

Model Specification for Bonded and Unbonded Post-tensioned Concrete Floors



3rd Edition

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This model specification offers guidance to organisations that are producing specifications for the bonded and unbonded post-tension floor slabs and slabs with beams not more than 1m deep containing monostrand or flat multistrand tendons. Notes for designers are given (where appropriate) in italics and do not form part of the specification.

It is the specifier's responsibility to ensure that the contract specification is suitable for and meets the requirements of the contract.

The Strand image throughout this Model Specification is courtesy of Bridon International Ltd



0.1 Standards and Design Guides

Design shall be in accordance with:

1. BS EN 1992-1-1 Eurocode 2 Design of concrete structures.
2. Concrete Society Technical Report 43 (TR43) Post-tensioned concrete floors.

Note: Further guidance can be found in Technical Report No. 72 Durable Post-tensioned Concrete Structures.

1.0 Post-tensioning contractors

- a) Post-tensioning systems shall only be installed by specialist post-tensioning contractors that have the necessary experience, knowledge, resources, materials and equipment. Post-tensioning contractors shall have CARES certification for the installation of post-tensioning systems in concrete structures against CARES Appendix PT2 or equivalent accredited product certification.

Note: evidence of certification should be obtained at tender stage and can be obtained from CARES' web site: www.ukcares.com

- b) Access to the works shall be granted to CARES for the purpose of quality auditing and maintenance of certification by arrangement with the post-tensioning contractor and/or Contract Administrator (CA).

The CA may nevertheless request an additional surveillance audit on a CARES approved post-tensioning contractor by CARES (at his own cost). If a quality audit is required by the CA during the contract then this shall be clearly stated in the project specification.

- c) All post-tensioning operations shall be carried out by operatives with appropriate knowledge, training and proven experience in carrying out similar operations. Supervisors and operators shall be trained and certified to meet the requirements given in CARES Appendix PT9.
- d) Trainee post-tensioning personnel shall be adequately supervised when performing post-tensioning activities.

Note: The number of trainees should be limited and the ratio of trainees to experienced trained staff should be balanced according to circumstances and normally not exceed 50% of the post-tensioning personnel.



1.1 Quality Plan

The post-tensioning contractor shall provide the CA with a quality plan giving details of all the proposed materials, equipment and methods statements relating to site activities, including work instructions, quality procedures, records, inspection and test arrangements and work acceptance procedures.

Note: The quality plan may comprise a single document or series of linked documents.

2.0 Materials and products

2.1 Tensile Element

- a) Strand shall comply with BS 5896. The grade and diameter shall be specified and shall be relaxation class 2 and shall be obtained from firm(s) holding a valid CARES certificate of approval and shall be of a type that is compatible with the anchorage testing or approval.
- b) Bar shall comply with BS 4486. The grade and diameter shall be specified and shall be obtained from firm(s) holding a valid CARES certificate of approval.

Confirmation of the strand or bar supplier's approval status can be obtained from CARES' web site: **www.ukcares.com**

2.2 Coating material (unbonded tendons)

The coating to unbonded strand shall be either high density polyethylene (HDPE) or polypropylene. The coating thickness shall be at least 1.0mm unless otherwise stated in the project specification and the friction between the coating and the strand shall not exceed 60N/metre. The friction shall be determined in accordance with the test methods defined in ETAG 013 Annex C clause "C.1.3.2.2 Friction test".

Note: High density polyethylene is more flexible and less liable to embrittlement at extremely low temperatures, while polypropylene is more stable at high temperatures. Both materials have high resistance to abrasion and creep, although polypropylene is slightly superior in these respects. The use of PVC is not recommended since it is known that chloride ions can be released in certain conditions.

The interstices between wires are normally filled with grease to repel moisture.

2.3 Anchorages

Anchorages for post-tensioning systems shall comply with the minimum performance requirements of BS EN 13391 as defined in CARES Appendix PT3 or the post tensioning kit shall hold a European Technical Approval (ETA) against ETAG013. Documentary evidence of product conformity shall be provided if requested.

Note: BS EN 13391 is a supplementary standard to BS EN 1992-1-1, BS EN 1992-2 and ETAG013.

Evidence of post-tensioning kit/post-tensioning anchorage qualification should be obtained at tender stage if possible.

2.4 Ducts and vents

Duct, vent and connection material shall be robust enough to resist damage during construction for example smooth galvanised steel with a minimum wall thickness of 0.35mm, corrugated galvanised steel with a minimum wall thickness of 0.30mm or high density polyethylene or polypropylene with a minimum wall thickness of 2.0mm.

