Right Side Mosul
Low Cost House Unit

Structural Documents

UN HABITAT
FOR A BETTER URBAN FUTURE

16/12/2018

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Structural Documents

CAST-IN-PLACE CONCRETE

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PART 1 – GENERAL

1.1. RELATED DOCUMENTS

A. Section 03100 Concrete Forms and Accessories.

B. Section 03200 Concrete Reinforcement.

1.2. SUMMARY

A. Concrete work shall consist of furnishing all materials and constructing structures of the forms, shapes and dimensions shown on the Drawings or as directed in accordance with the details shown on the Drawings and these Specifications.

B. Cast-in-place concrete shall be ready mixed concrete, batched off the site, generally as defined in ACI 301, ACI 318, ACI 350, BS5328, BS EN 206 and BS 8500 but as amended in these Specifications.

C. Hot weather shall be defined as any combination of high air temperature, low relative humidity and wind velocity tendering to impair the quality of fresh or hardened concrete. The climatic factors affecting concrete in hot weather are high air temperature and reduced relative humidity, the effects of which may be considerably more pronounced with increases in wind velocity. The effects of hot weather on concrete are most critical during periods of rising temperature, falling relative humidity or both.

D. Other References

1. BRE Special Digest 1: Concrete in aggressive ground
2. BRE Digest 54: Damp proofing solid floors
3. BRE Digest 357: Shrinkage of Natural Aggregates in Concrete
4. BRE Digest 330: Alkali Aggregate Reactions in Concrete
5. CIRIA report R91: Early-age thermal crack control in concrete
6. CIRIA report R165: Concrete mixes - planning and design for transporting, concrete placing and finishing
7. Concrete Society Technical Report 30: Alkali Silica Reaction - minimizing the risk of damage to concrete
8. Concrete Society: Spacers for Reinforced Concrete
9. Institution of Civil Engineers: Specification for Piling and Embedded Retaining Walls

10. Institution of Structural Engineers/Concrete Society: Standard Method of Detailing Structural Concrete

1. ACI117R Standard Specification for Tolerances for Concrete Construction and Materials		
2. ACI 201R Guide to Durable Concrete		
3. ACI 211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete		
4. ACI 224R Control of Cracking in Concrete Structures		
5. ACI 301M Specification for Structural Concrete		
6. ACI 302-IR Guide for Concrete Floor and Slab Construction		
7. ACI 304 Guide for Measuring, Mixing, Transporting and Placing Concrete		
8. ACI 305 Hot Weather Concreting		
9. ACI 309 Guide for Consolidation of Concrete		
10 ACI 315 Details and Detailing of Concrete Reinforcement		
11. ACI 318M Building Codes Requirements for Structural Concrete and Commentary		
12. ACI 336 Design and Construction of Drilled Piers		
13. ACI 347 Guide to Formwork for Concrete		
14. ACI 504R Guide to Sealing Joints in Concrete Structures		
15 AASHTO T 277 Rapid determination of chloride permeability of concrete		
16. ASTM A 82 Standard Specification for Steel Wire, Plain, for Concrete Reinforcement		
17. ASTM A 185 Standard Specification for Steel Welded Wire Reinforcement, Plain for Concrete		
18. ASTM A 615M Standard Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement		
19. ASTM C 31M Standard Practice for Making and Curing Concrete Test Specimens in the Field		
20. ASTM C 33 Standard Specification for Concrete Aggregates		
21. ASTM C 39M Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens		
22.	ASTM C 40	Standard Test Method for Organic Impurities in Fine Aggregates for concrete

1.3. REFERENCES

A. Standards

B. Other References

1. BRE Special Digest 1: Concrete in aggressive ground
2. BRE Digest 54: Damp proofing solid floors
3. BRE Digest 357: Shrinkage of Natural Aggregates in Concrete

4. BRE Digest 330: Alkali Aggregate Reactions in Concrete

5. CIRIA report R91: Early-age thermal crack control in concrete

6. CIRIA report R165: Concrete mixes - planning and design for transporting, concrete placing and finishing

7. Concrete Society Technical Report 30: Alkali Silica Reaction - minimizing the risk of damage to concrete

8. Concrete Society: Spacers for Reinforced Concrete

9. Institution of Civil Engineers: Specification for Piling and Embedded Retaining Walls

10. Institution of Structural Engineers/Concrete Society: Standard Method of Detailing Structural Concrete

11. US Army Corps of Engineers CRD-C 39-81: Test Method for the Coefficient of Linear Expansion of Concrete.

12. Concrete Reinforcing Steel Institute (CRSI) – Manual of Standard Practice

C. Where more than one applicable Standard are specified or in case of differences with this Specification, use the most restrictive provisions and recommendation or as directed by the Engineer.

1.4. SUBMITTALS

A. Four weeks prior to starting work on the Contract the Contractor shall submit for approval details of the proposed sources of all materials, together with full documentary evidence that the materials will comply with the specification.

B. Further submissions shall be made for any change of material quality or source and the Engineer's approval obtained before the new materials are used.

C. The Contractor shall engage an approved Specialist Concrete Technologist for the design of concrete mix. Similarly, the Contractor shall engage similar Specialist for the design of concrete mix for controlling temperature for concreting of large volume or sections thicker than 600mm. The Contractor shall submit CV of the specialist with experience in high performance concrete for the Engineer’s approval.

