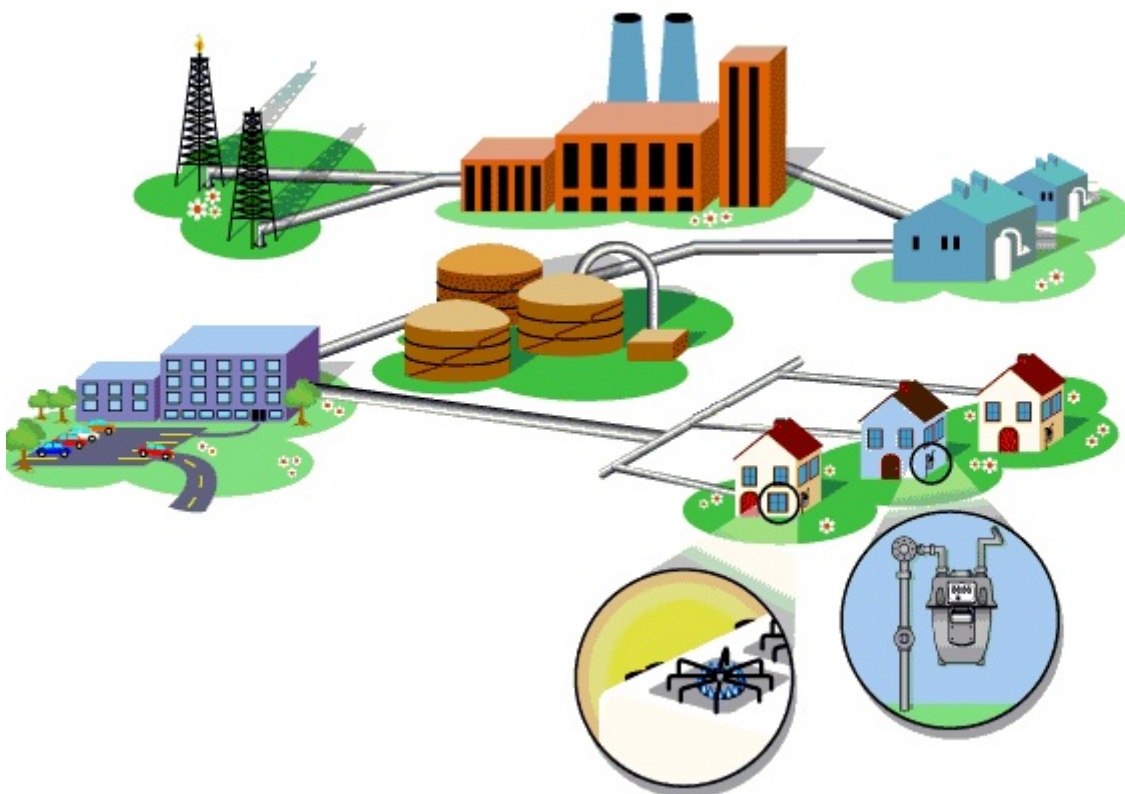




**Georgian Oil
&
Gas Corporation**

Executive Phase

Specification for Concrete Materials and Construction



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1. Scope

This specification defines the requirements for the materials, proportioning, mixing, placing, curing, coating, testing and all other related items for the total production of durable concrete work within North-South Gas Pipeline Rehabilitation Project.

2. Definitions and Abbreviations

Corporation: GOGC, as defined in the Contract Agreement

Contractor: Performing Company(s), as defined in the Contract Agreement

Sub- contractor: organisation appointed by the Contractor to execute a scope of work

Supplier: organisation appointed by the Contractor to supply goods

Organisation: collective term for any Contractor, supplier, and sub-contractor

ISO: International Standards Organisation

ITP: Inspection and Test Plans (also known as Quality Control Plan)

Work: the activity and processes and deliverables to be produced by the Contract Scope of Work

DCC: Document Control Centre

PEP: Project Execution Plan

QA: Quality Assurance

QC: Quality Control

Refer to General Conditions of Contract and/or Terms and Conditions of Purchase in Material Requisition Section 9.

Inspector	Engineer responsible for monitoring concrete work who will make ad hoc inspection to check that this Specification is being fully complied with.
Approved	Terms such as “approved”, “approved by”, “to approval”, “as directed”, and the like refer to approval or directions given by or on behalf of GOGC in writing, but do not in any way relieve the Contractor of the responsibility for compliance with this specification, nor does it in any way transfer responsibility to the GOGC.
Certification	As a minimum, certification shall contain a clear definition of what is being certified, the items involved,

	purchase order, date, and signature and title of a duly authorized representative of the company issuing the certificate. Additional requirements may be imposed by the applicable code, standard, or specification.
CQCE	Concrete Quality Control Engineer. A full-time, qualified, dedicated engineer appointed by the Contractor with the sole duty of ensuring that concrete is properly produced, placed, cured and protected.
NAMAS	National Measurement Accreditation Service

3. Codes and Standards

3.1 General

All materials, workmanship and testing shall be in accordance with the latest requirements at the time of contract award of the following documents. In the event of conflict among the various Codes and Standards and/or this specification, reference shall be made back to GIC for resolution. Unless specified otherwise the SI (International System) of metric units shall be used.

3.2 British Standards

BS 12: 1996	Specification for Portland cement
BS 812: Various	Methods of sampling and testing of mineral aggregates, sand and fillers
BS 882: 1992	Specification for aggregates from natural sources for concrete
BS 1199 and BS 1200: 1986	Specifications for building sands from natural sources
BS 1305: 1974	Batch type concrete mixers
BS 1763: 1975	Specification for thin PVC sheeting (calendared, flexible, unsupported)
BS 1881: Various	Methods of testing concrete
BS 2571: 1990	Specification for PVC water-stops

BS 3148: 1980	Methods of test for water for making concrete (including notes on the suitability of the water)
BS 3892-1: 1997	Specification for pulverised fuel ash for use with Portland cement
BS 3892-3: 1997	Specification for pulverised fuel ash for use in cementitious grouts
BS 4027: 1996	Specification for sulphate-resisting Portland cement
BS 4254: 1983	Two-part polysulphide-based sealants
BS 4449: 1997	Specification for carbon steel bars for the reinforcement of concrete
BS 4482: 1985	Specification for hard-drawn steel wire for the reinforcement of concrete
BS 4483: 1998	Specification for steel fabric for the reinforcement of concrete
BS 4550: 1978	Methods of testing cement
BS 5075-1: 1982	Concrete admixtures. Specification for accelerating, retarding and water-reducing admixtures
BS 5075-3: 1985	Concrete admixtures. Specification for super plasticizing admixtures
BS 5328:	Methods for specifying concrete including ready-mixed concrete
Part 1: 1997	Guide to specifying concrete
Part 2: 1997	Methods for specifying concrete mixes
Part 3: 1990	Procedures to be used in producing and transporting concrete
Part 4: 1990	Procedures to be used in sampling, testing and assessing compliance of concrete
BS 5606: 1990	Guide to accuracy in building
BS 5975: 1996	Code of practice for falsework
BS 8004: 1986	Code of practice for foundations
BS 8007: 1987	Code of practice for design of concrete structures for retaining aqueous liquids

BS 8110-1: 1997	Structural use of concrete. Code of practice for design & construction
BS 8666: 2000	Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete
BS EN 196: Various	Methods of testing cement
BS EN 480: Various	Admixtures for concrete, mortar and grout
BS EN 932-1: 1997	Tests for general properties of aggregates. Methods for sampling
BS EN 932-2: 1999	Tests for general properties of aggregates. Methods for reducing laboratory samples
BS EN 932-3: 1997	Tests for general properties of aggregates. Procedure and terminology for simplified petrographic description
BS EN 932-5: 2000	Tests for general properties of aggregates. Common equipment and calibration
BS EN 932-6: 1999	Tests for general properties of aggregates. Definitions of repeatability and reproducibility
BS EN 934: Various	Admixtures for concrete, mortar and grout

3.3 American Concrete Institute

ACI 305R-99	Hot Weather Concreting
ACI 306R-88	Cold Weather Concreting
ACI 318M-99	Metric Building Code Requirements for Structural Concrete
ACI 504R-90	Guide to Joint Sealants for Concrete Structures

3.4 American Society for Testing Materials

ASTM C-33-97	Specification for Concrete Aggregates
ASTM C-40-92	Tests for Organic Impurities in Sands for Concrete
ASTM C-88-90	Test for Soundness of Aggregates by Use of Sodium Sulphate or Magnesium Sulphate

ASTM C-114-97	Standard Method of Chemical Analysis of Hydraulic Cement
ASTM C-131-96 Angeles Machine	Test for Resistance to Abrasion of Small Size Coarse Aggregate by Use of Los Angeles Machine
ASTM C-142-97	Test for Clay Lumps and Friable Particles in Aggregates
ASTM C-150-97	Specification for Portland Cement
ASTM C-186-97	Tests for Heat of Hydration of Hydraulic Cement
ASTM C-227-90 Bar Methods)	Tests for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar Bar Methods)
ASTM C-289-94	Test for Potential Reactivity of Aggregates (Chemical Method)
ASTM C-309-97	Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
ASTM C-311-97	Sampling and Testing of Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland Cement Concrete
ASTM C-413-96	Standard Test Method for Absorption of Chemical-Resistant Mortars, Grouts and Monolithic Surfacing
ASTM C-452-97 Exposed to Sulphate	Standard Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulphate
ASTM C-531-95	Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts and Monolithic Surfacing
ASTM C-579-96	Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts and Monolithic Surfacing
ASTM C-586-92	Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates
ASTM C-827-95	Standard Test Method for Early Volume Change of Cementitious Mixtures
ASTM C-989-99	Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
ASTM C-1105-95	Test for Length Change of Concrete due to Alkali Carbonate Rock
ASTM C-1107-97	Specification for Packaged Dry, Hydraulic-Cement Grout (Non-shrink)
ASTM C-1260-94	Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

3.5 US Commercial Standard

National Ready-Mixed Concrete Association (NRMCA) - Check List.