Ducting shall prevent the entrance of paste from the concrete, and shall not cause harmful electrolytic action or any deterioration of the tendon or tendon components. The internal cross-sectional area of the duct shall be at least twice the net area of the tendon's prestressing steel. Ducting shall be capable of transmitting forces from grout to the surrounding concrete.

Note: For bonded tendons the designer should clearly specify the type of duct required to meet the required bond and durability requirements.

The use of PVC is not recommended since it is known that chloride ions can be released in certain conditions.

Ducts are usually steel with a folded seam and are not leaktight. Where a higher level of protection is required such as in car parks, plastic duct systems should be considered.

2.5 Grout

The properties of the grout, made with materials plant and personnel proposed for use on site, shall be assessed for suitability for the intended purpose sufficiently in advance of grouting operations to enable adjustments to be made to the materials plant or personnel.

Grout shall consist of pre-bagged material requiring only the addition of a measured amount of water and shall be CARES approved to Appendix PT10.

Grout shall be stored in accordance with the manufacturer's instructions.

Note: Bagged grout materials have a specified shelf life and the bags are normally date marked. The material must be used in date order by the specified date.

Bleed water is excess water in the grout that is not chemically bound and can lead to low density grout, grout cracking, grout shrinkage and porosity, therefore the w/c ratio must be kept as low as possible. The necessary grout properties can be achieved with properly formulated grout materials and the addition of minimum quantities of water.



3.0 Workmanship

3.1 Tendon installation

Tendons comprising: strand, duct/vent and anchors shall be installed to a vertical accuracy of:

- 6mm vertically for slabs less than 200mm thick.
- The smaller of slab thickness x 0.03 or 30mm for slabs greater than 200mm thick. and a horizontal accuracy of:
 - (a) 50mm in beams.
 - (b) 150mm in floor slabs.

Unbonded tendons may be deviated to avoid obstructions such as openings and columns with the agreement of the CA. The change of direction of the tendon should occur away from the opening and trimmer bars should be provided to avoid any possible cracking at the corners in accordance with TR43 Clause 6.7.

Note: Flat/oval ducts are relatively stiff in the transverse direction and it may not be possible for tendons with this type of duct to be deviated around obstructions without cutting the ducting and should be avoided if possible.

Tendons shall be fixed and supported at centres not exceeding 1m and shall be securely fixed to prevent movement and flotation during the construction process.

Note: Flat ducts are quite flexible in the vertical direction and it is common to install the strand within the duct and then place the tendon, which increases the stiffness and aids the achievement of a smooth tendon profile.

Vents shall be fixed at injection and exit points and, where tendon drape exceeds 500mm, intermediate vents shall be fixed at tendon high points. Vents shall extend approximately 500mm above the slab surface.

All inlets and outlets shall be suitably marked to identify the tendon and their location along the tendon.

Note: Consideration should be given to the use of intermediate vents on tendons over 20m in length.

3.1.1 Marking of tendon position

Unless otherwise stated in the project specification, the actual position of tendons shall be marked on the slab soffit to indicate the location in both plan and elevation within the slab. The system of marking shall be agreed with the CA.

Note: Where services etc are to be fixed to a slab, it is important that the slab is clearly identified as post-tensioned construction on all drawings and relevant documents. The actual position of tendons must be known accurately in both plan and elevation so that tendon damage can be avoided.

Where soffit marking has been used to indicate tendon position, caution is urged as the theoretical tendon position may have been marked which may vary from the tendon actual position.

Where the tendon position is not accurately and authoritatively documented, reinforcement detection equipment should be utilised to locate tendon positions prior to any cutting or drilling work on the slab.

3.1.2 Safety

The post-tensioning contractor shall document and implement all necessary precautions for safe working during and after tendon installation operations.

3.1.3 Records

Tendon installation shall be recorded. Records shall include:

- Date of installation.
- Strand source.
- Majority heat number.
- Anchorage batch number.
- Wedge batch number.
- Duct batch number.
- Supervisor.
- Operatives.
- Location of the products within the structure.
- Coil number.
- Drawing number and revision status.

3.2 Stressing

The post-tensioning contractor shall calculate the theoretical tendon extension. All relevant system data shall be stated e.g. μ , k , strand E value and area, wedge draw-in on lock off and any assumed movement at dead end etc. Extension calculations shall be submitted to the CA for acceptance at least 2 weeks before stressing. The CA shall confirm agreement, or comment otherwise at least one week before stressing.

