A **cement** and **concrete** industry publication

Model Specification

for the Design and Performance of Post-Tensioned Concrete Floors in Building Structures

For use in the UK

mpa The Concrete Centre

PTA POST-TENSIONING ASSOCIATION

Model Specification Working Group

A committee of the Post-Tensioning Association (PTA) prepared this specification. PTA acknowledge the contribution of this technical committee.

Attending Members

Rob Amphlett - Buro Happold (Chairman)

Graham Bowring - Conforce

Matthew Gilliver - CCL

Neil Harvey - Ramboll

Suren Nadarajah - Praeter Engineering Ltd

Alessia Piras - Kingscote Design Ltd / Morrisroe Group

Simon C E Rickett MICT - Parex Ltd

Jonathan Shaw - EDGE Consulting Engineers

Andy Truby - TrubyStevenson Ltd

Ben Ume - Walsh

PTA and the authors would like to thank the wider peer approval group and colleagues that have contributed to this publication, and MPA The Concrete Centre for publishing the guide on behalf of the PTA.

CCIP-0059
First edition: published February 2017
ISBN 978-1-908257-19-2

Published by MPA The Concrete Centre
Gillingham House
38-44 Gillingham St
London
SW1V 1HU

Tel: +44 (0)207 963 8000
www.concretecentre.com

Prepared by The Post-Tensioning Association

Email: info@posttensioning.co.uk
www.posttensioning.co.uk

Front cover image courtesy of CCL

Printed by Michael Burbridge Ltd, Maidenhead, UK.

Model Specification for the Design and Performance of Post-Tensioned Concrete Floors in Building Structures

Contents

Foreword

This Model Specification is written to provide clients and consultants with a base document for the procurement of post-tensioning (PT) services within the UK. It is written on the basis that the PT services will generally be on a "Performance Specified" basis with both design and installation of the PT system being the responsibility of the Specialist PT Contractor. However, in some instances the PT design may be completed by a separate design consultant.

The assumption is that the PT works will be part of the overall Concrete Frame Package Sub-Contract which in turn is part of an overall Main Contract.

Where the PT works are procured with the design responsibility allocated to the Specialist PT Contractor, the procurement is assumed to be either a Contractor Design Portion (CDP) of a Traditional Form of Contract (i.e. JCT 90) or as part of an overall Design and Build Contract.

If the above assumptions do not apply to a particular project set-up, the terminology in this Model Specification should be modified to suit (including the definitions below).

The Model Specification, pages 1 to 21 of the blue section, should be used as the basis of the specification to be given to the Specialist PT Contractor.

Definitions

Term	Definition
Main Contractor	Refers to the Contractor with direct contract to the client for the overall project.
Specialist PT Contractor	Refers to the sub-contractor responsible for the Post-Tensioning (PT) system – must be CARES accredited and approved by the Contract Administrator.
Specialist PT Designer (May be the same as the Specialist PT Contractor or a separate design consultant.)	Refers to the structural engineering designer responsible for the final design of the PT system – must be competent in PT design with suitable PT design experience and must have a Chartered Engineer taking overall responsibility for the design.
Concrete Frame Sub-Contractor	Refers to the sub-contractor responsible for the overall concrete frame works.
Contract Administrator	Refers to the client or their agent as administrator of the Main Contract.
Main Contractor's Engineer	Refers to the structural engineer employed by the Main Contractor under their contract with overall responsibility for checking the works.
Employer's Engineer	Refers to the structural engineer employed by the client as a design guardian with responsibility for checking compliance with technical aspects of the Employers Requirements under the contract.

Standards

Reference	Description
The Building Regulations 2000, Approved Document A	Regulations relating to building structures and requirements
BS EN 1992-1-1:2004	Eurocode 2: Design of concrete structures. General Rules and rules for buildings
Concrete Society Technical Report No 43	(2nd Edition – 2005): Post-Tensioned Concrete Floor: Design Handbook
Concrete Society Technical Report No 72	(2nd Edition – 2010): Durable Post-Tensioned concrete structures
CARES Model Specification (latest Edition)	Model Specification for Bonded and Unbonded Post-tensioned Concrete Floors
FIP Corrosion Protection	(Federation International de la Precontrainte) Corrosion Protection of Bonded Tendons
BS EN 13670: 2009	Execution of concrete structures
BS EN 13391: 2004	Mechanical tests for post-tensioning systems (replaces BS 4447: Specification for the performance of pre-stressing anchorages for post-tensioned construction)
ETAG 013/BS EN 445: 2007	Grout for pre-stressing tendons - Test methods
BS EN 446	Grout for pre-stressing tendons - Grouting procedures
BS EN 447: 2007	Grout for pre-stressing tendons – basic requirements
BS 4486: 1980	Specification for hot rolled and hot rolled and processed high tensile alloy steel bars for the pre-stressing of concrete
BS 5896: 2012	High tensile steel wire and strand for the pre-stressing of concrete - Specification
BS EN 206: 2013	Concrete. Specification, performance, production and conformity
BS 8500-1:2015	Concrete - Complementary British Standard to BS EN 206. Method of specifying and guidance for the specifier
BS EN ISO 7500-1:2004	Metallic materials. Verification of static uniaxial testing machines. Tension/compression testing machines. Verification and calibration of the force-measuring system
BS EN ISO 376:2011	Metallic materials. Calibration of force-proving instruments used for the verification of uniaxial testing machines
BS EN ISO 4157-1:1999	Construction drawings. Designation systems. Buildings and parts of buildings
BS EN ISO 9000: 2015	Quality management systems. Fundamentals and vocabulary
BS EN ISO 9001: 2015	Quality management systems. Requirements

Model Specification

for the Design and Performance of Post-Tensioned Concrete Floors in Building Structures

For use in the UK

Section 1 Scope of Specification

This specification identifies and defines the parameters for the structural design and installation of the proposed post-tensioned (PT) concrete floor systems for this project. The Specialist PT Designer will be responsible for the design of the complete floor plates including any beams, openings, areas of passive reinforcement, tendon positions, co-ordination with other building elements, etc., as outlined in the following document. This design role can either be performed by the Specialist PT Contractor (if appropriate) or by a separate design consultant.