3.6 Russian Standards

GOST 5781-82-85 Hot-rolled steel for reinforcement of ferro-concrete structures
Including Amendments 2, 3, 5

GOST 8267-93	Crushed stone and gravel obtained from dense rock for construction work
GOST 10178-85	Portland cement and Portland Blast-Furnace Cement
GOST 22266-94	Sulphate-Resisting Cement.
GOST 30108-94	Construction materials and products. Determination of the specific effective activity of national radio nuclides.

4. Water

4.1 Quality

Water used for mixing concrete, ice production, washing aggregates, cooling aggregates and curing concrete shall be in accordance with BS 3148 and the recommended limits for impurities given in Appendix A of BS 3148 shall not be exceeded. Additionally the limits given in Section 7.7 of this specification for the total salt content of the concrete shall not be exceeded.

4.2 Testing

Once a source of satisfactory supply has been established, further tests shall be made periodically with a portable electrical conductivity probe calibrated against the satisfactory supply. If the conductivity exceeds that of the satisfactory supply, then further chemical tests shall be performed.

5. Cement and Cement Replacements

5.1 Ordinary Portland Cement (OPC)

Ordinary Portland cement shall conform to ASTM C150 Type I or II, or GOST 10178 Grade 300 or 400. Cement meeting the requirement of rapid hardening Portland cement shall not be used and the heat of hydration shall not exceed 325kJ per kg when tested in accordance with ASTM C-186. Up to 50% blast furnace slag may be included in OPC.

5.2 Sulphate-resisting Portland cement (SRPC)

Sulphate-resisting Portland cement shall conform to or ASTM 150 Type V, or GOST 22266 Grade 300 or 400. The C_3A content shall not exceed 5%. The SO_3 content shall not exceed 2.3%. These shall be no mineral additives e.g. slag in the SRPC.

When the sulphate resistance is doubtful, testing in accordance with ASTM C-452 shall be performed prior to acceptance of the cement.

5.3 Portland cement - general

Cement types ordinary and sulphate-resisting shall be low-alkali cements in accordance with Table 1A of ASTM C-150 (0.6% maximum).

Manufacturer's test certification shall be supplied for each delivery of cement and shall confirm that the cement complies with the above requirements and shall be submitted by the Sub-Contractor not later than the day of delivery of the cement.

The Inspector shall have the right to call for tests on each delivery of cement if necessary to establish or confirm that the cement meets the above requirements.

There shall be no special additives in the cements.

6. Aggregates

6.1 General

Aggregates shall conform to the requirements of BS 882. Petrographic analyses shall be made to BS 812.

Fine and coarse aggregate shall be considered as separate ingredients.

In the case of carbonate or dolomite materials, if the petrographic analysis indicates the materials have a potential for alkali-carbonate reactivity, then they shall be checked by testing in accordance with ASTM C-586 and, if necessary, ASTM C-1105. In the case of other types of materials, if the petrographic analysis indicates the materials have a potential for alkali-silica reactivity, then they shall be checked by testing in accordance with ASTM C-289 and, if necessary ASTM C-1260.

Aggregates shall be tested for specific effective activity of natural radio nuclides in accordance with GOST 30108.

6.2 Coarse Aggregate

Coarse aggregate shall consist of crushed or uncrushed gravel or crushed stone and shall be selected, re-crushed, finish screened and washed with water meeting the requirements of section 4.0, all as necessary to comply with the following:

	Test Description	Standard	Limit
a)	Los Angeles abrasion loss (Grading A or B)	ASTM C-131	50% maximum
b)	Ratio of Los Angeles abrasion loss at 100 & 500 revolutions (100/500 revolutions value)	ASTM C-131 Note 6	0.25 maximum
c)	Clay lumps and friable particles	ASTM C-142	1.0% max.
d)	Material finer than 75 micron	BS 812	1.0% max.
e)	Water absorption	BS 812	2.5% max.
f)	Chlorides as Cl	BS 812	0.03% max.*
g)	Sulphates as SO ₃	BS 812	0.4% max.*
h)	Magnesium sulphate soundness loss (5 cycles)	ASTM C-88	18% max.
i)	Flakiness index	BS 812	30 maximum
j)	Elongation index	BS 812	45 maximum
k)	Reactive silica		Those given in
		ASTM C-289	Appendix XI of
		ASTM C-1260	ASTM C-33
l)	Frost-resistance	GOST 8267	F150 minimum

These requirements may be relaxed by the Contractor subject to very careful evaluation of satisfactory performance of concrete made with the aggregates with positive traceability of aggregate and cement characteristics and equivalent service environment.

*Additionally the limits given in section 7.7 of this specification for the total salt content of the concrete shall not be exceeded.

Coarse aggregate shall be limited to 20mm nominal size for all grades of concrete.

6.3 Fine Aggregate

Fine aggregate shall consist of crushed gravel; crushed stone or natural sand with rounded or surrounded particles and shall be washed as necessary to comply with the following:

	Test Description	Standard	Limit
a)	Clay lumps and friable particles	ASTM C-142	1.0% maximum
b)	Material finer than 75 microns	BS 812	BS 882
c)	Organic impurities	ASTM C-40	Lighter than Standard
d)	Water absorption	BS 812	1.0% maximum
e)	Chlorides as Cl	BS 812	0.06% maximum*
f)	Sulphates as SO ₃	BS 812	0.40% maximum*
g)	Reactive silica		Those given in
		ASTM C-289	Appendix XI of
		ASTM C-1260	ASTM C-33
h)	Magnesium sulphate soundness	ASTM C-88	18% maximum

*Additionally the limits given in section 7.7 of this specification for the total salt content of the concrete shall not be exceeded.

6.4 Sources

Aggregates shall be from approved sources.

The Sub-Contractor shall supply samples of the materials for approval by the Contractor and each aggregate source shall be subject to monitoring by the Inspector.

6.5 Certification

The Sub-Contractor shall obtain from each proposed source of supply Test Certification to confirm that the aggregates comply with the above requirements.

In detail, the following information shall be provided:

- a) Quarry location
- b) Aggregate type
- c) Petrographic analysis report
- d) Grading curve
- e) Shape
- f) Surface texture
- g) Flakiness index
- h) Fines value

- i) Impact value
- j) Shell content
- k) Chloride content
- l) Sulphate content
- m) Relative density
- n) Water absorption value
- o) Silt, clay and dust content
- p) Moisture content
- q) Results of reactive silica tests
- r) Organic impurities (fine aggregate only).
- s) Magnesium sulphate soundness
- t) LA abrasion

6.6 Testing

6.6.1 When a source of supply for each type of aggregate has been established, then samples of materials delivered to site shall be taken for testing in accordance with the following frequencies as a minimum.

Daily during production

Gradation (sieve analysis)

Material finer than 75 microns

Moisture content

3 days test

Cube Test

7 days test

Cube Test

28 days test

Cube test

6.6.2 The Inspector shall have the right to call at any time for additional samples for testing of aggregates delivered to site, or for aggregates at the source of supply, in order to confirm that the aggregates meet the above requirements.

6.6.3 Testing frequency shall be increased if unusual variations in results are observed.

6.7 Transportation

During transportation to the site, all aggregates shall be protected from wind-borne contaminants. Should these contaminants be present at the time of delivery to site, then the aggregates shall be washed with water meeting the requirements of section 4.0. Transport vehicles shall be cleaned from possible contamination due to previous use.

6.8 Storage

6.8.1 Aggregates shall be stored under shade on a hard concrete surface and each size and type shall be stored in separate heaps without intermixing. Storage shall prevent contamination of the aggregates by foreign material including wind blown dust.

6.8.2 Fine and coarse aggregates shall be separated by permanent substantial partitions in the store. Methods of storing, shading and cooling aggregates shall be agreed with the Inspector.

