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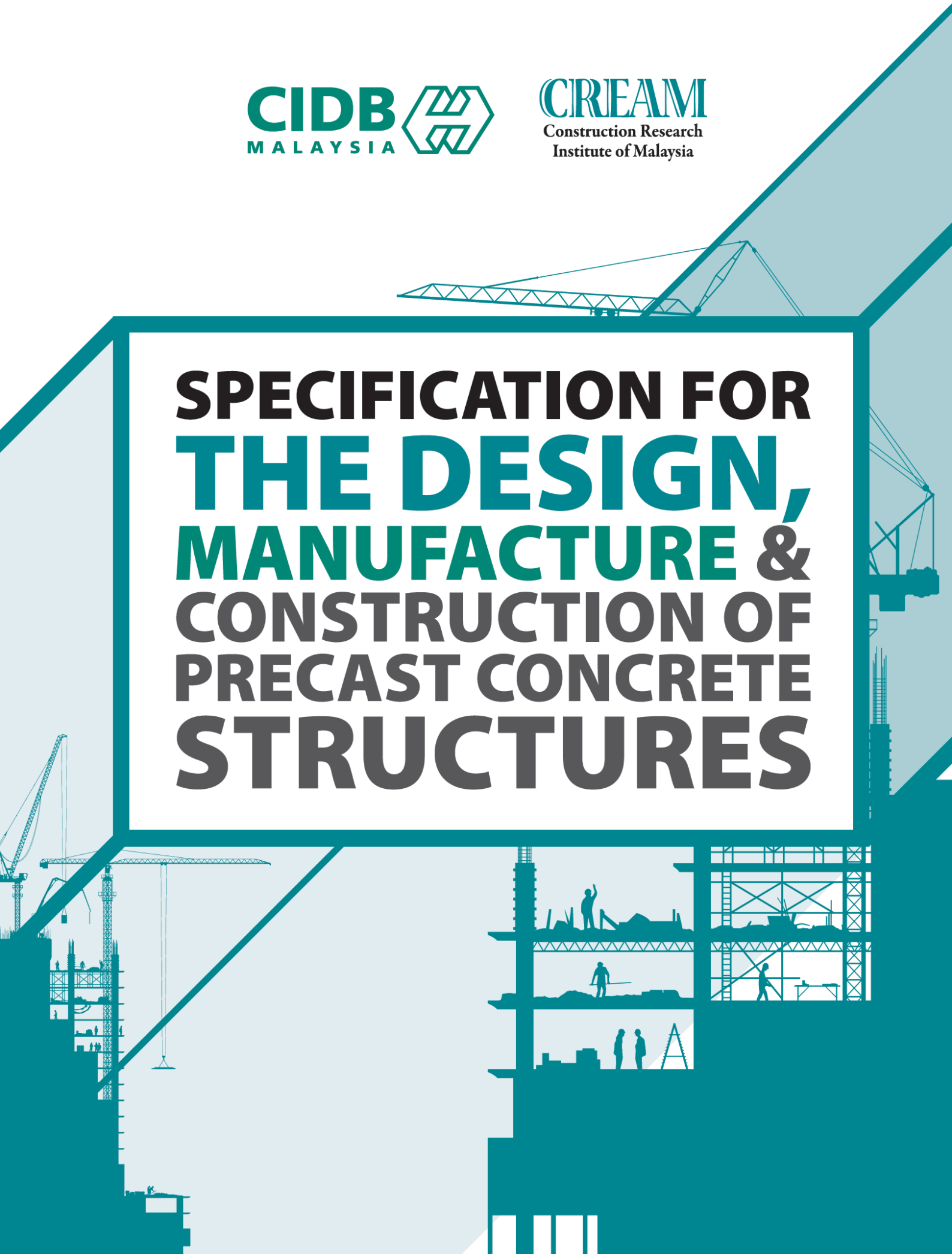
SPECIFICATION FOR THE DESIGN, MANUFACTURE & CONSTRUCTION OF PRECAST CONCRETE STRUCTURES



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FOREWORD

This document **"SPECIFICATION FOR THE DESIGN, MANUFACTURE & CONSTRUCTION OF PRECAST CONCRETE STRUCTURES"** commissioned by Construction Research Institute of Malaysia (CREAM) a research institute fully funded by CIDB Malaysia was prepared by a Technical Working Committee consisting of representatives from government technical agencies, consultant, contractor, manufacturer and practising engineers. This specification acts as the basic reference for the design, detailing, scheduling, manufacture, transportation and erection of low to medium rise precast concrete buildings. The specification serves as reference to consultants, precast manufacturers and contractors to enable them and their organisations to comply with the relevant and current documentation that accompanies the design of concrete structures.

This specification contains background requirements for a range of precast concrete elements, connections and associated methodologies for achieving robustness and temporary and final stability in these structures. This specification includes the basic specifications for materials and design procedures, manufacturing methods from raw materials to delivery, and site installation and erection methodologies, in addition to the requirements of installation equipment.

CREAM would like to express their gratitude to CREAM consultant, Dr. Kim S. Elliott as the main contributor to this specification. CREAM has great pleasure in acknowledging contributions of Technical Working Committee who have been involved in the development work of the specification.

Construction Research Institute of Malaysia (CREAM)

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BTH Technologies Sdn. Bhd.
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Setia Precast Sdn. Bhd.
Teraju Precast Services Sdn. Bhd.

Chapter 1 – Preliminaries

1.1 Terms of Reference

This specification is presented by the Construction Research Institute of Malaysia (CREAM) to act as the basic reference for the design, detailing, scheduling, manufacture, transportation and erection of precast concrete buildings according to British Standard BS 8110:1997, British Standard BS EN, British Standard BS (where the relevant BS EN does not exist), and Product Standards that may be used complimentary to BS 8110.

The document is issued to consultants, precast manufacturers and contractors to enable these organisations to comply with the relevant and current documentation that accompanies the design of concrete structures to BS 8110:1997, Structural use of concrete. Structural Use of Concrete – Part 1: Code of practice for design and construction; Part 2: Code of practice for special circumstances; Part 3: Design charts for singly reinforced beams, doubly reinforced beams and rectangular columns.

It is intended that the tendering companies will provide their own complementary specification where necessary, but that the non-contradictory background for the contracts will be based on this specification.

1.2 Scope of the Document

This specification is for low to medium rise multi-storey precast concrete skeletal and wall frame structures of undefined extent and use. Low rise buildings are typically up to 4 storeys, in which the robustness of the structure may be provided by the indirect method of providing stability ties alone. Medium rise buildings are typically up to 15 storeys, in which the horizontal stability of the structure can usually be designed using precast elements alone, unless the PCE chooses to use insitu concrete cores. The robustness may be provided by stability ties or the building should be designed in accordance with the requirements of the 'alternative path approach', i.e. the notional removal of each supporting element. Whilst the specification covers design and construction matters for buildings of greater height, it does not address such as torsional stiffness, dynamic response, etc. associated with tall buildings.

The specification includes the background requirements for a range of precast concrete elements, connections and associated methodologies for achieving robustness and temporary and final stability in these structures. Although the manufacture and erection of specialist products, such as proprietary hollow core and double-tee floor units, are covered by this specification the PCM and PCE reserve the right to substitute their specification and/or amend this specification because of the close relationship between design, manufacture and erection.

The specification includes the basic specifications for materials and design procedures, manufacturing methods from raw materials to delivery, and site installation and erection methodologies, in addition to the requirements of installation equipment.

1.3 Main Objectives

The aim of the specification is to produce a consistent approach to the manner of design, manufacture, concrete mix design, and erection, without imposing restrictions on designers, manufacturers and contractors in their mode of operation.

The objectives are:

(i) To provide PCE's with key information and references to the appropriate British Standards and Product Standards, and details of aspects of design to be included.
(ii) To provide PCM's of precast concrete elements (all components, units and slabs) with information and references for manufacture, handling and storage.
(iii) To provide contractors, sub-contractors and specialist suppliers with key information and references towards aspects of installation and frame erection to be included.
(iv) To understand the relationships between the designer, manufacturer and contractor through process engineering in both directions of information transfer.

1.4 Definitions and Notation

The main personnel and organisations are listed here. Although the architect, client or developer are not specifically included in this list, their role is acknowledged in the text where relevant.

Precast Consulting Engineer (PCE)
Precast Concrete Detailer (if different from the Precast Consulting Engineer) (PCd)
Precast Concrete Manufacturer (PCM)
General Contactor (GC)
Precast Erector (PE)
Sub Contractor to the PE (SC-PE)
Specialist Supplier to the PE (SS-PE)
Public Works Engineer, Supervising Officer (SO)

1.5 Health and Safety

It is the responsibility of all relevant parties to ensure that safety and health of the manufacturing plant and construction site conforms to legislations requirement, approved standards, code of practice, guidelines, specifications and contractual requirements. It shall also covers all practices during construction work activities, particularly work activities covered under Occupational Safety and Health Act, 1994, Factories and Machinery Act, 1967 and regulations made under this act such as Factories and Machinery (Building Operations and Works of Engineering Construction) (Safety) Regulations 1986, and Factories and Machinery (Safety, Health and Welfare) Regulations, 1970. For the purpose of terms and references, the following Acts, Regulations and OHS management system standards shall take precedence, Occupational Safety and Health Act, 1994 (Act 514) and Regulations, Factories and Machinery Act, 1967 (Act 139) and Regulations and Rules, OHSAS 18001: 2007, MS 1722: 2005 and ILO OHS MS: 2001.

1.6 Liabilities

While the author and publisher have used their best efforts in preparing this specification, they make no representations or warranties with respect to the accuracy or completeness of the contents of this specification and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the author nor publisher shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

1.7 Background Information

During the past 25 years, since the development of modern design and manufacturing techniques, the design and construction of precast concrete buildings in Malaysia has been carried out in an *adhoc* manner by either by:

(i) bona fide precast concrete construction companies, with in-house design and detailing expertise and facilities, or using structural consultants with a broad or limiting range of experience in precast construction, or
(ii) public works department engineers using commercial producers and contractors.

During this time the projects have been executed using bespoke techniques in design and construction, according to the PCM's preferred mode of operation. This has lead to a wide range of methods of design, manufacture and construction, such that it has been difficult to self regulate the industry and imposed a standard set of regulations, or indeed recommendations, for the PCE to follow and PCM to work to.

1.8 Format of the Document

The document follows the process of design, materials, manufacture and construction in four dedicated chapters. Each section and sub-section has been written in a manner for cross referencing design calculations, material specifications, production methods and on site erection methods. Each section refers to the appropriate British Standard BS EN or BS (if BS EN does not exist) or Product Standard.

Chapter 2 deals with the basis for design according to BS 8110, Parts 1 to 3, with reference to BS 5950 on steelwork and Product Standards where appropriate. The chapter is not intended to provide the blue-print for design, but to issue strict guidance to the aspects of design that should be included and not ignored.

Chapter 3 is standard documentation for specifying reinforced and prestressed concrete materials, associated fittings and connections, and some non cementitious materials.

Chapter 4 provides information for producers, focusing on the key aspects of precast manufacture, preparation, tolerances, finishing and quality control. Many of these clauses will already be familiar to producers, and whilst some of the clauses will be outside the scope and practice of some producers, the chapter provides the minimum requirements.

Chapter 5 gives the required best practice for the preparation and erection of precast components and structures, including connections, cast insitu work, permitted deviations, propping, temporary stability, inspection and making good.

Chapter 2 – Design and Detailing

2.1 Codes of Practice and Standards

All precast concrete manufactured and site work carried out shall be designed according to BS 8110:1997, Parts 1, 2 and 2. Gravity and imposed loads shall be according to BS 6399-1:1996, BS 6399-2:1997 and BS 6399-3:1988. Additional items for the design of steelwork, steel fixtures, etc. shall be according to BS 5950-1:2000. Infill or load bearing masonry as part of the precast structure shall be according to BS 5328:2005. Other relevant codes are given under items in this specification.

2.2 Product Standards

In all product standards, Annex ZA for the methods of CE marking does not apply. CE stands for Conformité Européenne, meaning "European Conformity. CE marking is a mandatory conformity marking for products sold in the European Economic Area since 1993.

2.2.1 Common rules for precast concrete products: BS EN 13369:2004

The design of structural products shall be verified according to BS EN 13369 in relation to conformity, standardisation, inspection, quality control and testing.

2.2.2 Precast concrete products – Hollow core slabs: BS EN 1168:2005 +A2:2008

The design of prestressed concrete hollow core floor units shall be verified according to BS EN 1168 in relation to design of cross section, prestressing requirements, tolerances, special design situations (torsion, shear, lateral load spreading and fire resistance), standardisation, inspection, quality control and testing.

2.2.3 Precast concrete products – Floor plates for floor systems: BS EN 13747:2005 +A2:2010

The design of prestressed concrete floor plates, such as half-slabs, shall be verified according to BS EN 13747 in relation to design of cross section, prestressing requirements, tolerances, standardisation, inspection, quality control and testing.

2.2.4 Precast concrete products – Beam and block flooring: BS EN 15037-1:2008, in 4 parts

The design of prestressed and reinforced concrete beams in beam-block flooring shall be verified according to BS EN 15037-1 in relation to design of cross section, prestressing requirements, tolerances, standardisation, inspection, quality control and testing. The specification for the blocks is given in BS EN 15037-2.

2.2.5 Precast concrete products – Ribbed floor elements: BS EN 13224:2004

The design of prestressed and reinforced concrete ribbed floors, such as double tee slabs, shall be verified according to BS EN 13224 in relation to design of cross section, prestressing requirements, tolerances, standardisation, inspection, quality control and testing.

2.2.6 Precast concrete products – Linear structural elements**:** BS EN 13225**:**2004

The design of prestressed and reinforced concrete columns and beams shall be verified according to BS EN 13225 with regard to tolerances, linearity, mass, strength, stability, fire resistance, durability, standardisation, inspection, quality control and testing.

2.2.7 Precast concrete products – Staircases: BS EN 14843:2007

The design of prestressed and reinforced concrete staircases, stairflights and landings shall be verified according to BS EN 14843 in relation to design of cross section, tolerances, standardisation, inspection, quality control and testing.

2.2.8 Precast concrete products – Wall elements: BS EN 14992:2007

The design of reinforced concrete walls, such as solid or cavity insulated units, shall be verified according to BS EN 13224 in relation to design of cross section, tolerances, standardisation, inspection, quality control and testing.

2.3 Limit State Design

2.3.1 Characteristic and notional loads

Characteristic loads for dead G_k, live Q_k, wind W_k, accidental A_k and prestressing P_k used in design will be taken from BS 6399 as follows, or from the Architect's specification or drawings. Imposed gravity loads shall be according to BS 6399-1 and BS 6399-3. Permitted reduction factors for live loads in multi-storey buildings or large floor areas are according to BS 6399-1. Loads will be shown on tendering documents.

BS 6399-1:1996. Loading for buildings. Code of practice for dead and imposed loads.
BS 6399-2:1997. Loading for buildings. Code of practice for wind loads.
BS 6399-3:1988. Loading for buildings. Code of practice for imposed roof loads.
Note that these documents have been withdrawn by BSI and are no longer maintained.

A notional horizontal load shall be according to BS 8110-1, Section 3.1.4.2 at the ultimate limit state.

2.3.2 Temporary loads with propping forces and back-reactions

Precast elements shall be designed for the temporary situations due to demoulding, handling in the stockyard, storage and support conditions, transportation to site, hoisting and assembly. The minimum mean compressive cube strength of concrete at each stage shall be given in the specification that should be according to BS 8110-1, clause 6.2.11.

Effects of construction methods shall be according to clauses 5.1.3 and 5.4.2 to 5.4.5. Allowances for construction traffic and other imposed loads during frame erection should be according to BS 6399-1, and specialist literature for horizontal wind loads acting on the partially complete structure. Bearing stresses due to accidental displacement at supports during erection should be assessed to clause 5.2.3.6 and 5.2.4.

Imposed loads due to the combined storage of materials, precast concrete elements and construction traffic, together with the loads due to back propping of elements above shall be assessed. Maximum allowances in the form of allowable load per unit area, or point load per element, shall be given to various parts of the structure and this shall be specified on the construction drawings.

2.3.3 Simplified load patterns and sub-framing

The combination of loads on different parts of a structure shall be according to BS 8110-1, clause 3.2.1.2.2 to enable the critical design conditions for the structure, or part thereof, taking into consideration the dead and temporary imposed load during construction prior to the completion of the structural frame. Sub-framing techniques according to clause 3.2.1.2.1 to 3.2.1.2.5 may not be appropriate prior to the completion of the structural frame.

Load patterns in slabs supported on walls or beams shall be according to either BS 8110-1, clause 3.2.1.2.2 or, in the case of continuous spans one-way spanning solid slabs provided with a structural shear key or a structural topping or screed, according to clause 3.5.2.3.

Effective widths for isolated point or line loads parallel with the span of one-way spanning solid slabs, or landings subjected to edge loads from stairs, may be assessed according to BS 8110-1, Figure 3.6.

2.3.4 Lateral load distribution to adjacent elements

Imposed dead and live loads acting on discrete precast concrete floor units, solid or voided, that are connected by a shear key to permit transfer of shear forces between the units, should be considered according to BS 8110-1, clause 5.2.2.2 and with a structural topping to clause 5.2.2.3.

2.3.5 Lateral distribution of section properties to adjacent elements

Lateral distribution of section properties (such as the reduced cross-section at a hole in one unit) in discrete precast concrete floor units that are connected by a shear key to permit transfer of shear forces between the units, should be considered acting over a width of 3 units, except at a free edge in which only 2 units should be considered.

2.3.6 Accidental loads

The robustness of the structure in resisting abnormal or accidental loads shall be considered according to BS 8110-1, clauses 2.2.2.2, 2.4.3.2 and 2.4.4.2. The strategy in prevention shall be considered as protective measures to eliminate accidental loads, and to ensure structural measures preventing progressive collapse.

This may be achieved either by the identification of ‘key’ elements designed according to BS 8110-2, clause 2.6, or the use of ‘bridging’ elements in an alternative load path design according to BS 8110-2, clause 2.6, or by the indirect method of providing stability ties. Horizontal floor ties, and vertical ties if

necessary, shall be designed according to BS 8110-1, clause 3.12.3, and to the intended use of the building according to Malaysian Building Regulations Uniform Building By-Laws 1984.

2.4 Design Life

The design life shall be specified on calculations. The Malaysia values for design life as present in The Malaysian National Annex to Eurocode EN 1990, clause 2.3, Table NA.1, are as follows

10 years	Temporary structures
10 to 30 years	Replaceable structural parts
15 to 25 years	Agricultural and similar structures
50 years	Building structures and other common structures
120 years	Monumental building structures, bridges and other civil engineering structures.

2.5 Building Utilization

The use of buildings and the category of the use of floors shall be according to the Architect's specification. The intended use of a building, its constituent parts and functions, and as if and when specified or instructed to do so, the anticipated future use of the building or any of its parts shall be considered in the design, such as vertical or horizontal extensions, removal of part of the building, removal of stabilising elements, change of use, and change of function.

2.6 Support Conditions

2.6.1 Bearings

The design of bearings shall be according to BS 8110-1, clause 5.2.3. The calculations shall specify whether a bearing is isolated or non-isolated, and whether bearing materials are used, or a direct bearing with no bearing medium is provided. The number and positions of the points of support should be given, particularly if this is greater than 2 (e.g. multiple bearing shims, 3-line support for one-way spanning slabs, or multi-point fixings for walls or panels).

The construction drawings shall give the nominal bearing length for all elements to BS 8110-1, clause 5.2.3.3, the bearing width of non-isolated elements to 5.2.3.2 and isolated to 5.2.3.5, the specification for the bearing material, and curing times for wet bedding. The nominal bearing width of wide precast elements shall be specified in the calculations. Bearing pressure at concrete-concrete contact surfaces or other bearing materials shall be according to BS 8110-1, clause 5.2.3.4, and at steel nodes to clause 5.3.5.1. Allowances for spalling shall be according to BS 8110-1, Tables 5.1 and 5.2.

2.6.2 Extended bearings

Extended bearings shall be considered not only for compression bearing at the support, but also for the transfer of shear and tension in the precast element. Special attention is required for elements without shear reinforcement, e.g. hollow core floors.

2.7 Fire Design

2.7.1 Definition

The design of precast concrete structures and elements shall be according to BS 8110-2, Section 4. The procedure should take account of the behaviour of the structural framework at elevated temperatures, the effects of heat exposure and cooling, and the effects of active or passive fire protection systems.

2.7.2 Fire rating

Nominal fire exposure shall be specified according to BS 8110-1, Table 3.4 and Figure 3.2 and according to the Architect's specification for the structural integrity of the building and the mechanical resistance of the elements. The minimum fire rating (hours) shall be given in the calculations.

2.7.3 Fire design options

The calculations shall specify the method of verification of fire resistance according to BS 8110-2, Section 4 or BS 8110-1, Figure 3.2 for the minimum requirements for section sizes (e.g. effective thickness of voided or ribbed units) and Table 3.4 for cover distance to reinforcements.

For prestressed hollow core floor units, refer to BS EN 1168, Annex. G. The data in Table G.1 are for siliceous aggregates, but granite, sandstone, greywacke perform no worse.

2.8 Durability

2.8.1 Exposure classification

The requirements for durability of precast concrete structures and elements and exposure classes shall be according to BS8500, Part 1: Table A.1, Table A.2 for concrete in contact with ground water, and Tables A.4 and A.5 for cover, and key mix design parameters.