This specification shall be read in conjunction with the general conditions of contract and all associated documentation, specifications and drawings and shall not preclude the Specialist PT Contractor from any of his responsibilities defined therein.

The design shall also comply with all relevant Health & Safety requirements.

For Materials and Workmanship, this specification also requires full compliance with the CARES Model Specification latest Edition.

The latest version of the CARES Model Specification can be downloaded from www.ukcares.com

For clarity an explanation of common terms regarding post-tensioned concrete are provided:

- Passive Reinforcement - this is non-post-tensioned reinforcement generally consisting of deformed solid steel bar.
- Strand - this refers to individual post-tensioning cables.
- Tendon - this refers to the assembly of a number of stands and duct/vent and anchorages.

For more information refer to TR43 Post-tensioned concrete floors - design handbook.

Section 2 General Project Requirements

The general project requirements are given in the overall project Specifications and Employers Requirements. The requirements below are specifically for the proposed PT concrete floor system.

2.1 Structural requirements

The overall structural requirements are described in the structural general arrangement (GA) drawings and associated documentation. These give the overall extent of the PT floor systems with further requirements given in this specification.

The structure is to conform to the structural layout shown on the structural GA drawings. Any change to the layout, or additional structure in other locations, is strictly by prior approval and may not be accepted.

The final design of the PT floor systems shall be undertaken by the Specialist PT Designer as defined in this specification.

2.2 Stability and robustness

The Concrete Frame Sub-Contractor shall be responsible for the stability of the PT floor plates while in the course of construction until handed over to the Main Contractor.

The overall permanent stability system and movement joints are described on the structural GA drawings and associated documentation. Any amendments to these are strictly by prior approval and may not be accepted.

The position of all construction joints and isolation joints in order to ensure transfer of pre-compression into the floor plate is to be submitted for approval. A method statement identifying the sequence of works and temporary works, including the method of maintaining temporary stability, is to be prepared and agreed with all relevant parties.

The building, including the PT floor systems, shall be designed to comply with the disproportionate collapse requirements of the relevant European Standards and Part A of the UK Building Regulations. All elements shall be designed with sufficient robustness to withstand normal building operations and service life, and any critical elements of the structure should be designed as key elements. Reference should be made to the Consequence Class as defined in the other project specifications.

2.3 Design life and durability

The design life and durability of the PT floor system is to be the same as the overall structural system unless noted otherwise – see other project specifications for details.

Reference should also be made to Concrete Society Technical Report No 72 for aggressive environments (such as car parks) where plastic ducts may be required for bonded systems.

2.4 Health and Safety

A pre-stressed tendon, when tensioned, contains considerable stored energy. In the rare event of a tendon breaking, serious injury to personnel and damage to equipment can be caused by the sudden release of energy. Therefore, reasonable precautions shall be taken when working with or near tendons which are in the process of being tensioned or have been tensioned but not yet grouted.

Work with pre-stressing equipment is only to be carried out by CARES accredited operatives. Due consideration is also to be given to others working on the construction site. Method statements are required to adequately address these issues.

The Specialist PT Contractor must carry out a CDM assessment for all sections of their works. This shall highlight residual risks during both construction and in operation. Guidance for the safe demolition of the PT floor system is to be included in the Operation and Maintenance manuals.

The Specialist PT Designer shall comply with all their duties as a designer as set out in the current Construction (Design and Management) Regulations.

2.5 Specialist PT Contractor responsibilities

The fixing, stressing and grouting of the tendons are specialist operations and shall be carried out by a Specialist PT Contractor, certified by UK CARES in accordance with CARES Appendix PT 2 as a minimum.

Refer to the Post Tensioning Association website, www.posttensioning.co.uk for a list of companies with suitable knowledge and experience.

Any structure provided or proposed by the Specialist PT Contractor or Specialist PT Designer will be subject to approval by the Employer's Engineer and Main Contractor where it varies from the Employer's Requirements.

The Specialist PT Contractor is responsible for providing all labour, materials, equipment and services necessary for the fabrication and installation of the post-tensioning works, complete with all necessary accessories, including but not necessarily limited to the following:

1 Pre-stressing devices.

2 Post-tensioning tendons complete with anchorage devices including normal and special accessories in compliance with CARES Model Specification latest Edition.

3 Post-tensioning operation including marking, fixing, stressing, grouting, etc.

4 Site attendance, supervision, quality checks, etc. (site logistics to be agreed with the Main Contractor/ Concrete Frame Sub-Contractor).

5 Site records for stressing and grouting works.

The Specialist PT Contractor shall liaise with others as necessary to help ensure full coordination of the work at all interfaces with related building elements and services in accordance with the Contract Programmes and as instructed by the Main Contractor.

The Specialist PT Contractor is responsible for providing the Main Contractor with all relevant information for obtaining Building Control approvals and permits from the local authorities associated with the PT floor system design and installation. In addition, the Specialist PT Contractor shall request supplementary information as necessary from the Main Contractor and provide information as necessary in time to meet both the Design Programme and the overall Construction Programme.

See Section 3.2, Design Responsibility, of this specification for a detailed list of design responsibilities.

2.6 Submissions

Notwithstanding the requirements outlined elsewhere in this specification the Specialist PT Contractor shall submit the following documentation to the Contract Administrator and Main Contractor for comment and/or approval:

2.6.1 Tender

As part of the tender offer, the Concrete Frame Sub-Contractor shall submit the following:

a Proposed Specialist PT Contractor, plus evidence of current CARES certification.

b Proposed Specialist PT Designer, plus evidence of suitability e.g. previous experience, Professional Indemnity (PI) cover, etc.

c Details of the proposed contractual arrangements for the proposed Specialist PT Designer and in particular their design responsibility and PI insurance requirements which are to be commensurate with the other design consultants.

d The CV(s) of the engineer(s) undertaking the design plus the engineer with overall responsibility for the PT design (who must be a chartered structural engineer).

e The proposed contents page of the design philosophy report to be submitted with design information during construction (see Appendix B for sample contents).

f Any information or comments regarding the scheme layout indicated on the design intent drawings likely to have an impact on the detailed design.

g An outline design programme, information required schedule and intended information release schedule of documents for approval.
h Proposal for locating of PT tendons by follow-on trades e.g. soffit marking (if allowed).