7. Concrete Mix Requirements

7.1 Cement and Pozzolan Content

7.1.1 Structural Concrete

Grade 35: Minimum 360kg/m^3 of SRPC, with air-entrainment per section 7.4.1
Minimum 28-day cube strength 35N/mm^2
Maximum free water/cement ratio 0.40

7.1.2 Fireproofing Concrete

Grade 30: Minimum 320kg/m^3 of OPC, with air-entrainment per section 7.4.1
Maximum aggregate 12mm
Minimum 28-day cube strength 30N/mm^2
Maximum free water/cement ratio 0.45

7.1.3 Mass Concrete

Grade 25: Minimum 275kg/m^3 of SRPC, with air-entrainment per section 7.4.1
Minimum 28-day cube strength 25N/mm^2
Maximum free water/cement ratio 0.45

7.1.4 Blinding or Mud mat Concrete

Grade 10: Sufficient SRPC to achieve characteristic strength of 10N/mm^2 .

7.2 Free Water / Cement Ratio

7.2.1 The design water content shall be continuously checked at the mixer with due allowance being made for water (if any) contained in the aggregates or any ice added for cooling. Under no circumstances is additional water to be added between the mixer and the place of concrete placement. Additionally the Inspector may call for the water/cement ratio to be checked by tests carried out on fresh concrete samples taken at the time of placement, as described in section **11.4**.

7.3 Characteristics Strength

7.3.1 Characteristic strength is defined as that value of the cube strength below which 5% of all possible test results would be expected to fall.

7.3.2 The characteristic strength of concrete grade 25, grade 30 and grade 35 shall be established by test mixes.

7.4 Admixtures

7.4.1 A suitable air-entraining agent complying with BS EN 480 (various parts), BS EN 934-2 and BS EN 934-6 shall be incorporated where specified under section 7.1. The total air content in the concrete shall be $6\% \pm 1.5\%$.

7.4.2 If necessary, and only with the Contractor's agreement, workability retention/retarding super-plasticizer shall be used to increase workability of the concrete and retard the initial set. It shall comply with BS 5075-3.

Acceptable brands are:

- a) Supaflow R from Don Construction Chemicals Ltd.
- b) Superplast SR from Cementaids Europe Ltd.
- c) PSI - Super from Gifford-Hill and Company, Inc. (Cormix).
- d) Sikament from Sika Chemical Corporation.
- e) Daracem 100 from W.R. Grace and Company.
- f) Rheobuild 561 or Glenium from Master Builders.
- g) Other COMPANY-approved equivalent brands.

7.4.3 The Contractor shall obtain from the supplier of the retarding super plasticizer, details of the material for review by the Contractor and confirmation that it is in accordance with this specification. Confirmation shall be obtained that the retarding super plasticizer is compatible with any pozzolan that is used.

7.4.4 No other admixtures shall be permitted to be used in the concrete without express permission and in no circumstances shall admixtures containing chlorides or other corrosive agent be allowed. Their compatibility with the type of cement used shall be proven.

7.4.5 The Contractor shall perform a trial batch and casting to substantiate the manufacturer's claims for workability, retardation and air-entrainment as described in section 8.

7.4.6 Very strict control shall be maintained to ensure that the correct quantity of admixture is used at all times. The equipment to be used for dispensing and method of incorporating the admixture in the concrete shall be subject to approval. The dispensing unit shall be translucent so that the operator can see the discharge of the admixture.

7.5 Initial Setting Time

7.5.1 The maximum time between mixing and placing concrete shall not exceed 1 hour and the total time between mixing and initial set shall be at least 2 hours. There shall be a maximum setting time of 6 hours, but it is desirable for this to be as soon after the initial set as possible.

7.5.2 When trial mixes are made to determine the workability of the concrete, as described in section 8.0, the initial setting time of the cement paste shall be determined using the method defined in BS EN 196 and BS 4550, but at the maximum allowable temperature, (see section 9.4) and with the same proportions of air-entrainer and super plasticizer.

7.6 Workability

7.6.1 The workability of fresh concrete shall be suitable for the conditions of handling and placing, so that, after compaction, concrete surrounds all reinforcement, tendons and ducts and completely fills the formwork. BS 5328-1 provides guidance on the workability appropriate to different uses and on the workability of concrete for general purposes.

7.6.2 The workability shall be such that the concrete can be transported, or pumped, placed into the forms and compacted without segregation and bleeding in accordance with section 15.0

7.7 Total Salt Content

7.7.1 Chlorides

The total chloride content of the concrete from all sources expressed as chloride ion, when tested in accordance with BS 1881 for the sum of both acid soluble and water soluble chlorides, shall not exceed the following by weight of dry cement, inclusive of pozzolana:

for OPC	-	0.3%
SRPC	-	0.15%

These figures shall be halved for pre-stressed concrete.

7.7.2 Sulphates

The total sulphate content of the concrete from all sources, expressed as SO_3 , when tested in accordance with BS 1881, shall not exceed 4% by weight of dry cement, inclusive of pozzolana.

8. Trial Mixes

8.1 Structural Concrete Grades

8.1.1 The mixes for grades 25, 30 and 35 shall be designed mixes in accordance with BS 5328 and as specified in this specification. The relative proportions of the fine and coarse aggregates and the workability and strengths of the mixes, shall be determined by production equipment trial mixes. Once the aggregate proportions have been accepted, they shall not be changed without the agreement of the Contractor.

8.1.2 The trial mixes shall be carried out in order to produce a concrete which can be properly placed and compacted, so that a dense impermeable concrete can be produced which shall adequately resist the ingress of damaging salts. A superplasticiser may be required and if so shall be used in the trial mixes. The required workability for large foundations may differ from that for tall thin sections of structural concrete cast above ground, and the trial mixes shall allow for both cases.

8.1.3 When the Sub-Contractor has established the proposed workability and proportion of the aggregates and super plasticizer (if any) for grades 25, 30 and 35 concrete as described in section 7, then test concrete shall be produced for approval by the Contractor. The following tests shall be carried out:

- a) Four separate test mixes shall be prepared and six test cubes shall be made from each test mix for each grade of concrete. The test cubes shall be made, cured and tested in accordance with BS 1881.
- b) The 24 cubes for each grade of concrete shall be tested for crushing strength at 28 days and the mean strength and standard deviation established for each grade.
- c) The test mixes shall be accepted provided that:
The mix proportions and workability are in accordance with this Specification.
The standard deviation for each grade is 3.5N/mm^2 or less.

The characteristic strength of each grade, to be calculated as 6N/mm^2 below the mean strength, is equal to or more than 25N/mm^2 , 30N/mm^2 and 35N/mm^2 respectively.

8.1.4 Strength will be closely monitored during production in order to measure the quality control that the Sub-Contractor exercises over the production of concrete.

8.2 Blinding or Mudmat Concrete

8.2.1 Concrete for blinding or mudmat shall be a designed mix with a characteristic strength of 10N/mm^2 .

8.2.2 The trial mix proportions shall be left to the discretion of the Sub-Contractor. Once they have been chosen, three separate test mixes shall be made with these proportions and three 150mm test cubes made from each mix for testing at 28 days. The trial mix proportions and water/cement ratio shall be approved if the average strength of the cubes is not less than 10N/mm^2 . Once the test mix proportions and water/cement ratios have been accepted for this grade of concrete, they shall not be changed without the agreement of the Contractor.

8.2.3 No production test shall be made for this grade of concrete, but the Inspector shall monitor the mix proportions and water/cement ratio.

8.3 Absorption Tests

8.3.1 The absorption of the hardened concrete from the trial mixes for structural grades shall be tested, as a measure of the ability of the concrete to resist the ingress of aggressive salts. No absorption tests shall be required for blinding or mudmat concrete.

8.3.2 Absorption tests to modified BS 1881 Part 122 shall be carried out as follows:

- a) After trial mixes have been accepted, three 150mm cubes shall be cast from each grade of concrete and immersed in water at 20°C for 7 days.

- b) At the end of the curing period 75mm diameter core specimens shall be cut from each cube for the full 150mm thickness, but subsequently trimmed to approximately 75mm length.
- c) The specimens shall be dried in an oven at 105⁰C for 72 hours.
- d) The specimens shall be cooled in a dry airtight vessel for 24 hours, weighed and then immediately immersed in a tank containing water at 20 °C, with the longitudinal axis of the cores horizontal, and with 25mm depth of water over the specimens.
- e) The specimens shall be left under immersion for 24 hours, then removed, shaken, surface dried, and re-weighed. The water absorption shall be calculated as the increase in mass resulting from immersion, expressed as a percentage of the dry mass.
- f) As the cores will be of lengths that differ from 75mm, a correction factor (graph given in BS 1881), shall be applied to standardise on the sample volume.
- g) The mean of the corrected absorption figures for each concrete grade shall be calculated and, provided that the mean absorption is less than 6%, then the absorption of the concrete mixes shall be acceptable. The mean absorption figure and the lowest absorption figure shall be recorded for each grade and used for comparison purposes with absorption tests to be carried out on cores cut from in situ concrete, as described in section 12.4.

