

Code of practice for

Design and installation of non-loadbearing precast concrete cladding

ICS 91.060.10

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- 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

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- 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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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 It supersedes BS 8297:1995 which is withdrawn.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

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 43 and a back cover.

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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**cladding¹⁾**

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 fixing¹⁾**

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

3.5.5**restraint fixing¹⁾**

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

3.6 joints**3.6.1****compression joint¹⁾**

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 joint¹⁾**

gap that permits movement between adjacent units

NOTE Also commonly known as an expansion joint.

3.6.4**open joint¹⁾**

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**baffle¹⁾**

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**gasket¹⁾**

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

3.7.4**sealant¹⁾**

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/manufacture 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/m³.

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 = $0.50 \text{ ml/m}^2\cdot\text{s}$;
- b) 1 hour test = $0.20 \text{ ml/m}^2\cdot\text{s}$.

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) $A_v > d$, the corbel should be designed as a short cantilever, with lever arm (L_a) taken from the line of action of the load (V) to the line of the panel reinforcement;
- 2) $A_v < d$, 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.

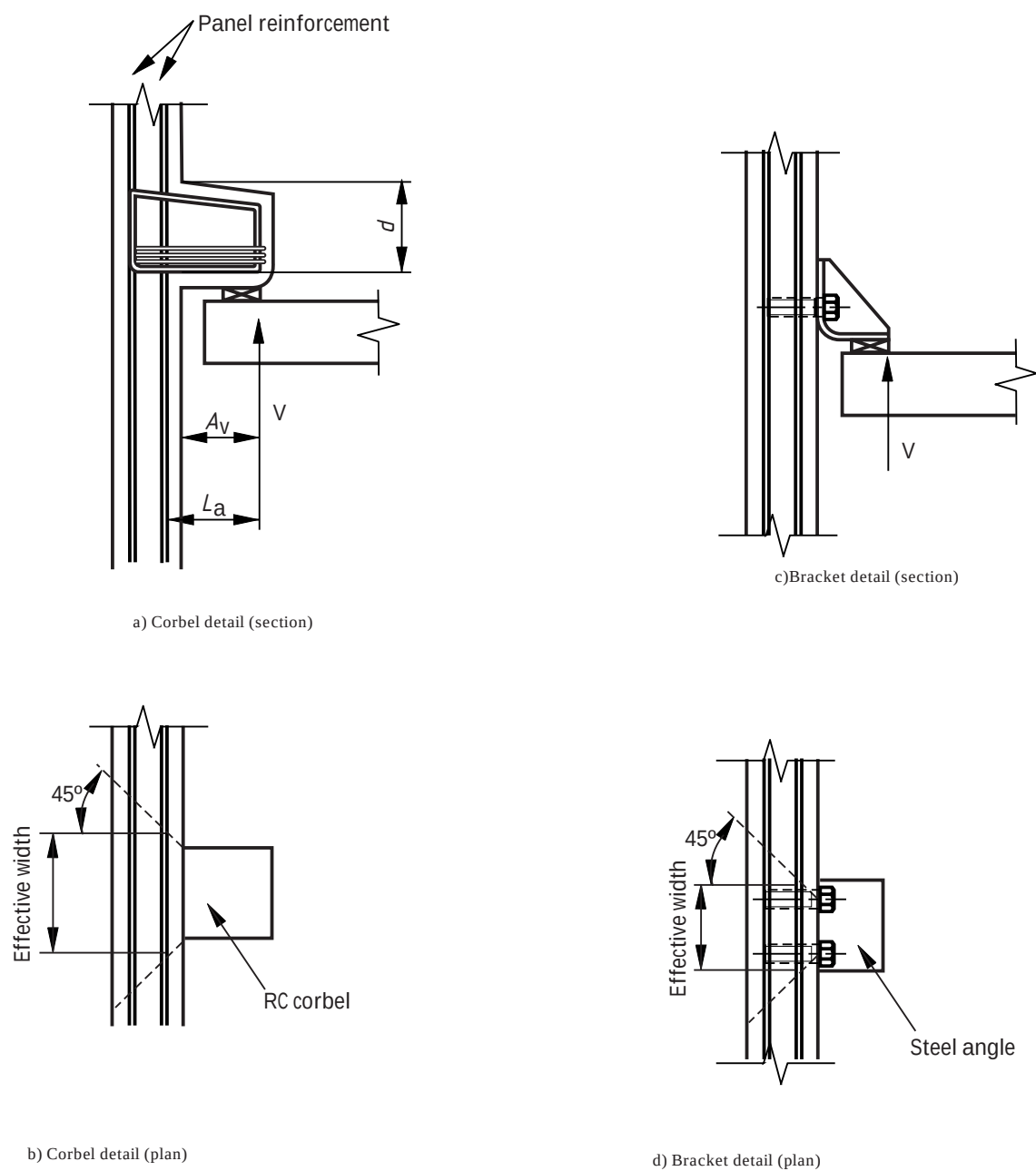


Figure 1 — Assumptions for design of units and corbels/brackets

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:

- whether the frame is entirely or partly inside the building envelope;
- ambient temperature;
- coefficients of thermal expansion of the various materials;
- 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/mm² and for any concrete casing a value of $E = 2.1 \times 10^4$ N/mm² 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/mm² and 40 N/mm² is 28 kN/mm².

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.