D. Design Mixtures: For each concrete mixture. Submit alternate design mixtures when characteristics of materials, Project conditions, weather, test results, or other circumstances warrant adjustments.

1.5. QUALITY ASSURANCE

A. Constituent materials shall be obtained from suppliers operating quality systems complies with ASTM and with an in-house system approved by the Engineer.

B. Concrete Generally - The Contractor shall be entirely responsible for the control of the quality of concrete manufactured and placed in the Works. Where concrete is required to resist water pressure, the Contractor shall ensure that the concrete remains completely watertight and shall guarantee the water-tightness of all such structures. The Contractor shall, at his own expense, carry out any remedial measures to the satisfaction of the Engineer which may be necessary to make such structures watertight whether leakage is through the concrete or through the joints.

C. Manufacturer Qualifications: A firm experienced in manufacturing ready-mixed concrete products and that complies with ASTM C 94/C 94M requirements for production facilities and equipment.

D. Concrete Testing Service: Engage a qualified independent testing agency to perform material evaluation tests and to design concrete mixtures.

1.6. DELIVERY, STORAGE & HANDLING

A. Cement

1. Bulk cement shall be stored in weatherproof purpose built silos that shall bear a clear indication of the type of cement contained in them. Different types of cement shall not be mixed in the same silo. Cement stored in silos shall be adequately protected against rain, humidity and dew fall.

2. Silo charging and discharging points shall be properly sealed. Silo aeration equipment shall, if necessary, incorporate dehumidifiers. Cement silo charging pipes shall be clearly marked with the cement type. Precautions shall be taken to reduce the effect of solar radiation on the temperature of the silos.

3. The Contractor shall provide sufficient storage capacity to ensure that his anticipated program of work is not interrupted due to lack of cement.

4. The temperature of cement shall not exceed 55° C at the time of incorporation within the mix.

5. Each consignment of cement shall bear manufacturer's name and identification number. Type of cement shall be the same as mentioned in the approved analysis report. Each separate consignment of cement shall be tested by the manufacturer before delivery and certified copies of such tests shall be supplied to the Engineer before any part of the consignment is used in the Works.

6. The Engineer reserves the right to order a re-test of cement at any time. Approval of cement does not relieve the Contractor of the responsibility to produce concrete of the specified strength.

7. Cement shall be delivered in bulk, or with the Engineer's approval, may be supplied

in sealed bags that shall bear the manufacturer's name and the date of manufacture. Each consignment shall be accompanied by a copy of the manufacturer's test certificate and certificate of guarantee.

8. Each consignment of cement shall be identified and used in order of delivery.

9. Any consignment not used within 2 months from the date of manufacture will not be allowed to be used in the Works.

10. Only one brand of cement as approved by the Engineer shall be used throughout the Works unless otherwise authorized by the Engineer in writing.

B. Aggregates

1 Aggregates shall be assembled in such quantities that sufficient material approved by the Engineer is available to complete any continuous pour necessary for any element. The batching plant shall be of adequate size to permit the stockpiling of sufficient, un-segregated materials, having proper and uniform moisture content, to ensure continuous and uniform operation.

2 Aggregates shall enter the mixer in a manner approved by the Engineer and in such a manner to ensure that no matter foreign to the concrete or matter capable of changing the desired proportions is included. In the event two (2) or more sizes or types of coarse or fine aggregates are used on the same project, only one (1) size or type of each aggregate may be used in one continuous concrete pour unless otherwise approved by the Engineer.

3 All aggregates shall be stockpiled before use in order to prevent segregation of material, to ensure uniform moisture content and to provide uniform conditions for proportioning plant control. Variations in moisture content shall be controlled and compensated for by continuous read-out moisture meters in either the aggregate storage bins or the weigh hoppers.

The use of equipment or methods of handling aggregates that result in the degradation and contamination of the aggregates is strictly prohibited. Bulldozers with metal tracks shall not be used on coarse aggregate stockpiles. All equipment used for handling aggregates shall be approved by the Engineer

1.7. CONCRETE TESTING SERVICE

A. The Contractor shall be responsible for all testing. The Contractor shall engage an independent testing agency acceptable to the Engineer to perform material evaluation tests. The testing agency shall be qualified according to ASTM C1077 and ASTM E329 to conduct the specified tests, as documented in accordance to ASTM E548. The Contractor shall also engage a Specialist Concrete Technologist for designing concrete mixes at Contractor’s own cost.

B. The Engineer shall be permitted access to the laboratories to witness any tests and he may request further tests if necessary. Two copies of all test results shall be submitted to the Engineer within 48 hours.

C. the Contractor shall demonstrate to the Engineer's satisfaction that the production of concrete cylinders and the measurement of slump are being carried out only by persons competent in the required techniques.

PART 2 – PRODUCTS

2.1. CONCRETE

2.1.1. General and Strength Class

As regards to material durability and construction requirements, mixing water, admixtures, aggregates and additives, concrete structures shall be in accordance with ACI-318 Code and the specifications hereinafter.

Concrete of classes as indicated on the structural drawings and these specifications shall be used for civil works.

