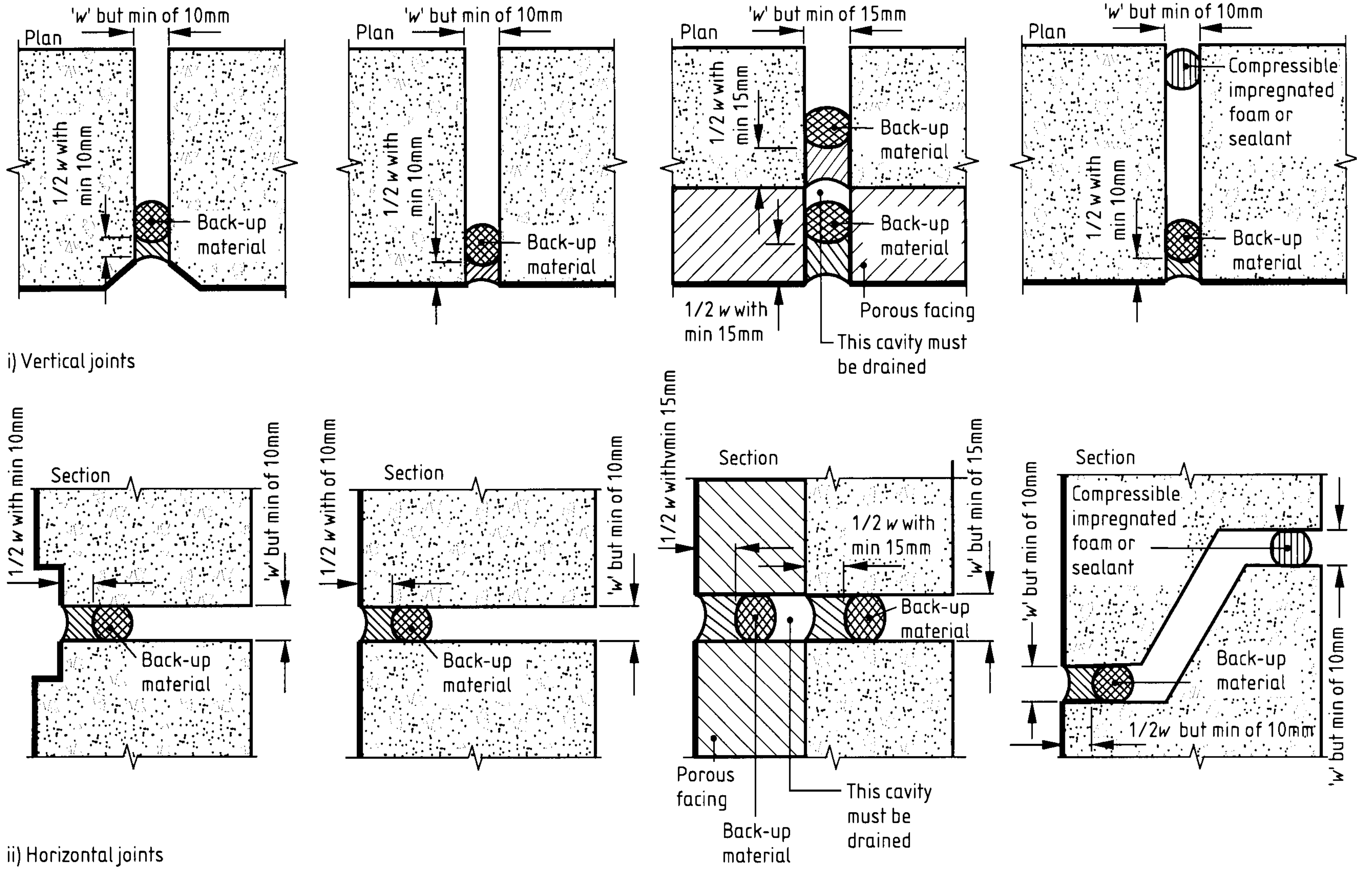
On no account should back-up material impregnated with a bitumen or wax be used.

6.5 Open drained joints

Open drained joints depend upon an air seal at the rear of the joint which prevents wind blowing past the units. This barrier should be weathertight so that any water reaching it does not pass by capillary action beyond the unit. It may also be necessary to design the baffle to withstand movement, particularly in large units.

In vertical joints, a baffle (see **4.4.5**) to limit the amount of water reaching the barrier should be placed not less than 50 mm back from the external face in grooves cast in the edges of the units (see Figure 3). A strip of the material is the most useful form of baffle, but other shapes may also be satisfactory. Baffles are expected to have a long life but wherever possible the joints should be designed so that the baffle can be replaced. However, they should also be designed to resist vandalism.

Dimensions in millimetres



a) Single joint seal between panels with rebated edges

b) Single joint seal between panels with straight edges

c) Double joint seal between panels with porous facing

d) Joint seal between panels with matching profiled edges with a compressable foam back-up seal at the back of the panel

NOTE Joint width sizes designed as recommended in BS 6093:1993.

Figure 2 — Examples of jointing profiles with sealants

The joint width should be calculated in accordance with BS 6093 and should be not less than 10 mm. The edges of the units should have a vertical groove to receive the baffle and may have other grooves to assist in preventing rain, driven across the face of the unit and into the joint, passing to the back of the joint. The baffle should be brought to the face of the unit at intervals wherever the joint is continuous down the face of the building, so as to shed the water. Alternatively, a flashing should be incorporated. Figure 3 shows a method of making the junction of a vertical drained joint with a horizontal joint.

Horizontal joints should be designed so that their faces are protected by the lower edge of the unit (above the joint) projecting downwards for a distance of at least 50 mm measured from the top of the upstand of the unit below the joint. It is essential that a flashing is provided at the intersection of vertical and horizontal joints, and that it provides continuity of the 50 mm overlap at the junction.

6.6 Gaskets and sealing strips

Materials for, and the design and installation of, gaskets and sealing strips should be in accordance with the recommendations of BS 6093.

7 Support and attachment of units to the structure

7.1 Support

Precast cladding units should preferably be base-supported (bearing on the lower edge-beam or cantilevered floor slab).

Each panel should normally have two support and four restraint points. Sizes of panel bearing surfaces should be established by calculation, taking into account the effects of tolerances which could accumulate to reduce the bearing surface. The dimensions of the bearing nibs may also be affected by practical details, such as dowel fixings and the minimum distance at which dowels can be spaced from the edge of the structures.

Structural design of supports is given in **5.5**.

7.2 Methods of attachment

7.2.1 *General*

The methods of attachment of cladding units to the structure vary widely, depending upon the type of cladding, the size of the units and the structure of the building.

Fixings used for the attachment of cladding fall into four categories as follows:

a) cast-in stainless steel sockets (see **4.3.3.2**) or proprietary anchor fixings;

b) post-installed proprietary anchors set in drilled holes. Includes torque controlled, deformation controlled, undercut and bonded (resin) anchors;

c) pre-positioned dowels or cleats on a steel structure, usually incorporated during fabrication;

d) dowels grouted in holes.

7.3 Design of fixings

7.3.1 *Type of fixing*

There are two types of fixings for precast concrete cladding:

a) loadbearing fixings;

b) restraint fixings.

Typical examples of these fixings are shown in Figures 4, 5 and 6.

7.3.2 *Loadbearing fixings*

Loadbearing fixings are designed to transfer the weight of the cladding units to the building structure and are usually designed as pin jointed supports. These fixings should take the form of reinforced concrete nibs or stainless steel fixings.

When calculating the size of fixings it is important to minimize the possibility of permanent deformation. The maximum permissible tip deflection of any fixing should be limited to 1.0 mm.

7.3.3 *Restraint fixings*

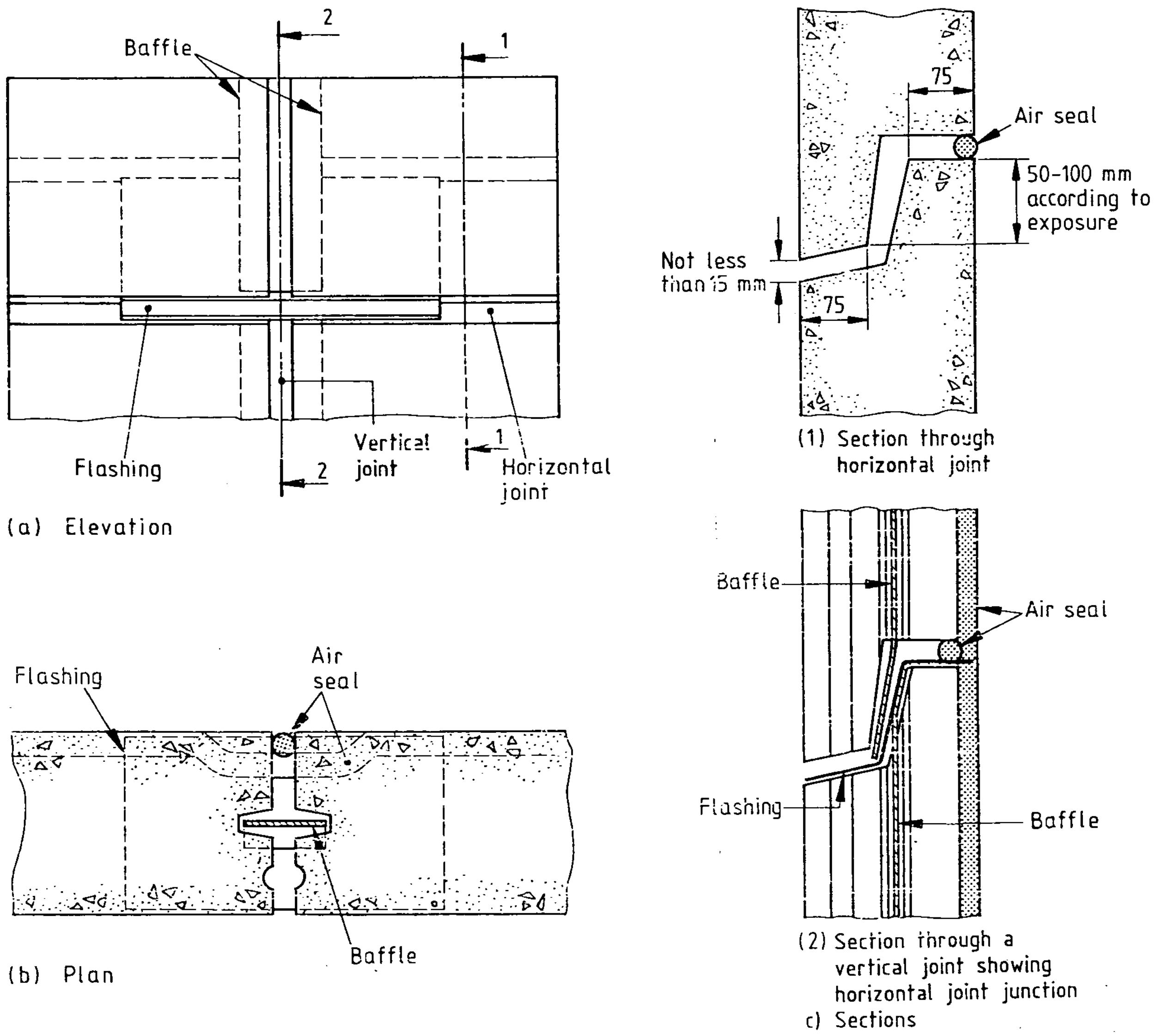
Restraint fixings are designed to hold panels back to the structure and transfer all horizontal forces (such as wind pressure or suction) to the structure. They should be fully adjustable to facilitate the plumbing and lining up of the panel and should be designed to accommodate any differential movement between structure and cladding. Account should be taken of tolerances in the structure of the building and the manufacture of the precast units. In most cases, for averaged-sized panels, four restraint fixings should be provided, as close as possible to the corners of the unit.

