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GENERAL TECHNICAL SPECIFICATION

PRESTRESSING

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1 MATERIALS

1.1 CONSTITUENT MATERIALS FOR MORTARS AND GROUTS

1.1.1 ADMIXTURES

Admixtures added to concrete to improve or retain workability, reduce mixing water, increase strength or for other purposes such as accelerating or retarding setting shall not contain harmful constituents in quantities that could impair the durability of the concrete or cause corrosion of the reinforcement.

- They shall comply with the applicable standard, namely NP EN 934-2, "Admixtures for concrete, mortar and grout – Part 2: Concrete admixtures – Definitions, requirements, conformity, marking and labelling".
- Workability retention shall be carefully checked against the planned placing times, so as to minimise the risk of unplanned construction joints.
- Storage conditions and maximum storage times shall follow the manufacturer's instructions. In their absence, tests shall be carried out to demonstrate that the specified and verified properties of the admixtures have been retained.
- Their effectiveness shall be carefully checked against the required consistence and the maximum permissible water/cement ratio.
- Admixtures shall be colourless or light-coloured, so as not to cause staining or subsequent oxidation.

Where there is any doubt about the properties of the admixtures used, or their compatibility with any other constituent of the concrete, the Engineer may order whatever tests are deemed necessary.

The Contractor shall support the admixture data with tests on the variation in workability of the concrete during the first hour after mixing and on its strength at 3, 7 and 28 days, so as to provide the Engineer with the information needed to approve their use.

Admixtures used in prestressing grouts shall be free from chlorides and aluminium.

1.2 REINFORCING AND PRESTRESSING STEELS

1.2.1 PRESTRESSING STEEL

Prestressing steel shall comply with Section 3.3 of NP EN 1992-1-1 and its National Annex, with the applicable LNEC Specifications and, once published, with EN 10138. For unbonded tendons, the requirements of the European Technical Assessment (ETA) for the selected post-tensioning system shall also apply.

In principle, any steel available on the market may be used, provided that it comes from a recognised source and that its mechanical properties, as required by the selected post-tensioning system, are duly certified by approval documents issued in the country of origin.

Only low-relaxation steels shall be used, and their properties shall in no case be lower than those set out in the applicable specifications.

The properties of certified steels are those given in the following LNEC Specifications:

- E 452-2004: Steel wire for prestressing – Properties and tests;
- E 453-2002: Steel strand for prestressing – Properties and tests;
- E 459-2002: Steel bars for prestressing – Properties and tests.

It shall be ensured that the steels used meet both the properties assumed in the design and those required by the selected post-tensioning system.

Prestressing steels shall be supplied in full compliance with the LNEC Specifications referred to above.

Each batch of steel shall be delivered with its stress–strain diagrams and the results of all other mill tests certifying its properties, with the modulus of elasticity clearly stated. These tests and supporting documents shall comply with the standard applicable to the type of steel used.

If the Engineer so requires, acceptance tests shall be carried out to verify the mechanical and technological properties of the steel, in accordance with the LNEC Specifications referred to above.

Only batches of steel that have been tested or accepted by the Engineer may be used in the Works.

Any identity tests ordered by the Engineer shall be carried out in accordance with EN ISO 15630.

Where steel is transported and delivered in coils, the coil diameter shall be such that the strands show no deformation when uncoiled. In any event, the inside diameter of the coils shall be not less than 200 times the diameter of the thickest wire in the strand.

All necessary precautions shall be taken during transport and storage to prevent corrosion and contamination of the steel.

Where steel is stored on site for more than one month, its condition shall be inspected periodically and the temporary protection renewed whenever necessary.

All steel coils shall be clearly identified by the supplier and labelled as tested, and shall only leave the store for immediate use. Any coils not used shall be returned to the store forthwith.

1.3 DUCTS, GROUT AND PRESTRESSING ANCHORAGES

For ducts, anchorages and accessories, lubricants, waxes and other post-tensioning products, as well as all associated operations, the rules of NP EN 13670 and of the ETA for the selected post-tensioning system shall apply.