2.6.2 At award of PT contract

The Specialist PT Contractor and Specialist PT Designer shall submit the following:
a Confirmation of all points of Section 2.6.1 within four weeks.
b The design philosophy report and calculation plan – this is to be submitted and approved before any detailed calculations and drawings are submitted.
c Agreed programme for the release of design information.
d PT floor system details – manufacturer details and specific system requirements.

2.6.3 Construction

2.6.3.1 Pre-commencement

The Specialist PT Contractor and Specialist PT Designer shall submit the following prior to commencement of the related works to allow sufficient time for review (as agreed) and ensure no impact on the programme:
a All structural calculations, including the finalised design philosophy and theoretical tendon extensions.
b All drawings indicating reinforcement, tendons, jacks and jacking loads (including shop drawings and schedules), major penetrations, construction and movement joints, etc.
c Erection and placing method statement and all CDM assessments.
d Proposed grout supplier and specification.
e Samples of materials where requested.
f Details of proposed tendons, ducts and anchorages.
g Other relevant information as reasonably required.
h Agreed procedures for 'Hold-Points' (see Section 2.7).

2.6.3.2 Prior to stressing

The following information shall be submitted to the Main Contractor and Contract Administrator and agreed prior to any stressing operations taking place:
a A detailed method statement for stressing of tendons.
b Concrete strength tests to prove that concrete has achieved the necessary strength as defined in the specification.
c Confirmation that allowance has been made for formwork to accommodate shortening, bending or uplift during stressing.
d Confirmation that all strands are free to move between jacking points and members are free to accommodate the horizontal and vertical movements due to the application of pre-stress.
e Calculations of the total force and extension for each tendon after allowances for anchorage friction, wedge pull-in, jack losses and duct friction have been approved.
f A summary of theoretical tendon extensions (not to be shared with site operatives).
g Details of the tendon material, including manufacture, type of strand, characteristic breaking load, proof load, relaxation values, and modulus of elasticity and all certification.
h Details of the anchorages, with a statement that they comply with the minimum requirements of BS EN 13391: 2004 and all certification.
i Details of the tensioning equipment to be used plus current calibration certificates (not greater than 6 months old) for all stressing equipment.
j Details of the grout mix to be used and confirmation of compliance with CARES requirements.

2.6.3.3 Installation

During the installation of the works, the Specialist PT Contractor shall submit the following:

- **a** Pre-pour inspection records.
- **b** Stressing records (including actual extensions).
- **c** Grouting records.
- **d** Grout test results.
- **e** Other test results required by this specification and reference standards.
- **f** All non-conformance records (NCRs) including records of resolution and sign-off.
- **g** All other quality assurance (QA) records required by the contract.

2.6.4 Completion

On completion of the contract, the Specialist PT Contractor and the Concrete Frame Sub-Contractor shall submit the following:

- **a** As built drawings for the PT layout and reinforced concrete (RC) placement and detailing.
- **b** Guidance for safe demolition.
- **c** PT strand certification and anchor/wedge certification.
- **d** Guidance for the safe forming of holes and for post drilled fixings into the floor plate.
- **e** All inspection and testing reports indicated in this specification.

2.7 Hold Points

At certain key points during the installation of the PT system, it is recommended that approval is obtained from the Main Contractor before further installation can proceed – these are the 'hold points'. The recommended hold points are:

Hold Point 1 - On completion of installing the PT system and passive reinforcement – Concrete not to be cast until PT installation and passive reinforcement placement has been signed off by Main Contractor (as agreed in the contract).

Hold Point 2 - Prior to stressing – All relevant information to be received by Main Contractor before stressing commences e.g. theoretical extensions, concrete cube results demonstrating adequate strength, calibration certificates of equipment, etc. See Section 2.6.3.

Hold Point 3 - On completion of stressing – Actual extensions and non-conformances to be approved by Main Contractor before strands are cut and ducts grouted (to take place within seven days of stressing – grouting to be complete within 28 days).

Timescales and procedures for these approvals to be agreed prior to the commencement of work.

Section 3 Basis of Design

The following definitions, in addition to those given in BS EN 13670: 2009, apply for the purpose of this Specification.

3.1 PT system design requirements

The structure must be designed to fulfil its intended function and the design must ensure the continued serviceability of the structure in accordance with all other requirements of this specification.

Pre-stressing of the concrete floor plates is to be carried out by a system of post-tensioning tendons. The fixing, stressing and grouting of the tendons are specialist operations and shall be carried out by the Specialist PT Contractor only.

3.1.1 Analysis models

The extent of the post-tensioned slabs is indicated on the structural GA drawings. The Specialist PT Designer shall model sufficient of the adjacent structures to allow the loads affecting the post-tensioned slabs to be derived. The analysis models used in the PT design should model the properties and stiffnesses of any adjacent slabs and beams.

3.1.2 Slab restraint and temporary release

The Specialist PT Designer shall consider the restraint offered by the supports to the PT floor plate including any columns, walls and any connecting beams and slabs and shall account and compensate for any associated loss of pre-stress force resulting from such restraint. Where considered necessary by the Specialist PT Designer, temporary release details shall be designed and provided and may take the form of sliding joints, temporary movement joints (lockable dowels) and/or selectively delaying the casting of sections of the slab.