8.4 Test Construction

8.4.1 Test Foundation

- a) A test foundation footing and plinth, all in accordance with this specification, and containing 2m³ of reinforced concrete shall be cast on grade to details provided by the Contractor. This shall be carried out before any permanent works are constructed.
- b) The concrete shall be cured for the period required in section 16.0 and after that period coatings shall be applied in accordance with section 18.0.

8.4.2 Test Floor Slab

A 3m x 4m test area of 150mm thick floor slab, all in accordance with this specification, of above ground reinforced concrete shall be cast on grade and given a class U4 finish as described in section 15.7. The concrete shall be cured for the period required in section 16.0.

8.4.3 The Inspector who will check and advise in order that the requirements of this specification are understood and complied with will observe both operations. The two constructions shall serve as standards for normal production concrete construction and may, in due course, have cores cut from them for further test standards.

8.4.4 The temperature of the concrete at the time of placement shall be recorded for both test constructions described above.

9. Concrete Production

9.1 General

9.1.1 Concrete production shall be in accordance with BS 5328.

9.1.2 Concrete shall be produced in a central batching and mixing plant that conforms to BS 1305. Consideration shall be given to the need for a backup plant to cover for the failure of the central batch plant during an important pour.

9.1.3 A check list for concrete production shall be produced, such as that used by the National Ready-Mixed Concrete Association or equal.

9.2 Batching

9.2.1 Batching of materials shall be by weight, except that volumetric batching will be acceptable for water and admixtures.

9.2.2 The concrete manufacturing facility shall be equipped with a device that automatically records the actual quantity of each ingredient that comprises each individual batch.

9.2.3 All weighing equipment shall be calibrated and documentation shall be provided by the Sub-Contractor to establish that the accuracy is continuously maintained in accordance with the requirements of BS 5328.

9.2.4 The Sub-Contractor shall furnish the necessary equipment and shall establish accurate procedures for determining the quantities of free moisture in the aggregates. Moisture determinations shall be made daily and whenever there is an apparent change in the moisture content. The moisture content shall be recorded. The moisture of aggregates shall be utilised to adjust the weight of aggregate added to the mix. The water added to the mix shall similarly be adjusted.

9.3 Mixing

9.3.1 All concrete mixed on site shall be in a batch mixer of approved size and design complying with BS 1305, and producing a uniform distribution of the materials throughout the mixed concrete in accordance BS 1305. The contents of the drum shall be completely discharged before re-charging.

9.3.2 After all the materials are in the mixer, mixing shall continue until the whole of the materials are uniformly distributed and the mass is of uniform colour and consistency.

9.3.3 Whenever mixing is to be suspended for half an hour or longer, the drum of the mixer shall be thoroughly washed out with clean water. The Sub-Contractor shall provide a competent operator who shall be in continuous control of the mixer.

9.3.4 No re-tempering of partially hardened concrete by the addition of cement, aggregate or water shall be allowed.

9.4 Concreting in Hot Weather

9.4.1 The temperature of concrete at the time of placement shall not exceed 30 °C, but for concrete items in excess of 30m³ and/or 900mm thickness, the temperature of concrete at the time of placement shall not exceed 25°C. Any concrete with a temperature in excess of the above figures shall not be used.

9.4.2 The Sub-Contractor shall make adequate provision before normal production concrete commences for the means of keeping within this temperature limit, taking into account the anticipated site temperatures during the period of concrete production.

9.4.3 Normal provisions for reducing the concrete temperature are as follows:

- a) Shading of mixing plant and trucks
- b) Shading of aggregates and water tank
- c) Painting white the mixing plant, trucks, water tank and cement silo
- d) Insulating the water tank and supply piping
- e) Using flaked ice in lieu of mixing water
- f) Concreting at night

9.5 Concreting in Cold Weather

9.5.1 Special precautions shall be taken to prevent the temperature of the concrete falling to 0°C during the early stages of hardening.

9.5.2 Concreting at air temperatures below 2°C may only be carried out if the following precautions are taken:

- a) The temperature of the concrete at the time of placing is at least 5°C (10°C is preferable).
- b) The temperature of the concrete is maintained by approved methods at not less than 5°C, and water curing is not used until the concrete reaches a strength of 5N/mm² as determined by tests on cubes which are cured as far as possible under the same conditions as the concrete in- place.
- c) The aggregates and water used in the mix are free from snow, ice and frost.
- d) Before placing concrete, the formwork, reinforcement, and any surface with which the fresh concrete will be in contact shall be free from snow, ice and frost, and heated to a temperature close to that of the freshly placed concrete. Special care shall be taken where small quantities of fresh concrete are placed in contact with larger quantities of previously cast concrete at a lower temperature.
- e) Any concrete damaged by frost shall be removed from the work.

9.5.3 Concrete Temperature

The required temperature of the concrete may be achieved in a number of ways including the following:

- a) Heating the mixing water and aggregate. Cement shall not come into contact with water at a temperature greater than 60°C. If the water is above 60°C, it is advisable to mix it with the aggregate first, before adding any cement.
- b) Increasing the cement content of the mix (but not to exceed 420kg per cubic metre).
- c) Covering the top face of slabs and beams with insulating material.
- d) Providing wind breaks to protect newly-placed concrete from cold winds.
- e) Using a heated enclosure, completely surrounding the freshly placed concrete, or using heated formwork panels. In either event care shall be taken to prevent loss of heat and excessive evaporation of water from the concrete.

- f) Introducing heating cables tied to the reinforcement in the concrete members. This measure will allow concreting to continue at temperatures of -10°C on rising thermometer and -7°C when the temperature is dropping. Concreting shall not be carried out at temperatures inside the enclosure below -10°C.
- g) Concrete in transit being maintained between 5°C and 10°C.
- h) Precautions being taken to prevent curing compound from freezing.

10. Testing - General

10.1 Appointment of Testing Laboratory

10.1.1 The Contractor shall appoint an independent testing laboratory.

10.1.2 The Sub-Contractor shall be responsible for the taking, identifying and delivering to the testing laboratory all test samples called for in this specification. The Contractor shall be responsible for the testing proper. The Sub-Contractor shall collect all test results and deliver them to the Contractor as called for in this specification.

10.2 Testing Laboratory Qualifications

The testing laboratory shall be accredited by NAMAS or equivalent National Standard and shall have a Quality System in accordance with BS EN ISO 9002.

11. Tests on Freshly Made Concrete

11.1 Crushing strength tests for structural grades

11.1.1 Testing

a) Sampling, curing and testing shall be carried out using the relevant procedures set out in BS 1881.

Samples for production concrete cube tests shall be taken at the average rate of one per 50m³ of concrete placed, with a minimum of one sample taken every day that the mix is used. A sample consists of three cubes. Initial sampling shall obtain forty results as soon as possible, eight samples per day during the first five days and thereafter as above.

b) Samples shall be taken at the point of placement. From each sample, three 150mm cubes shall be made, one for testing at 7 days after casting and two for testing at 28 days. All samples shall be clearly marked with their identification and accurate records shall be supplied to the Contractor giving:

- Identification of test cube
- Date and time of sampling
- Mix designation
- Location of sampled batch after placing
- Method of compaction
- Date of testing
- Results of test

- Cement type and country of origin
- Volume of pour
- Age of sample in days
- Weight of sample in grams
- Density in kg/m^3
- Crushing load in Newton
- Crushing strength N/mm^2
- Signature of person preparing cube
- Signature of person crushing cube

11.1.2 Compliance

For the 28-day tests, the concrete will be deemed to comply with characteristic strength (characteristic strength is defined in section 7.3 and determined from the test mixes described in that section) provided the following conditions are met:

The average strength determined from any group of four consecutive test results exceeds the characteristic strength by 3N/mm^2 .

The strength determined from any test result is not less than the characteristic strength minus 3N/mm^2 .

11.1.3 Unsatisfactory Concrete

If any test result fails to comply with either section 11.1.2.1 or 11.1.2.2, then the quantity of concrete represented by the results shall be at risk of being removed and replaced at Contractor's expense.

11.1.4 Standard Deviation

The 28-day cube crushing results shall be grouped consecutively in groups of 40 and each group shall have a standard deviation less than 3.5N/mm^2 .

If the standard deviation is greater than this, then concrete production shall be investigated by the Inspector. Further tests on trial mixes may be required.

11.1.5 7 Day Tests

a) Tests shall be carried out at 7 days to establish a relationship between the 7-day and 28-day strengths. The relationship shall be used to interpret further test results in order to predict the probable value of the corresponding 28-day strengths.

b) The Inspector shall be advised without delay of any 7-day test result that indicates that the corresponding 28-day test results are likely to fail to meet the specified strength, so that necessary action can be taken to minimise the effect of such possible failure.