1.3.1 DUCTS FOR PRESTRESSING TENDONS

1.3.1.1 BONDED POST-TENSIONING

Ducts shall be corrugated, comply with NP EN 523 and NP EN 1992-1-1, and be tested in accordance with NP EN 524 (Parts 1 to 6).

The minimum strip thickness of the ducts shall be as follows, according to their internal diameter:

- $\phi_i \leq 55$ mm - min. thickness = 0.31 mm
- $55 < \phi_i \leq 65$ mm - min. thickness = 0.45 mm
- $65 < \phi_i \leq 110$ mm - min. thickness = 0.53 mm
- $110 < \phi_i$ mm - min. thickness = 0.60 mm

The external diameter of the ducts shall be as follows, according to their internal diameter:

- $\phi_i < 65$ mm - $\phi_e = \phi_i + 5$ mm
- $\phi_i > 65$ mm - $\phi_e = \phi_i + 7$ mm

Ducts and accessories shall be accompanied by a manufacturer's certificate stating their properties and conditions of use.

The following acceptance tests shall be carried out:

- Flexibility

Ducts shall withstand three reverse bends to the design radii of curvature without any damage.

- Resistance to crushing

A length of duct approximately 1.00 m long is placed on a rigid base and the load given below, according to the internal diameter of the duct, is applied to the top generatrix, between two corrugations, by means of a punch with a semicircular tip 12 mm in diameter.

ϕ	F (kg)
25 to 75	75
75 to 85	90
85 to 95	105

The duct shall withstand these loads.

- Leak tightness

For the water-loss test, the same sample is filled with water to an internal pressure of 0.5 bar, held for 5 minutes; water loss shall not exceed 1.5% of the duct volume.

The Engineer reserves the right to have samples from each batch delivered to site tested at the Contractor's expense, for each type of duct, up to a total length of 50 m, to verify that materials, dimensions and properties meet the specified quality and tolerances.

1.3.1.2 UNBONDED MONOSTRAND POST-TENSIONING

Strands shall be sheathed in high-density polyethylene (HDPE) at least 1 mm thick, hot-extruded over the strand after coating with corrosion-protection grease or wax, in accordance with the system ETA issued on the basis of EAD 160004-00-0301, with the filling material complying with EAD 160027-00-0301.

The sheathing shall be robust enough not to be damaged during transport, handling and installation.

1.3.2 ANCHORAGES AND WEDGES

The post-tensioning system proposed by the Contractor and accepted by the Engineer shall hold a valid European Technical Assessment (ETA) issued on the basis of EAD 160004-00-0301 – Post-tensioning kits for prestressing of structures (which superseded ETAG 013), together with a Declaration of Performance and CE marking.

Anchorages and wedges shall be original system components and shall be accompanied by their specifications (material grades, dimensions and tolerances), quality and factory production control certificates, and approval documents.

No component will be accepted unless it has been manufactured either in the plant certified under the applicable ETA or in another plant designated by the system holder and certified for that purpose by a notified body.

In all cases, the Engineer may have any components tested at an accredited laboratory, before and during construction, to check their quality and confirm that they retain the properties stated in the approval documents. Samples shall be taken at random by the Engineer from components delivered to site, and testing shall be at the Contractor's expense up to 5% of the number of anchor heads of each type and 2% of the number of wedges.

Any tests beyond this limit shall be at the Contractor's expense if the results are unsatisfactory.

Otherwise, they shall be paid for by the Employer under the terms of the General Conditions of Contract.

Any conformity tests ordered by the Engineer shall be carried out in accordance with EAD 160004-00-0301 referred to above and with the control plan of the system ETA.

Each batch of anchorages delivered to site, including all accessories, shall be identified and numbered in the presence of the Engineer.

Each batch shall be accompanied by documents proving its origin and quality control.

1.3.3 CEMENT GROUT FOR DUCT GROUTING

Cement grout for prestressing ducts shall comply with NP EN 445 – Grout for prestressing tendons – Test methods, and NP EN 447 – Grout for prestressing tendons – Basic requirements. Grouting procedures shall comply with NP EN 446 and grout admixtures with NP EN 934-4.