7.3.4 *Mechanical properties for stainless steel components*

7.3.4.1 *Limit state design*

The recommended mechanical properties to be used for the limit state design of components when designing fixings manufactured from stainless steel are given in Tables 6 and 7.

All dimensions are in millimetres



3a) Elevation

3b) Plan view

3c) Section through A-A showing horizontal joint

3d) Section through B-B showing horizontal joint junction

Reproduced from *A guide to the design, detailing and economics of precast concrete cladding* [10] by kind permission of the Architectural Cladding Association.

Figure 3 — Open drained joint with plain baffle

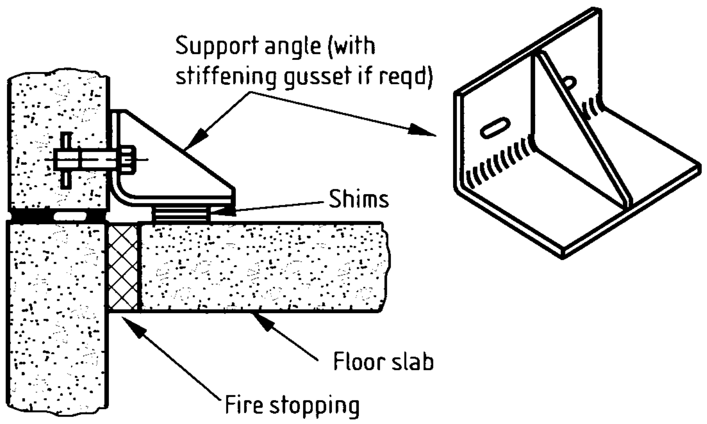


Figure 4 — Structural support angle

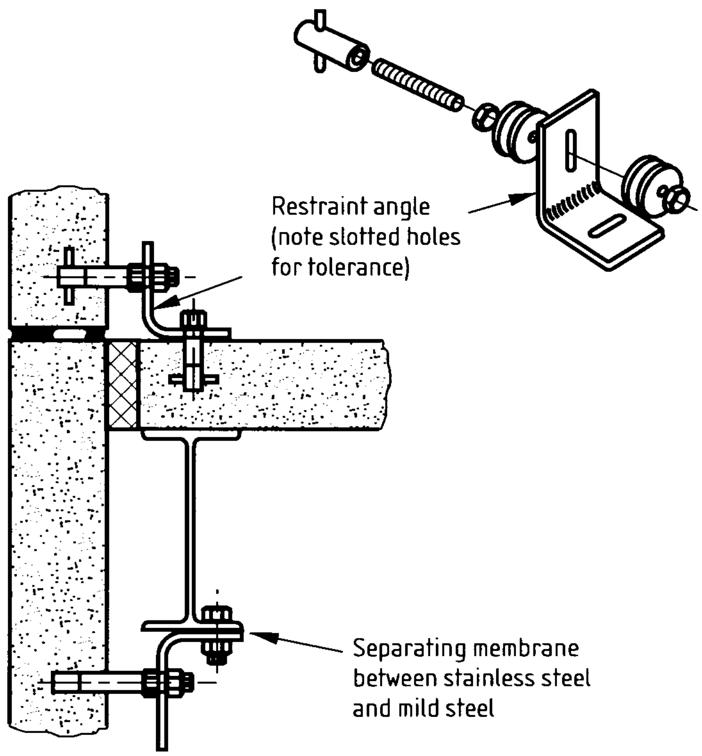


Figure 5 — Restraint fixings

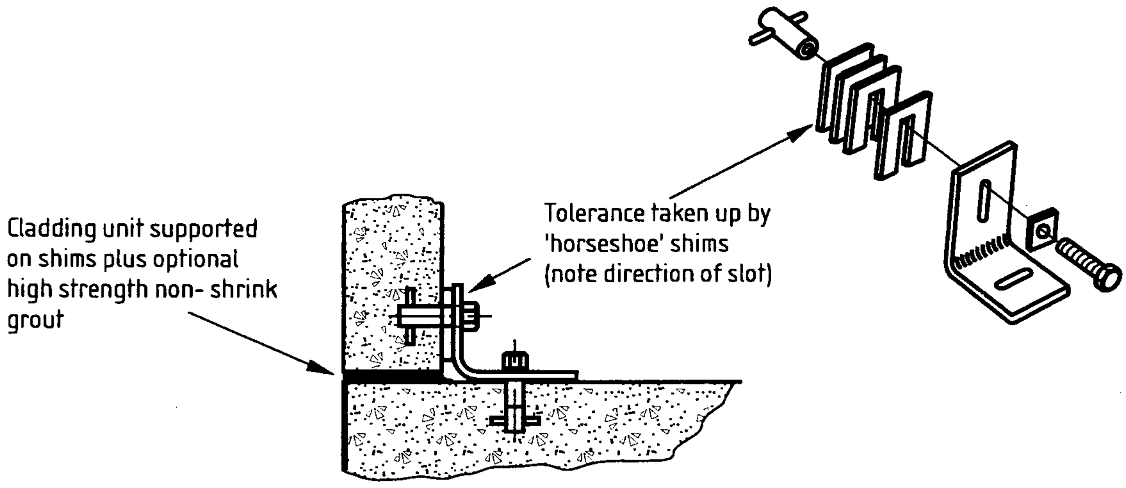


Figure 6 — Restraint fixing at bottom of panel

7.3.4.2 *Sheet, plate and strip*

Where verification is not available for components made from austenitic stainless steel sheet, plate or strip, the lowest values given in Table 6 should be used.

Table 6 — Minimum mechanical properties of austenitic stainless steel sheet, plate and strip given in BS EN 10088-2:1995

Grade	0.2 % Proof stress N/mm^2	Ultimate tensile strength N/mm^2
1.4301	210	520
1.4305	190	500
1.4307	200	500
1.4401	220	520
1.4404	220	520
1.4541	200	520

7.3.4.3 *Rod and bar*

Where verification is not available for components made from austenitic stainless steel rod or bar, the lowest values given in Table 7 should be used.

Table 7 — Minimum mechanical properties of austenitic stainless steel rod and bar given in BS EN 10088-3:1995

Grade	0.2 % Proof stress N/mm^2	Ultimate tensile strength N/mm^2
1.4301	190	500
1.4305	170	475
1.4307	180	460
1.4401	200	500
1.4404	200	500
1.4541	190	500

7.3.4.4 *Permissible stress method*

For simple fixings, design may be based on permissible stress methods. When designing components using this method, it is recommended that the 59 % value is used to calculate permissible stress, to minimize the possibility of permanent deformation when members are stressed above the proportional limit. This represents a safety factor of 1.69 on the 0.2 % proof stress value.

Where a detailed design using the mechanical properties of austenitic stainless steel specified in BS 10088-2 and -3 is to be undertaken, it is important that the raw material used is supported with certification confirming its mechanical properties and chemical composition. Where verification is not available, the lowest values in Table 8 should be used.

Due to variations in the mechanical properties of the different grades of austenitic stainless steel, it is recommended that the values in Table 8, which are minima, should be used.

Table 8 — Permissible stresses for austenitic stainless steel

Application	Permissible tensile stress N/mm^2	Permissible shear stress N/mm^2
Brackets made from sheet, plate or strip	129	77
Bolts, nuts and studs made from rod or bar	116	70

7.3.5 ***Mechanical properties of austenitic stainless steel bolts***

BS EN ISO 3506-1 and -2 specify the mechanical properties of stainless steel fasteners; those relating to austenitic bolts are summarized in Table 9.

Table 9 — Mechanical properties of austenitic stainless steel bolts

Bolt size	Property class	Shear capacity P_{sb} (kN)	Tensile capacity P_{tb} (kN)
M 12	50	12.2	14.7
	70	26.2	31.5
	80	32.4	41.8
M 16	50	22.7	27.4
	70	48.7	58.6
	80	60.5	77.9
M 20	50	35.5	42.7
	70	76.1	91.5
	80	94.1	122.0
NOTE Specified values are minima.			

Table 10 gives working stresses for stainless steel bolts in clearance holes.

Table 10 — Working stresses for stainless steel bolts in clearance hole

Grade	Property class	Shear strength p_{sb} (N/mm^2)	Bearing strength p_{bb} (N/mm^2)	Tensile strength p_{tb} (N/mm^2)
A1, A2 and A4	50	145	511	174
	70	311	828	374
	80	384	1 008	496
NOTE Values for tensile strength include a 20 % allowance for prying.				