2.1.2. Cover Requirements For Corrosion Protection

For corrosion protection, the concrete cover shall be at least:

30 mm for exposure classification 50 mm for exposure classification B

The above values are valid where standard formwork and compaction are used. Where concrete is cast directly on or against the ground the above covers shall be increased by 20 mm.

2.1.3. Substructure Concrete Protection

1 Slabs on grade: slabs on grade shall be placed on a concrete blinding layer of thickness as indicated on drawings, this blinding layer casted on PVC sheet of 0.5 mm thickness.

2 Substructure: Foundations, tie beams, ground beams, and all substructure elements in contact with soil shall be protected with three coats of waterproofing hot bitumen; the said material should be submitted to the Engineer approval. The substructure elements shall be placed on a concrete blinding layer of thickness indicated on drawings, this blinding layer casted on polyethylene sheet of 0.2 mm thickness.

2.1.4. Restrictions On Chemical Content In Concrete

The maximum acid-soluble chloride-ion content per unit volume of reinforced concrete as placed shall not exceed 0.8 kg/m3.

Chloride salts or chemical admixtures containing chlorides shall not be

added to reinforced concrete.
The sulphate content of concrete as placed, expressed as the percentage by mass of acid-soluble SO3 to cement, shall not be greater than 2%.
Other strongly ionized salts, such as nitrates, shall not be added to concrete unless it can be shown that they do not adversely affect durability.

2.1.5. Fire Resistance

Since the resistance to fire of a reinforced concrete member is affected considerably by the extent of the concrete cover, cover thickness in excess of those specified in clause 2.1.4. above may be required, particularly for slabs, walls and columns.
Reinforced concrete members subject to prolonged high temperatures shall, in addition to their normal reinforcement requirements.
, is fitted with a thin and closely spaced galvanized wire mesh which shall be placed near the surface to prevent spilling.

2.2. CEMENT

A. General Requirements
The cement to be used throughout the Works shall be obtained from manufacturers approved in writing and shall be as described under one of the following:

ASTM C150 type I Ordinary Portland Cement (OPC) shall be used for all concrete structures subject to Exposure Classification A and B as defined in clause 2.1.3. above the Tricalcium Aluminate (C3A) content of the cement shall not be less than 7%.

Sulphate Resisting Portland Cement (SRC): Cement complying with ASTM C150 Type V, but containing not more than 4% by weight of tricalcium aluminates (Ca3Al) shall be used for all below ground structures and where indicated on drawings.

Type I Ordinary Portland Cement with Pozzolanic Additions shall be used for all concrete structures subject to Exposure Classification C. The Tricalcium Aluminate (C3A) content of the cement shall be between 7% and 14%.

The only Pozzolanic materials accepted are silicafumes (i.e. Micro silica, Micropoz, or equivalent. The amount of silicafumes used, either in blended cement or added separately in the mixer, shall conform to the manufacturer’s recommendation but shall not be less than 7.14% by weight (equivalent to one 25 kg bag of Micro silica per 350 kg of cement)

of the total cementitious material in the concrete. Samples of the proposed silica fumes and the manufacturer's product information shall be submitted to the Employer/Engineer for testing and approval. Micro silica is dosed on a dry weight basis as a percentage of the cement content.

- Cement that fails to comply with this Specification in any way shall be removed from the site.

- Methods of test shall be in accordance with the relevant ASTM, Norsk Standard NS 3045 or BS 4550 as applicable.

- **2.3. AGGREGATES**

- A. General Requirements

- 1. Except as may be modified hereunder the aggregate (fine and coarse) for all types of concrete shall comply in all respects with the relevant ASTM, BS 882 "Concrete aggregates from natural sources " and shall also comply with Local Authorities Specification.

- Materials used as aggregates shall be chemically inert, strong, hard, durable, of limited porosity and free from adhering coatings and organic or other impurities that may cause corrosion of the reinforcement or may impair the strength and durability of the concrete.

- Fine aggregate shall be sharp and well graded; dune sand alone shall not be used. The grading, physical properties and deleterious substances of all aggregates shall be continuously monitored and are subject to approval by the Employer/Engineer.

2. The aggregates used in the permanent works shall be naturally occurring crushed materials suitable for high performance concrete obtained only from approved sources. Aggregates subject to high drying shrinkage such as quartz shall not be used. Aggregates shall be clean, hard, and durable and shall not contain iron pyrites, iron oxides, mica, shale, coal or other laminar, soft or porous materials or hollow shells. The Contractor should frequently check and monitor the chloride content of the materials used for making the concrete to ensure that the total quantity of chloride salts incorporated in concrete does not exceed recommended limits.

3. Before any material from a particular source is used, the Contractor shall obtain representative samples of fine and coarse aggregates and carry out the necessary tests and analyses to show that the samples comply with the Specification. During the progress of the Works, the grading and chemical characteristics shall be checked at frequent intervals.

4. The results of these tests shall be submitted to the Engineer and his approval shall be obtained before any of the material is used in the Works. Part of each sample will be required for concrete trial mixes and part shall be retained for comparison with subsequent deliveries.

5. Sampling for testing and analysis shall be carried out, where applicable, in

accordance with the relevant ASTM or BS 812 Part 102.

6. The maximum size of the aggregate shall not be larger than:

a. 20% of the narrowest dimension between sides of the member for which the concrete is to be used.

b. 75% of the maximum clear distance between reinforcing bars or the side form.