Colloidal grout or cement paste, with mix proportions established by trial tests and adjusted, also on the basis of tests, for water and plasticiser content according to temperature and to the length of the tendons to be grouted.

Following detailed trials, the Contractor shall submit the nominal grout mix for the Engineer's approval, stating:

- The nature, quality and source of the constituents;
- The proportion of each constituent by mass, with permissible tolerances;
- The order in which the constituents are added to the mixer.

In any event, the water/cement ratio shall be as low as possible consistent with adequate workability, and shall not exceed 0.40.

Cement shall be CEM I to NP EN 197-1, delivered in bags, of strength class 42.5 or 52.5, and shall, in addition to the applicable standards:

- Show no false set;
- Have a chloride ion content below 0.05%;
- Contain no sulphide ions or any other substance liable to cause corrosion of the steel.

The Contractor shall propose the brand of admixture to be used, in accordance with the admixtures clause, together with a certificate of origin stating its expiry date; it is understood that the admixture shall contain no substance corrosive to steel, such as chlorides or aluminium.

In addition to LNEC Specification E 372, mixing water shall meet the following requirements:

- Chlorides (Cl^-) < 500 mg/l;
- Sulphates (SO_4^{2-}) < 400 mg/l;
- No detergents.

For all constituents combined (cement, water and admixture), the total content of aggressive ions shall be less than:

- 0.1% by mass of cement for Cl^- ions;
- 0.1% by mass of cement for SO_4^{2-} ions;
- traces only of S^{2-} ions.

Batching tolerances shall be as follows:

- ±2% on the mass of cement;
- ±1% on the mass of water;
- ±2% on the mass of admixture.

Tests shall be carried out in accordance with NP EN 445, and the results shall meet the requirements of NP EN 447.

- The mix shall be designed for local conditions and actual grouting conditions so as to achieve good workability, which shall always be checked with the Marsh cone. The flow time through the cone outlet shall be less than 25 seconds for at least 30 minutes after mixing, or until the end of grouting.
- Bleeding, determined in accordance with NP EN 445, shall not exceed 0.3% after three hours, and all bleed water shall be reabsorbed within 24 hours.
- The volume change of the grout, measured on cylindrical specimens, shall be between −1% and +5%. Where expanding agents are used, no reduction in volume is permitted. Initial setting time at 30 °C shall in all cases exceed 3 hours.

Systematic strength tests at 3, 7 and 28 days shall be carried out to confirm the required strength and fine-tune the grout mix. Each test shall be performed on at least one set of three specimens per batch; the Engineer may increase the number of sets per batch.

- The 28-day compressive strength shall be not less than 50 MPa.

2 EXECUTION OF THE WORKS

2.1 PRESTRESSING

All post-tensioning work shall comply with NP ENV 13670-1, the European Technical Assessments (ETAs) for the selected system, and NP EN 1992-1-1 and its National Annex.

2.1.1 GENERAL

At least sixty days before tendon installation begins on site, the Contractor shall submit for the Engineer's approval the post-tensioning system or systems it intends to use.

The submission shall include a detailed description of the system, its approval documents, warranty certificates, the bodies responsible for quality control, the source of every system component, and a detailed description – with drawings at suitable scales – of component geometry, dimensions, material grades, tolerances, etc.

The Contractor shall also submit the stressing and grouting procedures for the proposed system, together with details of the proposed prestressing steels, their source, quality certificates, properties and any other documents needed to assess their suitability for the intended purpose.

The Engineer reserves the right to request further information and to reject the proposed system, the source of any or all of its components, or the bodies responsible for their quality control.

The Contractor shall state in its submission the personnel who will carry out the work, together with their qualifications and professional experience.

It shall also provide a list of the equipment to be used and of standby equipment; all such equipment shall remain permanently on site and shall not under any circumstances be used on other contracts.

The Engineer reserves the right to approve both personnel and equipment.

The latest jack–pump calibration certificates, issued by an accredited laboratory and not more than 6 months old, shall be submitted. Calibration shall thereafter be repeated at the same interval.