Stressing shall not commence without prior agreement on theoretical extensions nor before the concrete has achieved the transfer strength specified in the project specification.

The concrete transfer strength shall be based on match cured cubes taken at the point of concrete placement.

Note: There can be significant differences in concrete strength between the first and last loads to be poured, therefore the slab's concrete transfer strength should be based on cubes taken from the last concrete load.

Match curing of cubes requires the cubes to be cured at the same temperature as the concrete element from which the cubes were taken.

The designer shall specify any restrictions on stressing sequence and increments.

The jacking force should not exceed those given in the appropriate design standard.

Tendons shall be stressed in the specified sequence and load increments.

Where required by the CA, load/extension graphs shall be plotted for at least four points on nominated in situ trial tendons.

For routine stressing, extensions shall be measured prior to commencement of stressing, and after stressing and locking off to an accuracy of 2% or 2mm whichever is greater. Measurements shall take into consideration the possible strand movement at the dead end anchor.

The actual extensions shall be within the limits specified in BS EN13670 Clause 7.5.3. Tendon groups shall be defined by the CA for structural members and for slabs/walls between supports.

The theoretical extensions shall be calculated by the post-tensioning contractor, however the CA may undertake the calculations but should request the values of the necessary parameters from the post-tensioning contractor.

Note: Theoretical extensions are used as an indication that tendons have the correct load applied during stressing. The accuracy of extension calculations will depend on the accuracy of inter alia: the tendon profile and the assumptions made for movement at the anchorages, friction and wobble coefficients.

In the event that any failures occur during stressing (system components or concrete) the cause shall be thoroughly investigated and a formal report presented to the CA. No further stressing on that element shall be undertaken until the proposed corrective action has been approved by the CA.



3.2.1 Stressing equipment

Stressing jacks and their load measuring system should have an appropriate and current calibration certificate, which is traceable to national standards, and no more than 6 months old at the time of stressing. Master gauges should have a calibration certificate provided by a qualified laboratory and should include calibration curves establishing a correlation between the values given by the measuring system and the loads applied by the jacks. The stressing equipment shall be capable of establishing a tendon load to a maximum tolerance of $\pm 2\%$.

Tendons shall be cut to length using mechanical means.

Note: Flame cutting is not acceptable for cutting strand, as heat will adversely affect the properties of the strand.

3.2.2 Safety

The post-tensioning contractor shall document and implement all necessary precautions for safe working during and after stressing operations.

3.2.3 Records

Stressing operations shall be recorded:

- Date of stressing.
- Strength and age of concrete cubes.
- The minimum age of concrete at transfer.
- Stressing equipment.
- Calibration date.
- Supervisor and operators.
- Serial numbers of gauges and jacks.
- Tendon identification.
- Theoretical extension, actual extensions and corresponding loads (where required), initial and final jacking loads.
- Drawing number and revision status.

Stressing records shall be sent to the CA not more than one week after stressing.

3.3 Sealing of anchorage components

Anchorage components shall be sealed against the ingress of water or aggressive agents likely to cause corrosion of the steel or anchorage. The method of anchorage sealing shall be stated in the project specification.

The chosen method of sealing shall be capable of resisting the specified grout pressure.

Note: In the case of grouted tendons, proprietary non-shrink mortars and bonding agents are recommended.

Anchors are usually cast into pockets in edge beams and the pockets sealed with mortar/render. The detailing of this area requires some attention, as mortar/render can be permeable and subject to shrinkage.

For exposed anchors higher levels of protection should be considered such as end caps.

For unbonded tendons it is recommended that anchorage components are coated with grease of similar specification to that used in the tendon and that a watertight cap be applied over the coated area. The minimum concrete end cover to the cap shall be 25mm.

Data sheets and method statements for anchorage sealing shall be submitted to the CA.

3.4 Grouting

3.4.1 Grouting trials

Where required, full-scale grouting trials shall be carried out using the same personnel, equipment, materials and procedures as proposed for the Works. The trial shall demonstrate that the proposed grouting method, materials and equipment fills the ducts to the satisfaction of the CA.

Trials shall be undertaken as early as possible to allow proper inspection and any necessary modifications or adjustments.

The trials shall consist of two trials of a horizontal duct arrangement to simulate the slab arrangement. The trials shall reflect the actual duct geometry and shall include typical tendon arrangements. The tendons shall be nominally stressed to ensure that the tendons assume the proper position with respect to the ducts.