The nominal aggregate size specified for the mix

7. Fine Aggregate shall be clean sharp natural and/or crushed sand and shall be within the relevant ASTM or BS882 Table 4 zones C and M only.

8. Beach sand shall not be used in concrete mixes.

9. Coarse aggregate shall be crushed aggregate obtained from a single source quarry with document and approved by the Engineer.
10. Unless otherwise authorized by the Engineer coarse aggregate shall be delivered to the batching plant in separate sizes
according to the maximum specified aggregate size for each grade of concrete.
11. Coarse aggregate shall be prepared as single sized aggregate and blended to produce normal size grading. The combined grading shall be within the appropriate grading limits given in the relevant ASTM or BS882.

12. The Contractor may mechanically wash aggregate to remove salts and other impurities in order to meet the requirement specified.

13. No part of the aggregates shall contain any mineral known to have a potential to cause alkali silica, alkali silicate, alkali carbonate, or any other damaging chemical reaction between alkalis and aggregates. The Contractor shall demonstrate to the Engineer's satisfaction that the cement aggregate combination will be stable and not liable to excessive internal expansion due to alkali-aggregate reaction. The Contractor's proposals for demonstrating this shall be submitted and shall take account of the time necessary for any testing. Under exceptional circumstances, the demonstration may be based on previous long-term experience of the materials. Otherwise, the Contractor shall undertake a program of tests using an independent testing laboratory in accordance with the following requirements:

- Aggregates shall be initially assessed for reactivity in accordance with ASTM C289 and C1260 and if potential reactivity is indicated, then tests in accordance with ASTM C227 and C586 shall be carried out.

14. The Contractor shall carry out routine testing of aggregates for compliance with the Specification during the period in which concrete is being produced for the Permanent Works. The tests set out below shall be performed on aggregates from each separate source.

B. Delivery and Storage of Aggregates

1 Aggregates shall be delivered in clean and suitable vehicles. Different types or sizes of aggregates shall not be delivered in one vehicle.

2 Aggregates shall be stored on a hard, dust-free surface and shielded from dust and the direct rays of the sun. If dust-free environment cannot be achieved re-screening and washing of aggregates shall be carried out prior to their use.

3 Aggregates of each grade and type of material shall be kept separate until batched. Segregation in each stockpile shall be prevented. Stockpiles shall be protected against contamination from soil, evaporate salts, vegetable matter or other deleterious material. The floors of bins shall be 75mm thick mass concrete (or similar and approved) and shall be laid to fall to the outer edge or provide a free draining apron.

2.4. WATER FOR CONCRETE

A. The water used for mixing concrete shall be of potable quality. Generally the water used shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials, and other impurities that may be deleterious to concrete or the reinforcement, all to the satisfaction of the Engineer. It shall be tested in accordance with BS 3148 or ASTM C94.

B. Water used for mixing and curing of concrete shall have a PH value in the basic range of 7 to 9 and the soluble solids shall not exceed the following limits:

1. Total dissolved solids-2000 mg/l
2. Chlorides (NaCl)-250 mg/l
3. Sulphate (SO3)-350 mg/l
4. Alkali Carbonates & Bicarbonates-500 mg/l.

C. The temperature of water for concrete shall not be less than 5° C nor more than 25°C at the time of mixing. Water may be by the gradual addition of chilled water or flaked ice but no ice particles shall be present when the water is added to the mix. The ice to be used shall be the product of water that complies with the above acceptance criteria.

2.5. ADMIXTURES

A. The Contractor shall obtain the Engineer's approval prior to the use of admixtures in each mix. Where required use water-reducing admixture or high-range water-reducing admixture (super plasticizer) in concrete for placement and workability. The suitability of the admixture shall be verified by trial mixes.

B. Admixtures shall be stored to avoid deterioration and segregation.

C. Admixtures shall be used strictly in accordance with the manufacturers instructions unless directed otherwise by the Engineer.

The following chemical admixtures may be used :

-Air entrainment additives. -Water reducing and retarding admixtures. -High range water reducing admixtures (superplasticizers).

-Water reducing admixtures (superplasticizers) shall be used to ensure sufficient workability whilst keeping the water cement ratio to 0.40.

D. Admixtures shall be free of calcium chloride or chloride salt. The supplier shall satisfy the Engineer that any admixture or ingredient used, or their combination, does not detrimentally affect the strength or other properties of the concrete.

E. Both the amount of admixture to be added and the method of use require the approval of the Engineer for whom the following data shall be provided:

The chemical name(s) of the main active ingredient(s) in the admixture;

Whether or not the admixture contains chlorides;

The typical dosage and detrimental effects of under-dosage and over-dosage;
Whether or not the admixture leads to the entrainment of air when used at the manufacturer's recommended dosage;
Long-term and short-term effects of the admixture on concrete, and the effect of different types of cement and aggregate;

Storage life and any special storage requirements;

Safety precautions in handling;
Availability of on-site technical service.

F. Admixtures shall comply with one of the following British Standards: BS 1014, BS 3892 or BS 5075, ASTM or as appropriate.