The post-tensioning contractor shall have the equipment needed to carry out this check on site.

Once the post-tensioning system has been accepted, the Contractor shall submit the post-tensioning design for the Engineer's approval no later than 60 days before tendon installation begins on site.

The post-tensioning design shall comply with this Specification and with Eurocode 2, both as regards general design data and detailing – in particular stresses, losses, anchorage draw-in, number of tendons per member, arrangement and grouping of ducts, cover, minimum spacing, permissible curvature and anchorages.

Each design shall comprise the following:

- Written documents:
    - Design statement - General description of the system, material properties and execution of the work.
    - Calculations - Description of the formulae used to determine the final effective prestress, including calculation of initial and final steel stresses, prestress losses (immediate, due to anchorage draw-in, and time-dependent), the initial and final prestress at each stage at the design sections of the approved scheme design, jacking forces, predicted extensions and anchorage-zone reinforcement.
    - Stressing schedule - Sequence of stressing stages, equipment required for each stage, order in which tendons are to be stressed and the end(s) from which they are to be stressed, extensions and their tolerances, corresponding gauge pressures, maximum stress not to be exceeded during stressing, and draw-in values.
    - Documentation – Quality control certificates for components and prestressing steel, stress–strain and relaxation diagrams for each coil of steel to be used on site, and their moduli of elasticity.
    - Drawings – Tendon profiles, anchorage-zone reinforcement, anchorage details, dimensions of anchorage pockets and any other details needed for full understanding and correct execution of the work.

If the Engineer so requires, one sample of each anchorage system, selected by the Engineer, and one sample of each type of duct to be used shall be provided; these shall be retained by the Engineer until completion of the work as reference samples.

The construction drawings define the mean tendon profiles, anchorage sections, final effective prestress at the critical sections, minimum permissible areas of prestressing steel for the specified steel grade, and all other necessary information. Although details may differ and tendons may not follow the design profiles exactly, depending on the system adopted, the resultant of the tendon group (mean prestress axis) shall coincide with the axes shown on the approved design, and all other constraints shown on those drawings shall be respected. Any change required for reasons inherent to the system shall be duly justified in the post-tensioning design, and the Engineer shall decide whether to accept or reject it.

Post-tensioning work shall be carried out by a specialist company that holds the system ETA or is authorised by the holder, with the company and its personnel qualified in accordance with CWA 14646 – Requirements for the installation of post-tensioning kits for prestressing of structures and qualification of the specialist company and its personnel. The technical manager and the site supervisor shall be on site at all times during stressing and grouting.

2.1.2 PREPARATION AND PLACING OF TENDONS

Tendons shall be cut by mechanical means; flame cutting is prohibited.

No welding shall be carried out near the tendons unless special precautions are taken to protect them.

Tendons may only be bent using duly approved methods, mechanically, at constant speed and without impact, so as to give the tendons a uniform radius of curvature. The bending mandrel diameter shall never be less than the minimum permitted in the steel approval document. Straightening or re-bending tendons is prohibited.

Close to anchorages and couplers, and inside stressing and anchoring devices, tendons shall be straight over a length depending on the type of tendon and the system adopted.

Damaged tendons shall be rejected, in particular those showing corrosion, notches, signs of heating by flame or spatter, or significant deformations not allowed for in the design.

Tendons shall be free from foreign matter and shall not be used if contaminated with oil, graphite, detergents or any other film that would reduce bond.

Tendons shall follow the profiles shown on the approved design and shall be securely fixed so that they cannot be displaced before or during concreting.

2.1.3 DUCTS FOR TENDONS

The type, wall thickness and diameter of the ducts shall meet the design requirements and comply with clause 1.3.1 of this Specification, so that they withstand all transport, installation and concreting operations without damage and facilitate stressing and grouting.

Fixing ducts by welding is prohibited.

Duct arrangement, spacing and minimum cover shall comply with NP EN 1992-1-1, in particular Sections 4.4.1 (cover) and 8.10.1 (arrangement of tendons and ducts), and with the system ETA.