11.2 Crushing Strength Tests for Blinding Concrete

There shall be no production tests on blinding concrete. The Inspector shall call for tests to determine the strength of the concrete if there is reason to believe that the characteristic strength is falling below 10N/mm^2 . If tests confirm that this is so, then the Inspector shall call for revisions to the mix design in order that this concrete shall meet the specified requirements.

11.3 Measurement of Concrete Temperature

When required, the temperature of the concrete at the point of and prior to placement shall be measured in accordance with BS 5328 and recorded on the pour card for each pour. The temperature of the concrete shall meet the requirements of section 9.4 or 9.5, otherwise concreting shall cease until the requirements can be met.

11.4 Cement Content and Water/Cement Ratio

Samples of freshly mixed concrete shall be chosen by the Inspector at least once per month from each structural grade and determination made of cement content and water/cement ratio in accordance with BS 1881. The cement content and the water/cement ratio shall be within the requirements of section 7.1.

The Inspector shall have the right to call for analysis of fresh concrete from any pour.

No analyses of freshly mixed concrete shall be required for blinding or mudmat concrete.

11.5 Air Content

Air-entrained concrete shall be tested for air content every time that strength specimens are made.

11.6 Records

Records shall be kept and a copy supplied of the mix details and position in the works of all batches of concrete and of all samples taken for cubes and other specimens. These records shall include, but not be limited to:

- Date and time of pour.
- Ambient temperature and humidity.
- Cement type and manufacture.
- Volume of pour.
- Concrete temperature (at time of placement).
- Aggregate type and source.
- Admixture details.
- Water/cement ratio.
- Air content (if applicable).
- Position in the work.

12. Tests on Hardened Concrete

12.1 General

The Inspector may call for samples to be taken and tests carried out on hardened structural grade concrete as described below if there is reason to suspect that the concrete will not meet the specification.

Should the tests confirm that the concrete does not meet the requirements of this specification, and then the Contractor may ask for the concrete to be removed at the Contractor's expense. Should the tests confirm that the concrete meets the requirements of this specification, then the cost of taking the samples and testing shall not be to the account of the Contractor.

12.2 Crushing Strength Tests

The Inspector may call for a number of cores to be drilled from a particular pour. 100mm diameter cores shall be drilled as requested and sent for crushing. If the cores from that pour have an average crushing strength less than 85% of the characteristic strength, or an individual core has a crushing strength less than 75% of the characteristic strength, it shall be evidence that the concrete from which it was taken is not in accordance with the specified requirements. Cores shall be drilled in accordance with BS 1881.

12.3 Concrete Cover

12.3.1 The Inspector may on occasion check the concrete cover to the reinforcement with a cover meter. Any indication that the cover is generally less than the requirements given in section 14.11 shall be checked by limited surface concrete removal. If it is confirmed that the actual cover is generally less than specified, then the concrete shall be judged not to meet the specification and shall be removed, or the Sub-Contractor shall be required to present their proposals for remedial action to the Contractor for approval.

12.3.2 In the case of localised lack of cover and where appearance is not important, a repair shall be affected by removal of the inferior cover and the cutting back of concrete for 50mm behind the reinforcement. A specialist Sub-Contractor shall, as defined in section 17.0, carry out resurfacing of the concrete with the specified cover as a repair.

12.4 Absorption

12.4.1 A sample of three 75mm diameter cores, 75mm long shall be taken from the hardened concrete if directed by the Inspector. Absorption tests shall be carried out in accordance with section 8.3. Should the absorption of any core exceed 6% the concrete from which it was cut shall be judged not to meet the specification and shall be removed.

12.4.2 No absorption tests shall be required for blinding or mudmat concrete.

13. Reinforcement

13.1 Uncoated Grade

13.1.1 Reinforcement shall be uncoated and to the following grades:

All reinforcement shall be high yield deformed bars in accordance with BS 4449 or Class A-III, steel grade 25G2S in accordance with GOST 5781-82 with minimum specified characteristic strength of 390N/mm².

Welded steel wire fabric shall conform to BS 4483 and BS 4482 or GOST 5781-82.

13.1.2 BS and GOST reinforcement is not interchangeable. It shall be stored separately and not mixed in any individual foundation or structure.

13.2 Certification

13.2.1 A copy of the manufacturer's test certificate for ultimate strength, elongation and cold bending, together with the chemical analysis of the steel shall be submitted to the Inspector for each consignment of reinforcing steel delivered to site.

13.2.2 Only new material shall be furnished, and on receipt and at the time of installation shall be free of loose rust or loose mill scale, deleterious amounts of salts or coatings that reduce or destroy bond. Tight rust and mill scale or surface irregularities will be acceptable, provided the weight and the dimensions, including height of deformations and tensile properties of a test specimen which has been wire-brushed by hand, are not less than those required by the applicable Standards.

13.3 Shipping and Storage

13.3.1 Reinforcement shall be handled and shipped in a manner to avoid bending or other damage to the bars. Bars shall be bundled, preferably for one placement, in accordance with the placement schedule and as follows:

- a) All bars shall be tagged with schedule number and bar mark number. Bars for separate buildings or large structures shall not be bundled together. Bars for small structures may be bundled together.
- b) Metal tags or approved equal shall be provided and labelled with legible marks.
- c) All bundles shall be tagged at each end. Tags shall show piece marks corresponding to the mark numbers on the placement drawings and on the bar list.
- d) Bars shall be bundled in the largest size practical for handling and shipping.

13.3.2 Reinforcement shall be stored above ground on platforms, skids or other approved supports. Contact with the soil shall be avoided. Proper drainage and protection from the elements shall be provided to minimise corrosion.

13.4 Fabrication

13.4.1 Reinforcement shall be accurately bent, cut or formed to the dimensions and configurations shown on the drawings and within the tolerances specified in BS 8666:2000.

13.4.2 Reinforcement shall be bent cold using pin sizes in accordance to BS 8666:2000. Bars may be preheated only if prior approval has been requested and received from the Contractor. Reinforcement shall not be re-bent or straightened without prior approval.

13.4.3 Reinforcement having a reduced section, kinks, visible transverse cracks at bends, or otherwise damaged in any way, shall not be used.

13.4.4 Reinforcement shall not be welded, unless specifically shown on the drawings or permitted as an exception. Exceptional welding of reinforcement shall only be permitted after approval has been given to the method of welding appropriate to the grade of steel and type of welding rod to be used.

13.5 Placement

13.5.1 Reinforcement shall be accurately placed in accordance with the drawings and shall be adequately secured and held in position. Ties at intersections shall be made with 1.5mm diameter annealed wire; the wire ends shall be bent so that they do not protrude into the cover zone.

13.5.2 Particular attention shall be paid to the positioning of reinforcement so that adequate concrete cover can be achieved (all as described in section 14.11) as lack of cover can be the cause of premature chloride access to the reinforcement.

13.5.3 Lap splices shall be in accordance with the drawings or BS 8110. Welded wire fabric shall be lapped 1½ mesh plus the extension on the wires, unless shown otherwise on the contract drawings.

13.5.4 Reinforcement shall be supported on concrete blocks of a size to give the correct cover to the reinforcement. Concrete spacer blocks shall be made of the same materials, to the same specification and have the same inherent properties as the parent material, but with the exception that the maximum aggregate size shall be appropriate for the thickness of cover to the reinforcement.

13.5.5 Chairs made of reinforcement shall be used to support the top mats of slab reinforcement and they shall be so dimensioned as to be stable during concreting operations.

14. Formwork

14.1 Design

Formwork for concrete shall be designed to meet the requirements of the structure and the required surface finish of the concrete, as described in section 14.10. Forms shall be so designed and constructed that the concrete can be properly placed and thoroughly compacted and that the fresh concrete, while still being supported by the forms, shall conform accurately to the required shape, position and level, subject to the tolerances specified in section 23.1.

14.2 Strength and Stability

Formwork shall be of sufficient strength and stability to maintain its position and shape under loads associated with the placing of concrete, outlined in BS 5975, taking into account the expected rate of placement, and that concrete with a super plasticizer can exert forces equal to a liquid with a specific gravity up to 2.5.

14.3 Ties and Spacers

14.3.1 Internal form ties shall be of such a nature that no permanent metallic part has less cover than the reinforcement.

14.3.2 Snap-ties or through-bolts shall not be used. The ties shall be constructed so that removal of the ends or end fasteners can be accomplished by unskilled workmen without causing spalling at the faces

of the concrete. Form ties shall be so designed that removal of the ends or end fasteners will result in a recess having a maximum dimension of 50mm and a depth as described in section 14.11.1.

14.4 Coating

Before concreting is commenced, the forms and previously cast concrete shall be thoroughly cleaned and freed from all sawdust, tie wire, shavings, dust, dirt and other debris. Formwork shall be coated with a release agent before the reinforcement is placed. It shall be non-staining, non-reactive, rust preventive and guaranteed to be compatible with subsequent surface applications to the concrete. Surplus coating on the formwork shall be removed prior to concrete placement. Care shall be taken that the release agent does not get on concrete or reinforcement that is to bond with new concrete.