Values shown in Table 10 are only valid for bolt sizes up to M 20 and lengths up 8 times diameter. For sizes outside this range, mechanical properties may vary according to the method of forming used. Stud or threaded rod should be assumed to be property class 50 unless documentation can substantiate a higher class.

7.3.6 ***Special considerations for fixings***

7.3.6.1 *Concrete subject to tensile stresses*

Many areas of concrete structures are subject to tensile stresses which may result in cracking, even when designed in accordance with the relevant codes. Anchor performance may be significantly reduced if anchors are set in cracks. Where concrete surrounding anchors may be subjected to tensile stresses large enough to cause subsequent cracking, the fixing should be based on a design method and performance for “cracked concrete”.

Technical literature or design software from the anchor manufacturer should be checked to determine if the performance quoted is for “cracked” or “non-cracked” concrete and anchors are selected accordingly.

NOTE Guidance is given in ETAG 001:1997 [11] on the testing of fixings in cracked and non-cracked concrete.

7.3.6.2 *Fixings exposed to the risk of fire*

Fixings should be able to withstand a fire duration that has been agreed in advance with the statutory authorities. The applied loading should take account of any potential increase in loading due to the effects of fire, such as the differential expansion of materials. It should also take into account the mass of concrete into which the anchor is fixed, as this will act as a heat risk.

NOTE The yield strength and Youngs modulus of most steels are reduced to about half at 500 °C.

Failure of anchors in fire conditions is often caused by the weakening of the nut or bolt head at the surface. The time to failure can be extended by reducing the applied load.

For significant duration of exposure to fire, e.g. in excess of 30 minutes, special measures should be taken. These include:

a) specifying anchors with performance certification appropriate to the conditions of use;

b) increasing the embedment depth of resin bonded anchors to match the durability of the bond to that of the nut/stud connection at the surface;

c) applying a fire protection coating to the fixing and surrounding area, to a minimum radius equivalent to twice the embedment depth.

Guidance on the performance of fixings in fire is given in CFA Guidance Note, *Fixings and fire* [14].

Advice on the selection and application of sprayed mineral coatings is given in BS 8202-1.

7.3.6.3 *Fixings vulnerable to corrosion*

Stainless steels are very resistant to corrosion and will perform satisfactorily in most environments. Where there is a known risk of exposure to contamination by chloride ions, such as coastal sites or swimming pools, a higher alloy grade of stainless steel containing molybdenum should be used.

Bimetallic or galvanic corrosion is liable to occur when dissimilar metals are in electrical contact in any electrolyte, such as rainwater or condensation. This can be avoided by:

a) specifying compatible metals;

b) using non-conductive washers, sleeves etc. to isolate dissimilar metals in bolted connections;

c) painting or taping over assembled joints to exclude moisture.

7.3.7 *Anchors*

7.3.7.1 *Anchor selection*

It is important that anchors used for the fixing of cladding units are both correctly selected and installed, The following factors should be taken into account:

a) magnitude of applied load;

b) direction of applied load, tension, shear or bending (taking account of packing or shims);

c) condition of base material, e.g. if concrete is cracked or non-cracked;

d) strength of the base material;

e) structural thickness of the base material;

f) edge and spacing criteria;

g) anchor positioning in relation to reinforcement;

h) fixture thickness (taking account of packing or shims);

i) corrosion conditions;

j) performance under fire.

Selection should always take account of manufacturers recommendations.

The above criteria may be satisfied if an anchor has European Technical Approval (ETA) in accordance with ETAG 001:1997 [11], or a recognized national approval such as a British Board of Agrément (BBA) certificate.

Changes in the specification of proprietary anchors should only be made where the proposed alternative satisfies all the original design parameters.

Further guidance on the selection and installation of anchors is given in CIRIA report, *Cladding fixings — Good practice guidance* [12], and CFA *Guidance note*, *Anchor selection* [13].

7.3.7.2 *Anchor positioning in relation to reinforcement*

The location of anchor bolts needs to be considered carefully at the design stage to avoid clashes between fixings and reinforcement. If striking reinforcement is likely, this can be minimized by use of a covermeter before drilling starts.

Clear guidance should be given to installers, in specification sheets, on action to be taken if reinforcement is struck during drilling. This may include cutting through bars (only if allowed by the responsible engineer) or repositioning anchors. To facilitate the latter, additional or elongated holes may be provided in bracketry. Repositioned anchors should be set at a distance from the aborted hole equivalent to the depth of the aborted hole.

NOTE As this will usually equate to cover on reinforcement, this dimension can be used when designing additional or elongated holes in brackets.

Aborted holes should be filled with a non-shrink grout.

7.3.8 *Mortars and non-shrink grouts*

Where fixing components are to be set into pockets in the unit or the structure, the mortar should consist of 1:1 cement:sand, with a minimum water content; well tamped into the hole around the fixing and allowed cure before being subjected to stress. Where epoxy resin or polyester resin mixes (with or without fillers) or cementitious non- shrink grout mixes are used to set fixing components into pockets, the manufacturer's instructions should be strictly followed. Only proprietary products intended for this purpose should be used.

8 Surface finish of cladding units

8.1 Precast concrete

8.1.1 *General*

The surface appearance of precast concrete cladding units is derived from the character or profile of the moulds in which they are cast, the aggregate used in the mix or from work undertaken on the surface of the panel after removal from the mould.

The following are examples.

8.1.2 *Profiled finishes from the mould*

These are achieved by the use of timber ribs, fibreglass or rubber liners, specially adapted polystyrene liners, or any other appropriate techniques.

NOTE Exposed concrete finishes produced with special cements may have an initial colour that will vary from their final appearance following atmospheric exposure.

8.1.3 *Exposed aggregate finish*

Stones in exposed aggregate finishes, should be embedded in the matrix to a depth of not less than two-thirds of their thickness. If coarse aggregate is not premixed with the matrix but stones are bedded individually, the proportion of cement to fine aggregate (passing through a 5 mm sieve) used in the matrix should generally not be leaner than 1:4.

To ensure adequate strength in the case of units having a facing of large stones, special attention should be given to the thickness of the matrix in which the stones are held and to the overall thickness of the units.

8.1.4 *Abrasive blasted finishes*

These are achieved by removing a certain amount of surface material, the abrasive being carried in a jet of air or water.

8.1.5 *Tooled finishes*

These are generally achieved using an air gun and specially adapted heads appropriate to the finish required. Special tooling effects can also be achieved by hand.

8.1.6 *Machine-rubbed finishes.*

Very smooth finishes which can be achieved using industrial sanding equipment with selected face pads and water as a lubricant.

8.2 Stone-faced units

8.2.1 *General*

It is essential that the method of attachment of the stone ensures that it will be permanently attached to and supported by the concrete backing.

8.2.2 *Granite-faced units*

Where stainless steel dowels are used for attaching granite (see Figure 7) the following apply.

a) Fixings should be dowels not less than 4.7 mm in diameter and not less than 11 dowels per square metre inclined at approximately 45° to 60° to the back of the stone.

b) Approximately 50 % of the dowels should be reversed in direction.

c) Each dowel should be fitted with a flexible grommet with a wall thickness not less than 3 mm, to allow some differential movement.

d) The depth of penetration of the dowel into the stone should be two-thirds of the thickness of the material.

e) The dowel should be embedded in the concrete not less than 60 mm.

f) Particular care should be taken with narrow or irregular shaped stones to ensure that they are adequately supported by a sufficient number of fixings.

g) The bottom edges of stones which do not have a physical support or another stone immediately below them should have fixings not more than 100 mm above the edge and also within the reinforcement cage.

h) A de-bonding agent should be provided between the rear of the stone and the backing concrete, to allow for differential movement.

8.2.3 *Units faced with stone other than granite*

Stone other than granite should be fixed with dowels only after satisfactory tests have been carried out to establish their "loadbearing" and "pull-off" strengths and such other tests as may be required, or by reference to work previously executed, to ensure that the proposed method will be satisfactory for the anticipated life of the building.

Such tests should be carried out under conditions which ensure that no adhesion is present between the stone and the concrete panel.

8.2.4 *Stone attached to concrete with fixings other than dowels*

Fixings other than dowels may be used for attaching all stone to the precast units. These methods should be considered only after satisfactory tests have been carried out to establish their "loadbearing" and "pull-off" strengths and other such tests that may be required.

Such tests should be carried out under conditions which ensure that no adhesion is present between the stone and the concrete panel.

All linear dimensions are in millimetres.

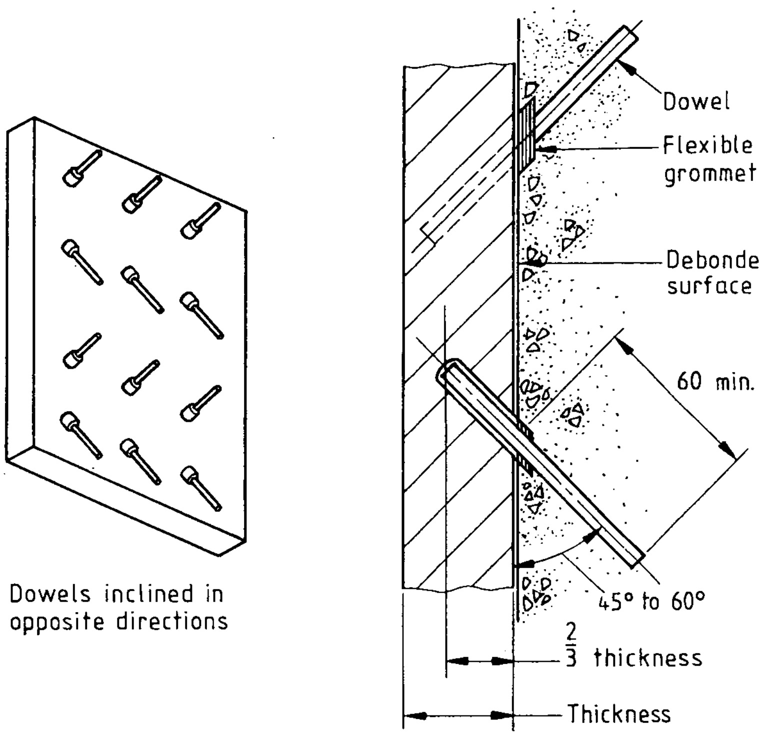


Figure 7 — Typical details of fixing pins for granite faced concrete units

8.3 Reconstructed stone faced units

Reconstructed or cast stone in effect simulates stone. By the use of special mixes, white or grey cement and pigments, the colour and texture of natural masonry can be achieved with the mouldability of concrete. After removal from the moulds the surface laitence on exposed faces of panels is removed, usually by acid etching, and small air holes are filled with a mix of fine aggregate and cement. Further finishing by etching completes the process. A finer surface texture can be achieved by hand or machine rubbing the etched surface with a fine abrasive. This is referred to as a rubbed finish.