2.8.2 Cover to rebars and bonded prestressing tendons

Nominal cover distances to reinforcement and prestressing tendons shall be given in the calculations and shown on production drawings, and be according to BS 8500-1:2006 Table A.4 and A.5 for 50 and 100 years design life, respectively (but see item 2.4). Allowance for deviation is according to BS 8110-1, clause 3.3.1.1. Where manufacture is subjected to a quality assurance system, which includes the measurement of cover, it is permitted to reduce the deviation to 5 mm. (Note that the cover distances for exposure classes XS1, XS2 and XS3 have been considerably increased in the UK revision of BS 8500-1:2015.)

The cover distance for low and high humidity, Class XC3 or greater, also applies to the inside surface to exposed (unsealed) voids and cores, such as in hollow core slabs.

2.8.3 Material conformity

The minimum requirements for concrete strength, cement content and maximum water/cement ratio shall be according to BS 8500-1:2006 Table A.4 and A.5, and the cement type according to BS 8500-2:2006 Table 1.

2.9 Building Services

2.9.1 Thermal requirements

The requirements for thermal insulation of the building shall be given in the Architect's specification.

2.9.2 Thermal transmittance R values

If applicable the calculation for thermal transmittance, R_T value (m^2 $^oK/W$), shall be according to BS EN ISO 6946:2007. *Building components and building elements, Thermal resistance and thermal transmittance, Calculation method*. The material data shall be from ISO/DIS 10456.2. *Thermal conductivity of materials*.

2.9.3 Acoustic requirements

The requirements for acoustic attenuation of compartments in the building shall be given in the Architect's specification. The calculation for airborne sound resistance (dB) shall be according to BS EN 12354-1:2000. *Building acoustics. Estimation of acoustic performance in buildings from the performance of elements*, and to BS EN 12354-1, Appendix B2. *Acoustic resistance for superficial mass*.

2.9.4 Dynamic requirements

The requirements for the dynamic behaviour of a part(s) of the structure, or individual elements shall be given in the Architect's specification. For building elements subjected to dynamic loading caused by seismic effects or machine vibration, the impact loading shall be in accordance with BS EN 1990.

2.9.5 Natural frequency of floor systems

In some design cases the natural frequency and resonance behaviour of floor slabs, both as individual units and as part of floor system, including the resonant behaviour of beams, may be required or as requested by the architect and/or client.

In this case these shall be determined according to ISO 10137:2007 *Basis for design of structures - Serviceability of buildings and walkways against vibrations*. If the natural frequency is less than 3 Hz a special evaluation of the floor shall be carried out, considering the planned use(s) for the room. Calculations shall consider the effect of passive and active damping. The maximum elastic static deflection of the floor shall be due to full service dead and 10% of the imposed live load, except for congregation on terraces where 80% of the imposed live load shall be used. The second moment of area uncracked in flexure, and a dynamic factor of 1.2 for Young's modulus shall be used.

2.9.6 Peak acceleration

The peak acceleration of the floor system due to walking shall be calculated, and should not exceed the acceleration limit for the appropriate occupancy according to ISO 2631-1:1997 (published 2011) *Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration - Part 1: General requirements*. The effective width of the floor system shall be the lesser of the width of the floor bay or span of the floor.

2.10 Surface Finishes

2.10.1 Definitions and benchmarking

Surface finishes shall be given on production drawings, and shall be specified according to BS EN 13670:2009 *Execution of concrete structures*, Annex F8.8 and Table F.4. However, the background document to the National Annex to BS EN 1992-1-1, PD6687, states that the provisions of the National Structural Concrete Specification Edition 4:2007 (NSCS-4) are considered equivalent to those in BS EN 13670 for all types.

Until further information available the surface finishes will be as described in NSCS-4, clause 8.6 as formed finishes:

Basic - for ground or foundations;
Ordinary - to receive finishes, but not painted directly;
Plain – visual concrete occasionally seen, to be painted directly;
Special – architectural finishes, controlled for irregularity, arrises, colour variation, blowholes.

This supersedes BS 8110-1, clause 6.2.7.3 although Types A, B and C are almost compatible with *Ordinary*, *Plain* and *Special*.

2.10.2 Visual concrete

Visual concrete is exposed to view, i.e. not covered by finishes, ceilings, cladding, etc. Plain visual concrete for external use where the surface finish has not been specified, e.g. car parks, will be *Plain* finish. Plain concrete for specified use will be *Plain* or *Special* according to the Architect's specification. Architectural visual concrete will be given in the Architect's specification.

2.10.3 Non visual concrete

Non visual concrete is not visible in the final building, and will be *Ordinary* finish.

2.10.4 Concrete to receive structural or architectural finishes

Concrete surfaces required to receive a non-structural sand/cement finishing screed will be *Ordinary* and prepared by tamping with a heavy board leaving ridges of less than 3 mm amplitude.

2.10.5 Concrete at waterproofing surfaces

Concrete surfaces required to receive waterproofing finishes will be Ordinary and prepared using a wood or plastic float.

2.10.6 Structural toppings

Surface preparation for precast elements to receive a structural topping is given in Section 5.14.2.

EN 1168:2005 Annex D does not specify any special surface finish or profile for precast floor diaphragm action.

Chapter 3 – Materials

3.1 Concrete

3.1.1 Strength

Concrete shall be specified according to BS EN 206-1:2000. Concrete - *Specification, performance, production and conformity*. The design strength shall be specified in calculations and on production drawings as the characteristic compressive cube strength, e.g. C40, at the 95% fractile. The strength of concrete at demoulding, or at detensioning in the case of prestressed concrete, shall be specified by the PCE, and approved by the PCM according to manufacturing and handling techniques, using mean compressive cube strengths.

3.1.2 Workability

The workability of the concrete shall be specified according to slump value, except in the case of concrete provided for slip forming or extrusion which has no workability requirements.

3.1.3 Mix design

The PCE shall specify the mix design according to BS EN 206-1:2000, and specify the quantities of cement, aggregates (coarse and fine), water and admixtures & additives. This will be approved by the PCM according to batching, casting, stripping and handling techniques. The PCE will specify, and the PCM will approve the early strength gain expected according to manufacturing methods. The quantity of mixing water, including the use of superplasticisers and self compacting admixtures, shall be the minimum required to ensure the correct workability and strength intended for purpose.

If a new family of concrete mixes is specified, trial mixes will be carried out to the satisfaction of the PCE to demonstrate early handling and 28 day strengths. The number of trials and results will be agreed by the PCE and PCM.

The minimum requirements for strength (N/mm^2), and type CEM 1 cement content (kg/m^3), and maximum water/cement ratio, for 50 years design life, are;

For exposure class up to and including XD1

Grade	Cement	w/c ratio
C25	240	0.70
C30	260	0.65
C35	280	0.60
C37	300	0.55
C40	320	0.55
C45	360	0.45
C50	360	0.45
C55	380	0.35

For exposure class greater than XD1:

Grade	Cement	w/c ratio
C35	320	0.55
C40	340	0.50
C45	360	0.45
C50	380	0.40
C55	380	0.35

3.1.4 Insitu concrete

Insitu concrete shall comply with the requirements of other sections of this specification in terms of materials and workmanship. Insitu concrete will either be mixed on site by the PE or SC-PE, in the latter shall be approved by the PE, or as a prescribed mix supplied as ready-mix from a nominated supplier as approved by the PE according to this specification and BS EN 206-1:2000.

The ready-mix supplier should be certified according to MS 523: Part 1: 2005, Concrete- Part 1: Specification, Performance, Production and Conformity. No extra water or admixtures should be added to the mix prior to delivery. Documentation throughout the contract should be made available to the PE. The PE retains the right to inspect the ready-mix plant and storage of raw materials, and has the right to amend the specification or cancel the supply according to MS 523: Part 3:2010, Concrete-Part 3: Constituent materials, production, transportation and conformity requirements.

The following information should be given in either the construction drawings or Work Method Statement:

Grade - compressive cube strength at 28 days
Compressive cube strength at 3 days
Workability (slump in mm)
Maximum size of coarse aggregate
Additives

A slump test shall be carried out at the commencement of delivery, but not taking concrete from the first 50 kg, according to BS EN 12350-1:2009: *Testing fresh concrete. Sampling*. The slump should be within ±25 mm of the design value. The result should be recorded and made available to the PE.

3.1.5 Control cubes

Control samples using 150 mm size test cubes shall be taken from site mixed or ready-mixed concrete. The cubes shall be manufactured according to BS EN 12390-2:2009: *Testing hardened concrete. Making and curing specimens for strength tests*, and tested according to BS EN 12390-3:2009: *Testing hardened concrete. Compressive strength of test specimens*. Proprietary steel moulds should be used (not manufactured on site). Surface saturated density shall be determined according to BS EN 12390-7:2009 *Testing hardened concrete - Density of hardened concrete*.

Samples shall be taken at the rate of 5 cubes per batch, or 6 m^3, whichever is the least*. Any reduced sampling rates proposed by the PCM shall be approved by the PCE. The date, time and temperature should be recorded.

The cubes should be kept on site for 24 hours and protected against rain and direct sun using an appropriate material. The cubes should be stripped, marked, wrapped to avoid moisture loss and

transported to an independent laboratory for testing at 24 hours (1 cube), and 7 and 28 days (2 cubes each).

The results should be made known to the PE at 24 and 72 hours before formwork, or props to permanent formwork, is removed. If the strength at 72 hours is less than given on construction drawings the PE should postpone removal of formwork until a further cube test result gives adequate strength. The PE should report to the PCE strengths at any age less than given on construction drawings, or densities less than 2250 kg/m^3, to enable further evaluation of the structural strength and properties.

*In JKR Standard Specifications for Building Works 2005, the sampling rate varies according to structural element and does not adopt a one-all approach as above. For example, the more critical structural elements (columns, etc) require **one sample per 10.0 m^3 or every group of 10 batches** while for beams **one sample per 20.0 m^3 or every group of 20 batches** is needed. From the sample, one cube is subjected to a 7-day compressive strength test while the remaining 2 cubes are subjected to a 28-day compressive strength test.

3.2 Mortars and grouts

3.2.1 General

Mortar is a sand-cement mix used for small infill and semi-dry packing of joints. The sand is typically graded at 0/4 mm, but may include 6 mm pea gravel for joints wider than 50 mm. BS EN 13139 lists the preferred sizes of aggregates for mortar as: (min/max) 0/2 mm, 0/4 mm, 2/4 mm and 2/8 mm. Sieve sizes and other information is according to PD 6682-3; *Aggregates for mortar- Guidance on the use of BS EN 13139*.

Grout is either a cement-water mix or a mortar mix used for infilling at joints and gaps. Grout may be used as dry pack, but may also contain admixtures such as non-shrink or expansive agents, latex bonding, or be a polyester grout or equivalent, added according to manufacturer's instructions.

The producer shall specify the mix design according to BS EN 206-1:2000, and specify the quantities of cement, fine aggregates, water and admixtures & additives.

3.2.2 Strength

The strength of mortars and grouts will be as specified on construction drawings or in the method statement, but in compression is generally not less than the parent material at the joint, but in other cases such as longitudinal joints between slabs in shear may be less.

The function of grout should be shown on construction drawings as either "structural" or "non-structural" infill. Structural grout includes the protection of precast elements or connections in which its integrity is necessary to ensure the correct structural function, including fire resistance and durability protection. Control cubes should be taken for structural grout. Non-structural grout serves no such function.

3.2.3 Workability

The workability of mortar is classed as "very low" with no slump. The workability of grout is as specified on construction drawings or in the method statement, and may be "high" with 100-150 mm slump.

3.2.4 Dry pack

Dry pack mortar or grout may be used where it is not possible to pour grout. The grout has a water/cement ratio of about 0.25-0.30 and is therefore mouldable in the hand. It should be placed by hand and trowel and hammered into position, which removes free air. It may be either “structural” or “non-structural” as above, but it is not possible to make control cubes.

3.3 Cement

3.3.1 Types and specifications

Cement shall be classified according to BS 8500-2:2006, Table 1. Cement type shall conform to BS EN 197-1:2000. *Cement - composition, specifications and conformity criteria for common cements*. The grade of cement (e.g. 42.5R, 52.5N) shall be appropriate to the required cube strength and time to demoulding or transfer of prestress.

3.3.2 Blended cements

Blended cements, if appropriate, shall conform to BS EN 197-1:2000, or if blended with ground granulated blast furnace slag (type IIIA or IIIB), to BS EN 197-4:2000, *Cement. Composition, specifications and conformity criteria for low early strength blast furnace cements*.

3.4 Aggregates

3.4.1 Types and specifications

EN 206-1:2000, clause 5.1.3 states that normal weight coarse aggregates from natural land sources shall conform to BS EN 12620:2002, *Aggregates for concrete.* Sea dredges aggregates shall not be used. The PCM shall supply the sources of all aggregates and suppliers name(s) for each category stored. Aggregates should be free from impurities, such as pyrites, which may cause surface defects.

3.4.2 Conformity

The moisture content of the aggregates shall be measured according to BS EN 1097-6:2000, *Tests for mechanical and physical properties of aggregates*, and should not be influenced after heavy rain. Samples should not be taken from the base of the stock pile. BS EN 206-1:2000, clause 5.5.2 states that normal weight aggregate shall have an oven-dry density between 2000 and 2600 kg/m^3.

EN 206-1:2000, clause 5.2.7 states that aggregate chloride content shall be ≤ 0.2% by mass of cement. Chloride content shall be certified by the aggregate supplier, both in bulk or in bags.

Aggregates shall be checked for reactive silica content, which may cause alkali silica reactions with cement and shall remain below a threshold value that has to be carefully experimentally assessed by the aggregate supplier. If this is not satisfied a low alkali cement with less than 0.75% alkalis may be used such that the total alkali content of the concrete is less than 3 kg/m^3 [ref Hawkins].

3.4.3 Storage

Aggregates shall be stored in separate, graded stock piles. The storage area shall be laid on a firm, impervious bed, laid to fall to facilitate drainage of surface water. The stock pile should preferably be covered to control direct sun light and rain.

3.5 Admixtures

3.5.1 Types and specifications

Admixtures shall comply with BS EN 934-1:2008, BS EN 934-2:2009+A1:2012 and BS EN 934-3:2009+A1:2012. *Admixtures for concrete, mortar and grout*. The precast manufacturer shall declare the use and dosages of all admixtures and provide certificates of conformity. Dosages are permitted not be within the range given in proprietary data sheets providing that the performance of the concrete is verified by the PCM or, in the case of supply only, by the supplier of the concrete.

Calcium chloride shall not be used as an admixture. Reference shall also be made to BS 8443:2005, *Specification for establishing the suitability of special purpose concrete admixtures* not covered by BS EN 934-2.

3.5.2 Superplasticisers

EN 206-1:2000, clause 5.1.5 states that superplasticisers, excluding SCC, may be used and shall comply with BS EN 934-2:2009+A1:2012, clause 4.2, Table 2 as a water reducing agent where total air content < 6%. Superplasticisers should comply with the testing standard BS EN 480-1:2006+A1:2011, *Admixtures for concrete, mortar and grout. Test methods. Reference concrete and reference mortar for testing*.

3.5.3 Self compacting concrete (SCC) admixtures

Self compacting admixtures shall comply with BS EN 206-9:2010, *Concrete - Additional rules for self-compacting concrete*. Note that BS EN 206-9 does not cover health and safety requirements for the protection of workers during production of SCC.

3.5.4 Air entrainment agents

BS EN 206-1:2000, clause 5.1.5 states that air entrainment agents may be used and shall comply with BS EN 934-2:2009, clause 4.2, Table 2 as a water reducing agent where total air content < 6%.

3.6 Water

3.6.1 Specifications

EN 206-1:2000, clause 5.1.4 states that mixing water shall conform to BS EN 1008:2002, *Mixing water for concrete* clause 3.1. Mixing water shall be potable from land sources. No sea water is permitted.

Water reclaimed from cement slurry must be filtered and that the cement content is calculated and known from the specific gravity of the filtered slurry.

3.6.2 Crushed ice

Crushed ice may be used to replace 50% of the mixing water, or according to the PCM's specification. The maximum particle size for crushed ice shall be not more than about 20 mm. No particles of crushed ice shall be visible in the final concrete as mixed.

3.7 Reinforcement

3.7.1 Specifications

Hot rolled reinforcing steel bars shall conform to BS EN 10080:2005, *Steel for the reinforcement of concrete*.

3.7.2 Hot rolled high tensile and mild steel bars

Characteristic strengths of reinforcement are given in BS 4482:2005, *Steel wire for the reinforcement of concrete products*, and are as shown in BS 8110-1, Table 3.1.

High tensile steel bars shall conform to BS EN 10080:2005 as ductility classes B500A, B500B and B500C (the latter is used as for grade B500B). The technical specification is according to clause 7.2.3. The supplier shall provide rolling certificates giving the above information such that the grades conform to the three recommended ductility classes. Grade 460 reinforcement may be used according to BS 4449:2005, BS 4482:2005 and BS 4483:2005 in order to fully specify requirements.

Reinforcement details shall conform to BS EN ISO 3766:2003. *Construction drawings. Simplified representation of concrete reinforcement*. Shape codes shall conform to BS 8666:2005, *Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete*.

3.7.3 Welded mesh

This should conform to BS 4483: 2005, *Steel fabric for the reinforcement of concrete*. A98 and B196 mesh do not conform to the strength of welded joints required in BS 8110-1, clause 3.2.5.

3.7.4 Stainless steel bars

Stainless steel for reinforcement shall conform to BS 6744:2001, *Stainless Steel Bars for the Reinforcement of and Use in Concrete*. Other requirements shall be according to BS EN 10088-5:2009, *Stainless steels. Technical delivery conditions for bars, rods, wire, sections and bright products of corrosion resisting steels for construction purposes*.

The yield strength shall be specified as R_e = 500 N/mm^2. R_m/R_e = 1.10. For non chloride exposure the grade shall be at least 1.4301 (was BS 6744 grade 304), otherwise grades 1.4401 or 1.4436 shall be used (was BS 6744 grade 316).

Stainless steel mesh fabric shall conform to BS 4483:2005.

3.7.5 Non ferrous bars

Hot-dip galvanized reinforcing steel shall conform to BS EN ISO 1461:1999 *Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods*.

3.8 Prestressing Tendons

3.8.1 Specifications

Prestressing tendons shall conform to BS EN 10138-1. *Prestressing steel - Part 1: General requirements*, and BS EN 10138-2. *Prestressing steel - Part 2: Stress relieved cold drawn wire*.

The relaxation of helical strand comprising of 3 or 7 hot rolled wires, and individual hot rolled plain or Belgian indented wires, shall be according to BS EN 10138 and BS 8110-1 as relaxation class 2. Class 1 is not covered by BS EN 10138.

3.8.2 Indented, plain and ribbed wire

Plain and indented wire of 5 and 7 mm diameter, and ribbed wire of 9 mm diameter may be used. Maximum diameter of wire shall be according to BS EN 1168:2005, clause 4.1.1.1.

3.8.3 Helical strand

Standard 7-wire helical strand of 9.3, 10.9, 12.5 and 15.7 mm diameter; standard 3-wire helical strand of 6.5 mm diameter, and super strand (Dyform) of 9.6, 12.9 and 15.2 mm diameter, may be used. For hollow core floor units, the maximum diameter of strand shall be according to BS EN 1168:2005, clause 4.1.1.1.

3.9 Structural Steelwork

3.9.1 Specifications

There may be cause to design and construct in structural steelwork, both as isolated elements or as sections cast into the precast elements (item 3.9.3).

Structural steelwork shall conform to BS EN 10025-1:2004 *Hot rolled products of structural steels. General technical delivery conditions*, and shall be designed according to BS 5950-1. The grade of hot rolled structural steel shall be S275 (f_y/f_u = 275/430 N/mm^2), S355 (355/510) or S450 (440/550) according to BS EN 10025-2:2004. The grade of rectangular hollow sections shall be S275H (275/430) or S355H (355/510) according to BS EN 10210-1:1994, *Hot finished structural hollow sections of non-alloy and fine grain structural steels – Part 1: Technical delivery requirements*.

Where steel with improved through-thickness properties is necessary, for example for beam-column connections made from full steel billet/sections, steel should be used according to the required quality class in BS EN 10164:2004, *Steel products with improved deformation properties perpendicular to the surface of the product.*

The steel process and specification shall be supplied by the manufacturer, including product analysis, carbon equivalent, yield strength, tensile strength, stress v strain data, elongation.

3.9.2 Exposed steelwork

Exposed steelwork should be cleaned by blasting to BS EN ISO 8501-1 to standard SA2, where most of the mill-scale rust and paint etc. are removed and any remaining is very well adhered, or may be by hand powered tools to standard ST2, with poorly adhering rust, mill-scale etc. are removed, leaving surface contamination that is well adhered. BS EN ISO 8501-3 is used for cleaning edges and at welds.

Steelwork shall be coated with zinc phosphate high performance metal primer, at a minimum quantity of 0.1 litres per m^2 to give a mean dry coating thickness of at least 0.08 mm, or polyamide cured epoxy primer, to give a mean dry coating thickness of at least 0.08 mm. Chlorinated rubber primer with a high degree of corrosion resistance may be used for use in aggressive environments.

3.9.3 Steelwork cast in concrete

Steelwork entirely cast in concrete should be cleaned by blasting to ISO 8501-1 to standard SA1, where poorly adhering mill-scale, rust and old paint and foreign matter are removed, but well adhered contaminants remain. No primer shall be used. Boundaries with exposed steelwork should be shown on production drawings.