3.1.3 In-plane forces

The PT floor plates shall be designed for the loadings indicated in the project information. In addition, the Specialist PT Designer shall take account of, and allow for, any 'in-plane' forces resulting from notional horizontal loads, shrinkage, creep and elastic shortening and temperature effects, including those resulting from early heat of hydration and normal climatic temperature variation.

3.1.4 Robustness and lateral ties

The Specialist PT Designer shall consider the requirement for lateral ties within the plane of the PT floor systems and shall provide all necessary PT tendons and ordinary reinforcement to resist the associated forces. In particular, the Specialist PT Designer shall provide bottom reinforcement at slab support locations in accordance with Code requirements and recognised good practice.

3.1.5 Punching shear

Punching shear checks are required at all column and concentrated load locations with due consideration of the column location, size and moment transfer plus recognition of the contribution of the pre-stressing force (note that edge and corner columns will not typically have a compression/stress (P/A) enhancement).

3.2 Design responsibility

For this project, the Specialist PT Designer will be employed by Main Contractor/Specialist PT Contractor/Concrete Frame Sub-Contractor/Employer's Engineer. [delete as appropriate]

The Specialist PT Designer will be responsible for the design of the following:

- Suspended concrete floor systems (slabs and beams unless specifically noted otherwise), both post-tensioned and any required passively reinforced areas integral to the floor plate, as defined on the drawings and project specifications, taking due account of:
  - The overall thermal movement and shrinkage (including elastic shortening and creep) of the floor systems taking due account of the fixity and support conditions.
  - The integration of any stability forces and moments required for the overall performance of the structure as specified in the project information.
- Drop caps and any thickenings allowing for service penetrations.
- Column interface and punching shear details.
- Detailing around riser and service holes.
- Continuity reinforcement to adjacent RC elements.
- Anti-bursting reinforcement.
- Movement joints, construction joints and infill strips.

The following elements are specifically excluded from the Specialist PT Designer's responsibility unless specifically noted on the drawings:

- Foundations and retaining walls.
- Columns and walls.
- Ground bearing slabs (unless specified as post-tensioned).
- Stairs, including half-landings.
- Other project specific elements as defined.

3.2.1 Coordination

The Specialist PT Contractor is responsible for the final coordination and detailing of all reinforcement, tendons, anchors, making due allowance for fixings for the cladding, inclusion of cladding movement criteria and all service openings as provided in advance by the Main Contractor. This includes provision of all detailed tendon layout drawings, reinforcement placement drawings and bar bending schedules. Note: This may be provided by the Specialist PT Designer with prior agreement.

The Specialist PT Designer is to agree a programme of release of information prior to the commencement of works on site to ensure sufficient time is provided for coordination and further design, and timely approval by the Main Contractor.

The design of the PT systems must take account of all provided openings for electrical, mechanical and drainage requirements, and should be fully coordinated with the structure. In addition, the PT systems should be designed and detailed to ensure full compatibility with building services and architectural requirements.

The Specialist PT Contractor shall allow for coordination of the design with (but not limited to) the following:

- Beams and upstands as shown on the GA drawings.
- Junctions with stairs.
- Junctions with column and wall reinforcement.

- Pour size, sequence and crane hole requirements as dictated by the Main Contractor and/or the Concrete Frame Sub-Contractor.
- Junctions with steelwork and any cast-in items.
- Tolerances and allowable deflections including those relating to cladding and partitions.
- Junctions with all other structural, architectural and/or MEP items.
- Fixings to cladding (supplied by others).
- Service holes (particularly those adjacent to columns), risers and other penetrations.
- Co-ordination of anchor locations allowing for any cladding interfaces and ensuring adequate room for jacking etc.
- Other project specific elements.

Note: anchorages within columns and walls shall not be permitted unless by prior agreement with the Employer's Engineer.

3.2.2 Design deliverables

Prior to the start of detailed design the Specialist PT Designer is to agree the design principles and record this in a design philosophy report (see Appendix B for sample contents) which must include the following:

- The overall design philosophy for the PT design.
- All final loadings to be considered in the PT design.
- The degree of fixity to the RC walls and columns.
- The grade of concrete and material requirements of all relevant structural elements.
- The location and pour sequence with regard to infill strips/construction joints.
- The average stress in the floor plate due to pre-stressing.

Adequate time is to be agreed to allow for any further design or coordination due to loading or dimensional information provided by the Main Contractor.

On completion of the design, the following information is to be provided by the Specialist PT Designer:

- Design calculations (as agreed in the calculation plan submitted at award of contract).
- A summary of all the unfactored dead and live loads applied to all vertical elements of structure supporting PT floor plates.
- Detailed deflections and movements of all elements of the floor system.
- Reinforcement and tendon layout requirements.
- Theoretical tendon extensions (but not shared with site operatives).
- All other specification requirements.
- All other information agreed with the Main Contractor to be submitted for Building Control approval.

3.3 Design standards

The PT floor system is to be designed and specified in accordance with the documents referenced in the table of design standards at the beginning of this specification (see page iv). Any other standard code or specification mentioned in the body or preface of these design standards is to be considered as part of this specification.

In addition, all structures shall be designed in accordance with all recommendations from material and component manufacturers. When a conflict arises in the requirements, the Specialist PT Designer is to highlight this conflict and seek clarification, with the current Eurocode Standards providing the minimum design requirements.

3.4 Loadings

The PT floor system shall be designed for all permanent, temporary and construction loads provided. The Specialist PT Designer shall liaise with the Main Contractor and Concrete Frame Sub-Contractor to ensure all agreed temporary loads have been incorporated in the design; including, but not limited to, storage of materials, access and other plant, lifting equipment, scaffold support and loading platforms, back-propping and shoring, etc.

3.4.1 Dead and imposed load

The PT floor system and any supporting elements of structure are to be designed for all relevant dead and imposed loads as defined by the relevant design standards and project specific information.

Loading information can be added here:

3.4.2 Stability loads

The PT floor system must also be designed to accommodate any stability loads and moments transferred to it as part of the stability system as outlined in the project specific information.