2.6. REINFORCEMENT BARS

A. RefeG to Section 03200 for Concrete Reinforcement.

2.7. OTHER REQUIREMENTS

A. Four weeks prior to starting Work on the concrete the Contractor shall submit to the Engineer, for approval, details of the proposed sources of all materials he proposes to use for making concrete. No concrete shall be placed in the Permanent Works until the Engineer has approved the materials of which it is composed. Approved materials shall not thereafter be altered or replaced by other materials without the consent of the Engineer.

2.8. Grouting

Grouting materials shall be able to resist the efforts of heating/cooling and wetting/drying. Grouting shall comply with the requirements defined in drawings. Major mechanical equipment and structural steel columns shall be grouted using a pre-packaged cement based non-shrink grouting material. Small or minor mechanical equipment and steel members may be grouted using a sand/cement mix with an expansive additive.

Proposed materials along with their data sheets should be submitted to the Engineer approval.

2.9. Embedded Steel Inserts

Embedded Steel Inserts shall be in accordance with DIN Standard (ST 37) or equivalent and according to the requirements shown on drawings.

All embedded items shall be protected from corrosion or deterioration and to this end shall be effectively coated, covered or otherwise treated to prevent chemical action between the metal and the concrete and electrolytic action between the metal and the reinforcing steel. One primer coat should be applied as protective measure for embedded steel inserts.

PART 3- EXECUTION

3.1. CONCRETE MIX SPECIFICATION

. The Contractor shall provide concrete that is described by the Engineer by reference to a combination of characteristic properties. These shall include the performance requirements described in table 3.

Table 3 Performance requirements for Concrete

Building / Elements	Min CCS (Cylinder Strength) at 28 Days Mpa	Cement Type	Concrete Classification	Min Cement Content (Kg/m³)	Max water cement Ratio	Slump mm	Additives (micro Silica)
Concrete below foundation	8	OPC	C8	150	According to exposure classifications : Refer to Clause 2.1.3 in this Section		–
Plain concrete for filling purpose	12	OPC	C12	250			–
For horizontal elements	25	OPC	C25	400 min.			–
For vertical elements	30	OPC	C30	400 min.			–

B. Concrete Mix Design.

1. Mixes for structural concrete shall be designed by the contractor to meet the specified performance requirements. The contractor shall engage a specialist concrete technologist for the design of mix in order for concrete to achieve all performance requirements.

2. The Contractor is responsible to the Engineer for demonstrating that the proposed mix meets with the performance requirements and is suitable for the intended purpose, including the building control measures.

3. The Contractor shall undertake extensive tests to ascertain strength, creep, and shrinkage characteristics and modulus of elasticity of the proposed mixes at various ages to determine the suitable mix. The contractor shall propose the concrete test programs for the Engineer's approval sufficiently ahead of the time before this information are required at site.

4. Sampling for test purposes shall comply with the relevant ASTM or BS 1881 Part 101 (on site) & Part 125 (in laboratory).

5. If air-entrainment is specified the average air content at the time of placing measured in accordance with either Method A or Method B of BS 1881 Part 106

shall be 5% ±1% or relevant ASTM for concrete containing 20mm maximum size aggregate.

6. Concrete for water-retaining elements shall be watertight and shall comply with the recommendations of ACI 350 and these specifications.

5. Before placing concrete the Contractor shall obtain approval of the mixes proposed for each class of concrete and the average target strengths. The mixes shall be designed to achieve the minimum workability for the Contractor to place and compact the concrete with the equipment proposed for use.

6. The design mean strength shall exceed the minimum CCS or 28 days cylinder strength of concrete specified in the :

performance requirements by a margin of 1.64 times the standard deviation expected from the concreting plant, except that no standard deviation less than 4.0 N/mm^2 shall be used as a basis for designing a mix.

C. Trial Mixes

Preliminary laboratory tests shall be carried out to determine if the mixes satisfy the specification with the approved materials.

Other tests as dictated by concrete performance requirements or directed by the Engineer:

1. If the values obtained do not comply with the Specification or are not to the full satisfaction of the Engineer then the mixes shall be re-designed.

2. At least 35 days before commencement of concreting approved trial mixes shall be prepared under full-scale site conditions and tested in accordance with the relevant standards.

3. Three trial batches of each mix shall be made and from each batch six cylinders shall be made. Three cylinders shall be tested at 7 days and three cylinders at 28 days by a laboratory approved by the Engineer. The results shall be submitted to the Engineer within 24 hours of testing.

4. Further trial mixes shall be made if the range (the maximum minus the minimum of the three cylinder results in any batch) exceeds 10% of the average of that batch, or if the range of the three batch averages exceeds 15% of the overall average of the batches.

5. Actual Characteristic Strength :

- The average 28 day cylinder strength achieved in the trials shall be designated as the Target Mean Strength and from this the Actual Characteristic Strength shall be calculated for each mix.

- The Actual Characteristic Strength equals the Target Mean Strength minus a margin of 1.64 times the standard deviation, except that the margin shall not be less than 4MPa.

- In no case shall the Actual Characteristic Strength be less than the

minimum CCS specified in the performance requirements.

- The Actual Characteristic Strength so determined shall be used throughout the duration of the project as the primary indicator of control of mix proportions and water/cement ratio.