3.10 Cast-in Fixings

3.10.1 Types and specifications

Cast-in fixings, such as threaded sockets, lifting loops and sockets, spherical head anchors, rotating anchors, flat steel, double wall and tail anchors, etc. should be specified and used according to manufacturers' instructions, including edge distances, depth of embedment, anchorage reinforcement, concrete strengths, etc.

Bespoke lifting devices cast into concrete may be designed and manufactured by the PCM or PE. Load tests should be carried out according to BS 5080:1993, *Structural fixings in concrete and masonry - Part 1: Method of test for tensile loading* and evaluated according to BS EN 1990, Part 1.

3.10.2 Lifting devices

Lifting systems should be designed according to intended use, and the mode of lifting, e.g. tilting, flat, vertical, number of lifters and angle of lifting chains, concrete strength, element dimensions, type of lifting equipment, speed of lifting, and ground conditions.

Spherical head lifting anchor and plate anchors are available in steel minimum grade S355 or stainless steel 304 or hot dip spun galvanized. Anchors should be manufactured in accordance with ISO 9001, batch checked and tested by an independent testing house. The anchorage requirements, in terms of concrete lifting strength and anchorage methods, and the safe working load should be used by the PCM. Rubber, steel or magnetic recess formers should be supplied with the anchor.

Lifting loops should be manufactured using galvanised steel wire minimum grade S500, and be supplied with anchorage.

Alternative polypropylene loops may be used where steel is not appropriate. Care should be taken not to pass the loop over sharp edges.

Anchors should have a minimum factor of safety of 3. The factor of safety against concrete failure shall be taken as 2.5.

3.11 Welding

3.11.1 Specifications

Welding shall conform to BS EN 1011-1:2009, *Recommendations for welding of metallic materials. General guidance for arc welding*. Welding equipment shall conform to BS EN 60974-1:2005, *Arc welding equipment*. This supersedes BS 5135.

Welding equipment shall conform to BS EN 60974-1:2005, *Arc welding equipment. Welding power*, and may use proprietary plant such as Murex, Thermadyne, Rand, Migatronic, Cebora, etc. The plant should have variable output between 10 and 250 amps direct current. This BS was published in January 2006, but is currently being revised.

Welding shall be carried out using persons qualified according to BS EN ISO 14731:2006, *Welding coordination: Tasks and responsibilities* – the UK's upgraded implementation of ISO 14731, replacing BS 719. This defines the job specifications for all welding personnel, and includes a summary of the tasks and responsibilities associated with each job description. The allocated responsibilities for each role are assigned according to a staff member's position in the welding organisation, and consider the level of authorisation needed to fulfil their tasks, such as procedure specification and supervision reports.

3.11.2 Electrodes

All welding electrodes shall conform to BS EN 1011-2:2001, *Arc welding of ferritic steels*, and BS EN 1011-3:2000, *Arc welding of stainless steels*. Rod sizes should vary between 2.5 and 6 mm.

3.11.3 Welding to rebars and cast-in fixings

Welding of ferrous reinforcing bars and ferrous cast in fixings, such as plates, rolled and hollow steel sections shall use either metal inert gas (MIG) welding or metal active gas (MAG) welding. The welding electrode rods for high tensile bar shall be low hydrogen type electrodes to cover a wide range of applications for welding carbon manganese and low alloy steels.

3.11.4 Butt and fillet welds

All welds are to be fully fused fillet welds to make lap joints, corner joints, and T joints, having a convex profile, may be either continuous or intermittent. Rebar T-joints, i.e. bars of equal diameter crossing at right angles, should be a flared V groove weld. Butt welds may be used along a single edge in a single plane. The throat thickness of the weld, run-out lengths, under cutting, cracks, inaccuracies of position, shall be inspected for compliance, recorded and if necessary rejected.

When thicker materials are welded, the edges must be bevelled to form a single or double V-groove. No back up weld or backing strip is required.

The required standards for fillet and butt welds depend on their location, and are given in BS EN 1011-1:2009.

3.11.5 Post weld heat treatment

Preheating is not required, and post weld heat treatment is normally not required unless specified on the production drawings.

3.11.6 Site welding

Site welding shall be carried out using persons qualified according to ISO 14731:2006. *Welding to mild steel and high tensile fixings shall be by manual metal arc processes*.

An intermediate reinforcing bar shall be provided in V grooved butting joints. The diameter of the bar shall be equal to 0.7 x the depth of V groove.

3.12 Bolting

3.12.1 Specifications

Metric bolts, set screws and nuts shall conform to BS 3692:2001, *ISO metric precision hexagon bolts, screws and nuts. Specification*, and washers to BS 4320:1968, *Specification for metal washers for general engineering purposes. Metric series*. These are current documents with no BS EN.

The minimum diameter for a structural bolt or threaded rod should be 12 mm.

Clearance holes should not be more than 2 mm greater than the nominal bolt or rod diameter. Holes should not be enlarged.

3.12.2 Contact surfaces

Mating surfaces shall be cleaned to standard SA2, where most of the mill-scale rust and paint etc. are removed and any remaining is very well adhered, and (excluding HSFG bolts) shall receive zinc or lead paint or similar priming unless the fixing is to be cast in concrete.

3.12.3 Black bolts

Strength grades for carbon steel should preferably be limited to Grade 4.6, 5.6, 6.8, 8.8 (both ≤ 16 mm and > 16 mm) and 10.9. Grade strength of nuts shall be 4, 5, 6, 8 and 10, respectively. Strength classes of stainless steels bolts and screws shall be 50, 70, 80 and 100.

3.12.4 High strength friction grip bolts

High strength friction grip bolts (HSFG) shall conform to BS 4395-3:1973, *Specification for high strength friction grip bolts and associated nuts and washers for structural engineering. Higher grade bolts (waisted shank), nuts and general grade washers*. Grade 8.8, 10.9 and 12.9. Preloading of HSFG bolts shall conform to BS EN 14399-1:2005, *High-strength structural bolting assemblies for preloading. General requirements*. HSFG bolts shall be tightened using power tools showing specified torque, or be tightened by hand using spanners according to the load indicating washer. Hand spanners are in accordance with BS 2583:1955, *Specification for podger spanners* (No BS EN).

3.12.5 Threaded rods

Threaded rods shall conform to the requirements of set screws.

3.12.6 Cast-in sockets and anchorage

Cast-in sockets do not have a BS EN, but are specified according to manufacturer's details. The grade may be 4.6 or 8.8, and may be stainless steel or bright zinc plated (ref UK manufacturer) to BS 7371-12:2008, *Coatings on metal fasteners. Requirements for imperial fasteners*.

Cast-in channels do not have a BS EN, but are specified according to manufacturer's details. The grade of steel may be S235 or S275, and be hot dipped galvanised to BS EN ISO 1461, or pre-galvanised grade Z275 (according to manufacturer's details as the BS for this is withdrawn). Stainless steel channels may be grade 1.4301. Anchors attached to the back face shall, edge distances and spacing comply with the manufacturer's details. T head bolts may be hot rolled steel in grade 4.6 or 8.8 or stainless steel.

3.12.7 Tightening

Tightening of bolts shall be by power tool only. The thread should project at least 2 turns beyond the nut. The torque should be applied as follows

Diameter	Grade 4.6 to 5.6 (Nm)	Grade 8.8 or more (Nm)
M30	400	
M27	300	500
M24	200	500
M20	120	300
M16	60	150
M12	25	70

3.13 Synthetic materials

3.13.1 Specifications

Concrete substrates must be prepared either by use of scabbling, grit blasting or needle gunning, or similar, and surfaces contaminated with oil or grease require suitable preparation such as steam cleaning in conjunction with a suitable detergent.

3.13.2 Epoxy resins

Epoxy resins shall conform to BS ISO 18280:2005, *Plastics. Epoxy resins*. They may be used as structural adhesives for connections, together with the requirements for confinement and ductility using reinforcement crossing the joint line. They may be used as the chemical for resin anchor bolts according to the proprietary information given by suppliers.

3.13.3 Acrylics

Acrylic-polymer modified cementitious materials, such as high build structural repair mortars, may be used for repair and infilling in joints of minimum width according to manufacturers requirements, typically 50 mm.

Chapter 4 – Manufacture

4.1 Moulds

4.1.1 Types

Steel, concrete, timber or other suitable forms such as fibreglass or resin based or coated materials shall be used. The moulds shall be capable of resisting all loads to which they are subjected to during the manufacture process, including handling and vibrating of concrete. They should be stiff enough to ensure that the tolerances specified for the elements are maintained throughout the life of the mould such that the integrity of the element is not affected. The function, appearance and durability of the elements shall not be impaired or damaged due to the performance of the mould. Joints shall be sufficiently tight so as to minimize loss of fines.

4.1.2 Mould design and manufacture

The design of the mould and other formwork shall be carried out by the precast manufacturer or nominated supplier, to satisfy concrete pressures during the casting, curing and demoulding cycle, allowing for lifting and tilting where necessary.

Steel moulds shall be manufactured using mild steel plate minimum grade S275 or locally equivalent.

Timber mould shall be manufactured using softwood timber of grade C18 minimum according to BS EN 338:2003, *Structural timber – strength classes,* or equivalent in terms of orthogonal strength and stiffness properties if an alternative grading system is used.

Concrete moulds shall be manufactured from patterns using concrete of minimum compressive cube strength 50 N/mm^2, using 10/4 mm coarse aggregate. Sodium silicate may be used for hardening the surface, or a surface lining may be used.

4.1.3 Accuracy

The accuracy of the mould, or formwork, shall be determined by the precast manufacturer, who may use experience to build the mould to dimensions outside standard tolerances in the knowledge that the as cast element will achieve conformity.

4.1.4 Maintenance

After use, the mould should be brushed and scraped free of concrete and grout fragments, and damaged surface repaired to the same standard as the mould. The surfaces should be treated with the release agent as follows.

4.1.5 Preparation and oiling

The mould shall be treated by painting or spraying mould oil (release agent) according to BS EN 13670:2009, *Execution of concrete structures*, clause 5.5.2. There is no Standard for the release agent

itself. The type shall depend on the surface nature of the mould. Approved release agents for steel and timber moulds include: polymer liquid wax, silicon-calcium spray, natural oil with surfactant, and chemical release agents. For concrete moulds water based release agents are approved. The coverage, usage, shelf life, application, etc. shall be according to the supplier's instructions.

In hot weather preparation, the surface of the mould shall be protected from direct sun rays to prevent absorption of water from fresh concrete. The surface of the mould shall be protected from rain and no free standing water shall be allowed.

4.2 Reinforcement Cages

4.2.1 Bar bending

Bending of reinforcement shall be according to BS 8666:2005, Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete. *Bar bending should be carried out in a sheltered environment. Bars should not be bent if raised to a temperature exceeding 100^{o}C. Bar bending after the fabrication of the cage is not permitted, except with the approval of the PCE, or where mild steel bars need to be bent on site to avoid collisions or obstructions.*

4.2.2 Positioning and cover

The accuracy of the position of bars in the cage shall conform to the tolerances in BS EN 13670, *Execution of concrete structures*, Section 10 and Annex G (supersedes BS 8110-1, clause 6.2.8.3) but should not be greater than

Cover to exposed edges and ends: ±5 mm
Cover to ends with protection: ±10 mm
Distances between stirrups: ±25 mm

The cover to the all bars, including links and secondary bars, but excluding bars provided for handling purposes only, shall be according to the production drawing, given as a nominal cover.

Spacers and chairs should conform to BS 7973-1:2001, *Spacers and chairs for steel reinforcement and their specification. Product performance requirements*, and BS 7973-2:2001*, Spacers and chairs fixing and application of spacers and chairs and tying of reinforcement*, and should not be hand made (e.g. grout blocks).

4.2.3 Tying

Ties between rebars shall be black annealed tying wire, 17 gauge (1.4 mm) or galvanised iron wire of similar specification. Wire loop ties may be used as 16 gauge (heavy duty) or PVC coating (for use with polymeric or epoxy coated steel). For stainless steel rebars, tie wire shall be stainless steel annealed wire 18 gauge (1.2mm).

4.2.4 Welding rebars

Unless otherwise specified in the contract specification, welding of reinforcing steel, and welding of reinforcing steel to structural steel, in load bearing joints shall be in accordance with BS EN ISO 17660-1:2006, *Welding of reinforcing steel - Part 1: Load-bearing welded joints*. The processes used are shielded metal arc, gas metal arc. The welding electrode rods for high tensile bar shall be low hydrogen type electrodes to cover a wide range of applications for welding carbon manganese and low alloy steels. Spot welding of non-load-bearing bars is according to BS EN ISO 17660-2:2006, *Welding of reinforcing steel - Part 2: Non-load-bearing welded joints*. See also BS EN 13670:2009, *Execution of concrete structures*, clause 6.4.

4.2.5 Cast-in fixings and lifting devices

Cast-in fixings (or fittings) do not have a BS EN, but are specified according to manufacturer's details. They may be proprietary or bespoke, and include cast-in sockets, channels, plates, wall anchors, rolled hollow sections, façade fixings, balcony connectors, staircase and brickwork supports. Proprietary systems are validated by testing. Bespoke systems should be similarly tested for compliance. See also BS EN 13670:2009, *Execution of concrete structures*, clause 5.6.

Cast-in lifting devices should be proprietary systems with proven testing in all situations. These include socket and eye systems, spherical head anchors, cast-in rebar and wire rope loops.

4.3 Prestressing

The PCM of prestressed concrete units shall submit technical details of all materials, pretensioning techniques, concreting methods, curing, quality control, handling and storage to be used. These should include tendon extension calculations, jacking requirements, anchorages, pull-in and relaxation calculations, and detensioning methods.

4.3.1 Tendons

Tendons, such as 3-wire or 7-wire helical strand, or plain or indented wire, shall be certified by the manufacturer who shall provide rolling certificates of the ultimate tensile strength f_{pk} and 0.1% proof strength $f_{p0.1}$, Young's modulus E_p, nominal cross sectional area A_p according to BS EN 10138-1. *Prestressing steels. General requirements*, BS EN 10138-2. *Prestressing steels. Wire*, and BS EN 10138-3. *Prestressing steels. Strand*. The specified relaxation R_{1000} of the tendons at 1000 hours shall be according to Class 2 in BS EN 10138 and BS 8110-1, clause 4.8.2.1.

Sample of tendons shall be taken by the PCM for testing by an independent testing laboratory to be nominated by the manufacturer at the approval of the PCE. The sampling rate shall be agreed by both parties but not be less than 1 m per 2000 m, or 2 samples per coil, which ever is greater. Tests shall be according to BS EN 10138. Results shall include the ultimate tensile strength and 0.1% proof strength and should not be less than f_{pk} and $f_{p0.1}$, respectively. Values of Young's modulus should be within ±10 kN/mm^2 of E_p and cross sectional area within ±2% of the nominal value of A_p. Relaxation shall be within 0.2% points lower than R_{1000}.

4.3.2 Tendon preparation

Tendons shall be stored in a clean environment, on rolled coils raised from the ground, and sheltered from rain and dust in the wind. Records shall be kept of the coils used for each casting.

Steel wires shall be free from pitting rust, but may have surface rusting that could be removed by rubbing using sand paper or similar. It is not necessary to remove such surface rusting. The tendons should pay out from the coils only without twisting, bending or kinking or be prevented from being laid out without interference.

Cutting of tendons shall be by an abrasive cutting wheel or flame cutting. The projection of the tendon from the anchorage to a cut shall be a minimum of 100 mm, and from fraying (if strands) a minimum of 150 mm. The projection of the tendon to the rear of the jacking head shall be according to the manufacturer's specification, but not less than 100 mm. Welding of tendons is not allowed.

4.3.3 Pretensioning operations

The jacking equipment shall be used according to the *equipment manufacturer's* specification, and no substitute parts by other manufacturers shall be allowed. The equipment shall be calibrated at not more than 4 months intervals, or after every 2500 stressing actions, whichever is less, at/by a certified testing laboratory to within an accuracy of ±2.5% of the mean tensioning load from a minimum of 6 measurements.

The above clause may be superceded by the PCM's own certified procedures and standards at the approval of the PCE.

The tendons shall be free of obstructions prior to tensioning. The manufacturer shall notify the sequence of stressing, unless bulk stressing or all tendons is used, and whether tensioning is from one end only.

4.3.4 Stressing limits

The PCM of prestressed concrete units shall submit calculation to show the required extension of the tendons, which would produce a mean stress f_{pmi} not exceeding 0.8 f_{pk} or 0.9 $f_{p,0.1}$ according to BS EN 13369. The rate of tensioning shall not exceed 2% elongation per minute. The elongation shall be accurate to an over-elongation of +7% and -0%.

4.3.5 Slippage and relaxation limits

Anchorages and collets & barrels shall be located on the centre of the tendon, and be secured at the jacking buttress. The jacking pressure shall be released gradually over a duration of at least 5 seconds. The pull-in of the tendon at the anchorage, and the immediate relaxation of the tendon, shall be measured, and shall not exceed the over-elongation. Pull-in of the tendon at the dead end shall be monitored and added to the pull-in at the jacking end.

The force in the tendons shall be measured twice by calibrated tension gauges, such as cross-bows or load cells as appropriate. The cross-bows shall be calibrated annually at/by a certified testing laboratory. If the tension is less than the mean value f_{pmi} A_p the tendon shall be released and re-tensioned.

4.3.6 Detensioning

Detensioning shall not take place until the compressive cube strength of 2 samples achieves the mean detensioning strength. If the cube strength is not satisfactory, a 3rd cube shall be taken after a dwell at the discretion of the manufacturer. Detensioning shall not take place in less than 18 hours unless approved accelerated curing has been specified and/or agreed with the PCE, in which case earlier time is allowed pending cube strength.

The PCM of prestressed concrete units shall notify the method of detensioning. The rate of detensioning shall be not less than 50% of the rate of tensioning, or a duration of 10 seconds, which ever is least.

The anchorages shall be removed, and mould ends moved away from the cast ends without disturbing the concrete around the tendons.

The tendons shall be cut using an abrasive cutting wheel or by flame cutting not closer than 20 mm (50 mm if flame cut) to 100 mm from the cast face. Slippage of the tendons at the cast face shall be monitored and measured to within 1 mm accuracy.

4.4 Concrete Mixing

4.4.1 Aggregate selection

The nominal size of the aggregate should not be greater than the nominal cover minus 5 mm, as specified on the production drawings. The aggregate crushing strength, obtained from a ten percent fines value test, shall not be less than the mean strength of the concrete, equal to the characteristic strength of concrete plus 8 N/mm^2, as specified on the production drawings. The angularity number for the aggregate, obtained from angularity index tests, shall not be greater than 10, or as obtained by the PCM's experience to produce concrete with the correct workability.

Special aggregates selected for architectural concrete finished work shall satisfy the same criteria. The moisture content of the aggregates shall be determined according to BS EN 1097-6:2000, *Tests for mechanical and physical properties of aggregates* in the surface saturated dry condition.

Thermal probes shall be used to monitor the temperature of aggregates, and readings greater than 50^{o}C shall be reported to the batching plant for corrective measures to be taken in the mixing water.

4.4.2 Substitute materials

Recycled concrete aggregate (RCA) may be used as a substitute for natural aggregates up to a maximum replacement of 20% by weight of coarse aggregate not passing a 4 mm sieve. Recycled concrete fine aggregate shall only be used if not passing a 1 mm sieve. Recycled fines as dust shall not be used. The water absorption of all RCA shall be determined according to BS EN 1097-6:2000 in the surface saturated dry condition. The chloride content of all RCA shall be determined according to BS EN 1744-1:2009, *Tests for chemical properties of aggregates - Chemical analysis*, clause 7, and shall not be greater than 0.2% CaCl content by weight.

Recycled crushed brick and mortar, or any other crushed material of unknown parentage, shall not be used as replacement aggregate.

4.4.3 Batching

Batching shall be carried out using electrical scales calibrated by an independent testing laboratory to an accuracy of ±1%. Raw materials shall be batched to ±5 kg/m^3 accuracy for water and cement, to ±10 kg/m^3 accuracy for coarse and fine aggregates, and to ±5% of the volume of admixtures. Admixtures shall be added to the mixing water and not dispensed alone.

4.4.4 Mixing

Concrete shall be mixed in mechanically driven mixers. Hand mixing is not allowed. The speed of mixing and the number of revolutions should be the minimum required to produce uniformity of the mix and ensure aggregates are coated with the cement paste. Approximately half the mixing water should first be added to enable the consistency and temperature of the concrete to be monitored. Only freshly mixed concrete should be discharged. Concrete which is not discharged shall be removed from the mixer and disposed.

Thermal probes shall be used to continuously monitor the temperature of concrete during mixing. Referring to BS 8500-2:2006, clause 5.4, *Concrete – Complementary British Standard* to BS EN 206-1 – Part 2: *Specification for constituent materials and concrete.* The temperature of the fresh concrete at the time of placement shall not exceed the value specified by the PCE and approved by the PCM. The mixer shall be cleaned after each working session.

Zero or low slump concrete will be batched for extruded or slipformed concrete according to the requirements of the manufacturing technique.

4.4.5 Time to deliver at work-piece

Pouring shall take place not more than 20 minutes after the completion of mixing if the mixing is carried out at the PCM's batching plant. For external batching, the concrete shall be placed not more than 20 minutes after the final introduction of the mixing water and any additives. If premature stiffening takes place, and the concrete cannot be deposited with less than 10 mm slump, the concrete shall be disposed. No extra water or admixtures shall be added to recover the workability.