Loading information can be added here:

3.4.3 Other loads

Other loading to be assessed and considered (if unavailable, reasonable allowance should be made) are:

- Line and point loads for the perimeter cladding to be based on the actual dead loads.
- An allowance for construction traffic, loading platforms, etc. – to be provided by the Main Contractor and/or Concrete Frame Sub-Contractor.
- Permanent loads on transfer structures.

Any other loading data which impacts the PT floor system design not indicated above should be requested from the Main Contractor.

Loading information can be added here:

The Specialist PT Designer shall also ensure all loads due to elastic shortening, creep shortening, temperature variations and shrinkage, restraint from adjacent elements in the short and long term have been considered.

The Specialist PT Designer is to include a load summary as part of the design philosophy submitted prior to the start of detailed calculations.

3.5 Multi-storey construction

It should be noted that back-propping and shoring of slabs in multi-storey construction can produce critical loading in certain situations – particularly with PT floor system if early striking is required. This is highly dependent on the method of construction and in particular the time allowed between transfer and stripping of the floors. This must be fully considered in the design, and stripping times should be in accordance with the current industry guidance. Construction methodology should be agreed with the Concrete Frame Sub-Contractor and Main Contractor prior to commencement on site and the design modified to suit if required.

3.6 Fire resistance and durability

The fire resistance and durability requirements for the PT floor system are to be determined by reference to the project specific information. The fire resistance and durability will inform the required concrete cover to the pre-stressing ducts and the passive reinforcement. The cover requirements shall be applied uniformly to all concrete surfaces.

The cover to passive reinforcement and post-tensioned ducts required for durability of the PT floor plates should be in accordance with BS EN 1992-1-1:2004 and BS 8500-1:2015.

The axis distance to normal reinforcement and post-tensioned strand should be determined with reference to BS EN 1992-1-2:2004.

3.7 Deflections

As a minimum, the deflections to the superstructure shall be designed in accordance with the requirements of the appropriate Standards and Codes of Practice.

Unless noted otherwise, floor plates should be designed for the general deflection limits as follows:

These limits may be edited to suit project requirements.

Default requirements unless noted otherwise

Maximum total deflection (including long term effects)	**span/250 <35mm**
Incremental deflection (live + creep etc. i.e. as seen by partitions and finishes)	**span/360 <25mm**

Project specific requirements can be added here: .....

.....

.....

.....

In addition, specific local deflection limits imposed by the cladding Contractor, partition supplier, or other deflection sensitive installations should be designed for – values to be agreed.

3.8 Vibration

The floor system has been designed for vibration criteria suitable for the location and use. If the slab depth is modified by the Specialist PT Designer then due consideration must be taken of the vibration requirements given below[1].

Project specific requirements can be added here:

3.9 Cracking control

The Specialist PT Designer, Specialist PT Contractor and Concrete Frame Sub-Contractor are to ensure cracks are controlled in accordance with the relevant Eurocode, with due regard for exposure and durability, installation and curing.

Analysis should be carried out to ascertain the extent of any cracking including shrinkage cracking or cracking induced by the tendon stressing process. In assessing cracking, the Specialist PT Designer shall take due consideration of the restraint of the complete structure including all vertical and stability elements outside the direct design responsibility of the Specialist PT Designer. Adequate reinforcement is to be provided in those areas deemed necessary by the Specialist PT Designer to limit the formation of cracks within the code limits.

Other factors that contribute to the control of cracking are given below and setting of project specific criteria for these aspects should be considered:

1. Minimum requirements for reinforcement.
2. Maximum concrete strength and rate of strength gain.
3. Maximum pour sizes and distances between joints.

Project specific requirements can be added here:

A bottom mesh would normally be required with the centres and density to suit the following:

- Ultimate strength
- Serviceability Limit States (Stress limits)
- Tendon spacing
- Fire and spalling
- Early thermal shrinkage
- Long term restraint
- Thermal strains
- Exposed (visual) concrete

[1] The specifier must satisfy themselves that the slab thickness given on the structural general arrangement drawings is sufficient to provide the required vibration performance OR give specific requirements here.

A top reinforcement mesh should also be considered for:

- Slabs of 400mm thickness or greater (due to increased hydration and allowing access for site personnel during concreting operations).
- Slabs laid to falls.

The size and spacing of the mesh should consider the construction traffic (personnel), availability, frequency and type of spacer blocks and the above factors.

Prefabricated mesh should be specified as 'flying end' to avoid build-up of layers at laps which may prevent achieving the correct tendon profiles, particularly at low points.

3.10 Temporary movement joints

Any temporary joint(s) must be designed and detailed to provide the same performance as the adjacent floor plate or elements and must not in any way compromise the strength and resilience of the floor system. The moment and shear capacity required by the design must be carried through the joint. The following requirements must be satisfied:

- Proposed details and calculations to be submitted for approval.
- Positions should generally be at locations with minimum bending moments.
- For proprietary systems, full test certification and approvals to be submitted.
- The visual appearance requirements of the project are to be considered and agreed when approving the location and detailing of joints.

3.11 Final construction information

The Specialist PT Contractor shall submit to the Main Contractor completed and coordinated drawings, schedules and other information relating to the post-tensioning works for examination prior to commencing of site installation with sufficient time (as agreed) to allow thorough review and approval to meet contract requirements.

This is to include final detailed reinforcement and tendon layout drawings indicating the following:

- Size and location of tendons and all anchorage components (i.e. referenced from grid).
- All other reinforcement and other associated components.
- Tendon positions to be numbered to allow checking of site test results with the drawings.
- Indication of coordination with any other structural fixings.
- The position and details of construction joints and any infill or closure strips required.
- The exact profiles of tendons (i.e. levels at all chair locations along the tendon).

And

- Bar bending schedules.
- Method statements.
- All information regarding the concrete mix, including exposure class and cover, the grout mix and locations of vents and vent closures.
- The required concrete strength at initial transfer and at 28 days.
- Jacking loads, the stressing procedure and sequence with all anchorage capabilities.
- Corrosion protection details.