Permissible deviations of duct position from the design profile are as follows:

1. Vertical deviations

   - Members with depth h < 0.60 m: 2 mm at points nearest the top and bottom faces and 5 mm at all other points.

   - Members with depth h ≥ 0.60 m: 4 mm at points nearest the top and bottom faces and 10 mm at all other points.

2. Horizontal deviations

   - Members with width b < 1.00 m: 5 mm at all points.

   - Members with width b > 1.00 m: 5 mm at all points on the tendons nearest the side faces and 10 mm elsewhere.

Ducts shall follow a smooth profile and be supported at enough points to keep within the fixing tolerances. In any case, support points shall be no more than one metre apart.

Ducts shall be watertight; special care shall be taken to ensure tightness at joints, in particular at connections to anchorages and couplers.

Ducts shall be fitted with vents at both ends and at all high points. Intermediate vents shall be provided on long tendons. Drains shall also be provided at low points where sub-zero temperatures may occur during construction. Ducts at couplers shall be fitted locally with suitably oriented and positioned vents, so that no water or air pockets are trapped during grouting.

Ducts shall be protected against the ingress of foreign matter and, in cold weather, special precautions shall be taken to prevent the ingress of water.

2.1.4 TENDON ANCHORAGES

Anchorages, couplers and tendon joints for the post-tensioning system used in the superstructure shall be of the type shown on the construction drawings and shall be accompanied by approval and quality control documents.

Anchorages shall be guaranteed to perform correctly, gripping the tendons securely without excessive prestress loss and without reducing the local and global resistance assumed in the calculations; couplers and tendon joints shall in addition ensure full continuity of the tendons.

When tested with unbonded tendons, anchorages shall develop at least 90% of the tendon's ultimate capacity without draw-in exceeding the predicted values. For couplers, this value shall be 95%.

Tendon joints are not permitted in zones of tight curvature.

Tensile (bursting and spalling) forces in the anchorage zones caused by prestressing shall be resisted by reinforcement arranged broadly along the tensile stress trajectories, designed in accordance with NP EN 1992-1-1 (Sections 6.5 and 8.10.3) and with the anchorage-zone reinforcement specified in the system ETA.

Anchorages shall be placed in the positions shown on the post-tensioning detail drawings.

Anchorages shall be positioned so that their axes coincide with the tendon axes and the centroid of the group matches the prestress eccentricity shown on the approved design drawings.

Sufficient clearance shall be left between anchorages for easy positioning of the stressing jacks, and sufficient space within the concrete for the passage of mild steel reinforcement and concrete.

Anchorages shall be securely fixed to the formwork so that they cannot be displaced by accidental impact or during concreting.

2.1.5 STRESSING OF TENDONS

Stressing operations shall be carried out in accordance with the approved stressing schedule.

Stressing shall not begin less than three days after the last concrete pour, nor before:

- The concrete in the member has reached a strength of at least 0.70 times its characteristic value;
- The mean compressive strength of the concrete in the anchorage zone is equal to or greater than the minimum value ($f_{cm,0}$) stated in the system ETA for the anchor plate used, taking into account the edge distances and anchorage spacing defined therein.

Stressing shall be carried out in accordance with the application rules of the selected system, following the sequence and the stressing stages set out in the stressing schedule approved by the Engineer.

The stressing sequence shall be arranged so as to avoid any harmful eccentricity of prestress.

The maximum stress applied by the jack shall not exceed the lesser of 0.80 f_{pk} and 0.90 $f_{p0,1k}$ (NP EN 1992-1-1, 5.10.2.1). The initial stress immediately after transfer (σ_{pm0}) shall not exceed the lesser of the following two values (NP EN 1992-1-1, 5.10.3):

- 85% of the characteristic 0.1% proof stress;
- 75% of the characteristic tensile strength.

Any overstressing that may prove necessary shall only be applied with the express authorisation of the Engineer; all such operations and readings shall be recorded and the tendons concerned identified.

The final (theoretical) steel stress under maximum actions, after all losses, shall not exceed 65% of the characteristic tensile strength.