Pouring of SCC shall take place not more than 20 minutes or sooner based on experience of the supplier, after the completion of mixing. If colloidal bridges start to appear around the aggregates, or aggregates will not flow together with the paste, or the flow diameter of SCC is less than 100 mm of the intended value, the SCC shall be disposed. No extra SCC admixture or rheology stabiliser shall be added to recover the flow.

4.5 Placement

4.5.1 Position and height to discharge

Concrete shall not be poured until the reinforcement cage, or tendons, is correctly positioned, with all spacer blocks correctly in place. The position of the bars shall be independently checked. The mould shall be free of dirt and other debris, and not be exposed to rain or direct sun rays. Concrete shall be deposited as close to the work place as possible, and shall not be stock piled away from the work place. If concrete has to be moved manually segregation and surface bleed water shall not be visible before placement.

Concrete shall be delivered in a manner to enable compaction in layers of depths of approximately 250 mm for section depths ≤ 600 mm, or 400 mm if greater depth. The height of discharge shall not exceed 2.0 m without additional aids such as tremie pipes.

Bars and other fixings left projecting from concrete surfaces at day joints shall be cleaned of concrete and grout immediately after casting.

4.5.2 Segregation and disturbance to rebars

Concrete should remain cohesive whilst poured and should not experience segregation of aggregates or excessive bleed water at the surface. Concrete should not displace reinforcing bars or other fixings.

4.5.3 Slump and flow table tests

A standard slump test shall be carried out according to BS EN 12350-2:2009, *Testing fresh concrete. Slump-test*, at the point of delivery at a sampling rate of 1 test per delivery of ready mix concrete, or 1 test per 4 m^3 of factory batched concrete. The test shall be carried out within 15 minutes after mixing. The slump shall be measured to the nearest 5 mm and compared with the specified slump on the PCM's production drawings.

A flow table test shall be carried out according to BS EN 12350-5:2009, Testing fresh concrete. Flow table test, at the point of delivery of self compacting concrete at a sampling rate of 1 test per delivery of ready mix concrete, or 1 test per 4 m^3 of factory batched SCC. The test shall be carried out within 15 minutes after mixing. The diameter of flow shall be measured across two sets of points to the nearest 10 mm and compared with the specified flow diameter on production drawings.

4.5.4 Faulty concrete

Concrete that has segregated, has bleed water visible, has set prematurely, or has become defective by whatever means, shall be disposed.

4.5.5 Incomplete work piece

If a work piece cannot be completed in a single pour, or there is a delay of more than the initial setting time of the cement such that the surface is unworkable, a suitable day joint shall be formed. Bars and fixings at the day joint shall be cleaned off and be free of grout. Completing a pour by depositing fresh concrete on top of, or to the side of hardened concrete, is not permitted.

4.6 Compaction

4.6.1 Vibration specification

The specification for vibration will depend on the nature of the work and the type of internal and/or external vibrators, e.g. poker, clamp. Poker vibrators of 25 mm to 50 mm diameter, and 400 mm to 600 mm long heads, shall be used continuously during pouring. The frequency of the poker shall be 35 to 50 Hz, and the amplitude shall be 3 to 6 mm.

Vibration shall be carried out in layers approximately 250 mm deep for section depths ≤ 600 mm, or 400 mm if greater depth. The vibrator shall not knowingly be held against, and should not disturb the mould, reinforcement or other fixings.

Vibration in each layer shall continue until air bubbles cease to rise to the surface in each layer, or at the onset of segregation, or grout loss through the mould. During vibration of subsequent layers the vibrator should briefly re-enter the lower layer. Vibrators should be withdrawn slowly on completion. Concrete deposited not at the work place shall not be vibrated.

Clamped vibrators on the mould should be tuned for frequency and amplitude according to the mass and natural resonant frequency of the mould and concrete pour. The range of frequency shall be 30 to 40 Hz. The number of vibrators, their position on the mould, and the distances between them, should be sufficient to compact the concrete fully, without segregation, bleed water, and blow holes.

4.6.2 Self compacting concrete

SCC shall not be vibrated, but make be lightly raked at the top surface if aggregate segregation is seen to be happening.

4.6.3 Control measures, control cubes

Sample cubes shall be manufactured according to BS EN 12390-3:2009 *Testing Hardened Concrete - Compressive Strength of Test Specimens*, using 100 or 150 mm steel cube moulds.

It may be necessary, at the request of the PCE, to determine the flexural tensile strength using 500 mm long x 100 x 100 mm prisms according to BS EN 12390-5:2009: *Testing hardened concrete. Flexural strength of test specimens*.

Samples shall be made from two separate deliveries at the rate of 2 samples per cast element ≤ 4 m^3, or 1 sample per additional 4 m^3 cast if greater, but not less than 2 samples per element.

Records shall be kept of all operations, including casting starting and finishing times, temperature, humidity, interruptions, settlement and delayed top up.

4.7 Curing

The PCM shall specify and submit for approval by the PCE the methods of curing.

4.7.1 Ambient temperature and humidity

Curing should take place to ensure that the correct maturity of the concrete is achieved depending on the type and fineness of the cement, which shall be documented under QA.

Means of curing shall be used to ensure the required compressive strength of concrete is achieved at demoulding, or at detensioning prestressed concrete, and the concrete surface is free from crazing, and/or shrinkage or thermal gradient cracks. Particular attention to curing shall be at changes in cross section (shallow to deep, wide to narrow, or at holes and corners). Special attention should be given to drying winds of more than 4 m/s at ambient temperatures of ≥ 25°C.

Steam curing is not recommended if the ambient temperature is ≥ 25°C.

4.7.2 Accelerated curing

Accelerate curing may be used using heated beds or steam. Thermo couples should be used to monitor surface temperatures do not exceed 50°C.

4.7.3 Curing membranes

Curing membranes, such as acrylic emulsions, or impermeable sheets such as polythene, waxed papers, hessian, shall be used if the ambient temperature is ≤ 25°C and the relative humidity is ≤ 75%. The curing membrane shall be applied within 10 minutes after horizontal casting, or 5 minutes for vertically cast elements. The elements shall be protected beneath an impervious curing sheet which should not be removed until the detensioning (transfer) strength of concrete is achieved.

4.8 Handling

4.8.1 Method statement

A lifting method statement will be prepared by the PCM and submitted for approval by the PCE. This should include at least: required concrete strengths at demoulding and stacking ages, types and positions of lifting sockets or rebars, demoulding and lifting techniques, use of chains or slings, design and function of lifting and spreader beams or other aids (such as tilting frames), turning and tilting, stacking and storage orientations and methods, types and positions of bearers, imposed loads acting on the precast elements.

4.8.2 Demoulding time and strength

The concrete shall have achieved its required compressive strength, as measured using the minimum strength from 2 no. cube samples, according to Section 3.1.5 of this specification, before the formwork is released from the mould. The required compressive cube strength for demoulding horizontal elements, that are to be lifted and subjected to bending stresses, is as approved by the PCE and PCM but not less than 15 N/mm^2. For vertical elements subjected only to self weight, the required compressive cube strength is as approved but not less than 10 N/mm^2.

4.8.3 Lifting methods

The elements shall be lifted from the mould according to the locations of the lifting devices and instructions on the production drawings, in a manner to avoid cracking and other damage. Lifting beams should be used where the inclination of the lifting slings or chains will cause cracking of the elements or the safe working load is exceeded. The lifting chains should be near vertical when attached to the lifting beam. The weight should be taken gradually without impact. Elements should be lowered onto the stockyard supports without impact.

Lifting devices, chains and slings should be tested by a certified testing house and be used according to manufacturer's specifications. The safe working load should be clearly marked and not exceeded. Elements should be lifted uniformly from the mould, and not removed from end-to-end of corner-to-corner.

Where proprietary lifting clutch is used with a lifting pin, e.g. Deha, the clutch should lay flat on the surface of the element such that the lug is touching the surface and the lifting pin is not bending.

4.8.4 Inspection

The elements should be inspected for cracking and other defects or damage. A cover meter survey should be carried out on a random selection of rebars positions to check for compliance, according to the manufacturer's procedures. The elements should be measured using tape measure for length, breadth and depth according to the manufacturer's procedures.

4.8.5 Cracking

Cracks which have a maximum width of more than 0.3 mm (or 0.2 mm in prestressed concrete) and do not close when the element is orientated in its intended position, should be referred to the PCE as to whether remedial action, including repairs, reinstatement or replacement of the element, is required.

4.8.6 Corrective measures

Cracks to be repaired should be carried out according to BS EN 1504, Parts 1-10. *Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity*, specifically BS EN 1504-3:2005, *Structural and non-structural repair*; BS EN 1504-4:2004, *Structural bonding*, BS EN 1504-5:2004, *Concrete injection*, and BS EN 1504-8:2004, *Quality control and evaluation of conformity*.

4.8.7 Stacking and tilting

Elements should be stacked on a firm storage bed using not more than two rows of bearers, which may be concrete, steel or timber at ground level. The distance from the ends of linear elements or corners of flat 2-dimensional elements shall not be more than 500 mm, unless indicated in manufacturing drawings. Subsequent rows of elements may be stacked on top of the first using timber bearers. The position of the timber bearers should align vertically to within +0 – 25 mm (towards the centre of the element) of the bearers beneath. The minimum cross section of the bearers, typically 100 mm, should avoid elements touching each other. The maximum number of elements to be stacked should be according to the manufacturer's procedures. The safety of the elements should be checked at all times.

Alternatively, flat 2-dimensional elements may be stacked individually on tilting frames, where not more than one element should be stacked against each side of the tilting frame. These elements may require the assistance of a tilting table to the desired inclination indicated in manufacturing drawings.

Bulk and 3-dimensional elements should be stacked, cross-braced and supported according to the details given in manufacturing drawings.

4.8.8 Weather protection

Elements should be protected from rain, strong wind (typically more than 4 m/s) and direct sun for the period of curing until the concrete strength has achieved the required lifting strength. This protection may be optional if the PCM can satisfy the PCE that the concrete is not adversely affected under these conditions.

4.9 Dimensional accuracy

4.9.1 Specifications and limits

Method of measurement for dimensional deviations for length, breadth, depth, squareness, warping, twist, etc. shall be in accordance with BS EN 13369:2004, Annex J. These supersede the dimension deviations and positional accuracy for fixings given in BS 8110-1, clause 6.2.8.3 to 6.2.8.8. Dimensional deviations shall be as shown on the manufacturing drawings but generally, or not without justification according to production control, greater than in clauses 4.9.2 to 4.9.4.

Tolerances are defined as the differences between the actual measured dimension and the working dimension, not the nominal dimensions. The effects of temperature differentials, relative humidity shrinkage and creep effects in prestressed concrete, during the time duration of measurement, should be taken into account. Tolerances may be in different categories for structural, architectural and foundation elements.

4.9.2 Linear dimensions - length, breadth, depth

Linear elements (columns, beams) including dimensions to haunches, rebates, etc.

Length: ±5 mm ≤ 3 m; maximum ±10 mm
Breadth, upstand breadth and depth: ±5 mm ≤ 3 m; maximum ±10 mm
End squareness: depth or breadth/100; maximum ±10 mm
Straightness ≤ ±5 mm ≤ per every 3 m; ±10 mm ≤ 12 m; maximum ±15 mm
Distance of haunches and nibs: ±3 mm
Bearing ledges and boot: ±5 mm
Stirrups or links projecting from elements: ±25 mm longitudinally, ±5 mm transversely
Camber variation for prestressed beams after transfer and including self weight as supported on battens in the stockyard ≤ ±50% of design calculated camber

Floor elements.

Hollow core floor units according to hollow core producer's specification, but not greater than according to BS EN 1168:2005, as:

- Length: ±25 mm
- Breadth: ±5 mm (based on working breadth, not nominal breadth)
- Breadth for longitudinally sawn units: ±25 mm
- Depth ≤ 150 mm: +10,-5 mm, Depth ≥ 250 mm: ±15 mm, linear interpolation between
- Web width: individual +0, -10 mm, total per unit +0, -20 mm
- Flange thickness: +15, -10 mm
- Camber for prestressed units as above.

Double-tee units according to slab producer's specification, but not greater than:

- Length: ±25 mm
- Breadth: ±10 mm
- Depth: +10,-5 mm
- Flange thickness: ±3 mm
- Distance between webs: ±5 mm
- Twist, straightness, squareness as below
- Flatness: ±10 mm
- Block outs, openings and notches: ±10 mm

Camber for prestressed units as above.

Half-plank units according to producer's specification, but not more than
Length: ±25 mm
Breadth: ±10 mm (based on working breadth, not nominal breadth)
Depth: +10,-5 mm
Camber for prestressed units as above

Flat 2-dimensional (wall, façade, landings, stairflights)

Visual elements. Length and width: ±3 mm ≤ 3 m; maximum ±6 mm
Non-visual elements. Length and width: ±6 mm ≤ 3 m; maximum ±10 mm
Dimension of haunches and nibs: ±5 mm
Distance between thickening webs: ±5 mm
Thickness: +10,-5 mm
Openings and notches: ±10 mm

Bulk 3-dimension (boxes, rooms, L and U shape)
Length and width: ±6 mm ≤ 3 m; maximum ±10 mm
Wall and slab thickness: +10,-5 mm
Openings and notches: ±10 mm
Corner diagonals: ±5 mm ≤ 3 m; maximum ±10 mm
Others as above

Staircase (flight with integral landing):
Length: ±15 mm
Width: ±5 mm
Waist: +10,-5 mm
Height from soffit to top step: ±10 mm
Going (tread) and rise ±5 mm per step
Tread tilt: -5 mm, +0
Rake (recess if permitted by Building Regulations): ±5 mm.
End squareness: depth or breadth/100; maximum ±10 mm

4.9.3 Squareness (skewness)

Squareness, which may not necessarily mean 90°, is the magnitude of the variation of end skew in plan of two adjacent edges. Maximum squareness ≤ length / 100, maximum ±10 mm.

4.9.4 Twist, straightness and flatness

Twist (or warping) in flat 2-dimension elements is the magnitude of the variation of one corner relative to the other corners. Differential twisting between site adjacent elements should not be greater than the twisting tolerance of individual elements. Special reduced tolerances for finished polished façade elements may be required. Maximum twist ≤ length / 300, maximum ±10 mm.

Maximum straightness ≤ length / 300, maximum 25 mm.

Surface out-of-flatness (local edge straightness) tolerances are specified according to the maximum dimension of an element. Maximum flatness ≤ ±5 mm ≤ per every 3 m; maximum ±10 mm.

4.9.5 Cover meter

Cover to reinforcement or other ferrous inserts may be measured using a calibrated cover meter. Tolerances shall be in accordance with BS EN 13670:2009, *Execution of concrete structures*, and shown on the manufacturing drawings.

4.9.6 Cast-in fixings and lifting points

Linear dimensions to fittings shall be in accordance with BS EN 13670:2009, *Execution of concrete structures*, and shown on the manufacturing drawings, but not greater than:

Block-outs, sleeves, inserts, fittings, etc. for services: ±15 mm
Distance between associated pairs of fittings: ±5 mm
Flushness and tipping: ±5 mm
Dimension to lifting points; ±50 mm longitudinally (longer edge), ±20 mm transversely (shorter).

4.10 Quality Control

The quality assurance system shall be according to BS EN ISO 9001:2008. Adequate inspection and testing should be carried out to ensure precast components manufactured have reached the required standards of finish, dimensional and strength.

4.10.1 Cement

Cement shall conform to BS EN 197-1:2000. *Cement - composition, specifications and conformity criteria for common cements*. Test certificates giving the physical and chemical composition, chloride and alkali content, initial setting time, soundness expansion, compressive strength at 1 and 28 days, all according to BS EN 196:2010, Parts 1-9 and 21, *Methods of testing cement*.

4.10.2 Aggregates

Annex E of BS EN 13139:2002, *Aggregates for mortar* prescribes minimum test frequencies for the various properties and the appropriate test method.

Aggregates shall conform to BS EN 932:1997 *Tests for general properties of aggregates*, and BS EN 933-9:2009, *Tests for geometrical properties of aggregates.* BS EN 933-1:1997, *Determination of particle size distribution - Sieving method*. BS EN 933-3:1997, Determination of particle shape - Flakiness index. Organic compounds are tested according to BS EN 1744-1:2009, *Tests for chemical properties of aggregates - Chemical analysis*, clause 15.1 (use of sodium hydroxide); to clause 7 for chloride content; and to clause 12 for sulphates. Determination of particle density and water absorption is according to BS EN 1097-6:2000, *Tests for mechanical and physical properties of aggregates*.

4.10.3 Concrete strength

Concrete shall be produced and conform to BS EN 206-1:2000. Concrete - *Specification, performance, production and conformity*. The sampling rates, testing and analysis of concrete cubes are given in Section 3.1.5.

4.10.4 Inspection and records

The PCE shall have access to production records and may visit the manufacturing plant for the purpose of inspection of materials and processes. The PCM shall keep permanent records of daily production, including cube strengths and densities, aggregate grading, impurities and moisture content, and weather conditions during manufacture, curing and storage.

4.11 Dispatch

4.11.1 Handling

All elements should be handled in the stockyard and prepared for transportation using the correct lifting devices or slings or chains with protective edges to avoid damage and cracking.

4.11.2 Cracking

The PCM should inspect the elements for cracking. Cracks which have a maximum width of more than 0.3 mm (or 0.2 mm in prestressed concrete) and do not close when the element is orientated in its intended position, should be referred to the PCE as to whether remedial action, including repairs, reinstatement or replacement of the element, is required. If the design specification calls for smaller crack widths this should take preference. Crack widths of between 0.1 and 0.3 mm for reinforced concrete, and 0.1 to 0.2 for prestressed concrete, shall be assessed by the PCE to whether remedial action is required, and may be monitored on site. The PCM should inform the PE of this action.

4.11.3 Stacking on vehicles

Loading arrangements by the PCM on delivery vehicles shall be so as not to subject the elements to forces not catered for in the design. The PCM should consult the PCE if uncertain. The elements should be loaded to distribute weight evenly, and should not subject other elements to tension, torsion, bending, etc. not catered for in design. The dynamic impact of the vehicle on uneven roads on the mass of the elements should be considered.

Elements should have semi-soft, e.g. softwood, bearers placed along their length according to the design. Where more than two bearers are used, the possibility of uneven bearing, and large cantilever forces should be realised. The distance from the ends of linear elements or corners of flat 2-dimensional elements shall not be more than 500 mm, unless indicated in manufacturing drawings.

Where elements are stacked above each other, the bearers should be vertically in line to tolerance of +0 -50 mm, i.e. bearers may be closer higher. The depth of the bearer should be sufficient to separate the elements and prevent dynamic impact during transit.

Elements greater than 3.0 m in dimension should be stacked vertically on upright frames. The PCE should assess the forces during transit and the element be reinforced accordingly. The PCM should inform the PCE of any variations to this.

Elements longer than a certain length, as recognised and specified by the PCE in conjunction with the PCM and haulier, should have special precautions during transit.

In JKR practice, the type of transport to be used shall be to the approval of the SO. In addition, the transportation method must also adhere to rules set by the Road Transportation Department/Jabatan Pengangkutan Jalan (JPJ).

Chapter 5 – Site Construction

5.1 Preliminaries

The duties, responsibilities and actions of the sub-contractors (SC-PE) and specialist suppliers (SS-PE) to the PE shall be given in writing to the GC. The same of the GC's sub-contractors shall be given to the PE.

Design

The supervising officer (SO) shall engage a PCE who shall evaluate, analyse and review the structural design and details in the plan and perform such original calculations with a view to determine the adequacy of key elements.

He shall verify that the key elements designed are consistent with general layout shown and in any amendments there to.

The PCE's shall produce a report that specifically describes the deficiencies, potential or real, which have been identified along with the relevant references to accepted standards, practices and design principles. The point shall be illustrated wherever practicable by marking up the plans or with sketches, drawings and such related materials. The report may include the PCE's suggestions, amendments, alternative solutions and designs for amendments and/or alternative solutions.

The SO shall engage a PCE who shall take full responsibility for integrity, thoroughness and competence of his report and recommendation that it has been adequately carried out in accordance with the accepted engineering practice and to ensure the structural integrity and stability of the proposed construction.

The PCE shall also certify in respect of the plans relating to the structure and associated works stating that, to the best of his knowledge and belief, the plans so checked do not show any inadequacy in the design and details of the key elements.

The GC shall ensure sufficient working drawing details and specifications shall be made to the PCE.

Installation

Prior to erection of the precast elements, the PE shall submit to the SO a method statement of erection through the GC.

The GC shall certify the completion of the works of the PE and submit the certification to the SO.

The requirements for the installation of precast elements and the erection of the frameworks are given in BS EN 13670:2009 *Execution of concrete structures*, section 9. These supersede the recommendations in BS 5606:1990, *Guide to accuracy in building*, although this BS is still current.

5.1.1 Health and safety

The PE and PCE shall meet with the GC (optionally with the PCE) on site as soon as possible to discuss and agree on health, welfare, site safety, and personal protection equipment requirements. The GC shall submit to the PE their standard forms of compliance. The PE should submit a Risk Assessment at least 4 weeks before commencement of frame erection. The PE should submit details of all substances to be used on site to comply with COSHH regulations, and to OSHA:1994 and MS 1772: Part 1:2005.

The GC shall carry out a safety induction of all contractors and sub-contractors employed or hired by the PE, and have all relevant certificate and competency approved by CIDB and DOSH.