Trial beams shall normally be cut at five sections for examination but more sections may be specified for complex tendon profiles.

Grouting of the ducts shall normally be shown to leave no void which has a radial dimension greater than 5% of the maximum duct sectional dimension or which poses a risk to the integrity of the tendon. Particular attention shall be given to avoiding bleed collection or void formation at high points in the ducts or anchorages.

There shall be a procedure for corrective action in the event of blockage or breakdown such as backup equipment or flushing out of ducts.

3.4.2 Preparation of ducts

Where necessary, all grouting and venting points shall be suitably marked to enable identification of the duct to which they are connected.

Note: In many slabs the duct layout is simple and repetitive and vent labelling may not be necessary. However with more complex duct/vent configurations where it is possible to confuse vents from different ducts, it is important to mark and identify the vents.

The ducts shall be kept free from contamination at all stages from storage to installation and shall be thoroughly clean before grouting.

Note: Ducts should be blown through with oil free compressed air prior to grouting (not water).

3.4.3 Grouting equipment

Grouting equipment shall comply with BS EN 446 Clause 7.

3.4.4 Grouting procedure

Grout injection shall be continuous at an agreed rate and shall be slow enough to avoid segregation of the grout and shall comply with BS EN 446 Clause 8.

All vents shall be closed one after another in the direction of the flow. The injection tubes shall then be sealed off under positive pressure of not greater than 0.1MPa.

The filled ducts shall be protected to the satisfaction of the CA to ensure that there is no damage to the grout due to shock or vibration for 24 hours after injection of the grout and that the temperature in the ducts does not fall below 5°C for 24 hours after injection of the grout.



There shall be a procedure for corrective action in the event of blockage or breakdown such as backup equipment or flushing out of ducts.

Note: The tendon encapsulation (i.e. the ducts and anchorage system enclosing the tendon) for bonded flat slabs cannot usually be sealed to the same degree as that used for civil engineering structures designed to TR72 as steel ducts are often used and the anchors are usually sealed with render instead of grout caps.

Additionally flat slabs are thinner in section and contain significantly less reinforcement and can be damaged by high grout pressure.

3.4.5 Grout testing

Grout shall comply with the performance requirements of BS EN 447 Clause 6 as follows:

Grout Properties

Fluidity	BS EN 447 clause 6.3 using the cone method
Bleeding	BS EN 447 Clause 6.4 wick induced test
Volume change*	BS EN 447 Clause 6.5 wick induced test $\geq -0.5\%$ and $\leq 2.5\%$
Strength*	BS EN 447 Clause 6.6 but 100mm cubes may be used
Sieve test	BS EN 447 Clause 6.2.
w/c ratio*	≤ 0.35
Grout temperature*	As specified by the grout manufacturer
Density	From cube tests

Table 1

Note: Items marked with an "" denote an additional or enhanced requirement over and above BS EN 447 requirements.*

The frequency of grout testing shall be in accordance with table 2 below.

Frequency of Grout Testing

Test	Frequency
Fluidity**	One set of tests per grout mix (at t_0 and t_{30})
Bleeding**	One wick induced test per day
Volume change**	One wick induced test per day
Strength	3 cubes per day taken at mixer
Density**	Recorded from cube tests above

Table 2

*Note: Items marked with an "***" denote a departure from BS EN 446 Table 3 Inspection Class 3 requirements and represent current best practice.*

Grout shall be batched in accordance with the manufacturer's instructions.

The sources of materials and procedures approved as a result of satisfactory trials shall not be departed from without the approval of the CA.

3.4.6 Safety

The post-tensioning contractor shall document and implement all necessary precautions to ensure safety during grouting operations.

3.4.7 Records

Records of each grouting operation shall be kept:

- The materials used, including batch numbers.
- The date, time and conditions under which the grouting operations were carried out.
- Ambient and structure temperatures and weather conditions.
- Grout properties including temperatures, bleed, volume change and fluidity.
- Details of any interruptions and any problems encountered during the grouting process, e.g. blockages, loss of grout or loss of grout pressure.
- Supervisor and operatives.
- Manufacturer's data sheet.



Electronic Copy www.ukcares.com

UK CARES

Pembroke House
21 Pembroke Road
Sevenoaks
Kent TN13 1XR

Phone: +44(0)1732 450000
Fax: +44(0)1732 455917
E-mail: general@ukcares.com
URL: www.ukcares.com



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