No stressing shall be carried out at temperatures below 0 °C.

Tendon extensions and draw-in values shall be measured to the nearest millimetre and recorded on the stressing record, together with the corresponding gauge and load-cell readings.

The jacking force shall be stated in the stressing schedule, and the measuring equipment shall ensure that the prestress applied to the tendons does not differ by more than 5% from the scheduled value.

Extensions shall be measured to an accuracy of at least 2% of the total and shall not differ from the scheduled values by more than 5%. They shall be entered on the stressing record, together with any incidents occurring during the operation.

The Contractor shall submit to the Engineer, in writing, a detailed calibration plan for readings and equipment covering the whole contract period. The plan shall include the initial calibration certificates issued by an accredited laboratory and a list and description of the equipment to be used.

The Contractor shall not begin stressing until the Engineer has approved this plan.

The plan shall also list the pressure gauges and load cells to be kept in reserve.

Stressing shall not be carried out without the Engineer being present.

During stressing, no one shall stand behind the jacks or in line with the tendon axis; this zone shall be marked out and protected by barriers. Jacks, pumps, gauges and hoses shall be inspected before each use, and any damaged equipment shall be withdrawn from service immediately.

If a tendon element (wire, strand or bar) fails during stressing, stressing shall be suspended and the Engineer shall decide on the action to be taken (overstressing, tendon replacement or additional tendons).

Such work shall be at the Contractor's expense.

Tendon ends shall not be cut until the Engineer has approved the stressing record.

2.1.6 GROUTING OF TENDON DUCTS

Cement grout as specified in clause 1.3.3 shall be injected into the ducts in accordance with the grouting procedures of the approved system, or NP EN 446 where more stringent, using a suitable grout pump connected to continuous mixing equipment, at a minimum pressure of 1 MPa depending on tendon length and minimum cover. The pressure shall never exceed 2 MPa, and the pump shall be fitted with the necessary safety devices.

Each duct shall be grouted continuously, with the grout advancing at 6 to 12 metres per minute.

Before grouting, ducts shall be blown through end to end with compressed air, then flushed with water and blown again with air, to clean and clear them.

Ducts shall be grouted within eight days of completion of stressing, after striking and before the falsework is moved to the next stage. The Contractor shall request approval of the stressing record in good time for this purpose.

For tendons with couplers, grouting shall always be carried out before the continuation tendon is connected, and always from the opposite end.

Filling of the ducts shall be checked at the vents, which shall be open before grouting begins; grout shall flow continuously from each vent, free from air or water pockets, before the vents are closed in turn.

Standby compressed-air and pressurised-water flushing equipment, with a power supply independent of that used for grouting, shall be available at all times during grouting. In an emergency – whether due to grouting equipment failure or duct blockage – the grout already injected shall be flushed out immediately using water and air jets from the standby equipment.

Grouting shall only be considered complete when grout flows continuously from the far end of the duct, for a sufficiently long period, with no visible traces of air or water.

A pressure of 0.5 MPa shall be maintained for five minutes after the vents have been closed.

Grouting is not permitted at temperatures of +5 °C or below, or if such temperatures are forecast within the next five days.

Nor is grouting permitted at temperatures above 32 °C, and the grout temperature shall be kept below this value throughout mixing.

2.1.6.1 QUALITY CONTROL

Grout acceptance tests shall be carried out throughout the work. The type and frequency of tests (fluidity, bleeding, volume change and strength) shall comply with NP EN 446, following the good practice set out in fib Bulletin 20 – Grouting of tendons in prestressed concrete.

Grouting operations shall be properly monitored, recording on the grouting record the mix composition (quantities of cement, water and plasticiser), mixing time, Marsh cone flow time, ambient temperatures and grouting pressure.

2.1.7 PROTECTION OF TENDON AND BAR ANCHORAGES

2.1.7.1 SEALING OF ANCHORAGES

Anchorages shall always be protected with watertight caps and, where embedded in concrete, sealed with Type III mortar.

In the latter case, the sealing mortar or concrete shall be fully bonded to the structural concrete and shall completely cover all metal parts; for this purpose, the concrete surfaces shall be suitably scabbled before sealing.