5.1.2 Site inspection

The PE should meet with the GC on site as soon as possible, but not less than about 8 weeks before commencement of frame erection, to agree on access for delivery vehicles, crane, plant, hard standing, provision for access between foundations, site facilities, location of PE's equipment, storage. See also Section 5.2.4 regarding the precast frame erection sequence.

5.1.3 Site preparation

The boundary of the site prepared for the erection of the precast frame should be agreed with the PE. GC should prepare the working ground in 5.1.3. The GC should provide a source of clean water suitable for making concrete, which should not be more than approximately 100 m from the site.

The PE should deliver the required quantities of fine aggregate (natural sand or crushed) and coarse aggregates (typically 10 mm size) according to the details on the construction drawings, which should be deposited outside the working area. The PE should deliver the required quantities of bagged cement (typically 42.5N) and admixtures (expanding agent) unless the cement supplied is non-shrink, which should be stored in a dry area protected from rain.

The GC shall provide a datum level point, and setting out reference points, a minimum of two orthogonal sight lines at one corner of the frame as agreed with the PE.

5.1.4 Ground level and stability

The GC shall prepare well consolidated and level ground around the full perimeter of the frame, and within the interior of the frame as agreed with the PE. Service pipes, culverts, etc. should be protected depending on the type of crane. The extent of the working ground should be as agreed with the PE but not be less than 5 m from the edge of the frame. The working ground should not be more than 0.5 m above or below the top of the foundations.

5.1.5 Crane and vehicle access and obstructions

The GC should provide the PE with firm haulage roads and hard standing for vehicles and crane(s). The PE shall inform the GC of their requirements in terms of area, width, axle load, turning circles, gradients, and heights. The GC shall inform the PE of obstructions, e.g. overhead or underground cables, and restricted access at any part of the site the PE identifies as required for crane and vehicle access.

5.1.6 Foundations and bases

The GC shall cast the foundations, pile caps, ground beams, etc. according to the PCE's construction drawings in sufficient time for the concrete to achieve the compressive cube strength specified by the PE, typically 10 N/mm^2, and typically 14 days before the commencement of the frame erection.

Foundations with pockets to receive columns should be covered to prevent rain water and other debris entering the pocket. At least 5 days before the commencement of the frame erection, the PE shall check

the level at the bottom of all pockets and advise the GC if the level is too high to permit the positioning of levelling pads. The GC shall take remedial action and prepare a new level at least 50 mm below the level of the levelling pads, which has the required strength to receive the levelling pads, or remove concrete to a level as agreed with the PE.

Foundations with holding down bolts to receive steel base plates to columns and walls, the GC shall ensure that the holding down bolts have a free sideways movement of ± 25 mm in all directions from the position shown the Consulting Engineer's construction drawings. This may be achieved by disturbing the bolt within a period of between 6 and 12 hours after casting.

Foundations with projecting waiting bars to receive sleeves in columns and walls, the GC shall ensure that the concrete between the bars is at the correct level so not to prevent the column/wall from its correct level.

In all cases the PE shall check the level of the foundation in the locality of the precast column or wall and advise the GC if the level is too high to permit the positioning of levelling pads. The GC shall take remedial action and prepare a new level at least 50 mm below the level of the levelling pads.

5.1.7 Foundation levelling pads

At least 3 days before the commencement of the frame erection, the PE shall prepare levelling pads comprising 2:1 sand:cement stiff mortar, approximately 200 mm square and tapered to receive a 3 mm thick bearing plate at least 150 x 150 mm in size. One pad per column and minimum of two per wall. The position of the levelling pad should be within ± 25 mm the centre of the column or centre line of the wall.

If it is not possible to prepare mortar pads, then 150 x 150 mm solid steel packs, or, if the levelling gap is more than 10 mm, sandwich steel-clay tile-steel packs may be used. The clay tiles (or similar) should have a compressive strength of at least 10 N/mm^2, or less if the PE satisfies the PCE of their performance.

If precast concrete ground beams are used, similar levelling pads, either 2 no. at each end of the beam, or, depending on the width of the beam, one pad 50 mm narrower than the width of the beam, shall be provided at approximately 200 mm from the edge of the foundation and not more than 300 mm from the end of the beam.

In all cases the foundation should be clean and dry with no standing water, and a sprinkling of dry cement should be used to soak up any moisture.

5.1.8 Prepared ground for stacking

The GC shall prepare a firm, level bed, within tolerances of ± 100 mm level over a distance of approximately 3 m, or pro-rate for shorter distances, of timber (or similar) in preparation for stacking precast elements. The bearers should be at least 100 mm square, and have protecting top surfaces if not in timber. Only 2 bearers should be used per element. For wide elements such as walls and landing the width of the bearers should not be at least 500 mm less than the width of the element.

The bearers should be located so as not to inhibit the movement of the crane or other site plant, and be within the permitted lifting reach of the crane when placing the precast element in the frame.

5.1.9 Prepared ground for propping

The GC shall prepare bases for props, within positional tolerances to its centre of ± 50 mm from the centre line of the column, and ± 100 mm from the position agreed with the PE for walls, and other elements, e.g. beams, stair landings, requiring props. The bases may be in cast insitu mass concrete, or using precast concrete blocks on prepared ground. The GC shall ensure the stability of the base.

Where access is available on all sides, compression props may be used on either side of columns or walls. The safe bearing capacity of the base shall be according to the specification by the PE, who will advise the GC.

Where access to one or more sides is restricted, props and bases with tension capacity shall be used. The safe bearing and uplift capacity of the base shall be according to the specification by the PE, who will advise the GC.

In all cases the PE shall be satisfied with the provisions of the bases before commencing propping.

5.2 Design Information

5.2.1 Drawings and specifications

The precast frame and individual elements should be detailed on the construction drawings to enable safe handling, transportation and fixing without damaging the elements.

5.2.2 Stacking methods and sequences

Where possible the stacking of elements should be at ground level, according to 5.1.7. Positions of stacked elements should not impede the movement of the crane. The maximum height for stacking shall depend on ground conditions, but generally be not more than 1.5 m.

Where necessary, stacking of elements on the framework, including incomplete framework, is permitted. The weight and position of the stacked element should be determined by the PE and unless the information is shown on the construction drawings. Positions of stacked elements should not impede insitu concrete and other operations necessary for safe working practice and to achieve permanent stability.

The GC and their sub-contractors, the SC-PE and SS-PE, are not allowed to stack materials and other elements and utilities on the framework without written permission from the PE.

The total dead load, due to the framework and stored materials, above the highest level of the stabilised framework should be stated on the construction drawings. The PE should keep a written record of (i) each fixing and storage event (including element type, weight, position, date, time), (ii) stabilising event (prop type, propped element, position, bearing position), and (iii) storage (weight, area, material).

The PE should record (i) dimensional inaccuracies for element dimensions, positions of connectors, fixtures, and projecting bars and dowels, (ii) fixing deviations, including clear gaps, squareness, verticality, level. The PE should report any deviations greater than those stated on the construction drawings to the PCE.

5.2.3 Lifting points and ultimate capacity

The PCE and PCd shall ensure that all lifting devices, whether proprietary or bespoke, are in the correct position and of sufficient ultimate capacity for the safe handling and fixing of the element, including the effects of forces during baring operations when not held by the crane.

The elements shall be designed for on-site lifting, at a minimum age of 7 days, or 3 days if the PCM can guarantee the required concrete strength.

5.2.4 Erection sequence

The sequence of erection for the precast frame should be agreed between the PCE and PE, and the information given in writing to the GC as is available at any time, including if the erection sequence is not finalised. Amendments to the construction sequence should be given in writing to the GC as soon as available.

The PE should determine the sequence of erection, and inform the PCE and PCd for special requirements for lifting, e.g. division of wall panels or stairs and landings for lighter weight, or provisions for eccentric lifting, e.g. panels with offsets.

5.2.5 Permanent stability points

The elements that provide permanent stability to the frame should be clearly marked on the construction drawings. The positions where the entire framework, or part of the framework, whether horizontally or vertically divided, is considered fully stable and may be allowed to stand free of any external restraint, should be stated on the construction drawings. The horizontal bracing system in the floor slab, whether within the precast floor units or out-with the floor slab (e.g. steel cross bracing) between points of vertical restraint should be completed structurally when removing temporary supports.

Where insitu concrete is used, or dowelled connections that rely on the maturity of insitu concrete or mortar for strength and stability are used, the effect should be considered when removing temporary supports.

5.2.6 Crack width limitations

The effect of small hairline cracks should be assessed by the PE according to its position in the element with regard to fixing and its function in the frame. For structural cracks, the PE should consult with the precast consultant PCE prior to fixing the element, and should make an assessment of the structural suitability of the element.

5.2.7 Connection methods

The PE shall be made aware of the connection methods used in the framework, including each type of fixing, materials and techniques, consumables. Permitted deviations should be stated on the construction drawings. The PE should ensure that the fixings perform their structural, durability and fire resistant functions, both in the temporary and permanent conditions.

5.2.8 Dimensional deviations

The requirements for the installation of precast elements and the erection of the frameworks are given in BS EN 13670:2009 *Execution of concrete structures*, Section 10 and Annex G, and shown on the construction drawings. These should be according to Tolerance Class 1.

BS EN 13670:2009, clause 10.1.(6) states “Tolerances for surfaces between components where forces are intended to be transmitted by full contact bearing between the surfaces are not defined in this standard. Any requirements to such surfaces shall be stated in the execution specification.” This includes differential camber between floor units and between floor units and connected beams or walls.

5.2.9 Bearing materials

Bearing materials should be stated on the construction drawings in terms of their function, position, specification, working temperature range, application, and deviations.

5.2.10 Levelling shims

A set of levelling shims in ferrous mild steel plate, stainless steel, plastic, and other materials such as PTFE should be made available to the PE. The grade of material, sizes, hole or slot details, total nominal thickness, and the positions where shims of different material, sizes and function are to be used should be specified by the PCE and stated on the PE’s construction drawings. A preferred range of thicknesses is 3, 6 and 10 mm. Horseshoe shaped shims (rectangle with one sided slot) should be available in all materials and sizes.

5.2.11 Assessment of damage to precast elements

Not withstanding 5.2.6, damage occurring to waiting elements or to those in the frame, due to impact or other reasons, should be recorded and reported to the PCE. The PCE shall inform the PE whether remedial action, including repairs, reinstatement or replacement of the element, is required. No further fixing activity that relies on the structural integrity of the damaged element shall continue until the remedial action, including no action, is taken and approved by the PCE. Damage caused by the SC-PE and SS-PE (e.g. damage to a beam when fixing floor slabs) should be dealt with similarly.

5.3 Lifting and Pitching

5.3.1 Lifting equipment

The type of lifting equipment, e.g. crane, hoist, grabs, should be appropriate to the size and height of the frame, ground conditions, access routes and positions, the size and weight of elements, the maximum reach of cranes (horizontally, vertically and combined) and obstructions to the crane radius or movement. More than one method, and more than one crane, may be considered.

To ensure proper handling of the precast concrete components, all lifting and erection devices shall be clearly shown in the construction drawings. The precast concrete components shall be lifted only at points specified in the Drawings or otherwise approved by the SO, and shall be handled and placed without

impact. The method of lifting, the type of equipment and transport to be used, and the minimum age of the components to be handled shall be to the approval of the SO.

Precast concrete components shall be lifted and supported during manufacturing, stockpiling, transporting and erection operations only at lifting or supporting points, as shown in the fabrication shop drawings, and with approved lifting devices.

Lifting beams (or cradles) should be used in situations that would otherwise cause lifting chains to imposed spurious forces and/or cracking on the element, or that the angle of the lifting chains subtended at the hook is greater than 90°, or will exceed the safe working load (SWL) of the chains. When attached to the lifting beam the chains should be close to the vertical. The lifting beam should be marked with its SWL.

The Contractor shall obtain the necessary clearances for the transportation of the precast elements and movement of the lifting equipment to the launching site.

All lifting equipment shall be designed, such that if the primary lifting mechanism fails, a secondary mechanism shall ensure that the precast element shall not fall.

In the design of the lifting points, when lifting inserts are used, the inserts shall be designed with minimum factor of safety of 4 at the ultimate limit state (ULS) against tensile, shear and bonding failures. If reusable lifting hardware or rigging are used, then they shall be designed with minimum factor of safety of 5 at ULS.

A certificate of test of lifting equipment shall be submitted to the SO, together with particulars of the experiences of the operator.

5.3.2 Temporary supports

Temporary support for precast concrete components during transportation shall be designed to withstand loads and extra forces during loading, transportation and unloading. Temporary shoring, propping or bracing, if necessary shall comply with their manufacturer's recommendations.

Temporary supports using timber or concrete bearers shall be prepared on firm ground. Linear elements (columns, beams) should be placed on two bearers only, set at 500 mm from the ends of the elements. The width of the bearers should be at least 150 mm, and the depth at least 150 mm according to the ground conditions.

When supporting elements more than 600 mm wide, the supports should be optically levelled to a deviation of ±3 mm per 1.0 m.

Immediately a unit of precast concrete component is in position, and before the lifting equipment is removed, temporary supports or connections between components as necessary, shall be provided. The final structural connections shall be completed as soon as is practicable.

5.3.3 Pitching and footings

Elements that are to be inclined by pitching should first be placed on firm ground, see 5.1.7, and pitched in a separate operation, and not directly from the delivery vehicle. A special *shoe*, bespoke manufactured in steel, timber or concrete, may be required when pitching heavy or shallow, e.g. length/depth > 40, to prevent the element sliding forwards, sideways or twisting during pitching. Dual pitching may be used on elements of more than 20 m in height, depending on the function of the crane.

5.3.4 Eccentric lifting

Where the centroid of an element is beyond the reach of the crane or lifting equipment, for example at the side of a building, a special lifting bracket may be required to enable an eccentric lift. There is no limit to the eccentricity, but alternative means of fixing may be considered if it is more than 500 mm typically.

5.4 Propping

5.4.1 Preliminaries for propping and falsework

All structural precast components shall be properly stabilised during erection stages by employing suitable temporary propping, bracing and/or shoring systems. The PE shall propose such a system and produce design calculations and drawings to allow for safe employment of the system on site.

All relevant shoring or propping equipments shall also be provided by the PE, for example if composite beams or slabs are specified.

All drawings (scheme, construction and, propping and shoring) shall be certified and duly signed by both the PCE and the PE's representative(s) who are registered as a Professional Engineer with the Board of Engineers, Malaysia.

The PE should prepare a method statement specifically related to temporary propping. No site personnel should move or remove props without permission from the site foreman, and no SC-PE should remove props without permission from the PE. Guidance on the use of props and Falsework is in BS EN 12812:2008, *Falsework – performance requirements and general guidance*. Note that the National Foreword to BS EN 12812 warns "The design methodology within BS EN 12812:2008 is significantly different from that in the more established British Standard BS 5975*+A1:2011. Code of practice for temporary works procedures and the permissible stress design of falsework*. Technical Committee B/514 advises that caution should be taken when applying BS EN 12812:2008.

5.4.2 Vertical elements - columns and walls

Although BS 5531:1988, *Code of practice for safety in erecting structural frames*, was withdrawn in 2009 it still contains useful information, in particular on the temporary stability of structural frames. There is no BS EN successor.

Temporary propping will be required to stabilise vertical elements prior to permanent stability being achieved. The PCE shall ensure that all elements are able to resist the forces imposed during propping, e.g. punching shear, torsion or tension. The contractor should resist doubling up on props in the name of additional stability, e.g. 3 props to one side of a wall panel where 2 would suffice, as this often causes redundancy in the propping system such that the actual forces in the props is unknown. A statically determinate system of props should be used.

The top end of the prop should be positioned against a head plate, and the bottom against a sole plate, in order to spread the prop force. The element should be reinforced at this point to cater for the prop force, and special fixings such as fully anchored threaded inserts to cater for tension and shear. The PE should determine the requirement for securing (i.e. bolting down, or gravity held) and cross b racing props.

Props should be adjusted manually through a turnbuckle. In larger elements props may also be adjusted using hydraulically driven jacks, in which great care is required when applying pressure.

Props and jacks should not be placed onto precast concrete stair flight elements.

5.4.3 Horizontal elements - beams, slabs and stairs

Temporary propping will be required to stabilise horizontal elements such as beams and staircases, particularly where eccentric reactions are present in non-symmetrical beams, or extended bearings are specified. Propping of precast concrete floor slabs may (not always) be required in half-slab, hollow core and double-tee where structural toppings are applied. The props should be erected vertically to within ± 50 mm over a 3.0 m height, or pro-rata if lower.

If hydraulic jacks are used, they should be stabilised to prevent sideways forces and movement. The PE should be advised of the maximum permitted load, and a calibrated load indicating device should be inserted to the system.

5.4.4 Prop capacity

Props should be obtained from proprietary sources and should not be made on site.

The compressive, and compressive/tensile, capacity of a prop should be assessed from the prop load, prop length and inclination, together with the manufacturer's specification

The prop load in horizontal elements is easily determined by the PCE. The prop load when stabilising a column in notionally zero, and must be assessed by the PCE based an notional sway and wind pressure, eccentric forces due to connectors, shrinkage forces in connected elements, and impact or accidental forces.

5.4.5 Back propping

Back propping from the floor below should line up vertically with the props above within ± half the depth of the precast element being propped. If this is not possible, the PCE should design for punching shear or shear in the element. Props should terminate at a solid footing, where a sole plate will be required depending on ground conditions. The distances between props and their location in a slab should be stated on the construction drawings. The duration should remove the props shall be controlled by the maturity of the connections or structural topping, and not by time.

5.4.6 Tow (guy) ropes

The specification and positions where guy ropes may be attached, in particular to projecting fixings, should be stated on the construction drawings. The elongation and strength of the ropes should be specified by the PCE. (Guide ropes are classified as lifting equipment.)

5.5 Erection of Columns

The PCM shall ensure that the precast columns are loaded in sequence compatible with the required unloading and erection sequence on site. Upon erection, a fail-safe method shall be used to temporarily secure all columns until the permanent fixing arrangements are implemented.

5.5.1 Base preparation

Columns founded in pockets (or sockets). The pocket should be tapered internally at about 5° to the vertical. The PE should check the setting out of the foundations to ensure that the position of the pocket is on the centre lines of the column. PE should clear the bottom of the pocket from debris, other contaminants and standing water. The level of the bottom of the pocket should be 50-75 mm below the finished level of the bottom of the column. If more than 72 hours before column erection is available, a levelling plate, 150 x 150 x 6 mm mild steel, should be set in the centre of the bottom of the pocket on dry pack mortar, of 2:1 sand/cement with a water/cement ratio of about 0.3. The dry pack should be heaped at an angle of 45° beneath the plate. If less than 72 hours is available, a composite packing of 150 x 150 x 3 mm mild steel plates and 150 x 150 x 10 mm ceramic or mortar tiles of minimum compressive strength 40 N/mm^2 should be set in an alternate sandwich manner, with a heaped dry pack mortar surround to hold the plates in position. The top plate should be set in position with a tolerance of ±10 mm and to a level of +0 -3 mm.

Columns founded on steel base plates or on projecting bars. The PE should check the setting out of the foundation, and of the holding down bolts or projecting bars, and prepare levelling plates on the top of the foundation on the centre-lines of the column as above.

5.5.2 Pitching

Columns should be offloaded from the delivery vehicle using at least two lifting points, stacked and pitched onto temporary supports according to Section 5.3. Pitching may be from a lifting device at the top of the column, or by pitching holes near to the top of the column, typically 0.3 x column length from the top. The diameter of the pitching pin through the hole should be determined by the PE, but should not be less than 40 mm mild steel grade S275. The diameter of the pitching hole should be 50-60 mm. The concrete around the pitching devices or pitching hole should be designed and reinforced to resist the forces at all stages of offloading and pitching.

Bespoke collars and yokes may be designed, manufactured and tested by the PE to the satisfaction of the PCE. There are no Standards to cover this.

The column should be inspected for any cracks (typically flexural at about 300 mm spacing) when at an inclination of about 5° from the horizontal. The cracks should be marked alongside them using a marker pen. If the cracks are visible when the column is upright, the PE should inform the PCE in order to assess the effects. If the cracks are no longer visible no further action is required.

The column should be pitched at a rate of less than 90 m vertically per minute.

If the column is in a pocket, 2 timber wedges per face (8 in total) equally spaced from the centre line of the column should be forced into the gaps between column and pocket sides. The bottom of the column may be positioned for line and twist by driving the wedges up and down.

If the column is positioned on a steel base plate, 4 steel wedges (1 per face) should be inserted and forced in the gap between the top of the foundation and the base plate, to provide a horizontal restraint

until the holding down bolts have been grouted and hardened. The PE should design and size the steel wedges.

If the column is positioned on projecting bars, similar steel wedges should be inserted and forced in the gap between the top of the foundation and the bottom of the column.

5.5.3 Propping at ground floor

The GC should provide the adequate foundations for the props at no extra charge. The PE may first attach the props to the columns before pitching, or after the column is erected.

If access is available on all 4 sides of the column, 4 props should be placed against a yoke or drilled or cast-in fixing, attached to the column approximately 500 mm below the soffit level of the beams at 1st floor. The centre line of the prop should be ±10 mm from the centre of the column. Cast-in fixings should be designed to resist the inclined force from the prop. The yoke may consist of two timber battens coupled through threaded rods, to tighten the timber against the sides of the column. The yoke may be a proprietary design; otherwise the PE should prove the capacity and strength of the yokes. The props should be inclined at between 45°-55° to the horizontal. The action of the props shall provide stability in two mutually perpendicular directions, and be coincident with the centre of the column and the spacing of the wedges.