8.4 Brick-faced units

8.4.1 *General*

Brick-faced finishes may be achieved by either laying the bricks into the mould and casting concrete on top or by casting fixings and/or supports into the concrete face and building the brickwork on site.

8.4.2 *Bricks cast-in*

The bricks should be laid into a predetermined grid placed in the mould, with a former in the joint to allow pointing later. Bricks will generally have been cut prior to placing in the mould. Machine-made bricks containing holes will be cut so that a little over half the brick is placed in the mould, leaving an undercut slot to provide good key to concrete. Slotted rather than circular hole bricks may require testing to ascertain the level of bond to the concrete. Solid bricks can also be cut and a proportion of the bricks provided with fixings as described in **9.2.2**.

Some handmade bricks are likely to prove unsuitable due to their inconsistent shape, dimensions or properties, and early reference to the cladding manufacturer is recommended to discuss feasibility.

8.4.3 ***Provision of fixings/supports for brickwork laid on site***

Fixings provided are generally stainless steel slotted fixings to take brick ties at appropriate centres. Support to the base of the brickwork may be provided by:

a) a reinforced concrete nib;

b) a brick-faced concrete nib;

c) an austenitic stainless steel angle bolted to fixings provided in the unit.

8.5 Tile and brick slip faced units

Tile and brick slip finishes can be applied either to the upper face of the concrete in the mould, monolithically, or laid on the base of the mould and the concrete cast on top. The latter method is more likely to provide better adhesion but to be successful, extra care should be taken when filling the mould to prevent displacement of the finishes.

Tiles and brick slips should be provided with well formed mechanical key grooves, unless pull-off tests demonstrate that these are unnecessary.

9 Manufacture

9.1 General

Competent persons should be employed to supervise all stages in the production and erection of the units. All tests on materials, the making and testing of cubes and the maintenance and calibration of all mixing and measuring plant should be carried out under direct supervision.

9.2 Casting, curing and inspection

The production, casting, curing and testing of concrete should conform to the requirements of BS 8110-1. Further information for cast stone is given in BS 1217.

Cutting, bending and positioning (including tolerances) of steel reinforcement should be in accordance with the requirements of BS 8110-1. Making good or repairs should be carried out before application of acceptance criteria.

9.3 Tolerances and accuracy

The permissible deviations given in Table 11 are those which are commonly worked to and have been found to be practicable. They are mostly to finer dimensions than those published in BS 8110-1 as it is felt that for architectural purposes cladding should be made more accurately than structural concrete generally. Where oversize units are not acceptable, the designer should make the necessary allowances in the dimensioning of the unit given in Table 11.

9.4 Removal of cast concrete units from moulds

When planning for the removal of cast concrete units from moulds, consideration should be given to the use of the following:

a) tilting moulds which permit the dead weight of large units to be taken in the most advantageous plane;

b) higher grades of concrete and additional reinforcement, permitting early striking and more rapid use of moulds;

c) surface treatments which may dictate face-up or face-down casting, and the time after casting which should elapse before handling in order to work on the surface;

d) designing special rigs or turning facilities to permit working on surfaces;

e) provision of facilities for lifting and final support and restraint.

NOTE When demoulding, a factor of 2 should be applied to the weight of the unit (see **5.2.3**).

9.5 Marking

Each unit should be clearly marked with an identification symbol either on the unit or by securely fixing a non-rusting metal tag to it. Where the geometry of the unit does not make it obvious, units should also have an orientation mark.

10 Handling and transportation of cladding units

10.1 Handling

To avoid damage to the units, the stresses induced at all stages of handling, whether in the factory, during transport or on site, should be properly and safely related to the strength of the particular units at the time of these operations. Handling should be planned and reduced to a minimum.

Lifting methods and handling positions, especially for large units, should be clearly defined. All lifting equipment should be suitably tested and clearly marked with the lifting capacity. In the case of proprietary lifting systems, the manufacturers capacities may be used. Lifting equipment should only be used as intended.

NOTE When lifting cladding units, a factor of 1.5 should be applied to the weight of the unit to allow for the dynamic effect of "crane snatch" (see **5.2.3**).

Table 11 — Permissible deviations in the manufacture of cladding units

	Target size	Permissible deviation
a) Length and height	<3 m	±3 mm
	3 m to 6 m	±5 mm
	6 m to 9 m	±8 mm
	9 m to 12 m	±10 mm
b) Thickness	<500 mm	±3 mm
	500 mm to 750 mm	±5 mm
c) Straightness or bow i.e. deviation from the intended line	<3 m	6 mm
	3 m to 6 m	9 mm
	6 m to 12 m	12 mm
d) Squareness i.e. the difference in length of the two diagonals		3 mm per 2 m of diagonal up to a maximum of 9 mm
e) Twist i.e. any corner should not be more than the dimension stated from the plane containing the other three corners.	**Length of longer side**	
	<3 m	6 mm
	3 m to 6 m	9 mm
	6 m to 12 m	12 mm
f) Openings	i) Within one unit (size)	±6 mm
	ii) Within one unit (location)	
	a) With structural or cover implications	±6 mm
	b) Without structural or cover implications	±12 mm
	iii) Formed by several units e.g. spandrels, mullions etc.	±8 mm
g) Anchors and inserts	i) Isolated insert or group of inserts	±6 mm
	ii) Individual insert relative to others within a group	±3 mm
	iii) Non-structural cast-in items	Twice the above

10.2 Design of lifting points

It is essential that consideration is given to the handling and lifting equipment available at all stages, including production, transportation and erection, and also to the stresses induced by these operations.

The shapes, sizes and weights of units should be related to the equipment available and the lifting methods chosen should be of a type unlikely to cause damage to the units.

Lifting points in units should be formed by the following devices:

a) cast-in metal sockets, female-threaded to receive a screwed lifting plug;

b) cast-in dowels, partially recessed or projecting, threaded to receive female lifting rings;

c) steel loops partially recessed or projecting from the concrete;

d) holes to take carrying bars;

e) proprietary lifting systems.

Non-ferrous devices should not be used if the possibility of electrolytic action with reinforcement or other ferrous items exists. Lifting devices should be designed to avoid damage to units and for maximum ease of use commensurate with safety. Recessed devices should be provided with recesses large enough to accommodate the correct size of lifting hook. Threaded dowels with nuts screwed on can be used as lifting points with a box-type lifting hook.

Care should be taken to avoid rusting and/or bimetallic corrosion where they are liable to occur (see **7.3.6.3**). It is essential that lifting devices positioned in exposed faces are recessed, sufficiently, to achieve the appropriate reinforcement cover when made good. Lifting holes and holes leading to recessed or cast-in devices should be covered in some manner to prevent rusting and to avoid corrosion products staining exposed faces.

If units are designed for handling in a particular direction only, it is essential that this is made clear by means of instructions on drawings and appropriate markings on the units.

10.3 Protection against damage

Care should be taken to avoid damage from any cause at all stages. Packing pieces used for protection should not disfigure or otherwise permanently mark the units.

Surface protection should be afforded by careful handling and the avoidance of the use of hooks, crowbars or other implements that are likely to cause damage. Oils, grease, paint, cement slurry and liquid agents liable to cause staining should not be used in close proximity to the area in which the units are stacked.

10.4 Storage

Storage of units should be arranged so that delivery in accurate sequence for site fixing is possible. During storage of units, protection should be provided against staining, particularly from corroding metal, and accidental damage.

10.5 Transportation of units to the site

It is preferable for units to be transported in the plane in which they are to be fixed in the building. Consequently, anchorage points should be provided for straps and/or frames to hold the units safely in position during transport. Consideration should be given to the design of racks and other equipment for large units for transport, and allowance should be made for the flexing of the truck platform. Details of any temporary supports and their positioning should be shown on the drawings.

11 On-site erection and fixing

11.1 General

Lifting areas should be selected so that the units clear all permanent and temporary structures during the lift. Sufficient room should always be available for movement around units being handled for transportation or fixing. All temporary supports should be adequately fixed. Wedges, shims, spacers and other items not designed for permanent inclusion should be removed and the voids made good. Further information is given in BS 8000-2.

11.2 Storage of materials on site

11.2.1 *General*

All materials should be stored off the ground in a dry structure and should be protected against freezing temperatures. All stored materials should be used in sequence and date order.

The storage of admixtures, sealants and sealant primers should be in accordance with the manufacturer's instructions and within their shelf life. In the absence of such information it should be safe to store at temperatures between 5 °C and 25 °C, in dry conditions, out of direct sunlight.

11.2.2 *Storage of cladding units*

If site storage is necessary, panels should be arranged in sequence for erection, with markings visible and with adequate access for lifting gear. Stacking of units should be arranged to prevent accumulation of trapped water.

Storage areas should be clean and dry, level and free from contaminants which could attack or stain the concrete.

Protection should be provided against staining and accidental damage by storing units from site traffic. Units should be stacked in the same plane as they are delivered. Stacking of units one upon the other should be minimized, but where this is unavoidable, bearing points should be aligned and should be at appropriate, designed centres.

11.3 Erection of cladding units

11.3.1 *General*

Erection work should conform to the requirements of BS 8110-1.

Safe and adequate access should be provided to and about the working area. Lifting areas should be selected so that the units clear all permanent and temporary structures during the lift.