Anchorage pockets shall be sealed immediately after grouting and cutting of the strand ends, once it has been confirmed that the extensions are within the tolerances specified in clause 2.1.5 of this Specification.

The cost of the Type III mortar used to seal the anchorage pockets is deemed to be included in the contract unit rate for concrete; the Contractor shall not be entitled to any additional payment for its supply and placing.

The sealing mortar shall be fully bonded to the structural concrete and shall completely cover all metal parts.

2.1.7.2 PROTECTIVE CAPS

Protective caps shall be suitably protected against corrosion (galvanised and painted). They shall be of the type commonly used to protect external post-tensioning anchorages and shall be supplied by the same source as the post-tensioning system used on site.

The cost of the caps and their installation is deemed to be included in the contract rate for post-tensioning.

2.1.7.3 CORROSION PROTECTION LEVELS

The level of corrosion protection of the tendons shall be defined in the design according to the exposure classes (NP EN 206 and NP EN 1992-1-1) and inspection requirements, using protection levels PL1, PL2 and PL3 of fib Bulletin 33 – Durability of post-tensioning tendons. In aggressive environments, plastic ducts and watertight encapsulated anchorages (PL2) or, where required, electrically isolated systems (PL3) shall be used.

2.1.8 UNBONDED POST-TENSIONED SLABS (MONOSTRAND)

This clause applies to unbonded post-tensioning systems in slabs and floors using greased and sheathed strands (monostrand), consisting of low-relaxation steel strand coated with corrosion-protection grease or wax and individually sheathed in extruded HDPE, in accordance with the ETA for the selected system.

Strands shall be supported on chairs or spacers at a maximum spacing of 1.00 m and secured with tying wire or cable ties, without damaging the sheathing, so as to achieve the design profile and cover.

The HDPE sheathing shall be inspected before concreting. Any damage shall be repaired with compatible waterproof tape or heat-shrink sleeving, in accordance with the system holder's instructions. Sheathing shall not be stripped beyond the length strictly necessary at the anchorages.

At live and dead anchorages, the unsheathed length of strand shall be protected by a watertight transition sleeve between the sheathing and the anchorage. After stressing, the wedge cavity shall be filled with corrosion-protection grease before the watertight cap is fitted, so as to form an encapsulated anchorage.

Stressing may be carried out in two stages: partial stressing, to control shrinkage cracking, once the concrete has reached the strength specified in the design for that stage; and final stressing once the concrete has reached the minimum strength $f_{cm,0}$ stated in the ETA for the anchorage used.

Once the Engineer has approved the stressing record, strand tails shall be cut by mechanical means, at a distance from the wedges not less than that stated in the ETA; flame cutting is prohibited.

Drilling, coring or forming openings in post-tensioned slabs at a later stage shall only be permitted after the strands have been located and with the designer's approval. Cutting strands without a previously approved de-tensioning procedure is prohibited. This requirement shall be recorded on the as-built drawings and in the Health and Safety File.

The Contractor shall provide as-built drawings showing the actual strand profiles, the location of live and dead anchorages, and the stressing records.