Section 4 Materials

The overall design of the PT floor system is to be based on the following material specification. The Specialist PT Designer and Specialist PT Contractor are to comply with this specification and it should be read in conjunction with both the other project specific specifications and the CARES Model Specification latest Edition.

4.1 Concrete

Refer to the main project concrete specification for detailed requirements of the concrete works including general concrete mix requirements. The requirements of this specification are additional to those contained in the project specific information. Particular attention is drawn to the concrete strength requirements and concrete finishes outlined below.

The minimum characteristic 28-day cube strength of the concrete in the pre-stressed floors is to be 35 MPa (C28/35).

The minimum concrete cube strength at transfer is to be 25 MPa.

Preliminary stressing will be required at a concrete cube strength of about 12.5 MPa (or as per the PT system requirements) to minimise the risk of shrinkage cracking in slabs.

The maximum concrete strength must be compatible with the assumptions on restraint and the control of cracking – see 3.9 Cracking Control.

Over and above any requirements in project specific information, for post-tensioned slabs, cement replacement is to be limited to 25% maximum, unless agreed with the Employer's Engineer.

Where slab soffits are to have a fair faced finish, the extent and detail are to be according to the architect's requirements and the specification as per the project specific information.

4.2 PT system components and reinforcement

The general requirements of the passive reinforcement bar are as the main project concrete specification.

For detailed material and workmanship requirements for strands, ducts, anchorages, grout and other miscellaneous components, refer to the CARES Model Specification latest Edition.

All PT floor system components must be CARES accredited and installed by the Specialist PT Contractor using CARES approved personnel. The Specialist PT Contractor must only install PT systems for which they have been certified to use and all system components must be compatible and unique to the system being used.

Under no circumstance should components from different systems be used in any one assembly. Once details of the PT system to be used on this project have been submitted and approved, and installation has commenced, no alternative systems are permitted unless by prior agreement with the Contract Administrator and Employer's Engineer.

4.3 Miscellaneous proprietary components

The overall floor system may require other components such as couplers, shear connectors, pull-out bars, etc. These components must be compatible with the overall PT floor system and

design requirements. Any such items must be suitably tested and approved, and must be suitable for the purpose for which they are intended. Bespoke fabrications and installation of proprietary components for unorthodox uses will not be permitted unless by prior agreement with the Contract Administrator and Employer's Engineer. This applies at both permanent movement joints and temporary construction joints in particular – see also section 3.10 Temporary Movement Joints.

Section 5 Site Installation and Stressing Operations

This specification requires full compliance with the CARES Model Specification latest Edition.

An unscheduled CARES audit is to be requested by the Main Contractor and the findings shared with the Contract Administrator to safeguard levels of workmanship and quality. Particular attention should be paid to grouting procedures. All costs to be borne by the Specialist PT Contractor.

The following sections provide detailed project requirements and enhancements to the CARES requirements.

5.1 Positioning of tendons

For general requirements see CARES Model Specification latest Edition.

5.1.1 Tolerances

General construction tolerances should be limited to those stipulated in project specific information. Tendons (comprising strand, duct/vent and anchors) shall be installed to a smooth profile, and generally straight between anchorages, to the following tolerances:

Vertical alignment	+/- 5mm (t/40 for slabs <200mm thick)
Horizontal alignment	+/- 50mm in beams
	+/- 150mm in slabs

Particular care must be taken to ensure that the tendon is correctly located near the anchorages so that unintentional angular deviations are not introduced at these points which could lead to pinching, grout loss and other defects.

The horizontal deviation of tendons beyond these limits may be permitted as long as they are fully incorporated into the design of the PT system and indicated on the shop drawings. The resultant increased frictional losses and lateral loads from the tendon to the surrounding floor plate must be fully allowed for and be shown in the calculations.

5.1.2 Facets to curved tendons

For bonded PT systems, tendon profiles which require a curve in plan may be provided by faceting straight lengths of flat duct providing the following provisions are satisfied:

- The required curve has a minimum radius of approximately 50m or greater and an approximate 7° maximum facet angle.
- Joints should be minimised and approval will be required if duct lengths shorter than 6m are proposed.
- The design of the PT system must take due account of any such facets with all resultant actions and forces fully assessed.

- The stressing sequence must ensure inner strands are not trapped or pinched prior to stressing. Reverse curvature of tendons is not recommended.
- Joints in the ducts must be fully sealed to prevent grout ingress during concreting.
- For tighter radii, circular ducts must be used.

Alternatively, unbonded tendons may be more appropriate and should be considered with the approval of the Contract Administrator and Employer's Engineer.

5.2 Stressing

See Section 2.6.3 for submission requirements and Section 2.7 for Hold Points.

The load in the tendon shall not exceed 80% of the specified characteristic breaking load during stressing or 75% of the specified characteristic breaking load after anchoring, without the approval of Contract Administrator and Employer's Engineer.

At transfer, initial pre-stress shall not normally exceed 70% of the tendons characteristic strength, and in no case should it exceed 75%of the tendon characteristic strength.

5.2.1 Stressing Equipment

Tensioning apparatus shall comply with BS EN 13670: 2009 and have an appropriate and current calibration certificate. Apparatus shall be operated strictly in accordance with the system manufacturer's written instructions.

For general requirements see CARES Model Specification latest Edition.

5.2.2 Stressing sequence

To limit the formation of early age cracks it is important that an initial stressing operation is carried out with 25% of the final pre-stress force.

When the concrete has reached the required transfer strength the tendons shall be gradually tensioned to the agreed sequence forces indicated on the Specialist PT Contractor's shop drawings.

The Specialist PT Contractor shall confirm that the specified initial forces have been achieved by measuring the extension of each tendon, and by measuring the jacking force pressures and deducting the appropriate transfer losses from it.

The method for recording extensions is to be submitted and agreed. Tolerance on actual extensions and record requirements are as the CARES Model Specification latest Edition.