14.5 Cleaning

Formwork shall be so designed that it is capable of being cleaned out immediately prior to concreting, with temporary access holes provided as necessary. Access holes shall also be provided to enable cover to reinforcement to be checked, as required in section 14.11.

14.6 Form Striking and Removal

Formwork shall be removed in accordance with clause 6.9.3 and table 6.6 of BS 8110-1.

The times stated in table 6.6 of BS 8110-1 are given as a guide and are based on the use of ordinary Portland cement.

Subject to test cube results, the minimum times at which any load other than its own weight may be placed on a member shall be as follows:-

Member days after concreting at which load may be imposed

Description	May to October inclusive	November to April inclusive
Columns	21	28
Beams	21	28
Slabs	21	28
Walls	21	28
Foundations	14	21

14.7 Sloping Work

Formwork shall be provided to the top face of sloping work where the slope exceeds 15° from the horizontal.

14.8 Chamfers

All exposed finished edges of concrete shall be chamfered by fillets cut from nominal 25mm x 25mm timber unless special architectural finishes are specified.

14.9 Formwork Material

Formwork shall be constructed of wood or steel, provided that where plywood is used for exposed surfaces it is of a type (plastic coated marine plywood, etc.) to achieve the specified finish. The number of uses of any particular formwork shall be such that the quality of the specified finish is maintained and, where the concrete has subsequently to be coated, that the coating can be effectively applied.

14.10 Formed Surfaces

(See section **15.7** for unformed finishes.)

Class F1

This finish is for surfaces against which backfill, rendering or further concrete will be placed. Appearance is not important, but where backfill is to be placed against the concrete, it is vital that the surface finish is smooth so that the coating (see section 18.4) can be applied as a continuous membrane.

Class F2

This finish is for surfaces that are permanently exposed to view, but where the highest standard of finish is not required.

Joints between the panels shall be horizontal or vertical unless otherwise directed. This finish shall be such as to require no general filling of surface pitting; however, fins, surface discoloration, or other minor defects shall be remedied by approved methods.

The cast surface may be coated to protect it from ingress of chlorides, but in any case no ledges shall be permitted at the position of joints in the formwork where they can collect salts washed down by dew or rainwater, or as contained in saline process or operations water.

Class F3

This finish is for surfaces prominently exposed to view where good appearance and alignment are of special architectural importance.

To achieve this finish, the formwork shall be faced with large sheets. The sheets shall be arranged in an approved uniform pattern. Wherever possible, joints between sheets shall be arranged to coincide with architectural features, sills, window heads or changes in direction of the surface. All joints between panels shall be vertical or horizontal, unless otherwise directed. Suitable joints shall be arranged and fitted so that no blemish or mark is imparted to the finished surfaces. Steel panels will not be permitted for Class F3 finish.

14.11 Cover

14.11.1 Concrete cover to reinforcement, including links or ties, shall be indicated on drawings, but in general shall be not less than the following:

- a) Cover to all reinforcement to surfaces in contact with the soil and in foundations up to structural steel or equipment base plate level shall be 75mm.
- b) Cover to all other reinforcement in external exposed concrete faces shall be 50mm.
- c) Cover to reinforcement in internal protected faces shall be 35mm.

d) Cover to reinforcement in internal building concrete shall be 20mm, or bar diameter, whichever is greater.

14.11.2 Cover to reinforcement shall be carefully checked before any concrete is cast, as lack of adequate cover can be the cause of premature chloride access to reinforcement. Particular attention shall be paid to reinforcement at kicker strip level as misplaced starter bars can impede the fixing of reinforcement for the next lift at the correct cover. The bending of reinforcement at a concrete cold joint is not permitted.

14.11.3 As soon as formwork is removed, concrete cover shall be checked by Sub-Contractor with a cover meter.

15. Concrete Transportation, Placement and Compaction

15.1 Transportation

15.1.1 Concrete, after being discharged from the mixer, shall be transported as rapidly as possible to its final position in the works by agitator trucks that shall prevent adulteration, segregation, loss of workability or contamination of the ingredients. The containers that convey the concrete shall at all times be kept clean and free from hardened or partially hardened concrete.

15.1.2 The uncontrolled addition of water at the point of discharge is prohibited.

15.1.3 The use of chutes, spouts, skips and pumps shall be permitted if the Contractor's approval is obtained, but under no circumstances shall any aluminium pipe or other conveying equipment containing aluminium be allowed to be in contact with fresh concrete.

15.2 Inspection of Formwork, Reinforcement and Embedded Items

Concrete shall not be placed unless the positioning, fixing and condition of the reinforcement and other items to be embedded, the cleanliness, alignment and suitability of the containing surfaces, have all been previously examined and approved. Adequate time shall be allowed for inspection when concrete pours are scheduled.

15.3 Placement

15.3.1 Placement of concrete shall generally be in accordance BS 8110, unless stated otherwise below:

15.3.2 The temperature of concrete at the time of placement shall be in accordance with section 9.4 and 9.5.

15.3.3 The concrete shall be compacted in its final position within two hours from the time of introduction of the cement and water into the aggregates.

15.3.4 Concrete shall not be dropped into place from a height exceeding 2 metres, nor shall it be dropped through dense reinforcing steel that could cause segregation of the coarse aggregate. Spouts, or flexible drop chutes shall be employed, subject to the conditions in section 15.1.

15.3.5 The concrete shall be placed in the positions and sequence shown on the drawings and be deposited within 1.5m of its final position and in such a manner as to avoid segregation of the concrete, or displacement of the reinforcement or formwork. It shall be deposited in regular courses or layers not exceeding 600mm thickness unless otherwise directed. Every precaution shall be taken to prevent the formwork and reinforcement moving during the placing or setting of the concrete and any remedial work that is necessary shall be executed promptly.

15.3.6 The work shall be organised so that the placing of concrete is efficient and continuous between specified or approved construction joints.

15.3.7 Great care shall be taken to prevent foreign matter from being introduced into the concrete from any source. Structural concreting against open excavation will not be permitted.

15.4 Compaction and Vibration

15.4.1 Full compaction of the concrete shall be achieved throughout the entire depth of the layer. It shall be thoroughly worked against the formwork and around the reinforcement and successive layers shall be thoroughly bonded together.

15.4.2 Air bubbles formed during the mixing and casting shall be expelled and particular care shall be taken where sloping soffits occur.

15.4.3 Unless directed otherwise, approved power driven poker vibrators shall be used for compaction. They shall be inserted vertically at such distances apart, or applied in such a manner, as will ensure that the concrete is satisfactorily and uniformly compacted. Immersion vibrators shall penetrate the full depth of the layer, and when the underlying layer is of fresh concrete, shall enter and re-vibrate that layer to ensure that successive layers are bonded together.

15.4.4 Over-vibration causing segregation, surface laitance or leakage through formwork, shall be avoided. Immersion vibrators shall be withdrawn slowly to prevent the formation of voids.

15.4.5 Vibrators shall not be used to work the concrete along the forms, or in such a way as to segregate the mix, damage formwork or other parts of the works, or displace the reinforcement. External vibrators shall not be used without approval being obtained for the formwork design and the configuration of the vibrators.

15.5 Concrete Joints

15.5.1 General

Joints in concrete shall be positioned, so far as is possible, so that saline water from any source cannot collect and pond over them. The normal requirements for cover shall apply to expansion and contraction joints. Watertight joints are described in section **22.2**.

15.5.2 Construction Joints

a) Where construction joints are defined in construction documents, no deviation shall be allowed without the agreement of the Contractor. Additional construction joints (i.e. joints required because of limitation of concreting or shuttering) shall be kept to a minimum and be limited to those agreed by the

Contractor. Where construction joints are not defined in construction documents, their location shall be carefully considered and agreed before concrete is placed.

b) The position of the joints shall generally be at points of minimum shear and at right angles to the main rebar in the member. Stop ends for vertical joints should be removed as soon as it is practical to do so without damaging the concrete face. The joint surface should be roughened to remove laitance without disturbing the coarse aggregate by pressure jetting with air and water or wire brushing. Care shall be taken to ensure that the joint is clean prior to placing fresh concrete. The joint may be damp but not wet. The new concrete should be well worked against the old face to ensure a good joint.

c) The use of expanded metal or other perforated material as a stop-end is expressly forbidden. Whilst this material ensures a good key between pours, it allows grout to escape, thus forming a honeycombed joint.

15.5.3 Expansion and Construction Joints

Expansion and contraction joints shall be designed and constructed in accordance with BS 8007. Details and the positioning of these joints, together with the materials to be used, shall be shown on the working drawings. Reinforcement shall not extend across joints and cover to the reinforcement at the sides of joints shall be as specified, as failure of the joint sealant would permit chlorides to attack the reinforcement.