6. The Engineer will review the Contractor's trial-mixes and all test results. The Engineer will then determine which of the trial mixes shall be used. If none of the trial mixes for a class of concrete meets the Specifications, the Engineer will direct the Contractor to prepare additional trial-mixes. No class of concrete shall be prepared or placed until its job-mix proportions have been approved by the Engineer.

7. The approval of the job-mix proportions by the Engineer in establishing those proportions, in no way relieves the Contractor of the responsibility of producing concrete which meets the requirements of these Specifications.

8. The Engineer may also require practical tests to be made on the site by filling trial moulds incorporating the reinforcing details to confirm the suitability of the mix for the Works. In these tests, the type of plant used for mixing, the method of placing and compaction used and the type of formwork intended for use in the Works shall be used

9. All costs connected with the preparations of trial-mixes and the design of the job-mixes shall be borne by the Contractor

10. When the mix has been approved, no variations shall be made in the proportions, the source of the cement and aggregates, or in the type, size and grading zone of the latter without the consent of the Engineer who prior to giving such consent may require further tests to be made.

11. The heat of hydration test sample shall comprise a 1m x 1m x 1m test cube, insulated with polystyrene. Temperature measurements shall be carried out in accordance with the specification clauses for controlling heat and shall determine the peak temperature generated within the test sample.

D. Tolerances in Proportioning the Materials

1. Cement and aggregates shall be measured to the tolerances stated in mixing concrete below.

2. The mixing water shall be measured by weight or by volume. In either case the measurement shall be accurate to within one (1) percent throughout the range of use.

3. Admixtures shall be dispensed by a system approved by the admixture supplier and the Engineer and shall be capable of dispensing the admixture to an accuracy of 1% by weight or by volume

3.2. MIXING CONCRETE

A. Cast-in-place concrete shall be ready mixed concrete, batched off the site, generally as defined in ASTM, BS 5328, BS EN 206 and BS 8500 but as amended in these Specifications.

B. The weighing and water-dispensing mechanisms shall be maintained in good order. Their accuracy shall be maintained within the tolerances described in ASTM or BS 1305 and checked against accurate weights and volumes when required by the Engineer.

C. The mass of cement and of aggregate indicated by the mechanism employed shall be within a tolerance of 2% of the respective mass per batch agreed by the Engineer. The mass of the fine and coarse aggregates shall be adjusted to allow for the free water contained in them. The water to be added to the mix shall be reduced by the quantity of free water contained in the fine and coarse aggregates, which shall be determined by the Contractor by a method approved by the Engineer immediately before mixing begins and further as the Engineer requires.

D. Unless otherwise agreed by the Engineer, concrete shall be mixed in a batch type mixer manufactured in accordance with ASTM or BS 1305. The mixing blades of pan mixers shall be maintained within the tolerances specified by the manufacturer of the mixer and the blades shall be replaced when it is no longer possible to maintain the tolerance by adjustment. The period of mixing, judged from the time that all the ingredients including water are in the mixing drum shall be as ordered by the Engineer's representative and shall be in accordance with the mixer manufacturer's recommendations.

E. Mixers that have been out of use for more than 30 minutes shall be thoroughly cleaned before any fresh concrete is mixed

F. The method of discharge from the mixer shall be such as to cause no segregation whether partial or otherwise of the concrete materials.

G. The Contractor shall ensure that the constituent materials of the concrete are sufficiently cool to prevent the concrete from stiffening in the interval between its discharge from the mixer and compaction in its final position. Precautions shall include the shading of aggregate stockpiles and the use of chilled water.

H. The Concrete shall be carried in purpose-made agitators, operating continuously, or truck mixers. The concrete shall be compacted and in its final position within 1 hour of the introduction of cement to the aggregates, unless a longer time is agreed by the Engineer. The time of such introduction shall be recorded on the delivery note together with the weight of the constituents of each mix.

I. Concrete shall only be mixed at a depot approved by the Engineer.

J. Unless specially authorized by the Engineer, the concrete shall be mixed and the Water added to the mixer at the depot. No additional water shall be added at any stage from batching to placing. When the Engineer is asked to authorize dry batching, he will require to be satisfied that appropriate steps will be taken to ensure the quality, consistency and strength of the concrete as placed and that the water will be added to the dry ingredients under properly controlled conditions.

K. Truck mixer units and their mixing and discharge performance shall be to the satisfaction of the Engineer. Mixing shall continue for the number and rate of

revolutions recommended in the manufacturer's instructions, in the absence of which mixing shall continue for not less than 100 revolutions at a rate of not less than 7 revolutions per minute.

L. Pumping concrete through delivery pipes may be permitted but only with the prior approval of the Engineer.

M. Re-mixing of concrete that has commenced to set shall not be allowed and in no case shall such concrete be used in the Works.

3.3. PREPARATION AND PERMISSION TO CONCRETE

A. Prior to the commencement of concrete works, the Contractor shall provide the Engineer with fully detailed proposals of the method of placing, compacting, finishing and curing the concrete. The method statements, which shall be subject to the approval of the Engineer, shall cover all principle types of concrete elements, e.g. foundations, walls, columns, beams, slabs etc.

B. Before placing concrete, verify that installation of formwork, reinforcement, and embedded items is complete and that required inspections have been performed

C. As a minimum requirement, preparations for concreting shall follow the guidelines given in ACI 305R-91 Section 4.

D. The concrete-mixing plant, mixers, pipelines, pumps chutes and transport equipment shall be shaded and/or painted white. Pump lines and other surfaces shall be kept cool by insulating them or by covering them with hessian kept damp by spraying with water.