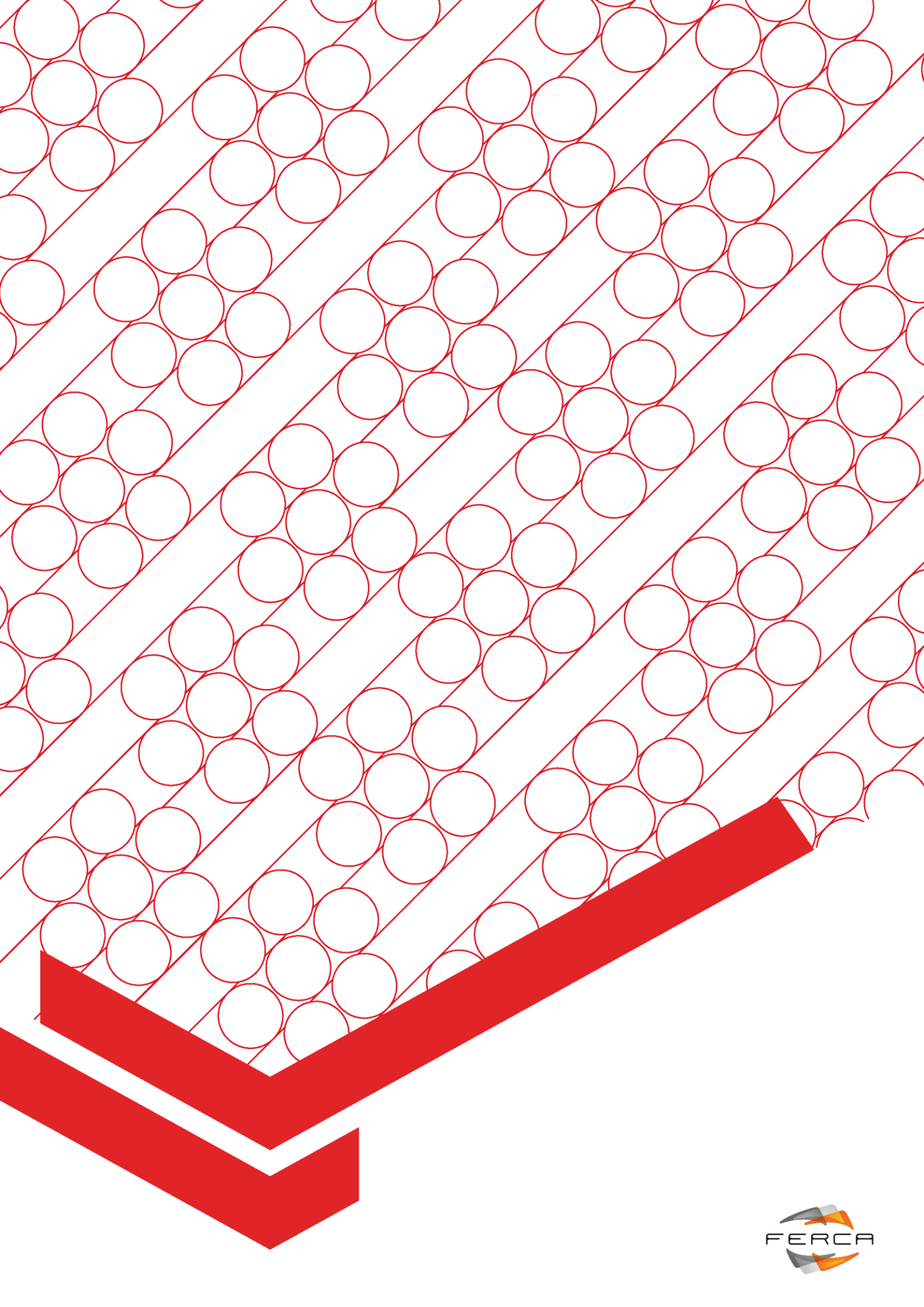
3 METHOD OF MEASUREMENT

3.1 PRESTRESSING STEEL

The contract unit rate includes ducts, sheathing, individual strand protection, sealing mortar, anchorages, anchorage-zone reinforcement to resist deviation forces, installation, stressing, grouting, protective waxes and all other materials and work needed to complete the post-tensioning, so as to achieve the effective prestress shown on the drawings after allowing for the overstressing needed to offset losses due to steel relaxation, friction, concrete creep, etc.

For measurement purposes, high-strength steel tendons are measured by mass **(kg)**, based on the mass of bare strand or bar for bonded systems. For unbonded systems such as monostrand, the mass to be measured is that of the steel plus its sheathing.

The areas of prestressing steel shown on the construction drawings are the minimum required to satisfy the serviceability and ultimate limit states of the prestressed members, provided that high-strength steel of the grade specified is used. The Contractor shall therefore provide not only the effective prestress shown, but also the minimum area required by the design – or an equivalent area if steels with different properties are proposed – always in accordance with clause 1.2.1 of this Specification.


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