The bottom of the prop should be founded on firm ground, or on a prepared base. The PE should calculate the axial compression in the props and procure props from an ISO 9001:2000 accredited manufacturing supplier that are fully and independently tested to the relevant British quality standards. The props in each direction should be able to support the load from the inclined column by itself.

If access is not available on one or two sides, push-pull props with compression and tension capacity shall be used. The props should be attached to a drilled or cast-in fixing at both ends. The PE should calculate the axial tension and compression in the props and supply props as above.

The concrete at the propping points should be designed and reinforced to resist the forces at all stages of pitching.

5.5.4 Propping at upper floors

Internal columns with access on 4 sides should be propped in the same manner as at ground floor, except that the bottom fixing should be drilled or cast-in to the beams and floor slabs at 1st floor, and subsequent floor levels. Props at 1st floor level are not required if the column terminates at 2nd floor.

Tall columns, more than 15 m in height should be propped at both ground and 1st floor level to ensure that not more than about 9-10 m height of column is unpropped whilst fixing commences at second floor level. Similarly at upper floors, although the height of upper storey columns should not be more than 3 storeys, or 10 m, and for corner columns not more than 2 storeys or 7 m.

At edge columns, compression props may be used on one axis and push-pull props on the other axis, according to the same requirements as above.

At corner columns, push-pull props are required in both axes according to the same requirements as above.

5.5.5 Propping at obstructions

If an obstruction prevents a single prop being placed on the centre line of the column or on the ground or at an upper level beam or slab, either a push-pull prop may be used on the opposite face, or two inclined props tapering towards the top of the column may be used.

5.5.6 Grouting at the base

The columns may be manoeuvred into position and aligned vertically using the couple generated between the top of the props and the wedges. Optical instruments, such as 2 theodolites, or a plumb bob and string (for columns < 10 m), may be used for verticality.

When aligned, the annulus between the column and pocket should be filled using flowable (slump 75 mm) concrete of minimum grade C40 using 10 mm coarse aggregate, containing non-shrink or expansive cement or admixtures according to the manufacturer's instruction. The first pour should just cover the bottom of the timber wedges, or 250 mm whichever is greater. A poker vibrator with a 25 mm head should be used to compact the infill. Protection of the exposed surface is not necessary unless in heavy rain.

The gap between a steel base plate and foundation, or bottom of column and foundation, should be shuttered, and filled using a flowable (slump 100 mm) mortar grout of minimum grade C40 using 4/0 sharp sand containing non-shrink or expansive cement or admixtures according to the manufacturer's instruction.

Control cubes shall be manufactured as in Section 3.1.4 and tested at 24 and 72 hours, and 28 days. Compliance shall also be as in Section 3.1.4.

The wedges may be removed a minimum of 24 hours after casting, or when the compressive cube strength reaches 10 N/mm^2. The pocket is topped up using the same specification mix, and any other work around the outside of the base plate or column is made up.

5.5.7 Removal of props at ground floor

The props should remain in position until all the props supporting columns in the stabilised building block are fully tied into the first floor slab, at least 3 days after the completion of reinforced insitu concrete infill in the beams and slabs has been shown by cube tests to be adequate, but not necessarily the structural topping. Props should not be removed from single columns until the above has been completed.

Where columns are asymmetrically loaded, e.g. balconies, cantilevers, etc., but excluding asymmetrical beam arrangements, the props should remain in position until the second floor is fully tied. This is to provide the necessary horizontal prop reaction forces.

In situations of bad weather or high winds, the PE may choose to leave all props in place until the second floor is completed.

The removal of the temporary props, bracing or shoring devices shall only be done after certification by the PE that the installation is stable and safe and approved by the SO. The PE shall inform the SO and obtain his approval before removing any temporary work but such approval does not relieved the PE of responsibilities for the safety of the work.

Formwork shall be removed without such shock or vibration as would damage the concrete. A period of time shall elapse between the placing of the concrete and the removal of the formwork for various parts of the structure so as to suit the requirements for its curing.

The minimum periods between concreting and the removal of forms are given as follows:

i) Vertical faces of beams, wall, columns, piles, foundation plinths and precast components: 3 days
ii) Slabs (props left under) : 4 days
iii) Removal of props to slab : 10 days
iv) Beam soffits (props left under) : 8 days
v) Removal of props to beams : 21 days

Following the removal of forms, no further loads shall be imposed upon the concrete until at least after the completion of the curing period or until such later time as directed by the SO. The concrete shall have attained sufficient strength to safely withstand such loads. Full design loads shall not be applied to any structure until all loads bearing concrete is at least 28 days old.

5.5.8 Removal of props at upper floors

The props should remain in position until all the props supporting columns in the stabilised building block are fully tied at two floors above the level of the props.

5.5.9 Upper column extension splices

Extensions to upper level columns should be made by a mechanical or grouted connection at the level of the splice. The level of the splice should not be more than 1.0 m above the floor level, and the positions of the splices through the frame should be staggered over two successive storeys, i.e. do not form all splices at the same level. Props should be positioned and secured as in Section 5.5.4.

If a welded or bolted splice is used, the PCE should ensure that the horizontal capacity of the splice in its temporary ungrouted condition will resist the horizontal reaction from the prop.

If projecting rebars in grouted sleeves is used, a temporary bracket should be designed and secured to the upper and lower parts of the column to resist the horizontal reaction from the prop, until such time as the splice is completed by filling the sleeves around the rebars.

Upper column welded or bolted splices are shuttered fully on 3 sides, taking care to avoid grout loss, with an opening on one side to allow filling using flowable (slump 100 mm) mortar grout of minimum grade equal to that of the parent column, using 4/0 sharp sand containing non-shrink or expansive cement or admixtures according to the manufacturer's instruction. The opening is filled to 10 mm shy of the upper column. Control cubes are taken as before. The formwork is removed after 24 hours and a dry pack mortar of the same strength is inserted by hand and trowel into the 10 mm gap, and floated flush and smooth.

Upper column splices using projecting bars in sleeves are gravity filled using the same mortar grout, control cubes and removal time as above. The gap between the columns should be sealed to prevent grout loss using foam or expansive materials, which is removed and later filled using dry pack and floated flush and smooth.

5.5.10 Verticality and position

Column fixing tolerances are according to BS EN 13670:2009, *Execution of concrete structures.* Columns should be vertically plumb to within ± 6 mm per storey and ± 15 mm over the full height. Horizontal position should be within ± 6 mm per column, and ± 15 mm over the total length of a building façade. Distances between faces of column should be within ± 6 mm, but not cumulative. The twist of the column across the face of the façade should be within ± 6 mm.

5.6 Erection of Walls

5.6.1 Base preparation

Walls founded on steel base plates or on projecting bars. The PE should check the setting out of the foundations to ensure that the position is on the centre lines of the wall. PE should clear the foundation surface from debris, other contaminants and standing water. The level of the bottom of the wall should be 50-75 mm below the finished level of the bottom of the wall. If more than 72 hours before wall erection is available, two levelling plates, 150 x 150 x 6 mm mild steel, should be set in the centre of foundation approximately 500 mm from the ends of the wall, on dry pack mortar, of 2:1 sand/cement with a water/cement ratio of about 0.3. The dry pack should be heaped at an angle of 45° beneath the plate. If less than 72 hours is available, a composite packing of 150 x 150 x 3 mm mild steel plates and 150 x 150 x 10 mm ceramic or mortar tiles of minimum compressive strength 40 N/mm^2 should be set in an alternate sandwich manner, with a heaped dry pack mortar surround to hold the plates in position. The top plate should be set in position with a tolerance of ±10 mm and to a level of +0 -3 mm.

Infill walls attached to columns and supported on insitu concrete foundations or precast ground beams shall use the same levelling plates as above.

5.6.2 Pitching

Walls delivered vertically should be offloaded from the delivery vehicle using at 2 lifting points and preferably fixed directly. Walls delivered horizontally should use 4 lifting points, stacked and pitched onto temporary supports according to Section 5.3. Pitching will be from the lifting sockets at the top of the wall. They should not interfere with any connections.

The concrete around the pitching devices or pitching hole should be designed and reinforced to resist the forces at all stages of offloading and pitching.

The wall should be inspected for any cracks, particularly around the lifting points, when at an inclination of about 5^o from the horizontal. The cracks should be marked alongside them using a marker pen. If the cracks are visible when the wall is upright, the PE should inform the PCE in order to assess the effects. If the cracks are no longer visible no further action is required.

The wall should be pitched at a rate of less than 90 m vertically per minute.

5.6.3 Propping at ground floor

The GC should provide the adequate foundations for the props at no extra charge. The PE may first attach the props to the walls before pitching, or after the wall is erected.

If access is available on both sides, at least 2 props per side, or as shown on the construction drawings as maximum distances between props, should be attached at approximately 500 mm below the top of the wall and at 1/5th distances along the wall, into drilled or cast-in fixings in the wall, inclined at between 45°-55° to the horizontal and within ±50 mm vertically. Where more than one wall panel forms a completed wall system, the walls should not be propped off each other. Cast-in fixings should be designed to resist the inclined force from the prop.

The bottom of the props should be founded on firm ground, or on a prepared base. The PE should calculate the axial compression in the props at a calculated spacing and procure props according to Section 5.5.3.

If access is not available on one side, push-pull props with compression and tension capacity shall be used. The props should be attached to a drilled or cast-in fixing at both ends. The PE should calculate the axial tension and compression in the props and supply props as above.

Infill walls attached to columns by bolted connections directly to the columns do not require propping. Infill walls attached to columns by welding or by grouted dowels require either the same props as above, or temporary brackets or yokes positioned at all 4 corners.

Walls which rely on composite action with beams and floor slabs should be propped until the insitu concrete infill in the floor zone is cast and hardened according to the construction drawings.

5.6.4 Propping at upper floors

The same procedures as in Section 5.6.3 shall be used, except that the bottom fixing should be drilled or cast-in to the beams and floor slabs at 1st floor, and subsequent floor levels.

5.6.5 Temporary fixings for stability

Infill walls attached to columns by bolted connections into cast-in threaded sockets shall be secured according to the construction drawings whilst being held in place by the crane.

Infill walls attached to columns by welding or by grouted dowels, if not propped, shall use steel brackets or yokes secured to the column at approximately 500 mm from each corner of the wall. The brackets should be designed and manufactured to resist the horizontal reactions from the walls, including out-of-plumb forces and wind pressure.

5.6.6 Grouting at base and upper connections

The walls may be aligned vertically using a plumb bob and string, or spirit level.

When aligned, the gap between the wall and foundation should be shuttered and filled using a flowable (slump 100 mm) mortar grout of minimum grade C40 using 4/0 sharp sand containing non-shrink or expansive cement or admixtures according to the manufacturer's instruction. Control cubes shall be manufactured as in Section 3.1.4 and tested at 24 and 72 hours, and 28 days. Compliance shall also be as in Section 3.1.4. Brackets or yokes may be removed a minimum of 24 hours after casting, or when the compressive cube strength reaches 10 N/mm^2.

The gap between infill walls and beams/columns at bolted and welded connections shall be hand and trowel filled using dry pack mortar, of 2:1 sand/cement with a water/cement ratio of about 0.3.

The connections between infill walls and columns at dowelled connections shall be filled using a medium workability (50 mm slump) mortar as above. The gap between the wall and beams/columns shall be filled using dry pack mortar as above.

Protection of the exposed surfaces is not necessary.

5.6.7 Removal of props at all floors

The props should remain in position for at least 3 days after casting or when the compressive cube strength reaches 10 N/mm^2, whichever is later. In situations of bad weather or high winds, the PE may choose to leave all props in place until the next upper walls and floor slab is completed.

5.6.8 Wall extension splices

Extensions to upper level walls should be made by a mechanical or grouted connection. The level of the splice should be at the floor level. Props should be positioned and secured as in Section 5.6.3, and connections to columns as in Section 5.6.5.

If a welded or bolted splice is used, the PCE should ensure that the horizontal capacity of the splice in its temporary ungrouted condition will resist the horizontal reaction from the prop.

If projecting rebars in grouted sleeves is used, a temporary bracket should be designed and secured to the upper and lower parts of the wall to resist the horizontal reaction from the prop, until such time as the splice is completed by filling the sleeves around the rebars.

Upper wall welded or bolted splices are shuttered fully on both sides, taking care to avoid grout loss, with an opening on one side to allow filling, dry pack and floating as in Section 5.5.9.

Upper wall splices using projecting bars in sleeves to allow gravity filling, dry pack and floating as in Section 5.5.9.

5.6.9 Verticality and position

Wall fixing tolerances are according to BS EN 13670:2009, *Execution of concrete structures.* Walls should be vertically plumb to within ± 6 mm per storey and be corrected for each storey height. Horizontal position should be within ± 6 mm per wall, and ± 15 mm over the total length of a building façade. The twist and straightness of the wall across the face of the façade should be within ± 6 mm per 3 m, but not cumulative

5.7 Erection of Beams at Column Face and Corbels

5.7.1 Preparation of column face at bearing level

The level of the seating is determined from a scribed mark on the column, which is of known level relative to the level of the soffit of the beam, e.g. 1.0 m below.

Beams supported on steel billets with vertical dowels. The billet surface should be cleaned to remove debris such as mortar. Steel horseshoe shims (rectangular with a slot on one side) 75 x 75 mm in size of

thickness 3, 6 and 10 mm typically are placed centrally on steel bearings over the dowel hole or dowel to establish the bearing level to within +0 -3 mm.

Beams supported on concrete corbels or haunches. The concrete surface should be cleaned to remove debris such as mortar. Neoprene or similar elastomeric horseshoe bearing pad, of size to within 25 mm of the edges of the corbel are placed centrally to establish the bearing level to within ±3 mm.

5.7.2 Lifting

Beam should be offloaded from the delivery vehicle using 2 lifting points and preferably fixed directly, or may be placed on temporary supports according to Section 5.3. The positions of the lifting points and lifting devices, such as spreader beams or chain separators, should not interfere with connections or fixing methods.

5.7.3 Levelling and position

Precast beams shall be properly aligned and levelled as required by the approved PCM's drawings. Variations between adjacent components shall be reasonably levelled out by jacking, loading or any other feasible methods as recommended by the PCM and approved by the SO.

The beam shall be positioned on the bearing pads and checked for level against the datum. If the level of the top of the beam or the edges of the beam either side of centre line are not within ±6 mm of the construction drawings, the beam should be hoisted clear of the support to allow modifications to be made as in Section 5.7.1. The position of the beam should be as in Section 5.7.6.

Beams using bolted connections should be made to the column whilst the beam is held by the crane. The PE must ensure that the threaded part of dowels is undamaged and that any protective covering is still in place. Grout splashes should be removed from the threaded part. The nut should have a full thread. If in the course of tightening the concrete is damaged or cracked this should be reported to the PCE who should advise on remedial action or replacement. No attempt should be made to manoeuvre the beam using the nut and dowel as leverage.

Beams using welded connections can be made to the column whilst the beam is held by the crane, or temporarily secured using brackets or yokes. The provisions for welding in Section 3.11 should be followed. Care should be taken not to input too much heat to cause distortion to the level of the beam. If during welding the concrete is damaged, over heated or cracked this should be reported to the PCE who should advise on remedial action or replacement.

Beams using dowelled connections should be secured using brackets or yokes to provide restraint against twisting. The cavities provided to place the dowels and bars should be cleared of debris and other contaminants, such as polystyrene recess formers. If the concrete surface is smooth as an ex-steel mould finish a bonding agent should be applied to the surfaces, otherwise the surface should be dampened prior to grouting.

All brackets and yokes should be designed, manufactured and tested by the PE to the satisfaction of the PCE. There are no Standards to cover this.

5.7.4 Propping against twist

Beams without restraint against twisting shall be propped to ensure the beam is restrained. At least 2 props should be placed at either side of the beam at approximately ¼ span of the beam, and should be designed, positioned and secured by the PE. The props should be placed concurrently with the beam fixing. Protective cross heads will be required to prevent damage to overhanging parts of the beam. The props should be back propped at lower levels terminating on firm footing at ground level. These props should be removed from the upper floors proceeding downwards.

The props should remain in position for at least 3 days after completion of the floor slab or when the compressive cube strength of the insitu infill reaches 10 N/mm^2, whichever is later.

5.7.5 Grouting

When aligned and levelled, the connections should be completed using small reinforcement cages as/if shown on construction drawings, shuttered and the gaps gravity filled using a flowable (slump 100 mm) mortar grout of minimum grade C40 or equal to the grade of the precast component, using 4/0 sharp sand containing non-shrink or expansive cement or admixtures according to their manufacturer's instruction. The mortar may be poured directly in to the gaps, or through grouting holes according to the construction drawings. If the gap is greater than 100 mm minimum dimension, 6 or 10 mm coarse aggregate may be used.

Control cubes shall be manufactured as in Section 3.1.4 and tested at 24 and 72 hours, and 28 days. Compliance shall also be as in Section 3.1.4. Shuttering, brackets or yokes may be removed a minimum of 24 hours after casting, or when the compressive cube strength reaches 10 N/mm^2. Remaining gaps shall be hand and trowel filled using dry pack mortar, of 2:1 sand/cement with a water/cement ratio of about 0.3.

The insitu infill shall be inspected for voids and lack of compaction particularly at under soffits. Small voids, less than 20 mm in size, may be filled using dry pack as above. Larger voids should be broken out to enable inspection behind surface defects and made good using dry pack as above. This remedial action will delay removal or brackets and props etc. by the same time duration.

5.7.6 Dimensional tolerances

Beam fixing tolerances are according to BS EN 13670:2009, *Execution of concrete structures*. The top of the beam should be within ± 6 mm. The edges of the beam either side of the centre line should be within ± 6 mm.

5.8 Erection of Beams at Column Head

5.8.1 Preparation of column head

The level of the seating is determined from a scribed mark on the column, which is of known level relative to the level of the soffit of the beam, e.g. 1.0 m below.

The concrete surface should be cleaned to remove debris such as mortar. Neoprene or similar elastomeric horseshoe bearing pad, of size to within 25 mm of the edges of the column head are placed

centrally to establish the bearing level to within ±3 mm. Projecting dowels or rebars from the top of the column should be cleaned for adhered mortar or other obstructions preventing the flow of grout around the dowels.

5.8.2 Lifting

As Section 5.7.2.

5.8.3 Levelling and position

The beam shall be positioned on the bearing pads and checked for level against the datum. If the level of the top of the beam or the edges of the beam either side of centre line are not within ±6 mm of the construction drawings, the beam should be hoisted clear of the support to allow modifications to be made as in Section 5.7.1. The position of the beam should be as in Section 5.8.6.

Beams should be secured using brackets or yokes to provide restraint against twisting. The brackets should be designed, manufactured and tested by the PE to the satisfaction of the PCE. There are no Standards to cover this.

The gaps between the bottom of the beam and the column head should be either dry packed or filled using foam or similar to prevent grout loss.

If the construction drawings show the vertical gap between the ends of the beams is filled, the gap should be sealed as above, otherwise left open.

5.8.4 Propping against twist

As Section 5.7.4.

5.8.5 Grouting

When aligned and levelled, the connections should be shuttered and the gaps gravity filled using a flowable (slump 100 mm) mortar grout of minimum grade C40 using 4/0 sharp sand containing non-shrink or expansive cement or admixtures according to the manufacturer's instruction.

Control cubes shall be manufactured as in Section 3.1.4 and tested at 24 and 72 hours, and 28 days. Compliance shall also be as in Section 3.1.4. Shuttering, brackets or yokes may be removed a minimum of 24 hours after casting, or when the compressive cube strength reaches 10 N/mm^2. Remaining gaps shall be hand and trowel filled using dry pack mortar, of 2:1 sand/cement with a water/cement ratio of about 0.3.

If the construction drawings shows the vertical gap between the ends of the beams unfilled, and if grout enters and fills the gap, it should be removed without damage to the ends of the beams to ensure a physical gap as shown on the construction drawings.

5.8.6 Dimensional tolerances

As Section 5.7.6.

5.9 Erection of Prestressed Concrete Hollow Core Slabs

This specification has been written in general terms without specific reference to proprietary hollow core units and other associated components such as trimmer angles, lifting hooks/pins, as provided by the hollow core PCM.

The PCM of the hollow core units can provide additional their own complimentary specification where necessary in compliance with the conditions of contract undertaken.

5.9.1 Preparation of slab bearing areas and levels

Bearing areas should be cleaned of debris and all obstructions to fitting the units. The finished structural floor level should be measured at the supports near to columns or at supporting walls. Allowances for upward camber of prestressed hollow core units and in prestressed beams should be allowed for in design, and should not form part of the floor tolerances. The variation in level of the top of the precast unit, or the top of the structural topping, should be as given on the construction drawings.

5.9.2 Lifting

The units should be inspected for damage, defects and cracks before being offloaded from the delivery vehicle. These should be reported to the PCM of the hollow core units and the PCE, and to the PE if a sub-contractor is erecting the units.

Prestressed units should be lifted using either under-slung lifting chains, lifting clamps, or lifting hooks or pins.

Lifting chains should be positioned not more than 500 mm from the ends of the units, and the brothers should be adjusted to ensure that the unit is not tilted across its width. The unit should be level, or within a slope of approximately 100 mm per 6 m length, and pro-rata. A small gap between units is left in order to withdraw the chains.