5.3 Grouting of bonded systems

Ducts shall be grouted as soon as possible after stressing of the tendons but not later than 28 days.

Quality records must be provided for each individual duct grouted which includes verification by both the site supervisor and Main Contractor that each duct has been adequately grouted. **Records where batches of ducts have been signed off will not be accepted.**

Any construction or temporary loads applied to the floor plate before the ducts have been grouted must be within the capacity of the incomplete PT system at time of loading and justified in the final design calculations.

5.4 Sealing of anchorages

Sealing of anchorages must be with an agreed product and method. See CARES Model Specification latest Edition for detailed requirements.

Strand shall be cut to length using mechanical means only. Under no circumstances should strand be cut by flame cutting.

5.5 Early stripping and back propping

Restrictions to the early stripping of concrete elements are dictated in the project specific information (to which reference should be made) and the PT design assumptions. The Concrete Frame Sub-Contractor must propose and agree a curing time with the Specialist PT Designer before any slab support shuttering or tables are removed and back props stressed. The designer should ensure that the revised load path, changes in the stress distribution and creep and shrinkage regimes are all accounted for. It is imperative that back propping of floors is in accordance with the current industry guidelines at all times.

5.6 Testing and inspections

The Specialist PT Contractor is to offer for inspection to the Main Contractor areas that the placement of tendons and reinforcement is complete in sufficient time to allow detailed inspection and remedial actions. See Section 2.7 for detailed Hold Point requirements.

All components of the pre-stressing works shall be tested in accordance with CARES requirements and certificates containing all relevant information shall be submitted to the Main Contractor and Employer's Engineer for approval as set out in Section 2.6.

The following test certificates for the tensioning steel shall be submitted to the Contract Administrator and Main Contractor:

- A certified stress-strain curve of each sample.
- Manufacturer's original test certificate for comparison.
- Confirmation from the Manufacturer that the steel has the required relaxation characteristics.

The Specialist PT Contractor is to offer the works for inspection by the Main Contractor at the following stages with a minimum notice period as agreed:

- Tendons fixed in place.
- Commencement of initial stressing.
- Stressing of tendons.
- Filling of anchor pockets.
- Grouting of tendons.

See also Section 2.7 for Hold Points.

For general requirements on testing and inspections see CARES Model Specification latest Edition.

Section A Appendices

A.1 Design Checklist

The following is guidance on what should be reviewed/checked at design stage to help ensure best practice.

A.1.1 Calculations:

Ref	Check	Compliance
C01	Are loading assumptions correct and defined correctly in the analysis model? Do they match the specification? [super-imposed dead loads, imposed loads, edge loads, temporary loads etc.]	
C02	Are the material properties defined correctly in the analysis model and as per the specifications? [tendon properties, concrete grades, reinforcement etc.]	
C03	Are the slab (and beam) elements defined correctly in the analysis model? [element thicknesses, material properties, torsion properties etc.]	
C04	Are the support / boundary conditions correct in the analysis model? Are the modelling assumptions consistent with the specification and agreed design philosophy? [element sizes for columns and walls, supports modelled above slab and below the slab, modelling of elements providing restraint, assumptions on fixity etc.]	
C05	Are the load combinations correct and defined correctly?	
C06	Has pattern loading been considered with appropriate patterns?	
C07	If required, are the design strips / section locations and settings appropriate? [column strip/middle strip, full tributary width, one-way slab, two-way slab etc.]	
C08	Are the support reactions as expected?	
C09	Has restraint been adequately considered? [temporary release details etc.]	
C10	Are the tendon high and low points achievable? [cover to reinforcement/tendons to be considered, layering/fixing of reinforcement and tendons]	
C11	Is the tendon arrangement and profiles achievable and logical? [do the profiles look sensible relative to the bending moment envelope?]	
C12	Are the service stress results acceptable and in accordance with the specification and design philosophy? [one-way or two-way slab limits, based on column strip/middle strip or full tributary width approach]	
C13	Are the crack width results acceptable and in accordance with the specification and design philosophy?	
C14	Has a minimum level of pre-compression been achieved in accordance with the specification and design philosophy?	
C15	Are the maximum deflections (both long term and incremental) acceptable and in accordance with the requirements of the specification?	
C16	Are punching shear calculations acceptable? [has V_{eff} been used and openings considered etc.]	
C17	Has the requirement for reinforcement for moment transfer to edge and corner columns been checked and provided?	

Ref	Check	Compliance
C18	Have theoretical extensions been provided, and are they as expected?	
C19	Are there any critical details requiring specific attention? [corbels, shear connections, key elements, load transfer conditions etc.]	

A.1.2 Drawings:

Ref	Check	Compliance
D01	Do the General Notes meet the requirements of the specification and are in accordance with the design? [material properties (strand, reinforcement, concrete, duct etc.), cover requirements, tolerances etc.]	
D02	Have details of layering/fixing sequence been included on the drawings either as typical or specific details? Do these match the tendon profile and reinforcement layer assumptions in the design? Check for congestion. Is it practical to fix on site?	
D03	Have typical details for dead end anchorages, live end anchorages, tendon couplers, pan boxes etc. been provided, and are they in accordance with manufacturer details?	
D04	Do the horizontal tendon alignments match the design, and do they comply with minimum anchorage setting out dimensions and maximum tendon spacing requirements? Have tendons been coordinated to avoid slab openings?	
D05	Do the vertical tendon profiles match the design and high and low points, and have profile points been provided at maximum 1m centres to suit support chair locations?	
D06	Have anchorages been coordinated with façade or slab edge fixing locations?	
D07	Does the tendon schedule identify the post-tensioning system information (bonded or unbonded), anchor type information (mono strand, multi strand, flat slab system etc.), number of live ends (single or double end stressing, stressing from pan box etc.), strand type (12.9mm or 15.7mm etc.), number of strands per tendon, tendon length, jacking force, theoretical extension?	
D08	Has a tendon stressing sequence been provided?	
D09	Have temporary release detail requirements been shown on the drawings, and have any specific propping requirements been identified to the Contractor?	
D10	Has pour strip reinforcement been properly detailed to allow free movement of the slab/beams?	
D11	Has punching shear reinforcement, if required by design, been detailed?	
D12	Has moment transfer reinforcement, if required by design, been detailed?	
D13	Has a continuous bottom mat of reinforcement to satisfy Eurocode fire resistance requirements been detailed?	
D14	Has flexural reinforcement been provided at support locations (columns, walls, beams) as expected? Do strands from cantilevers extend suitably far back into the slab?	
D15	Has any crack mitigation reinforcement been provided for details that are prone to cracking?	
D16	Has bursting reinforcement for dead and live end anchorages been provided?	
D17	Has edge cage reinforcement been provided?	
D18	Does reinforcement within coffered zones meet expectations?	