15.5.4 Joint Filler and Sealant

- a) Joint filler shall be pre-moulded bitumen, impregnated fibre board, or similar approved.
- b) Joint sealant shall conform to BS 4254.

15.6 Embedded Items

All inserts shall be placed prior to concreting and if made of unprotected steel, shall have the cover specified in section 14.11. Anchor bolts shall be in accordance with the drawings. Inserts which project through the cover shall only be those shown on drawings and shall be made of material specified as being non-corroding (galvanised or stainless steel).

15.7 Uniformed Finishes

U1

A finish for surfaces of roads, subsequent stages of construction, bonded concrete topping or cement mortar bed to receive paving. The concrete shall be uniformly levelled and tamped. Proper surface treatment at the time of topping application shall be required.

U2

A broom finish for paving, ramps and sidewalks. This shall be achieved by drawing a broom across the float-finished concrete prior to final set.

U3

A floated finish for surfaces of beds and slabs to receive mastic paving, tile paving bedded in mastic, and for exposed surfaces when a hard smooth steel-trowelled surface is not required. When the concrete

has hardened sufficiently, the U3 finish shall be wood floated to give a uniform surface free from tamping marks.

U4

A hard smooth steel trowelled finish for tops of buried foundations (as they have subsequently to be coated), surfaces of concrete paving, tops of walls, coping and other members exposed to weathering. It also applies to surfaces of beds and slabs to receive thin flexible sheet and tile pavings bedded in adhesives. The U4 finish shall be steel trowelled by hand or machine to produce a dense, smooth uniform surface free from trowel marks.

16. Curing

16.1 General

16.1.1 The Contractor's attention is drawn to the importance of curing. Regular and frequent inspection shall be made of concrete being cured and tests shall be made on the permeability of cured concrete which will establish whether or not curing has been correctly carried out.

16.1.2 Curing of concrete containing pfa shall proceed for 14 days. Curing of other concrete shall proceed for 7 days.

16.1.3 The Sub-Contractor shall have in place a concrete curing system providing checking facilities for the Inspector. All water used for curing shall be of the quality specified in section 4.0.

16.2 Horizontal Surfaces

For concrete surfaces not in contact with forms, one of the following procedures shall be applied after completion of placement and finishing.

16.2.1 Ponding or continuous sprinkling: Pond shall cover the entire surface of concrete. Water shall be continuously replenished to assure that the concrete surface is totally immersed. Sudden release of ponded water may result in damage to the concrete and shall be avoided. Intermittent sprinkling is not acceptable if there is a drying of the concrete surface.

16.2.2 Wet Burlap Curing: Wet burlap curing shall comprise at least two layers of constantly damped burlap laid tight against the pre-soaked concrete surface. The burlap shall be kept uniformly damp (lighter patches of drier burlap shall not be evident) and shall completely cover the concrete.

16.3 Vertical Surfaces

Vertical timber formwork shall be draped with wet hessian as soon as concrete is placed. Vertical surfaces shall be treated with curing compound as soon as formwork is removed, draped with wet hessian and kept continuously wet for the duration of the curing period. All surfaces shall also be covered with white impervious sheeting firmly held in place along all edges.

16.4 Drying Winds

Care shall be taken to avoid drying winds caused by a wind tunnel arrangement of the coverings or formwork that has been slackened from the concrete.

16.5 Hessian

Hessian shall be in accordance with AASHTO:M-182 and shall weigh 0.29kg/m^2 .

16.6 Impervious Sheeting

Impervious sheeting shall be 1000-gauge polyethylene.

16.7 Curing Compound

The curing compound shall be an approved proprietary product and shall comply with ASTM C-309. The curing compound shall be compatible with the coating to be applied and may serve as a primer to the finish coating (see section 18.0). The Sub-Contractor shall obtain from the supplier of the curing compound confirmation that it meets these requirements.

17. Remedial Work

17.1 Inspection

Concrete exposed by the removal of formwork shall be inspected before any remedial work, subsequent coating or any other treatment which would hinder the proper inspection of the concrete is, carried out. Any concrete that has had remedial work carried out on it, prior to being inspected, shall be liable for rejection.

17.2 Removal and Replacement

Concrete which does not meet the requirements of this specification shall be removed and replaced without delay, unless the Inspector agrees that a repair may be satisfactorily affected. This agreement shall not preclude the subsequent rejection of the repaired work. The method to be used in removal and replacement of defective work shall be submitted for approval by the Contractor for each concrete placement before the removal commences.

17.3 Repairs

All repairs shall be carried out by a Sub-Contractor specialising in the repair of concrete and prepared to guarantee the work. Any repair method submitted for approval by the Contractor shall produce a result that is as impermeable as the original concrete. Subsequent tests on the repaired concrete shall be

carried out at the discretion of the Inspector in order to establish the quality of the repair. Particular care shall be given to the joint between the original and repair concretes.

18. Protection to Concrete Surfaces

18.1 General

All concrete shall have any surface holes investigated and provided they are small and formed by air bubbles caught against formwork, they shall be filled with a filler compatible with the coating to be applied, if that coating alone cannot fill the holes. For surface holes having any dimension greater than 10mm, reference shall be made to section **17.0**.

18.2 Blinding Concrete

18.2.1 Unless otherwise shown on design drawings, all foundations shall be placed on 50mm thick blinding concrete. Prior to placing this concrete, the subsoil shall be compacted and shall be free from soft spots.

18.2.2 The top surface of the blinding concrete shall be covered with heavy gauge polythene sheet (0.25mm thick) before formwork is fixed. The sheeting shall extend a minimum of 100 mm outside the edge of the foundation.

18.2.3 Where piling is involved and there is a danger of the soil dropping away from the underside of a pile cap, the impervious membrane shall consist of bituminous roofing felt impregnated with small stone chippings. The stone chipping covered surface shall be laid uppermost so that when concrete is cast onto it, it will remain firmly adhered to the pile cap when the ground subsequently drops away.

18.3 Surfaces below Ground Level

18.3.1 Surfaces below ground level shall be coated with a proprietary or bituminous coating to give a total minimum thickness of 1mm. The bituminous coating shall be an emulsion with a solids content of at least 55% bitumen and also containing 10% of rubber latex compound. The coating shall not become brittle at below-freezing temperatures.

18.3.2 A square scrape master sample shall be taken to determine the weight of specified thickness of coating from a 300mm x 300mm patch. The weight can then be compared with test samples described below.

18.3.3 With surfaces at grade to be painted as described in section 18.4, this coating shall overlap the ground level coating by 75mm. Care shall be taken to ensure a watertight seal between the applied coating and the polythene sheet below the foundation.

18.4 Exposed External Surfaces at Ground Level

18.4.1 Exposed external concrete surfaces for a depth of 150mm below ground level and 500mm above, or to the underside of baseplate whichever is the lowest, shall be primed with a low viscosity primer and coated with two coats of a light grey coloured epoxy paint with a minimum thickness of 125 microns

per coat, or a polymer modified cement system with minimum thickness of 500 microns. Where coating is to underside of base plate, it shall cover the grout.

18.4.2 Paint brands shall be one of the following or equal and approved:

- Hempadur primer 0597 plus Hempadur HI Build 4523,
- Quickmast 173 primer plus Quickmast 40.
- Master seal 550 by Master Builders.

18.4.3 Application trials shall be carried out on the chosen coating. Concrete surface preparation and application shall be strictly in accordance with the manufacturer's recommendations.

19. Grouting

19.1 Preparation

Concrete foundation tops shall be cleaned of all dirt, laitance, oil or grease and anchor bolt boxes shall be cleaned of all polystyrene and other deleterious material. The surface of the concrete shall be thoroughly wetted just prior to grouting (except for epoxy grout), but no excess water shall be allowed to remain, particularly in the bolt boxes.

19.2 Materials

19.2.1 Strength

The strength of all grout except epoxy grout shall be not less than 30N/mm^2 at 28 days.

19.2.2 Type G1 – Sand/Cement

Grout type G1 shall be used for all internal bases:

- a) protected from the weather,
- b) not heavily loaded,
- c) not subject to vibration loads.

The grout shall be composed of one part of Portland cement to two parts of well-graded sand by volume. Sand shall meet the requirements of section 6.3. If necessary, in order to obtain the correct fluidity in high ambient temperatures, a super plasticizer may be used.

19.2.3 Type G2 – Non-shrink

For all heavily loaded structural column bases or equipment bases subjected to vibration loads, or external work exposed to freeze-thaw, a proprietary non-shrink high-strength grout shall be used. The grout shall be non-metallic and shall comply with ASTM C-1107, Grade B or C.