Lifting clamps should be used according to the manufacturer's instructions, which will ensure that the unit is symmetrically balanced and not tilted. Safety chains must be used, which are removed just before final positioning.

Lifting hooks and spherical head pins should used according to the manufacturer's instructions, and be positioned at about 1.2 m from the ends and at the 2nd or 3rd hollow core in from the edges, according to the hcu producer's instructions. The top of the lifting pins should not project above the top surface of the unit. The lifting clutch should sit down fully and be in contact with the top of the concrete in front of the pin. Their positions across the units should be symmetrical - this is particularly necessary in ripped (reduced width) units where symmetry may be lost leading to tilted units that may be difficult to fit in some situations. Safety chains must be used, which are removed just before final positioning.

5.9.3 Bearing materials and levelling shims

Unless a unit straddles two bearings of different level, no bearing or bedding material is required on structural steelwork for any length, or on precast concrete for units of less than 10 m span.

Bearing materials should be provided on cast insitu concrete and masonry. Neoprene or similar elastomeric materials may be laid in a single strip, or in two narrower strips, to be in position according to the construction drawings. This should not be displaced when the unit is fitted, and be checked using a feeler gauge afterwards.

Wet bedding using low workability sand-cement mortar of minimum grade C30 or as shown on the construction drawings, may be used. Two plastic, or similar visco-elastic material, shims, approximately 60 x 60 x 3 mm, should be placed on the support at least 30 mm from the leading edge and at ¼ distances across the width. Mortar bedding is laid continuously (should not be intermittent) across the width of the unit around the shims. After fixing the mortar will be squeezed towards the front edge of the support. This should be pointed off to give a recess or rake at the edge of the supporting member of at least 15 mm.

5.9.4 Bearing lengths

Nominal bearing lengths should be specified on the construction drawings. For site fixers this means "actual" bearing length. The tolerance should be ±10 mm. The minimum bearing on structural steelwork should not be less than 40 mm; on precast concrete 55 mm; and on insitu concrete and masonry 75 mm. Attempts should be made to equalise bearing lengths, except in restricted areas where a greater than nominal bearing may be provided at one end. If bearing lengths are less than this the PCE should be informed to assess whether the unit should be replaced or whether an extended bearing can be provided.

Where a single unit straddles across two bearings, e.g. at a beam-column, or beam-beam junction, the minimum bearing should govern.

5.9.5 Longitudinal gaps

Units should be closed together such that the visible width of the longitudinal gap at the bottom is not more than 10 mm, and should not be cumulative. The PCE and hollow core producer should be informed if the gaps accumulate.

Units should not be forced together such that the lip at the bottom edge of one unit rides over and onto the lip of the adjacent unit.

5.9.6 Differential camber and levels

Maximum differential camber is not specified in BS EN 13670:2009 for units without a structural topping, nor in BS EN's 1992, 1168 and 13369. The limits given in BS 8110-1, clause 6.2.8.4 (6 mm for span up to 4.5 m, or 9 mm if greater) have been shown to be impractical and unnecessary. Unless maximum differential camber is agreed between the PCE and PE, with approval by the slab producer, this specification proposes the following irrespective of the design and prestressing moment. The difference in camber between two adjacent units should not be more than 9 mm for a span of up to 6 m, and 15 mm for greater.

The units may be propped to reduce excessive differential camber. Attempts to equalise differential camber by clamping and wedging units together or using dead weights to reduce the higher camber should not be used as this reduces the load bearing capacity of the unit.

Where differential camber is due to different spans in adjacent units, or units meeting in different directions, this should be shown on the construction drawings.

5.9.7 Uneven bearings and rocking

Units having uneven bearings or are rocking after fitting are susceptible to torsion and longitudinal cracking, and should be lifted and repositioned on bedding according to Section 5.9.3.

5.9.8 Insitu cutting of hollow core units

Units may only be site cut with written notification from the PCE and the producer. When given, a stihl saw of similar should be used and cuts made according to a construction drawings. Photographic evidence of the cutting before and afterwards should be made.

5.9.9 Grouting longitudinal joints and milled end slots (shear key grouting)

Longitudinal joints should be sealed to prevent grout loss using dry pack mortar or foam strips. They should afterwards be filled using flowable concrete containing 10 mm coarse aggregate, of minimum grade C25 or according to the construction drawings. It is not necessary for the joints to be dampened.

If a structural topping is to be used, grout splashes should be avoided as these cause flaky laitance as a bonding hazard to the insitu topping. The joints should be completed at least 24 hours before the topping is cast.

5.9.10 Propping for structural topping

The number and position of props will be shown on the construction drawings. The PE should calculate the axial compression in the props at a calculated spacing and procure props according to Section 5.5.3. The props should contain head plates, and be back propped down to a firm foundation at ground level. The PE should brace and secure the props as necessary. A continuous timber or steel batten should be inserted between the prop and under soffit of the units if the head plates do not cover the width of the units. No part of the unit width should be unsupported.

The props should remain in position for at least 3 days after the completion of the topping, or when the compressive cube strength has achieved 20 N/mm^2. The props should be removed alternately, working from the ends of the floor bay inwards. Back props at lower floors should be removed after all higher level props are removed.

5.10 Erection of Double-tee Slabs

This specification has been written in general terms without specific reference to proprietary double tee units and other associated components such as trimmer angles, lifting hooks, welded flange plates, as provided by the PCM of the double-tee units.

The PCM of the double-tee units can provide additional their own complimentary specification where necessary in compliance with the conditions of contract undertaken.

5.10.1 Preparation of slab bearing areas and levels

As Section 5.9.1, in addition to setting out the position of the bearing pads.

5.10.2 Lifting

The slabs should be inspected for damage, defects and cracks before being offloaded from the delivery vehicle. These should be reported to the double-tee slab producer and the PCE, and to the PE if a sub-contractor is erecting the units. Double-tee slabs should be lifted directly from the vehicle if possible using the 4 no. lifting hooks projecting above the top of the webs. The hooks may be cut off (or bent down) after installation of a full bay of slabs, or at such time as the slabs are permanently in place.

Lifting chains brothers should be adjusted to ensure that the slab is not tilted across its width. The slab should be level, or within a slope of approximately 100 mm per 10 m length, and pro-rata.

5.10.3 Bearing pads and position

The position and level of bearing pads beneath the ribs of the double-tee units should be set out and marked on the bearing ledge. The front edge of the bearing pad should not be closer than 25 mm from the front edge of the support, including where a chamfer is provided at the edge of the support.

The material, size and thickness of the bearing pad should be given on the construction drawings, typically 100 x 100 x 6 mm neoprene or felt.

The clear gap between adjacent units shall be according to the construction drawings, typically 10 mm, but not more than 20 mm at any point along the length of the slabs.

5.10.4 Welded plate connections

After installation of a complete bay of double-tee slabs, i.e. as bounded by columns or intersecting walls, a welded connection is made between plates cast into the edges of the flanges, and between the flange and edge beams or spandrels. Site welding is according to Section 5.18. An intermediate plain round mild steel dowel, of diameter 5 mm greater than the clear gap between the edges of the plates, shall be welded either side to the plates according to the construction drawings.

5.10.5 Differential camber and levels

Maximum differential camber for double-tee slabs that will receive a structural topping is not specified, and is decided by the fixing contractor on practical grounds due to the welded connections. However the difference in camber between two adjacent units should not be more than approximately ±span/600, or ±15 mm maximum. Slabs with more than this should be repositioned or replaced according to the situation. Reduction of differential camber to enable the welded connection to be successfully made can be achieved by propping until the welded connections are made. The concrete area around the plates should be inspected for cracking after the props are removed.

5.10.6 Insitu cutting of slab

Double-tee slabs may only be site cut with written notification from the PCE and the producer. When given, a stihl saw of similar should be used and cuts made according to a construction drawings. Photographic evidence of the cutting before and afterwards should be made.

5.10.7 Propping for structural topping

As Section 5.9.10, in addition the props should only be positioned beneath the webs of the double-tee slabs.

5.11 Erection of Precast Half Slab

This specification has been written in general terms without specific reference to proprietary half-slab or solid prestressed units and other associated components such as trimmer angles, lifting hooks, as provided by the PCM of the half-slab.

The PCM of the half-slab can provide additional their own complimentary specification where necessary in compliance with the conditions of contract undertaken.

5.11.1 Preparation of slab bearing areas and levels

As Section 5.9.1.

5.11.2 Lifting

The slabs should be inspected for damage, defects and cracks before being offloaded from the delivery vehicle. These should be reported to the slab producer and the PCE, and to the PE if a sub-contractor is erecting the units. Half-slabs should be lifted directly from the vehicle if possible using the 4 or 6 no. lifting hooks (1.2 and 2.4 m wide, respectively) projecting above the top surface. In the case of slabs containing reinforcement cages with diagonal links, the reinforcement cage should not be used for lifting. The hooks may be cut off (or bent down) after installation of a full bay of slabs, or at such time as the slabs are permanently in place.

Lifting chains brothers should be adjusted to ensure that the slab is not tilted across its width. The slab should be level, or within a slope of approximately 100 mm per 6 m length, and pro-rata.

5.11.3 Bearing materials and levelling shims

As Section 5.9.3. Unless a half-slab straddles two bearings of different level, no bearing or bedding material is required on structural steelwork for any length, or on precast concrete for half-slabs of less than 6 m span.

5.11.4 Bearing lengths

As Section 5.9.4.

5.11.5 Longitudinal gaps

Half-slab should be closed together such that the visible width of the longitudinal gap at the bottom is not more than 15 mm, and should not be cumulative. The PCE and half-slab producer should be informed if the gaps accumulate. They should not be forced together such that the lip at the bottom edge of one unit rides over and onto the lip of the adjacent unit.

5.11.6 Differential camber and levels

Maximum differential camber for half-slabs that will receive a structural topping is not specified. The slabs may be propped to reduce excessive differential camber. Attempts to equalise differential camber by wedging units together or using dead weights to reduce the higher camber should not be used as this reduces the load bearing capacity of the slab.

Where differential camber is due to different spans in adjacent slabs, or units meeting in different directions, this should be shown on the construction drawings.

5.11.7 Uneven bearings and rocking

As Section 5.9.7.

5.11.8 Insitu cutting of half-slab

As Section 5.9.8.

5.11.9 Grouting of longitudinal joints

Longitudinal joints should be sealed to prevent grout loss using dry pack mortar or foam strips.

5.11.10 Propping for structural topping

As Section 5.9.10.

5.11.11 Storage of materials on precast half-slab

Loads due to temporary storage of materials acting on the precast part of the half-slab should be assessed by the PE. This information in permissible kg/m^2 or kN/m^2 shall be given on the construction drawings.

5.12 Stability Ties

5.12.1 Types and specifications

Stability ties, as specified and design in Section 2.3.7, take the form of continuous bands of reinforcement over the perimeter and interior beams or walls, and if necessary continuous vertical reinforcement in columns and walls.

If a structural topping is used, all ties will be provided by a continuous mesh in the topping, as designed by the PE and given on the construction drawings. The sheets of mesh will be lapped (inverted nesting) and also lapped to ties projecting from edge beams and walls. If no structural topping is available site placed tie bars are used as follows.

The type of reinforcement will be given on the construction drawings in the form of high tensile rebars (typically 16 to 25 mm diameter) or strand (typically 9.3 to 12.5 mm diameter standard 7-wire helical strand). The strand is laid unstressed but taut. Tie bars are placed on site and insitu concreted after installation of a complete, or part complete, floor slab area(s). Any separate area will be shown on the construction drawings.

5.12.2 Positioning and cover

The positions and cover of the ties relative to other reinforcement in the elements, e.g. projecting links, and site placed tie bars, will be shown on the construction drawings. Tie bars should pass beneath and inside any projecting reinforcement in the elements, e.g. beam stirrups. The PE should check the lengths of tie bars are report any variations, particularly short bars, to the PE.

Floor ties from beams and walls may be used either as site placed rebars, straight, L-shape, or U-shape, or may be cast into the beams and manoeuvred into position by hand on site.

5.12.3 Lapping

Ties should be lapped a full anchorage bond length as given on the construction drawings. Helical strand should be lapped a distance equal to 100 diameters. Lapped bars should be touching and wired together.

5.12.4 Fixings to cast-in sockets

Ties may be coupled to elements by threading into cast-in sockets. The length of the thread must be at least equal to the tie bar diameter. The socket must be fully anchored in the element.

5.12.5 Internal and external corners

At internal corners where it is not practical, or structurally possible, to continue a tie around a corner, the tie may either be mechanically anchored as Section 5.12.4, or may be extended a full anchorage bond length past the corner into the floor slab, and with the required cover be cast in insitu concrete.

At external corners tie bars may be continuous around the bends. Rebars should have an internal bend radius of about 7 diameters, and strand at least 500 mm.

5.12.6 Insitu concrete

Insitu concrete for the casting of ties is according to Section 5.13. The concrete should be grade C25 cube strength, using a with a 10 mm coarse aggregate, a 75-100 mm slump.

5.12.7 Continued stability

Ties should be concreted into position at not more than three days and two floor levels below the level at which precast erection is taking place, i.e. erection at the 5th floor means ties should have been cast in hardened insitu concrete at the 3rd floor three days earlier.

5.13 Insitu Concrete

5.13.1 Specification

The specification is given in Section 3.1.4. The requirements for the preparation, delivery, placement, compaction and curing of insitu concrete are given in BS EN 13670:2009 *Execution of concrete structures*, Section 8, except clauses 8.4.3 to 8.4.6.

5.13.2 Preparation and placement

Insitu concrete may be supported either on temporary or permanent formwork, such as half-slab, precast shutter units.

Temporary formwork should be designed and installed, including for any propping, according to BS EN 12812:2004, *Falsework. Performance Requirements and General Design*, taking account of the total mass of concrete and reinforcement on the formwork. Formwork should be tight fitting so that grout loss is avoided. Narrow gaps may be filled using foam or other fillers. Gaps wider than 50 mm should be shuttered.

Permanent shutters should be tight fitting such that the total mass of concrete is supported, and grout loss is avoided. They should be examined for cracks and other defects before the concrete is placed. If propping is required the shutter units should be designed to cater for localised shear at the prop head, and for negative bending over the top of the prop. Props should remain until the insitu concrete has achieved the necessary strength as specified on the construction drawings or in the method statement. Props should be installed vertically, with back propping to a foundation, and where necessary should be braced.

Where insitu concrete is used to make up floor or beam sections, the final dimension for the depth or thickness should not vary by more than +10 mm, -5 mm.

Where insitu concrete is used to fill gaps between floor units, a variation of more than 50 mm per 1200 mm wide floor unit, or proportionately less for narrower units, is allowed, otherwise the PE should consult with the PCE so the effects may be assessed.

Reinforcement in the infill should be placed according to the construction drawings, with any restrictions and variations reported to the PCE.

Surface preparation should be cleaned by brushing or air-jets to remove all debris, mortar, oil or other contaminants that could impair bond, in particular at joints.

Before concreting commences, the PE should ensure that the weather conditions are satisfactory as foreseeable. Concrete should not be placed in conditions that are likely to cause excessive water in heavy rain.

Concrete should be compacted using a poker vibrator to liberate air until surface bubbles appear. The diameter of the poker should appropriate to the dimensions of the infill, but in generally not more than 40 mm, or 25 mm if the minimum dimension is less than 200 mm.

5.13.3 Surface finish for concrete and curing

Concrete surfaces shall be of Class F13 finish and all concrete work shall be cured for the full period of curing which shall not be less than three days.

Insitu concrete should be protected against rain and direct sun, using an appropriate membrane for a minimum of 12 hours. Ponding using water is not recommended. Curing and protection shall start immediately after compaction of the concrete to protect it from (i) impact damage such as shock, overloading or falling earth which may disrupt the concrete and interface with its bond to reinforcements, (ii) premature drying out from direct sunlight and wind, (iii) Leaching out by rain and flowing water and (iv) high internal thermal gradients.

5.13.4 Grouting operations

Flowable grout shall be cast either (i) by gravity into the annulus between precast elements or cast-in sleeves, e.g. grout tubes in beams and columns or (ii) by pressure from the bottom up. Gravity fed grout should have a clear gap of at least 5 mm greater than the size of aggregate, or at least 20 mm. The grout should have a slump of at least 100 mm or use a self compacting admixture. In the former, a small tamping rod (12 dia. max) or similar should be inserted to aid compaction. The operative should calculate the approximate volume of material required and report any variation in the grout consumed. Pressure grouting shall be carried out using a grout pump of working pressure of 1 bar ±20% using a flexible hose of 40 mm nominal diameter connected to the input sleeves. An open vent should be provided at an appropriate height, but not more than about 1 m, above the input hose.

A formwork box or otherwise a dam should be formed around the infilling, using foam strips or dry pack to prevent grout loss.

5.13.5 Dry packing operations

Dry pack is specified in Section 3.2.4. The preparation bed for the dry pack should be cleaned free of debris and mortar. Loose mortar around projected rebars should be chiselled free, and the surfaces are free from obstruction. A backing strip of formwork, or dry pack mortar should be made to prevent losses.

Access to both internal and external faces of the joint should be possible. After filling the gap the mortar should be pointed off flush with the vertical faces.

If dry pack is used to complete a slab to beam or wall bearing, the dry pack should be pointed off to give a recess or rake at the edge of the supporting member of at least 15 mm.

5.13.6 Quality control

Cubes should be manufactured and tested for all dry pack and grouting operations according to Section 3.1.4.

5.14 Structural Toppings, including Half Slab

5.14.1 Specification

Structural toppings are added to the top surfaces of precast concrete floor elements so as to act in composite action as a monolithic slab. The design for shear capacity is according to BS EN 1168:2004, clauses F.2 and F.4. The design for shear at the interface between the precast and insitu concrete is according to BS 8110-1, clause 5.4.7 and Table 5.5. All materials and construction methods used shall be according to this Specification in addition to the special clauses given in this Section.

Structural toppings may be constructed by the PE, or by a flooring subcontractor to the PE (SC-PE). The SC-PE shall be responsible to the PE and not directly to the PE.

Structural toppings should not be cast onto precast floor units that are themselves less than 14 days of age.

5.14.2 Surface preparation

The top surface of the precast element shall be as produced during manufacture as “as-cast” without further treatment after casting, or “brushed, screeded or rough tamped” in attempts to expose the aggregate beneath the cement laitance. These definitions are according to BS 8110-1, Table 5.5.

The surface preparation shall be stated on the construction drawing. Prior to placing the topping, the surface shall be brushed clean to remove all loose debris, dirt, laitance, or any other contaminants. Surface laitance due to cutting of hollow core slabs shall be removed at the factory. Laitance at the edges of units adjacent to where joints have been filled shall be brushed clean during the filling operation. The surface of the floor element shall be wetted using approximately 1.5 litres of water per sq. m, depending on the ambient conditions. The surface shall not be allowed to dry out, and free water shall be removed.

5.14.3 Special machine production

Surface finishes produced by the slip forming or extrusion technique shall be “as-cast or extruded”, unless raking or brushing with steel bristles is carried out perpendicular to the direction of casting immediately after casting to comply as “brushed or rough tamped” to BS8110-1, Table 5.5. This is the maximum surface roughness advisable after machine production. The surface finish shall be given on the production drawings.

5.14.4 Mesh position, cover and laps

If a structural topping is used, all ties will be provided by mesh in the topping, as designed by the PCE and given on the construction drawings. Any restrictions and variations shall be reported to the PE who should report to the PCE.

A structurally continuous mesh (typically square mesh A142 or A193) or other orthogonal high tensile reinforcing bars shall be used in a structural topping, according to BS 8110-1, Table 3.25 for rectangular sections considered as a solid slab.

The reinforcement bars or sheets of mesh will be lapped (inverted nesting) and also lapped to ties projecting from edge beams and walls according to anchorage bond lengths in BS 8110-1, clause 3.12.8.3, but not less than 300 mm. Loose bars of equal size may be used for lapping where three sheets of mesh come together, thereby violating the cover requirements.

The top cover to the reinforcement shall be specified on the construction drawings. The cover to the top surface of the precast floor unit should not be less than 15 mm. Reinforcing bars should be supported on proprietary plastic or cement cover spacers. All bars shall be tied using black annealed tying wire, minimum 17 gauge (1.4 mm), at intervals to prevent the sheets or bars moving apart during concreting operations.

Additional reinforcement may be required in wider gaps as shown on the working drawings. The reinforcement cage should be connected to the interface shear reinforcement as follows.

5.14.5 Site placed interface shear reinforcement in longitudinal joints

Interface shear reinforcement, in the form of mild steel or high tensile U loops (preferable) or dowels shall be as specified on the construction drawings. The loops should be positioned over the top of the bars in the topping at the top cover distance, and be anchored into the longitudinal joints between the precast floor units.

5.14.6 Construction joints

Construction and day joints shall be as specified on the construction drawings, but the construction bay widths should generally not be greater than 15.0 m along the span of the floor units and not greater than 6.0 m across the width of the units. The positions of the joints should not be where there are narrow or small, isolated areas of topping.

The position of the joints should greater than 300 mm from the longitudinal joints between the floor units, and more than two times the breadth of beams or walls parallel with the span. The position along the span of the floor units should be in the middle-third of the span, not at the supports. Formwork shall be levelled and constructed to form the joint. The bars in the topping shall be continuous and perpendicular through the formwork, projecting a lap length according to Section 5.14.4.

5.14.7 Delivery and placement

The longitudinal joints between hollow core units and precast half-slab planks, and the milled end slots in hollow core floor units, should first be filled according to Section 5.9.9 at least 24 hours before the topping is cast.