All erection gear should be tested to ensure conformity to the requirements of the Factories Act 1961 [17] and regulations governing the use of lifting and transport equipment.

Temporary supports, jointing and bedding materials, fixings and tools should be pre- positioned at the fixing point. All temporary wedges, shims, spacers and other items not designed for permanent inclusion in the structure should be removed and the spaces made good as necessary.

11.3.2 *Temporary supports*

Temporary headtrees should be adequate for all the construction loads, including wind, to be sustained and should be securely but temporarily fixed and easily removed. They should be rigid and independent of movement of the scaffolding.

Where the supports are of timber or metal, care should be taken by means of backing and polyethylene sheeting or non-staining protective materials to protect any units on which they rest from staining and damage.

11.3.3 *Protection of cladding units during erection and fixing*

During delivery, erection and fixing, cladding panels are liable to marking and/or damage. Unprotected steel scaffolding may cause rust staining, and the cladding should be protected. During erection, debris should be collected from each lift of scaffolding and should not be swept on to the ground, as this can damage other parts of the building.

11.3.4 ***Fixings***

11.3.4.1 *Quality control*

Close liaison between all concerned including the supplier of fixings should be maintained to ensure that the type and number of fixings used in the cladding are in accordance with the approved production drawings. Any approved variations (see **11.3.4.2**) should be recorded.

Where the need for corrosion resistance is paramount and there is a risk, despite normal precautions, of the accidental use of fixings made from a plain grade of austenitic stainless steel, instead of a grade containing molybdenum (see Table 1), testing should be carried out to confirm the presence of molybdenum.

NOTE The Decapoli 304/316 test kit obtainable from Broadway Products Billericay, 14 Hatfield Drive, Billericay, Essex CM11 2NQ (tel: 01277 656589) can be use to give this confirmation with a simple and almost immediate chemical spot test.

11.3.4.2 *On-site performance testing of anchors*

Where the base material does not, for any reason, closely correspond to that for which the anchor manufacturer's performance data is quoted, sufficient tests should be carried out on site to check the suitability of the anchor for the base material and/or to establish that the performance is adequate in relation to the applied load.

Depending on the requirement, this may be achieved by tests to a proof load or to failure.

Guidance on site based methods of test are given in CFA Guidance note: *Procedure for site testing fixings* [16], which includes advice on test equipment, number of tests, assessment of results etc.

Recommendations on the use of laboratory based test procedures is given in BS 5080-1.

11.3.5 ***Installation of proprietary anchors set in drilled holes***

The contractor, cladding subcontractor, structural engineer and/or architect should ensure that the use and positioning of fixing components, whether in the structure before the application of the cladding or in the cladding, and formation of movement and compression joints are carefully supervised at all times, and that where any variations have to occur, adequate measures are taken to ensure satisfactory fixing.

All preparation for and installation of proprietary sockets and anchors should be carried out strictly in accordance with the manufacturer's recommendations.

For proprietary anchors set in drilled holes the following procedures should be adopted.

— Drill hole to the correct diameter and depth.

— Clean hole thoroughly.

— Insert anchor using correct equipment.

— Allow curing time for bonded anchors.

— Tighten to recommended installation torque, using a calibrated torque wrench.

If striking reinforcement is likely, the risk can be minimized by the use of a covermeter before the drilling starts. To ensure installation parameters are complied with, installers should be provided with a detailed fixings schedule.

NOTE Most manufacturers will provide method statements which can be referred to, or be included in a fixings schedule

Further guidance is given in CFA Guidance note: *Anchor installation* [15].

11.3.6 ***Cladding units used as permanent formwork***

It is essential that the units are positioned accurately and restrained to withstand the hydraulic pressure of the fluid concrete and the vibration from mechanical vibrators. Jointing between units as permanent formwork should not allow leakage of concrete fines. A temporary jointing can suffice in this respect.

11.4 Bedding, jointing and sealing

11.4.1 ***General***

The condition of the edges of the units should be examined and dirt, dust, grease and mould-release agents should be removed. It is essential that the application of sealants is properly carried out and that any sealant or sealant primer is not used after the manufacturer's stipulated shelf-life.

Particular attention should be paid to compression and movement joints to see that they are kept free of any material that is not compressible.

11.4.2 ***Bed joints***

Correctly levelled shims may assist fixings. Shims should be either well protected from weathering or of a non-staining material.

Small units such as copings etc. which are manhandled may be stood on pads of mortar and tapped home. Cladding units requiring mechanical handling/lifting should have support, using one of the following methods.

a) Permanent support points, using packing shims, without the use of cementitious materials. These are positioned under the unit support corbels or at two defined locations under a continuous nib. The size, positions and material of such shims should be specified on the drawings.

b) Where continuous support bedding of cementitious materials is a design requirement, units should be initially supported at specified points by levelling screws that should subsequently be relaxed, or by plastic shims which shed the load gradually on to the bed joint filler. Upon completion of alignment, the bed joint should be either grouted or dry-packed with cementitious materials. The composition of such grouts/dry packing should be specified.

11.4.3 ***Sealant-filled joints***

It is particularly important that the manufacturer's instructions should be followed. Particular attention is drawn to the problems of applying sealants in unsuitable weather conditions.

11.4.4 ***Flashings and weatherings***

Metal flashings and weatherings should be in accordance with the recommendations given in **4.5**, and should be securely anchored to avoid lifting due to wind action. Where they are tucked into a groove the depth of tuck should be at least 25 mm and the joint adequately pointed. Aluminium flashings should be painted with bitumen of the solution (not emulsion) type where they are likely to be in contact with concrete or mortar.

11.5 Accuracy of erection

Responsibility for surveying the structure, including the setting out of any fixing insets, should be clearly established between contractor and cladding subcontractor. Adequate time should be allowed between such survey and timing of delivery of panels, to ensure any adjustment work to structure can be carried out to avoid delay in the erection on site of panels. Further guidance is given in *Code of practice for the safe erection of precast concrete cladding* [18].

Grid reference lines for actual joint centres should be established for a row along an entire elevation of panels. During initial erection of panels, these should be accurately centred within the grid spacing to be occupied. Panels should be positively fixed to the structure to an accurate line and level.

NOTE Special circumstances may arise when it may be necessary to leave the first row of panels not finally bedded. This is to allow for subsequent fine adjustments to align vertical and horizontal offsets in joint widths, minimization of offsets arising from bow or twist, etc., after subsequent rows of panels are erected above.

The finished work should have a satisfactory appearance, being square, regular, true to line, level and plane, with a satisfactory fit at all junctions.

The following permissible deviations from theoretical centre lines are recommended to achieve the satisfactory appearance of the cladding, uniformity of width and consistency of joints between panels.

a) The average width of an individual joint between panels compared with nominal design width of joint should not vary by more than ±6 mm, otherwise unacceptable variations to straightness of line of joint vertically, floor-to-floor, and horizontally may occur

b) Panel edges at a joint out of parallel should not taper by more than 5 mm in overall height of joint between panels.

c) Difference in alignment of a panel edge, from one panel to another, should not exceed 6 mm.

The offset in planes formed between vertical faces of one panel to another should not exceed 6 mm.

Bowed panels (within allowable manufacturing tolerances) should be arranged so that offset between adjacent panels caused by bowing does not exceed offset tolerances.

The widths of joints should be such as to ensure that joints perform as intended and conform with the recommendations of the joint sealant or gasket manufacturer.

11.6 Final fixing

Approval of appearance of each level or levels of panels should be obtained before filling bed joints, also of the final tightening of fixings, grouting or sealing.

Threaded fixings should be tightened to torque figures recommended by the manufacturer, using a calibrated torque wrench. Restraint fixings designed to allow lateral movement should not be overtightened.

Recessed lifting devices should be made good to the manufacturer's specification.

11.7 Protection of finished work

At all times it is essential that units are properly protected and consideration should be given to damage which might be caused by following trades. The greatest risks encountered on site are:

a) concrete stains and damage, e.g. due to construction of structure at a higher level;

b) oil from cranes and other plant;

c) bituminous stains, e.g. from flooring, roofing, waterproofing;

d) fixing of windows;

e) scaffold board marks.

Particular attention should be given to permanently exposed surfaces, especially arrises and decorative features. The protection may be by timber strips, hessian or polyethylene, but should not be such as will damage, mark or otherwise disfigure the units.

Where external tubular scaffolding and boards are provided, it is feasible to arrange on certain designs of cladding (e.g. columns and spandrel panels) to provide thick plastic sheeting as protection against rain, snow and frost. It may be necessary to avoid contact with the units. Such protection may have to be removed when other trades commence their work. Timber battens protecting cills or other arrises should remain in position as long as possible. Suitable packing should be used to ensure that scaffolding does not damage erected units.

Particular problems of protection also exist where no external tubular scaffolding is to be used for erection of storey height panels, and special arrangements may be necessary to provide access for protection work.

Unless precautions are taken for winter working, the use of mortar should be avoided when there is a risk of frost damage. It is essential that joints are protected against frost.

11.8 Site repairs

Minor localized damage to units should be repaired on site with the consent of, and to repair procedures approved by, the architect or structural engineer or other authorizing agent. The bond between the original and remedial work should remain unimpaired for the life of the unit. Where it is agreed that remedial work to faced concrete is necessary, it is essential that the aggregate and cement used is from the same source as the original materials.

NOTE After a period of weathering, remedial work may not match the original. Natural variations in the colour of aggregates from one source, and of cement, may also affect match and this should not exceed the agreed range of variation.

11.9 Cleaning on completion of work

11.9.1 *General*

All dust, rust and other stains, adhering mortar and other droppings, should be removed from units at the earliest opportunity. Where possible, scaffolding should be progressively dismantled as cleaning down proceeds, to avoid back-splashing from scaffold boards and rust staining from scaffold tubes on to completed work.

Guidance on cleaning of natural stone, brick, terracotta and concrete is given in BS 8221-1.

11.9.2 *Efflorescence and lime bloom*

Lime bloom is a stain somewhat similar in appearance to that of efflorescence. It is caused when carbon dioxide (dissolved in water) reacts with free lime produced during the setting of Portland cement, to form an insoluble deposit of calcium carbonate. It should be removed by washing the face of the concrete cladding with dilute hydrochloric acid, after having first thoroughly wetted the units to avoid excessive absorption, and should be followed by copious washing with water.