A.2 Site Checklist

The following is guidance on what should be reviewed/checked on site to help ensure best practice.

Ref	Check	Compliance
	PT fixed and offered for inspection	
HP1	**HOLD POINT 1 – pre-pour checks to be approved as the specification before concrete cast – check points as below**	
S01	Are the number of tendons and horizontal setting-out as the approved drawings?	
S02	Are openings and builders work holes as the approved drawings?	
S03	Are the number of strands in the tendons as the approved drawings? Are the strands clean and rust free? If signs of rusting, check how bad and extent of pitting.	
S04	Is the passive reinforcement as the approved drawings? Has sufficient edge reinforcement been provided? Are connections to cores as detailed on the approved drawings?	
S05	Is the layering of the tendons and reinforcement as the approved drawings? Have the required high and low points, and the general profile been achieved? Are the correct profiles and covers achieved?	
S06	Are anchorage details for dead and live ends, pans, etc. as the approved drawings?	
S07	Are live ends neatly installed with no gaps? Do the marks on the anchorage match the PT system approved under the CARES accreditation?	
S08	Has the spiral bursting reinforcement around anchorages been installed and correctly located? Check details on drawings.	
S09	Are the strands at dead ends suitably spread out (tied as required) and not bunched together? Have spacers been used? (Spacers not always used at dead-ends but strands should be spread apart).	
S10	Have chairs to ducts been installed as per drawings? Are they fixed/secured (often stapled to formwork)? Is there any damage? Are chairs straight and properly aligned?	
S11	Are the tendon duct connections tight with no gaps, and any taping neat around connections? Has the correct tape been used? Check specification.	
S12	Have grouting tubes been provided; including intermediate tubes as required? Are they secure? Any damage? (Bent tubes may inhibit grout flow).	
S13	Are temporary joints required and are they detailed as the approved drawings?	
	After concrete poured	
HP2	**HOLD-POINT 2 – before stressing commences check concrete strength plus see other checks in specification**	
	Tendon stressing	
S14	If jacking is monitored, check jacking forces? Ask to see calibration certificate. Does the jack match the calibration certificate? Is it current (less than 6 months old)?	

Ref	Check	Compliance
	After tendon stressing	
S15	Have site extensions have been taken? Request records. Ask for engineers check vs theoretical extensions and if these are with-in specified tolerance?	
S16	Any NCRs? If so, what is the proposed remedial action?	
	Striking formwork	
S17	Before striking, check that concrete has achieved sufficient strength to suit the back-propping proposal and construction loads given the concrete age.	
S18	Following striking, check soffits have suitable finish with no voids or visible problems? How will tendon locations be identified by follow-on trades? Is soffit marking called for in the specification? If an exposed/fair-faced soffit, make sure no markings.	
HP3	**HOLD POINT 3 - Approval of extensions required before strands cut and grouted**	
	Grouting and finishing	
S19	Check strands at live ends are suitably cut and grouted over (usually a dry pack grout) – check specification requirements. Has minimum cover been achieved?	
S20	If grouting is monitored: • Check grout being used is as approved specification. • Check method and pump pressures as specification. • Check bleed volumes and site testing as specification. • Request grouting records. Note: grouting is critical for ultimate limit case design requirements long term durability – good procedures and recorded keeping is critical to ensure ALL tendons are grouted with none being missed. Also that tendons are fully grouted with no pockets air or water.	
S21	Check grouting of ducts takes place as outlined within specified time-scale (must be within 28 days). Check grout tubes are protected in bad weather?	

B.1 Sample contents for Design Philosophy Report

1 General project description

2 Extent of PT floor plates

3 Design loadings including construction loadings

4 Design Codes used

5 Specifications/Reports relevant to the PT Design

6 Minimum/Maximum PT levels

7 Minimum passive reinforcement

8 PT System used – details of material properties including strand, anchorages, ducts and grout

9 Concrete properties and mix design

10 Durability and Fire resistance requirements

11 Minimum concrete cover to PT ducts and passive reinforcement

12 Assumptions used in analysis models – column/wall fixity, modelling of joints

13 Strategy for layering of PT tendons and ordinary reinforcement

14 Deflection requirements – summarise design limits and design approach

15 Vibration requirements – summarise design limits and design approach

16 Thermal actions – summarise design requirements and design assumptions

17 Strategy for temporary release – pour size, pour volume, joint positions/details and release details

Model Specification for the Design and Performance of Post-Tensioned Concrete Floors in Building Structures

Prepared by a technical committee of the Post-Tensioning Association (PTA), the trade association for practitioners of post-tensioning in the UK, this publication provides a clear and flexible model specification for procuring post-tensioned concrete floors.

CCIP-0059
Published February 2017
ISBN 978-1-908257-19-2

Published by
MPA The Concrete Centre
Gillingham House
38-44 Gillingham Street
London
SW1V 1HU
Tel: +44 (0)207 963 8000
www.concretecentre.com

Prepared by
The Post Tensioning Association

Email: info@posttensioning.co.uk
www.posttensioning.co.uk