The depth and levels of the top of the topping shall be specified on the working drawings as the minimum depth d according to Section 5.14.4. Screeding rails shall be constructed to levels and falls, to enable the topping to be laid using a screeding beam or similar to the correct final levels, within the tolerances given in Section 5.14.9. Gaps between the precast floor units wider than 50 mm should be shuttered. Narrow gaps may be filled using foam, dry pack or other fillers.

Before concreting commences, the PE should ensure that the weather conditions are satisfactory as foreseeable. Concrete should not be placed in conditions that are likely to cause excessive water in heavy rain.

The specification shall be specified on the working drawings, but should not be less than grade C25 cube strength. Self compacting concrete may be used. Workability of the concrete shall be within a slump limit ± 25mm or ± one third of the workability shown on the construction drawings, whichever is greater.

Wet concrete may be discharged by skip, pump or other appropriate means as close as possible to the working area to avoid carriage of concrete across the beds of reinforcement. Wet concrete should not be heaped to a height greater than given on the working drawings. A slump test should be carried out at the point of delivery and the result recorded to the PE. A slump below 50 mm is not acceptable and should be rejected. No additional water should be added to the mix.

Concrete should be compacted using a vibrating screeding beam or similar, resulting in a tamped, brushed or hand floated surface according to the type of floor finishes to be applied, as given on the working drawings. The surface finish should be consistent in appearance. Excessive, standing bleed water should be removed from the surface.

Concrete spilling over the edge of the formwork at construction joints should be cleaned off.

5.14.8 Power floating

Power floating may be carried out using a mechanical float within about 3 hours of casting depending on weather conditions and the workability of the mix. However, the concrete should be hardened sufficiently to stand the weight of the operative, who will make an indentation in the surface with his foot of about 3 mm. The finishing stage should be started when the surface has dried, and walking over the surface leaves no indents.

The diameter of the blades shall suit the application, but is generally between 0.6 m and 0.9 m, or 1.2 m for large areas. The power (HP) of the float shall suit the application, but generally is 10 hp for pedestrian models and 20 hp for ride models. All areas of the concrete should be covered by the float, using special hand floats to enter corners, etc. Power floating shall only be undertaken by adequately trained operatives, with full health and safety precautions in place.

5.14.9 Tolerances for structural toppings

Toppings shall be cast to the levels according to construction drawings, but not greater than

Depth at thinnest point: +10 mm, -5 mm
Depth at thickest point: +20 mm, -5 mm
Level of floor: +15 mm, -5 mm
Flatness: tamped ≤ 10 mm under 3.0 m straight edge
Flatness: power floated ≤ 5 mm under 3.0 m straight edge
No steps unless shown on construction drawings

For roofs with drainage falls, tolerances should be relative to levels shown on construction drawings

5.14.10 Curing

Insitu concrete should be protected against rain and direct sun, using an appropriate membrane for a minimum of 12 hours. Ponding using water is not recommended. Water based emulsions may be used. The surface should not be disturbed for a minimum of approximately 12 hours, depending on weather conditions and the workability of the mix, or until the cube strength of the concrete is 5 N/mm^2.

5.14.11 Removal of formwork and further concreting

Formwork may be removed after a minimum period of 24 hours or later when the cube strength of the concrete is 5 N/mm^2. The formwork shall be removed to avoid damage to the edges of the topping.

Preparation of further bays may proceed immediately, but concreting shall not take place for 3 working days after casting an adjacent bay.

5.14.12 Quality control

Concrete shall be produced and conform to BS EN 206-1:2000. Concrete - *Specification, performance, production and conformity*. The sampling rates, testing and analysis of concrete cubes are given in Section 3.1.5.

The PCE shall have access to casting records and may visit the site for the purpose of inspection of reinforcement, concrete and processes. The PE shall keep permanent records of cube strengths and densities, and weather conditions during casting and curing.

5.14.13 Crack inspections

The topping should be inspected for cracks within 2-3 days of casting, and again within 2 weeks afterwards, unless the floor finishes are preventing this.

Cracks may form in the topping due to plastic shrinkage, particularly at obstructions and corners, e.g. around columns. Shrinkage cracks are not of structural concern, but can be a source of water entry if exposed. Settlement cracks in the topping may indicate movement of precast floor units beneath the topping, and tend to be straight lines and located over the top of the joints. Cracks wider than 0.3 mm should be referred to the PCE, who should give an instruction to fill the crack, usually by slitting with a diamond wheel to a shallow depth, typically 10-15 mm, and filling with proprietary filler.

5.15 Repairs and Making good

5.15.1 Structural repairs

Repairs to structural elements shall only be carried out following instructions from the PCE, otherwise the element will remain undisturbed or replaced. Where reinforcement is exposed, or rust stains from the reinforcement may be seen, the concrete should be broken back to 10 mm beyond the depth of the reinforcement, fully exposing the reinforcement. The surface should be cleaned free of debris and dust using a wire brush, and primed using a proprietary bonding agent according to BS 5270-1:1989, *Bonding agents for use with gypsum plasters and cement*.

Reinforcement may be coated using anti-carbonation paint. There is no national standard test for carbon dioxide permeability, but it is ready for inclusion under part 6 of a new *BS EN for Masonry Paints*. The infill should use semi-dry mortar containing a non-shrink or expansive cement, and small 6 mm to 10 mm coarse aggregate, depending on the size of the repair.

Cracks to be repaired should be carried out according to BS EN 1504, Parts 1-10. *Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity.*

The surface of the precast concrete components shall not be coated with cement wash or any other preparations that may hide the actual condition of the concrete surface. No repairs shall be permitted on the precast concrete components under any circumstances.

5.15.2 Non-structural repairs

Surface and cosmetic repairs, where the damage is within the depth of the cover concrete, and no reinforcement or rust stains due to reinforcement are visible, may be made with semi-dry mortar or grout of equal strength to the parent concrete. The surface should be prepared as above.

5.15.3 Use of synthetic materials

Alternatively a proprietary acrylic, resin or polymer, etc. modified cementitious mortar may be used as tested according to BS 6319-3:1990, *Testing of resin and polymer/cement compositions for use in construction. Methods for measurement of modulus of elasticity in flexure and flexural strength*.

5.16 Drilling and Cutting

5.16.1 Specification and limitations

Drilling and cutting on site to structural elements shall only be carried out following instructions from the PCE, who should specify the type of drill or saw to be used, the position, depth and diameter of the hole or extent of cutting. If necessary a cover meter survey shall be carried out to determine positions and sizes of reinforcement to be avoided. If reinforcement is contacted during the operation the PE should be informed and alternative instructions issued.

Drilling and cutting shall only be undertaken by adequately trained operatives, with full health and safety precautions in place.

5.16.2 Types of drilling

Drilling of concrete shall be carried out using electrically or pneumatically powered percussive drills, of power appropriate to the operation. If reinforcement is drilled unintentionally, the PCE should be consulted for further instructions. The cutting tip of the drill should be inspected for damage before and during the operations.

5.16.3 Types of cutting

Cutting of concrete shall be carried out using electrically powered chain or diamond wheel saw, or similar, using abrasive wheels or blades, of power appropriate to the operation. The areas to be cut should be clearly marked. The correct water or lubricant supply should be provided. If reinforcement is cut unintentionally, the PCE should be consulted for further instructions. The blade should be inspected for damage before and during the operations.

5.16.4 Temporary support

Temporary support during a drilling or cutting operation shall be designed and instructions given in writing to the PE before work commences.

5.16.5 Cartridge operated fixings

These should not be used.

5.17 Flame Cutting

5.17.1 Specification and limitations

Flame cutting on site to structural reinforcement or inserts shall only be carried out following instructions from the PCE, who should specify the type of equipment, gas supply, power, and the position and dimensions of the cutting. The design implications of excess heat on the concrete during flame cutting should be assessed by the PE. The steel should be uncoated.

Flame cutting shall only be undertaken by adequately trained operatives, with full health and safety precautions in place.

5.18 Site Welding

5.18.1 Specification and limitations

Site welding to steel reinforcement or inserts shall only be carried out following instructions from the PCE, who should specify the type of welding equipment, power, type and size of electrode, and the position and dimensions of the weld. The design implications of site welding should be assessed by the PE. This includes tack welding of reinforcement as a means of assistance during installation.

Site welding shall only be undertaken by adequately trained operatives, with full health and safety precautions in place. All structural welding, if required shall be done by qualified welders using equipments and materials compatible to the base material.

Procedures shall be according to Section 3.11.

5.19 Bolting

5.19.1 Specification and limitations

Bolting should be carried out according to details shown on the construction drawings. Bolts should be clearly marked according to material, diameter, length and grade. The appropriate nut and washer, including friction grip load indicating washers, should be marked. The specification for bolts is given in Section 3.12.

5.19.2 Operations

Unless special instructions are given with respect to bolt torque, bolts should be tightened to a firm torque using a hand wrench. If damage occurs before or during tightening the bolt shall be replaced with an equal specification. If damage, e.g. bending, cracking of concrete around the bolt or cast-in socket, occurs to the connecting members, this should be reported to the PCE.

High strength friction grip bolts should be tightened according to the fixing's specification using a calibrated power or hand wrench, see Section 3.12.4.

5.19.3 Expanding and resin anchor bolts

Proprietary expanding anchor bolts (e.g. Hilti bolts) and resin or chemical anchor bolts (e.g. epoxy acrylate, polyester) should only be used following instructions from the PCE, who should specify the type, diameter, length, location and details of making the fixing. Bolts and resin anchor studs may be galvanised metal, zinc plated or stainless steel, and should be electrochemically compatible with the connecting members. The bore holes should be hammer drilled, twice blown using compressed air and brushed with a stiff round metal brush, and must be free of dust, water, oil grease or other contaminates.

Expanding anchor bolts with internal or external threaded sleeves should be supplied according to ISO 898-1:2009, *Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs with specified property classes*.

Resin anchor bolts should be supplied according to manufacturer's instructions. There is no British standard for resin anchor bolts.

The chemicals used in the resin anchor bolts should be checked for shelf life and mixed, operated and used in temperatures according to manufacturer's specification, particularly above 25°C.

5.20 List of Site Equipment and Materials

The following is a list of equipment required to erect precast concrete frames. It is based on a fixing gang of 5, employing 2 skilled fixers and 3 labourers. The list is not exhaustive, and certain contractors may wish to use alternatives. Minimum number of items in brackets.

Adjustable spanners, M6 to M40 range
Box spanners, ditto
Hammers; claw, lump, sledge
Trowels (2), floats (2)

Spirit level; 1 m long, 200-300 m long (2)
Hand saw, steel saw, stihl saw, pliers, try square, pinchers, shovels (2), spade, pick, brooms (2)
Crow bars, approx. 1.5 m long x 40 mm diameter (2)
Leverage bars, approx 500 mm long (2)
Lifting rod, 40 mm dia. x 600 mm long (or to suit maximum breadth to be lifted) and rope
Pinching bar, 40 mm dia.
Bar bending equipment, 16 mm dia. capacity
Bolt / bar cropper, 25 mm capacity
Concrete drum mixer, capacity 250 litres
Small concrete mortar mixer, capacity 90 litres
Electric drill and bits, 6 to 32 mm range
Petrol or otherwise powered 110 v. electrical generator and leads
Power saw
Diamond blade (spare)
Portable welded equipment, leads and gun
Electrodes
Concrete skip, capacity 0.5 m^3
Water supply and hose pipe, buckets (4)
Cube moulds (6), compacting bar
Hessian or polythene covers for cubes, plastic bags for cubes
Slump cone, steel plate, tamping bar
25 mm diameter vibrating poker with power leads
Wheel barrows (2)
Theodolites (2)
Dumpy level
3 m staff
Tapes; 3 m (2), 6 m, 30 m
Plumb bobs (2), string line
G clamps, 200 mm range (6), 400 mm range (6)
Chains, adjustable chains, slings (1 set each to suit contract)
Lifting loops (2) and Deha clutch (4)
Ratchet wrench and chain attachments
Ladders; 3 m (3), 9 m extendable
Adjustable Acrow (or similar) props; number, length and capacity to suit contract
Angle brackets, column yokes, wall clamps etc. designed and number to suit contract
Steel plates 150 x 150 x 3 mm; 50 kept in store for rolling contracts
Horseshoe shims; square shims; 3 mm, 6 mm, 9 mm thickness or nearest (large number)
Timber battens; timber ply sheets (number to suit contract)
Mould oil, brush, tie wire, nips
Timber wedges; 150 x 50 mm tapered from 75 to 50 mm, 150 x 50 mm tapered from 25 to 0 mm (number to suit contract)
Cement; CEM I grade 42.5N
Sharp sand medium grade 0/4 mm
6 mm gravel and 10 mm coarse aggregate (quantities to suit contract)
Expanding or non-shrink agents (quantities to suit cement)
Bonding agent (quantities to suit contract)

Appendix – List of codes and standards

References are listed in the order they appear in the text.

BS 8110:1997, Structural use of concrete. Structural Use of Concrete -
Part 1: Code of practice for design and construction;
Part 2: Code of practice for special circumstances;
Part 3: Design charts for singly reinforced beams, doubly reinforced beams and rectangular columns.

BS 6399-1:1996, Loading for buildings. Code of practice for dead and imposed loads.

BS 6399-2:1997, Loading for buildings. Code of practice for wind loads.

BS 6399-3:1988, Loading for buildings. Code of practice for imposed roof loads.

BS 5950-1:2000, Structural use of steelwork in building. Code of practice for design.

BS 5628-1:2005. Code of practice for the use of masonry. Structural use of unreinforced masonry

BS EN 13369:2004, Common rules for precast concrete products.

BS EN 1168:2005 +A3:2011, Precast concrete products - Hollow core slabs.

BS EN 13747:2005 +A2:2010, Precast concrete products – Floor plates for floor systems.

BS EN 15037-1:2008, Precast concrete products – Beam and block flooring: in 4 parts.

BS EN 13224:2004, Precast concrete products – Ribbed floor elements.

BS EN 13225:2004, Precast concrete products. Linear structural elements.

BS EN 14843:2007, Precast concrete products – Staircases.

BS EN 14992:2007, Precast concrete products – Wall elements.

BS 8500-1:2006+A1:2012, Concrete. Complementary British Standard to BS EN 206-1. Method of specifying and guidance for the specifier.

BS 8500-2:2006+A1:2012, Concrete. Complementary British Standard to BS EN 206-1. Specification for constituent materials and concrete.

BS EN ISO 6946:2007, Building components and building elements, Thermal resistance and thermal transmittance, Calculation method.

ISO/DIS 10456.2, Thermal conductivity of materials.

BS EN 12354-1:2000, Building acoustics. Estimation of acoustic performance in buildings from the performance of elements.

BS EN 12354-1, Acoustic resistance for superficial mass.

ISO 10137:2007, Basis for design of structures - Serviceability of buildings and walkways against vibrations.

ISO 2631-2001, Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration - Part 1: General requirements.

BS EN 13670:2009, Execution of concrete structures.

BS EN 206-1:2000, Concrete - Specification, performance, production and conformity.

BS EN 12350-1:2009, Testing fresh concrete. Sampling.

BS EN 12390-2:2009, Testing hardened concrete. Making and curing specimens for strength tests.

BS EN 12390-3:2009, Testing hardened concrete. Compressive strength of test specimens.

BS EN 12390-7:2009, Testing hardened concrete - Density of hardened concrete.

BS EN 13139, Aggregates for mortar.

PD 6682-3, Aggregates for mortar- Guidance on the use of BS EN 13139.

BS EN 197-1:2000, Cement - composition, specifications and conformity criteria for common cements.

BS EN 197-4:2000, Cement. Composition, specifications and conformity criteria for low early strength blast furnace cements.

BS EN 12620:2002, Aggregates for concrete.

BS EN 1097-6:2000, Tests for mechanical and physical properties of aggregates.

BS EN 934-1:2008, Admixtures for concrete, mortar and grout. Common requirements.

BS EN 934-2:2009+A1:2012. Admixtures for concrete, mortar and grout . Concrete admixtures. Definitions, requirements, conformity, marking and labelling.

BS EN 934-3:2009+A1:2012, Admixtures for concrete, mortar and grout. Admixtures for masonry mortar. Definitions, requirements, conformity, marking and labelling.

BS 8443:2005, Specification for establishing the suitability of special purpose concrete admixtures.

BS EN 480-1:2006+A1:2011, Admixtures for concrete, mortar and grout. Test methods. Reference concrete and reference mortar for testing.

BS EN 206-9:2010, Concrete - Additional rules for self-compacting concrete.

BS EN 1008:2002, Mixing water for concrete.

BS EN 10080:2005, Steel for the reinforcement of concrete.

BS EN ISO 3766:2003, Construction drawings. Simplified representation of concrete reinforcement.

BS 4449:2005 +A2:2009. Steel for the reinforcement of concrete. Weldable reinforcing steel. Bar, coil and decoiled product.

BS 4482:2005, Steel wire for the reinforcement of concrete products.

BS 8666:2005, Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete.

BS 4483: 2005, Steel fabric for the reinforcement of concrete.

BS 6744:2001, Stainless Steel Bars for the Reinforcement of and Use in Concrete.

BS EN 10088-5:2009. Stainless steels. Technical delivery conditions for bars, rods, wire, sections and bright products of corrosion resisting steels for construction purposes.

BS EN 10138-1, Prestressing steel - Part 1: General requirements.

BS EN 10138-2, Prestressing steel - Part 2: Stress relieved cold drawn wire.

BS EN 10025-1:2004, Hot rolled products of structural steels. General technical delivery conditions.

BS EN 10210-1:1994, Hot finished structural hollow sections of non-alloy and fine grain structural steels – Part 1: Technical delivery requirements.

BS EN ISO 8501-1:2007. Preparation of steel substrates before application of paints and related products. Visual assessment of surface cleanliness. Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings.

BS EN 10164, Steel products with improved deformation properties perpendicular to the surface of the product. Technical delivery conditions.

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

BS EN 1011-1:2009, Recommendations for welding of metallic materials. General guidance for arc welding.

BS EN 60974-1:2005, Arc welding equipment. Welding power.

BS EN ISO 14731:2006, Welding coordination: Tasks and responsibilities.

BS EN 1011-1:2009, Welding. Recommendations for welding of metallic materials. General guidance for arc welding.

BS EN 1011-2:2001, Arc welding of ferritic steels.

BS EN 1011-3:2000, Arc welding of stainless steels.

BS 3692:2001, ISO metric precision hexagon bolts, screws and nuts. Specification.

BS 4320:1968, Specification for metal washers for general engineering purposes. Metric series.

BS 4395-3:1973. Specification for high strength friction grip bolts and associated nuts and washers for structural engineering. Higher grade bolts (waisted shank), nuts and general grade washers.

BS EN 14399-1:2005, High-strength structural bolting assemblies for preloading. General requirements.

BS 2583:1955, Specification for podger spanners.

BS 7371-12:2008, Coatings on metal fasteners. Requirements for imperial fasteners.

BS EN ISO 1461:1999 Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods.

BS ISO 18280:2005, Plastics. Epoxy resins.

BS EN 338:2003, Structural timber – strength classes.

BS 8666:2005, Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete.

BS 7973-1:2001, Spacers and chairs for steel reinforcement and their specification. Product performance requirements.

BS 7973-2:2001, Spacers and chairs fixing and application of spacers and chairs and tying of reinforcement.

BS EN ISO 17660-1:2006, Welding of reinforcing steel - Part 1: Load-bearing welded joints.

BS EN ISO 17660-2:2006, Welding of reinforcing steel - Part 2: Non-load-bearing welded joints.

BS EN 10138-3, Prestressing steels. Strand.

BS EN 1744-1:2009, Tests for chemical properties of aggregates - Chemical analysis.

BS EN 12350-2:2009, Testing fresh concrete. Slump-test.

BS EN 12350-5:2009, Testing fresh concrete. Flow table test.

BS EN 12390-3:2009 Testing Hardened Concrete - Compressive Strength of Test Specimens.

BS EN 12390-5:2009, Testing hardened concrete. Flexural strength of test specimens.

BS EN 1504, Parts 1-10, Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity.

BS EN 1504-3:2005, Structural and non-structural repair.

BS EN 1504-4:2004, Structural bonding.

BS EN 1504-5:2004, Concrete injection.

BS EN 1504-8:2004, Quality control and evaluation of conformity.

BS EN ISO 9001:2008, Quality management systems. Requirements.

BS EN 196:2010, Parts 1-9 and 21, Methods of testing cement.

BS EN 932:1997, Tests for general properties of aggregates.

BS EN 933-9:2009, Tests for geometrical properties of aggregates.

BS EN 933-1:1997, Determination of particle size distribution - Sieving method.

BS EN 933-3:1997, Determination of particle shape - Flakiness index.

BS EN 1744-1:2009, Tests for chemical properties of aggregates - Chemical analysis.

BS EN 1097-6:2000, Tests for mechanical and physical properties of aggregates.

BS 5606:1990, Guide to accuracy in building.

BS EN 12812:2008, Falsework – performance requirements and general guidance.

BS 5975+A1:2011. Code of practice for temporary works procedures and the permissible stress design of falsework.

BS 5270-1:1989, Bonding agents for use with gypsum plasters and cement.

BS EN 1504, Parts 1-10, Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity.

BS 6319-3:1990, Testing of resin and polymer/cement compositions for use in construction. Methods for measurement of modulus of elasticity in flexure and flexural strength.

ISO 898-1:2009, Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs with specified property classes

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