A 5 % hydrochloric acid solution is usually satisfactory but trials should be carried out to determine the minimum acid strength capable of removing the deposits or stains.

NOTE Lime bloom is a natural phenomenon that will diminish in time.

11.9.3 *Faced cladding units*

11.9.3.1 *General*

Any large cementitious deposits should be removed as far as possible, with wooden or plastic implements to avoid damage to the surface.

All pointing should be checked and throats and weep holes should be thoroughly cleaned.

The cementitious surface of as-cast or steel-floated finishes is likely to be visibly affected by acids. Cleaning methods should be chosen to minimize the effect on existing surfaces and fine textures.

Concrete and rendered finishes contain cement and aggregate. Since aggregates can vary from hard to soft and from acid-soluble to acid-insoluble, and cements are acid-soluble, it is desirable to assess the proposed cleaning method on a typical trial area.

11.9.3.2 *As-cast, exposed aggregate, rendered and aggregate transfer finishes*

Surfaces should be cleaned using water spray and a non-metallic bristle brush.

11.9.3.3 *Polished stonework (granite, marble and slate)*

Surfaces should be washed with clean water and a mild detergent. They should then be wiped down with a clean cloth or chamois leather. The quantity of water should be kept to a minimum.

11.9.3.4 *Unpolished stonework (granite, sandstone and limestone)*

Tooled or textured granite and sandstone surfaces should be brushed down with water spray and a non-metallic bristle brush. Other surfaces should be cleaned by hand rubbing with an abrasive block.

11.9.3.5 *Brickwork*

The cleaning of newly erected clay and calcium silicate brickwork faced cladding units should be in accordance with the recommendations given in BS 8221-1.

12 Performance testing of cladding units

12.1 Test procedures

12.1.1 *General*

The testing of complete cladding units including any joints between panels and windows should be considered as a means of determining the performance of the construction.

The following tests are available and may be imposed when considered applicable.

a) Air permeability/draught test.

b) Water penetration (static) test.

c) Water penetration (dynamic) test.

d) Wind resistance (serviceability) test.

e) Wind resistance (safety) test.

f) Hard and soft body impact test.

It should be agreed at the start of the contract which tests, if any, are required to be carried out.

12.1.2 *Testing authority*

All tests should be conducted by, or witnessed and certified by, an independent testing authority identified by the manufacturer and approved by the specifier.

Either the testing facilities of the testing authority or those of the manufacturer may be used but, in either case, the results should be reported and certified by the testing authority.

12.1.3 *Test specimens*

The specimen(s) should be designed and constructed exactly as the cladding to be installed on the building. It should be assembled and installed in the test rig using the same techniques, skills and quality control as used for the installation of the cladding on the building.

Where practicable, the test specimen should be mounted and supported in the test rig with the same conditions of attachment and support and the same degree of restraint to lateral and vertical movement as elements on the building. The structure supporting the test specimen should be similar in stiffness and reaction to that supporting the cladding.

The height of the test specimen should be not less than a typical building storey height and should include at least one vertical joint and one horizontal joint. Joint details and connections should replicate those used in the construction. The specimen should also incorporate glazed window frames, where appropriate.

The testing authority should witness the installation and dismantling of the test specimen and should record any variations to the agreed details on a set of the test specimen assembly drawings. The extent of water penetration into the system should also be recorded.

12.1.4 *Required information*

The specifier should provide drawings showing the size and arrangement of the specimen to be tested. These drawings should be discussed and modified if necessary in consultation with the manufacturer and the testing authority. Assembly drawings, details and method statements, and calculations if necessary, of the agreed test specimens should then be prepared by the manufacturer prior to testing. The drawings should show the number and location of any measuring devices required.

12.1.5 *Test report*

The report should contain the following information:

a) names and addresses of the testing agency that conducted the tests and the requester of the tests;

b) date of the test and the report;

c) identification of the elements under test (manufacturer, source of supply, dimensions, model types, material and other pertinent information);

d) detailed drawings of the elements, anchorage, weather stripping, sealants, glazing details, test specimen sealing methods and any other pertinent construction details. Any deviation from the drawings or any modifications made to the specimens to obtain the reported values should be noted on the drawing and in the report;

e) the magnitude and duration of test loads, including incremental loads;

f) a record of observations of performance;

g) when the tests are made to check conformity of the specimen to a particular specification, an identification or description of that specification;

h) a statement that the tests were conducted in accordance with this test method, or full description of any deviations from this test method;

i) a statement as to whether or not type, sealant or film, or all three were used to seal against air leakage, and whether in the judgement of the test engineer, they influenced the results of the test;

j) ambient conditions, including temperature, before and during tests;

k) the name of the author;

l) signatures of persons responsible for supervision of the tests and a list of official observers.

12.2 Test requirements

12.2.1 *Design test pressures*

The design wind pressure *p* as determined in **5.2.2** should be used for the wind resistance serviceability test. Pressures for other tests are given in Table 12, in terms of this pressure.

12.2.2 *Air permeability test*

12.2.2.1 *Method of test*

Unless otherwise agreed, the specimen should conform to the requirements of BS 5368-1.

12.2.2.2 *Draught test*

Either during or separately from the air permeability test, a check for regions of concentrated air leakage should be made.

12.2.3 Water penetration test

12.2.3.1 *Method of test*

There are two principal test methods: the static test method, which utilizes a test box within which pressures are raised and lowered relative to the external pressure, and the dynamic test method, which utilizes a wind generator to develop positive pressure on the face of the sample.

12.2.3.2 *Static water penetration test*

The specimen should be tested in accordance with BS 5368-2:1980, utilizing spraying method No. 2, except that the minimum water rate should be 3.4 l/m^2. The test pressure should always be a positive differential across the test specimen, and may be provided either by using suction on the inside, or positive pressure on the outside.

12.2.3.3 *Dynamic water penetration test*

The specimen should be tested in accordance with the procedure given in annex C. The minimum water rate should be 3.4 l/m^2. The specimen should be tested to an equivalent pressure, averaged over the duration of the test, to that used in the static test. The test authority should state clearly in its report how the test equipment is set up and how the test specimen is calibrated to ensure that the specified dynamic test pressure is actually achieved.

12.2.3.4 *Testing of specimens containing openable windows*

Opening lights should be opened and closed at least 5 times immediately before each series of water penetration tests.

12.2.3.5 *Acceptance criteria for water penetration tests*

There should be no leakage at any time during the test. In addition, water should not lodge in places intended to remain dry.

Table 12 — Test pressures

Test description		Peak test pressure	But not less than
a) Wind resistance	Serviceability	+(−)*p*	+(−)1 200 Pa
	Safety	+(−)1.5*p*	+(−)1 800 Pa
b) Water penetration	Higher grade	+0.2*p*	+600 Pa
	Lower grade	+0.2*p*	+300 Pa
c) Air permeability	Air conditioned	—	+(−)600 Pa
	Non air-conditioned	—	+(−)300 Pa

NOTE 1 1 000 Pa = 1 kN/m^2.

NOTE 2 "+" indicates a positive pressure and "−" indicates a negative pressure. Tests to be carried out under both conditions.

12.2.4 ***Wind resistance test***

12.2.4.1 *General*

There should be two wind resistance tests:

a) a serviceability test; and

b) a safety test.

12.2.4.2 *Method of test*

The specimen should be tested in accordance with BS 5368-3:1978, both under positive and negative pressure.

12.2.4.3 *Acceptance criteria for serviceability*

At the end of the test there should be no residual deformations. Elastic deformations at the design pressure should be within the limits prescribed in the performance clauses of this code.

12.2.4.4 *Acceptance criteria for safety*

At the end of the test there should be no failure, permanent damage or breakage.

12.2.5 ***Hard and soft body impact***

The visible surfaces of precast concrete cladding should be capable of withstanding applied or transferred impacts that occur during normal use, without sustaining damage which is not easily repairable and without deterioration to its performance.

When tested in accordance with annex D, minimum test impact values should be as given in Table 13.

Table 13 — Impact resistance of external surface

Type of impactor		Test impact to ensure safety of persons	Test impact for retention of performance of external surface	Max height above floor level of zone to be tested
Hard	H1	—	6 N·m	1.5 m
	H2	10 N·m	—	
Soft S1		500 N·m	120 N·m	

Special consideration should be given to cladding units adjacent to areas used by vehicular traffic. The installation of guard rails is often appropriate in this type of situation and where vehicle speed is low (less than 16 km/h) guardrails should conform to BS 6180.

13 Inspection and maintenance

13.1 Periodic inspection

The expected life of sealants may by 20 years, depending on correct installation and environmental conditions. A thorough inspection is recommended within 2 years of handing over and annually thereafter.

During inspection attention should be particularly directed to the aspects covered in **13.2** to **13.4**.

13.2 Cracks and crazing

Because cracks or crazing in precast concrete units may be either structural or non-structural, it is important to identify the cause(s) before deciding what course of action is appropriate.

The causes of non-structural cracking may include:

a) plastic settlement and shrinkage;

b) early thermal contraction;

c) long-term drying;

d) surface crazing.

The causes of structural cracking may include:

a) corrosion of reinforcement;

b) flexural stresses during handling;

c) impact or other damage;

d) movement of restrained units;

e) Alkali-silica reaction (see **5.3.2**).

Further guidance on the identification and treatment of cracking may be found in Concrete Society Reports No 22 *Non-structural cracks in concrete* [19]; and TR 44 *The relevance of cracking in concrete to corrosion reinforcement* [20].

All cracks should receive immediate remedial treatment, as they provide paths for the penetration of rain.

13.3 Open movement joints

The width of all open movement joints should be checked visually, to ensure that they have not become fully closed at any point. Particular attention should be paid to compression joints and the condition, position and continuity of baffles in open drained joints should be checked.

13.4 Joint seals

The condition of sealant filled joints, should be checked for:

a) continuity of the seal (portions of seal may have been removed by birds, pests or vandals);

b) adhesive failure of the sealant (the sealant may have pulled away from the joint surface);

c) cohesive failure of the sealant (the sealant may have cracked across the width of the joint or split lengthways along the joint).