E. Surfaces on which concrete is to be placed shall be moist but free of standing water at the time of concreting. This shall be achieved by spraying the forms and reinforcement prior to placing concrete. Shading shall be provided to prevent solar heat gain of forms and reinforcement.

F. When daytime temperature and drying conditions are critical the concreting shall be scheduled to begin during the late afternoon to prevent the occurrence of severe thermal effects. Consideration should also be given to night time concreting

G. The Contractor shall give the Engineer at least 24 hours written notice before concreting to allow time for final inspection and approval.

3.4. TRANSPORT AND PLACING

A. The method of transport and placing concrete shall be to the approval of the Engineer. Concrete shall be so transported and placed that contamination, segregation or loss of the constituent materials does not occur.

B. All formwork and reinforcement shall be clean and free from standing water

immediately before placing concrete.

C. Prior to placing any concrete on natural surfaces a blinding layer of concrete shall be laid to a minimum of 100 mm thickness whether indicated on drawings or not. This blinding shall be suitably cured prior to subsequent concrete placement. The blinding shall be clean and free from any dust or impurities prior to subsequent concrete placement.

D. No concrete shall be placed in a foundation until the extent of excavation and the character of bearing material have been approved and no concrete shall be placed in any structure until the placement of reinforcing steel and the adequacy of the forms and false work have been approved.

E. Concrete shall not be placed in any part of the Works until the Engineer's approval has been given. If concrete has not started within 24 hours of such approval being given, approval shall again be requested. Concreting shall then proceed continuously over the area between construction joints. Fresh concrete shall not be placed against in-situ concrete that has been in position for more than 30 minutes unless a construction joint is formed in accordance with the Specification. When the concrete has been in place for 4 hours, or less as directed by the Engineer, further concrete shall not be placed against it for at least a further 20 hours.

F. Concreting in Hot Weather

1. Hot weather is defined as any combination of the following conditions that tend to impair the quality of the freshly mixed or hardened concrete:

    a. High ambient temperature.

    b. High concrete temperature.

    c. Low relative humidity.

    d. Wind velocity.

    e. Solar radiation.

2. When the rate of evaporation of surface moisture from concrete is expected to approach 1 kg/m²/hr (using Fig. 2.1.5 in ACI 305R91) or when the shade air temperature is 35^{0} C and rising, precautions shall be taken, to comply with ACI 305, including the following:

    - Dampening the forms.

    - Reducing the concrete temperature to the lowest practical level by procedures such as:

        1) Shading the aggregate.

2) Cooling the mixing water before use.

3) Screening the mixing plant and transporting vehicles from wind, rain and sun.

a. Erecting wind breaks and sunshades at the concrete placing location.

b. Reducing the time between the placing of the concrete and the start of curing to the minimum possible.

c. Minimizing evaporation (particularly during the first few hours subsequent to placing the concrete) by suitable means such as applying moisture by fog spraying.

1 All precautions to be taken shall be subject to the Engineer's approval and the Contractor shall demonstrate that all approved precautions are available for use prior to the Engineer granting approval to any concreting operations.

2 In the event that conditions become such that these requirements cannot be met, concreting shall be suspended immediately and not resumed until the requirements can be met again. Under such circumstances, additional precautions shall be taken to avoid the hot weather concreting conditions being exceeded on future pours.

G. Control of Temperature

1 The temperature of the concrete when placed shall not exceed 30° C, except for large volume it shall not exceed 25°C, nor shall concrete be mixed or placed when the shade air temperature is 40° C or above, or is expected to reach such a level during concreting and 3 hours after placing, without special permission from the Engineer.

2 For all concrete sections the Contractor shall take precautions to limit the effects of heat of hydration.

3 The Contractor shall determine the expected heat of hydration for the concrete batch by testing a 1mx1mx1m insulated concrete cubes, in accordance with the specification clauses for the trial mix.

4 For concrete section exceeding 600mm the Contractor shall propose and adopt special precautions, to be approved by the Engineer, to avoid thermal cracking due to external and core temperature differentials. Any cracks shall be rectified by grouting using low viscosity epoxy resin at the Contractor's expense to the Engineer's approval.

5 For concrete sections equal or greater than 1400 mm thick, the Contractor shall submit to the Engineer for approval detailed proposals of the measures to be taken. These measures shall include: control of concrete mix constituents; curing water; formwork type; surface insulation; and, cooling by embedded pipes. All submissions shall be based on measured values of heat of hydration generated by the proposed mix to meet the criteria set out below:

- Maximum temperature difference between the core and the surface of any pour. Design target 15°C. Field maximum 20° C.
- Maximum temperature difference between a new pour and a previous

pour. Design target 12°C. Field maximum 15°C.

- Absolute maximum temperature anywhere in a pour. Design target 60°C. Field maximum 70°C.

- The Contractor shall install instrumentation in the Works to verify compliance with the above criteria. Temperature measurements shall be made by means of thermocouples positioned in a line perpendicular to the concrete faces. The thermocouples shall be fixed: at the concrete faces; at the centre of the section; and, at equal intervals of approximately 300mm.