19.2.4 Type G3 – Epoxy Grout

Grout type G3 shall be used for equipment bases subject to vibration loads (if required by equipment vendor), or work exposed to aggressive chemicals. Properties of the proprietary grout shall be as follows:

- a) Volume change: Epoxy grout shall exhibit no shrinkage (0.0%) and maximum of 0.4% expansion when tested in accordance with ASTM C-827, modified to use an indicator ball with a specific gravity between 0.9 and 1.1.
- b) Compressive strength: Epoxy grout shall have a minimum compressive strength at 7 days of 65N/mm² when tested in accordance with ASTM C-579.
- c) Heat development: The peak exotherm of a 50mm diameter by 100mm high cylinder of grout shall not exceed 35°C when tested at 27°C material and laboratory temperatures.
- d) Thermal expansion: Epoxy grout shall not exceed a coefficient of thermal expansion of 25×10^{-6} mm/mm/°C when tested in accordance with ASTM C-531.
- e) Irritants: The use of epoxy grout that gives off noxious fumes or volatiles shall be prohibited.
- f) Creep resistance: Manufacturer shall provide information on creep resistance including a description of the test method used.
- g) Water absorption: Epoxy grout shall have a maximum absorption of 0.1% when tested in accordance with ASTM C-413.

19.3 Mixing

All grout mortar shall be machine mixed to an even consistency. Under no circumstances shall hand mixing be used.

The water/cement ratio shall be kept to the minimum compatible with adequate workability.

Proprietary products shall be mixed strictly in accordance with the manufacturer's instructions.

19.4 Placement

19.4.1 The manufacturer's recommendations shall be strictly followed for proprietary grouts.

19.4.2 In hot weather the temperature of the grout at the time of placement shall not exceed 30 °C and the temperature of the elements in contact with the grout shall not exceed 40 °C.

In order to achieve these temperatures, it may be necessary to do the following:

- a) Shield materials from the direct rays of the sun.
- b) Mix materials with flaked ice.
- c) Cool base plates with water, but ensuring that anchor bolt pockets are free from water.

19.4.3 Grouting shall not be carried out until the steelwork or equipment has been finally levelled and plumbed, the bases being supported meanwhile by steel packers and shims.

19.4.4 Special care shall be taken to ensure that sleeves around anchor bolts are completely filled with grout before placing grout under base plates.

19.4.5 The gravity grouting method shall be employed where the flowable self-levelling grout is poured on one side of a base until it flows out at the opposite side or through a grout venting hole in a base plate where provided.

19.4.6 Packers and shims used to level bases shall be removed after the grout has set, and the resulting pocket shall be made good with similar grout.

The grout head shall be greater than 300mm and if necessary a header box shall be used to ensure that a continuous head and flow of grout is maintained during the grouting operation.

At the completion of grouting operations, all surplus grout shall be removed, including any grout splatter onto base plates, equipment and concrete faces. Within a period not exceeding 24 hours, the work shall be neatly pointed and trowelled off and left in a workmanlike condition to the satisfaction of the Inspector. All exposed edges shall be adequately protected against damage.

19.4.7 Limitations on grouting in cold weather shall be as for concreting (see section 9.5), unless the manufacturer's instructions are more stringent.

19.5 Curing

Exposed edges of grout shall be kept damp to prevent uneven drying of the grout.

Exposed edges of grout and the surfaces of base plates, equipment saddles and other similar items under which grout has been placed shall be insulated against sunrays or frost.

During cold weather conditions, care shall be taken to ensure that proprietary non-shrink grouts are cured at or above the minimum temperature recommended by the manufacturer.

20. Off-Site Mixed Concrete

20.1 Specification Compliance

Off-site mixed concrete (sometimes referred to as ready-mixed concrete) shall be permitted providing it complies with the following:

This specification

It is centrally mixed off-site

It is transported in an agitator truck

The correct quantity of water is introduced to the mix at the batcher and not at the point of discharge

The plant and trucks are certified to meet the requirements of the NRMCA checklist, or equal and approved

20.2 Delivery Ticket

Before discharging the concrete at the point of delivery, the Sub-Contractor shall provide the Inspector with a delivery ticket for each batch of concrete on which is printed, stamped or written the following minimum information:

Name or number of off-site concrete depot

Serial number for ticket

Date

Truck number

Name of supplier
Grade or mix description of concrete
Type of cement
Cement content
Water/cement ratio
Nominal maximum size of aggregate
Source of aggregates
Type or name of admixture, if included
Quantity of concrete in cubic metres

21. Pre-cast Concrete

21.1 General

The requirements of this specification shall be observed for precast concrete, in addition to those indicated on the drawings and the following relating to precast work in particular. However, removal times for formwork may be reduced by agreement between the Precaster and the Contractor.

21.2 Marking

All units shall have marked on a face which will not be exposed in the permanent works the date of manufacture and such distinguishing letters or numbers as are required to identify the work.

21.3 Curing, Maturing and Stacking

The production schedule shall allow for curing pre-cast concrete in accordance with this specification. Slinging, transporting, stacking and installation may take place only when concrete strengths designed for these purposes have been attained.

21.4 Cement/Sand Mortar

Cement/sand mortar for bedding and jointing pre-cast members shall be of equivalent strength, quality and colour to that of the concrete member being bedded or jointed. Cement/sand mortar shall be mixed in small quantities and used immediately. Particular attention shall be paid to compacting the cement/sand mortar to prevent the formation of voids and air pockets.

22. Water Retaining Construction

22.1 General

Water retaining construction shall comply with this specification and BS 8007. As this specification has been particularly designed to produce impermeable concrete, it will meet the requirements of BS 8007 for concrete quality.

22.2 Joints

22.2.1 Joints shall be designed and constructed in accordance with BS 8007. Details and the positioning of these joints, together with the materials to be used, shall be shown on the working drawings.

22.2.2 Where waterbars are called for on the drawings for joints, they shall be fabricated from PVC in accordance with BS 2571. Jointing of waterbars shall be by welding in an approved fashion. The lapping of waterbars at joints and the use of adhesives for jointing purposes will not be permitted unless specifically authorised by the Contractor. Care shall be taken at all times to ensure that waterbars are not perforated or damaged in any way, and concrete shall be carefully placed and compacted to ensure dense impervious concrete.

22.2.3 Particular attention shall be paid to the placing and vibration of the concrete to ensure well compacted concrete around the ribs of the waterbars. At all joints the concrete shall be placed up to the centre line of the waterbar.

22.2.4 All starters to walls of watertight construction shall be cast using hung formwork so that the concrete in the starters may be placed monolithically with the concrete in the slab.

22.3 Testing

22.3.1 In addition to the testing required in section 12.0, particularly absorption tests, further tests to determine the overall water-tightness of the structure and particularly the joints, shall be carried out in accordance with BS 8007.

22.3.2 The structure under test shall be filled with fresh water to the designed level and, after a period to allow for absorption of water, the faces remote from the liquid shall be inspected for leaks over a 7-day period. Any defects shall be made good by an approved method which could involve demolition and rebuilding, or lining of the structure in the case of leaks at the joints, as they are particularly difficult to repair.

23. Quality Control

23.1 Tolerances on Construction

Except where shown on the drawings, or otherwise accepted, the following tolerances after completion of the works represent acceptable limits:

23.1.1 Foundations and Structures

The maximum deviation allowable is:

Plan position:		+ or - 10mm
Elevations below ground:		+ or - 15mm
Elevations above ground:		+ or - 15mm
Plumb alignment for columns and walls:		+ or - 6mm in 3m
		+ or - 12mm in 6m
Straightness of bow (plan) for walls:		+ or - 6mm in 3m
		+ or - 12mm in 12m
Overall dimensions:		+ or - 6mm
Anchor bolts:	Location	+ or - 2mm
	Projection	+ 10mm or - 0mm
	Verticality	+ 1:100 or - 1:100

23.2 Concrete Quality Control

23.2.1 Concrete Quality Control Engineer

The Contractor shall appoint a full-time, qualified, dedicated concrete quality control engineer (CQCE), who shall have no other duties than to ensure that concrete is properly produced, placed, cured and protected. The CQCE shall be at least equivalent to a Member of the Institute of Concrete Technology (MICT) and shall be responsible for the maintenance and submission of all specified records. The CQCE shall not report to his/her own Company's site Construction Management but to his/her own Company's Management and to the Contractor.

23.2.2 Programme

Prior to start of concrete work the CQCE shall prepare for approval a Quality Control Programme for the inspection and testing of concrete and the maintenance of all reports and records, to meet the requirements of this specification and of the Contractor.

23.2.3 CQCE Authority

The CQCE shall be authorised to:

- Postpone concreting operations until outstanding requirements are corrected.
- Reject materials or workmanship that do not conform to this specification.
- Prevent the use of equipment that could cause improper construction relative to this specification.
- Stop any work that is not being done in accordance with this specification.
- Report within 24 hours and provide records to and as required by the Contractor upon discovery of non-compliance.

23.3 Non-compliance

Any concrete that is ultimately deemed by the Contractor not to comply with this specification shall be broken out and replaced.