Remedial work will normally consist of removal/ replacement. When replacing sealants, weak or friable surfaces may need a primer/binder to strengthen the surface, together with the use of a low modulus sealant.

13.5 Surface cleaning

Recommendations concerning the cleaning of buildings are given in BS 8221-1.

Annex A (normative)
Abbreviated method of determination of design loadings for low rise buildings

A.1 Site terrain

Categories of site terrain are given in Table A.1.

Table A.1 — Categories of site terrain

Description	Distance from sea	Category
Open country	up to 10 km	A
	10 km to 50 km	B
	over 50 km	C
Town areas	up to 10 km	D
	10 km to 50 km	E
	over 50 km	F

NOTE For sites on the outskirts of towns, not sheltered by other buildings, the site terrain category should be taken as open country.

A.2 Wind loading at sea level (W_L)

To find the design wind loading, select:

a) the site terrain category from Table A.1; and

b) the basic wind speed from Figure A.1;

then use these to obtain the wind loading at sea level (W_S) from Table A.2.

A.3 Design wind loading for the site (W_s)

To calculate the design wind loading for the site, multiply the wind loading at sea level (W_L) by the appropriate altitude factor (F_A) and topographical factor (F_r) from Table A.3.

$$W_S = W_L \times F_A \times F_r$$

where

$F_A = \left(1 + \frac{H_A}{1\,000}\right)^2$ is the altitude of the site above sea level (metres).

To select topographical factor (F_r) for a site in a hilly area, the steepness of the slope and the distance of the site from the peak, ridge, cliff or escarpment should be determined. Factors are given in Table A.3 for three topographic zones in three categories of terrain. The method for identifying the position of each zone, relative to the up-slope (L_u) or down-slope (L_u) is shown in Figure A.2.

Funnelling of wind between adjacent buildings may affect the loading. To compensate for this type of situation, the wind loading (W_s) should be multiplied by a factor of 1.2.

NOTE The abbreviated method assumes a combined pressure coefficient of 1.5, which takes into account the possibility that the cladding may be exposed to pressure on one side and suction on the other.

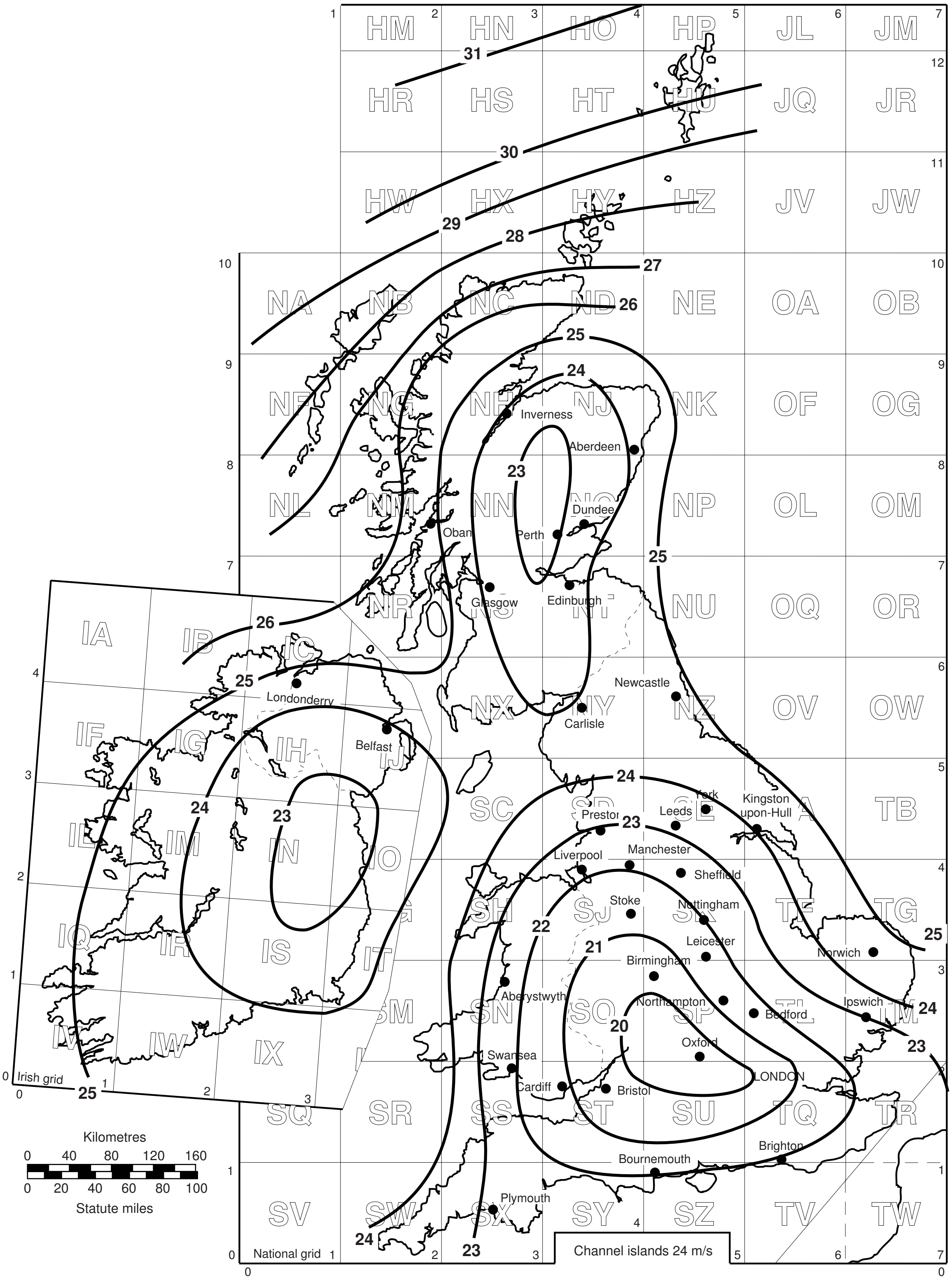


Figure A.1 — Basic hourly mean wind speeds (m/s) in the United Kingdom

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Table A.2 — Wind loading for site at sea level (W_L)

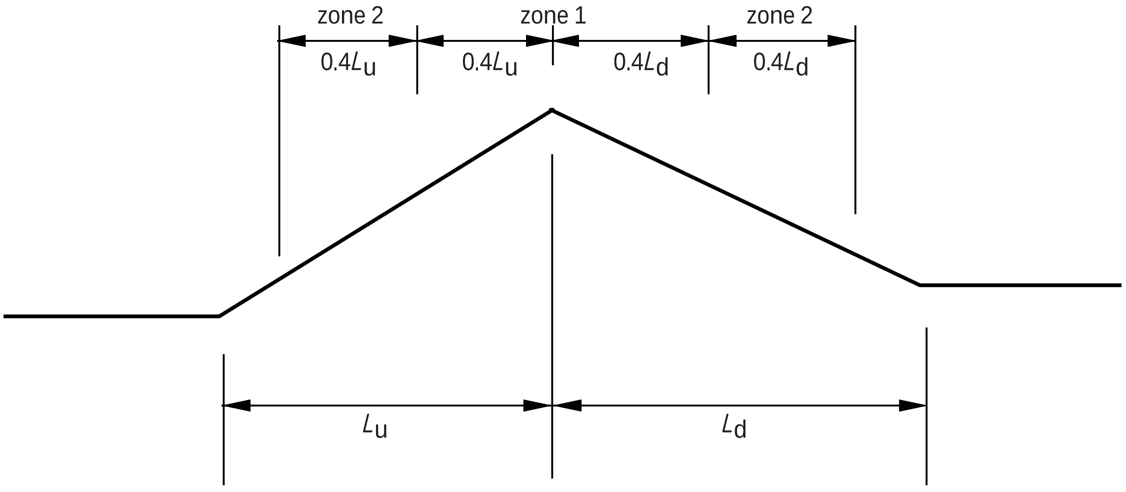
Basic wind speed from Figure A.2 m/s	Height of building m	Categories of site terrain from Table A.1 N/m²					
		A	B	C	D	E	F
20	<5	1 001	907	839	512	486	453
	5 to 10	1 165	1 101	1 026	872	828	773
	10 to 15	1 259	1 218	1 139	1 126	1 075	1 001
21	<5	1 104	1 000	925	565	536	500
	5 to 10	1 285	1 214	1 131	962	912	853
	10 to 15	1 388	1 343	1 256	1 242	1 186	1 104
22	<5	1 212	1 097	1 015	620	589	548
	5 to 10	1 410	1 332	1 241	1 055	1 001	936
	10 to 15	1 523	1 474	1 379	1 363	1 301	1 212
23	<5	1 324	1 199	1 109	677	643	599
	5 to 10	1 541	1 456	1 357	1 154	1 094	1 023
	10 to 15	1 665	1 611	1 507	1 490	1 422	1 324
24	<5	1 442	1 305	1 208	737	700	653
	5 to 10	1 678	1 585	1 477	1 256	1 192	1 114
	10 to 15	1 813	1 754	1 641	1 622	1 549	1 442
25	<5	1 565	1 417	1 310	800	760	708
	5 to 10	1 821	1 720	1 603	1 363	1 293	1 208
	10 to 15	1 967	1 904	1 780	1 760	1 680	1 565
26	<5	1 692	1 532	1 417	865	822	766
	5 to 10	1 969	1 860	1 734	1 474	1 399	1 307
	10 to 15	2 127	2 059	1 925	1 904	1 818	1 692
27	<5	1 825	1 652	1 528	833	886	826
	5 to 10	2 124	2 006	1 869	1 590	1 508	1 409
	10 to 15	2 294	2 220	2 076	2 053	1 960	1 825
28	<5	1 963	1 777	1 644	1 004	953	888
	5 to 10	2 284	2 158	2 010	1 710	1 622	1 516
	10 to 15	2 467	2 388	2 233	2 208	2 108	1 963
29	<5	2 105	1 906	1 763	1 077	1 023	953
	5 to 10	2 450	2 314	2 157	1 834	1 740	1 626
	10 to 15	2 647	2 561	2 395	2 368	2 261	2 105
30	<5	2 253	2 040	1 887	1 152	1 094	1 020
	5 to 10	2 622	2 477	2 308	1 963	1 862	1 740
	10 to 15	2 832	2 741	2 563	2 534	2 420	2 253
31	<5	2 406	2 178	2 015	1 230	1 169	1 089
	5 to 10	2 800	2 645	2 464	2 096	1 988	1 858
	10 to 15	3 024	2 927	2 737	2 706	2 584	2 406

NOTE 1 The values are rounded.

NOTE 2 N/m² = Pa.

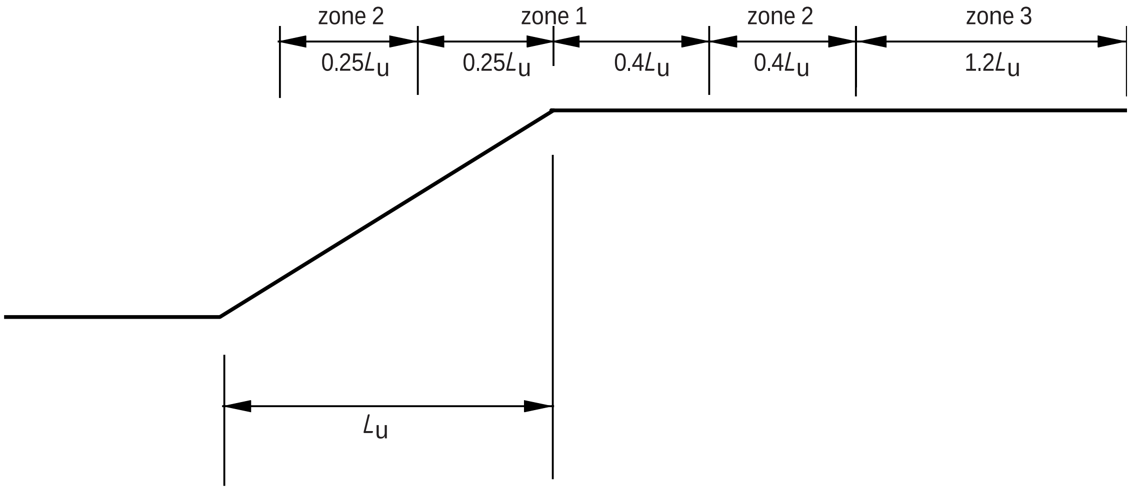
Table A.3 — Topographical factor (F_T) of sites

Topographical category	Description of terrain	Zone 1	Zone 2	Zone 3	Elsewhere
1	Nominally flat terrain slope <1:20 (5°)	1.0	1.0	1.0	1.0
2	Moderately steep terrain slope ≤1:5 (20°)	1.54	1.28	1.21	1.0
3	Steep terrain slope >1:5 (20°)	1.85	1.44	1.32	1.0



a) Hills and ridges

Figure A.2a



a)Cliffs and escarpments

Figure A.2b

Annex B (informative)
Checklists for the exchange of information

B.1 General

Before tenders are invited, a cladding specialist should be consulted to discuss practical time scales, availability and suitability of materials, etc. This is especially important for contracts with large quantities of special aggregates or finishes.

The information needed in order to schedule the work satisfactorily, obtain an accurate price, minimize supply and production difficulties, and ensure safe and practical site fixing, is given in **B.2**, **B.3** and **B.4**.

B.2 At the feasibility planning stage

The information needed at the feasibility planning stage should include:

a) total areas to be clad and their locations on the buildings;

b) aesthetic and/or visual effect required, in terms of colour; jointing pattern, surface finish and durability;

c) limitations on the use of the materials;

d) functions of the cladding, and the type of structure to which it is to be fixed;

e) variations in colour, tone and markings that can occur in the selected materials;

f) approximate time between placing the order and commencing on site;

g) approximate duration of the cladding work on site, taking account of the work of other trades.

B.3 At the tender stage

B.3.1 *Design and performance specification*

Cladding specialists invited to tender should be provided with the following information:

a) conditions regarding the building site and site access, and any particular restrictions on the site of units or of deliveries, the time of deliveries or on storage, handling, or distributing facilities, including maximum crane capacities at different radii;

b) programme and/or bar chart defining sequence and duration of site fixing, or an invitation to present recommendations;

c) sufficiently explicit drawings to show the basic construction requirements, including the relationship between the structural frame and the cladding units, unit thicknesses, jointing (including movement joints) and any additional items of special work e.g. fire stopping;

d) building tolerance(s) allowed in the structure;

e) type(s) of materials and finishes, and any demands on matching or selection, or limits on variations in appearance;

f) type of pointing, where applicable;

g) type of sealant;

h) method of fixing to be used, or an invitation to present a suitable method;

i) any requirements for the routine, or special, testing of components, before or after erection, or for sample areas or mock-up panels and whether tested units should be retained or placed on the building;

j) criteria for the acceptance or rejection of individual units and fixings.

B.3.2 *Facilities and materials required on site*

To prevent misunderstanding, particularly when tenders are being called, it should be made clear whether or not the following will be provided and by whom:

a) tower, or mobile crane, for off-loading, distributing and raising cladding to fixing positions at each level, and elevation;

b) hard and level access road on to site and to hoisting positions all suitable for the passage and working of delivery vehicles and mobile cranes;

c) safe storage areas, with firm level access, for use when cladding cannot be directly off-loaded and fixed to buildings;

d) scaffolding, if required;

e) cradles, if required;

f) push-pull props or other items for temporary restraint or supports during fixing operations;

g) materials for bedding and grouting;

h) datum lines and levels at each level and on each elevation;

i) accurate and properly prepared fixing positions, marking out, forming, drilling all holes, mortices, pockets or bolts, dowels;

j) water and electrical (110 V) supply to within 30 m of working areas to each level;

k) compressed air for hand tools, if required;

l) adequate task lighting to enable work to be continued;

m) space for the provision of site accommodation/lock up store and installation of 240 V supply;

n) messing, toilet, medical and other welfare facilities;

o) protection of fixed units from any likely physical damage or staining;

p) removal of debris from agreed collecting areas;

q) site security and protection of work, goods and materials fixed and unfixed.

B.4 Order documentation

If not previously notified, the following should be clearly stated and mutually agreed as part of the order documentation and should be agreed before awarding any subcontract:

a) fixing programme, and sequence, by elevation and levels;

b) availability of a full set of latest architect's and/or structural engineer's design drawings giving all data relevant to the cladding;

c) availability for taking site dimensions, if these are necessary;

d) time for the preparation of production drawings (in fixing sequence when many involved);

e) time for the architect to check and return production drawings, either approved or for amendment, incorporating all the design team comments;

f) time between approval of production drawings and delivery of units to site.

Minimum notice for any changes to the fixing programme and opportunity to assess cost or extension implications.

Annex C (normative)
Water penetration test by dynamic pressure

C.1 Introduction

This annex establishes the equipment and procedures to be used in testing curtain walls for water penetration using dynamic pressure. It is based on AAMA 501.1-83 [21].

C.2 Test specimen

The test specimen should be installed in or as one face of the air chamber with the periphery joint sealed against water leakage, so that the outdoor face of the wall can be subjected to both the dynamic pressure and the water flow. All weep-holes in the wall should be left open.

Before the test is conducted, sufficient time should be allowed to permit all chemically curing sealants to achieve their proper cure as recommended by the manufacturer.

C.3 Test equipment

The test chamber, air system, pressure measuring apparatus and water spray system should conform to the requirements of BS 6375-2.

A wind generating device should be provided capable of directing a jet of air at the specimen. The width of the jet should be not less than one-half of the greater dimension of the test specimen but need not be more than 4 m.

Deflection transducers should be supplied.

C.4 Test pressure

The nominal test pressure for the dynamic test should be the same as that for the static test, i.e. as given in **12.2.3.2**.

Suction may be applied to the inside of the test specimen to achieve the required test pressure, but it should be limited to 25 % of the static test pressure. Suction is usually only applied if the dynamic test machinery cannot deliver the specified test pressure on its own. If suction is used, the total specified test pressure should not change (i.e. the suction forms part of and is not additional to the specified test pressure).

C.5 Testing procedures

The deflection of the unit, measured as closely as practical to the central axis of the air jet, should be established using a static positive differential pressure equal to the nominal test pressure.

NOTE These measurements may be carried out as part of the static water penetration test.

The unit should be subjected to increasing wind flow until the average deflections of the same measuring points are the same as the deflections under the static nominal test pressure.

Maintaining the wind flow, water should be applied to the external face of the specimen at the rate of 3.4 l/min per square metre of unit frontal area, in such a way as to cover the face completely and continuously. These conditions should be maintained for a period of not less than 15 min.

Any water leakage occurring during the period of testing should be noted and reported, stating both the source and amount of leakage.

Annex D (normative)
Method of test for impact resistance

D.1 Test equipment

Hard and soft body impactors as described in Table D.1.

D.2 Testing procedures

D.2.1 *General*

Fix the sample cladding to be tested, on all edges to a rigid frame.

The vertical distance through which an impactor has to freely fall, to achieve a given test impact energy value, is determined from the following equation:

$$H = \frac{e}{9.8m}$$

where

e = the test impact energy (N·m);

m = the mass of the impactor (kg).

D.2.2 *Hard body impact tests*

For hard body tests, where the influence of the test impact will be concentrated on a local area only, the test panel should be supported horizontally, with the impactor allowed to drop vertically on to it. A number of repeat tests should be carried out over the surface of the unit

D.2.3 *Soft body impact tests*

Allow the soft body impactor, suspended on a cord at least 3 m long, to swing in a pendulum movement until it hits the specimen normal to its face. This test should be repeated at different locations on the surface of the panel.

Table D.1 — Impactors for test purposes

Reference	Type	Description	Diameter mm	Approx. mass kg
H1	Hard body	Steel ball	50	0.5
H2			62.5	1.0
S1	Soft body	Canvas, spherical/conical bag filled with 3 mm diameter glass spheres	400	50

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