- Temperatures shall be measured and logged continuously from the start of the pour until instructed to stop by the Engineer.

- The Contractor shall submit to the Engineer for approval details of the proposed methods and equipment for the measuring and logging of temperatures. An automatic data logger or other suitable device shall log data. The equipment shall be capable of reading all thermocouples in less than one minute.

- If temperature measurements exceed any of the criteria above then action shall be taken on defective concrete in accordance with the specifications or as directed by the Engineer.

- **H. Cold weather requirements**:

a. Adequate equipment shall be provided for heating concrete materials and protecting concrete during freezing or near-freezing weather.
b. All concrete materials and all reinforcement, forms, fillers, and ground with which concrete is to come in contact shall be free from frost.
c. Frozen materials or materials containing ice shall not be used.
d. Concrete shall be compacted in its final position within 30 minutes of discharge from the mixer unless carried in purpose made agitators operating continuously, when the time shall be within 1 hour of the introduction of cement to the mix and within 30 minutes of discharge from the agitator.
e. Precautions shall be taken to ensure that the loss of slump due to temperature rise during transport, pumping and placing does not exceed 25mm.
f. Except where otherwise agreed by the Engineer, concrete shall be deposited in horizontal layers to a compacted depth not exceeding 400mm where internal vibrators are used or 300mm in all other cases.
g. Unless otherwise agreed by the Engineer, concrete shall not be dropped into place from a height exceeding 2m. When trunking or chutes are used they shall be kept clean and used in such a way as to avoid segregation. Where steep slopes are required for placing concrete with chutes, the chutes shall be equipped with baffle boards or be in short lengths that reverse the direction of the movement. Chutes and the use of chutes must be approved by the Engineer. All chutes shall be kept clean and free from coating of

hardened concrete by thoroughly flushing with water after each run. The water used for flushing shall be discharged clear of the concrete already in place.

h. Concrete shall not be pumped through aluminum alloy conduits.

i. No concrete shall be placed in flowing water. Underwater concrete shall be placed in position by tremie or by pipeline from the mixer.

j. Full details of the method proposed shall be submitted in advance to the Engineer and his approval obtained before placing begins. Where the concrete is placed by the tremie, its size and method of operation shall be in accordance with ACI 336 or BS 8004. During and after concreting under water, pumping or dewatering operations in the immediate vicinity shall be suspended until the Engineer permits them to be continued.

k. Approved measures shall be taken to avoid premature stiffening of concrete placed in contact with hot, dry surfaces. Surfaces including reinforcement against which concrete is to be placed shall be shielded against the direct rays of the sun and shall be sprayed with water to prevent excessive absorption by the surfaces of water from the fresh concrete.

l. A complete record shall be kept of the date, time, temperature and conditions of placing, the concrete in each portion of the work and shall be available for inspection by the Engineer at any time.

m. No concrete shall be mixed or placed when the light is insufficient, unless an adequate and approved artificial lighting system is operated and such night work is approved by the Engineer.

3.5. EXTENT OF POURS

A. The Contractor shall consider maximizing the size of pours and minimizing the number of construction joints. In this regard the Contractor shall submit proposal, calculations, provide critical reinforcement ratio for crack control, for Engineer's approval, justifying such proposal. The Contractor is deemed to have allowed for this in his tender.

B. The sequence of pours shall be arranged to minimize thermal and shrinkage strains. In determining suitable construction joint locations and reinforcement ratio to suit construction method/sequence, the Contractor shall seek Engineers approval well in advance for the limit of individual pours and the height of lifts.

3.6. COMPACTION OF CONCRETE

A. All concrete shall be compacted to produce a dense homogeneous mass.

Unless otherwise agreed by the Engineer, it shall be compacted with the assistance of vibrators. Sufficient vibrators in serviceable condition shall be on site so that spare equipment is available in the event of breakdown. A 50mm diameter internal vibrator shall be deemed capable of compacting 20 m^3/hr. Internal vibrators shall be capable of producing not less than 10,000 cycles per minute.

B. Vibration shall not be applied by way of the reinforcement. Where immersion vibrators are used, contact with reinforcement and all inserts shall be avoided.

C. Vibrators shall be so manipulated as to work the concrete thoroughly around the reinforcement and embedded fixtures and into corners and angles of the forms. Vibrators shall not be used as a means to cause concrete to flow to its position in lieu of placing. The vibration at any point shall be of sufficient duration to accomplish compaction. After initial set of the concrete, the forms shall not be jarred and no strain shall be placed on the ends of projecting reinforcement.

3.7. CURING OF CONCRETE

A. Immediately after compaction and for 14 days thereafter, concrete shall be protected from the harmful effects of weather, including rain and rapid temperature changes, and from drying out. The methods of protection shall be subject to the Engineer’s approval. The Engineer's approval will be conditional upon the proposed curing method proving to be satisfactory on site.

B. The method of curing used shall minimize the loss of moisture from the concrete. On concrete surfaces that are to be waterproofed or coated, curing membranes shall not be used unless agreed by the Engineer. Details of all curing methods to be used shall be subject to the approval of the Engineer.

C. Concrete surfaces shall be kept damp using soaked hessian sheeting. Polythene sheet covering shall be used where directed by the Engineer to minimize evaporation. The hessian sheeting shall be maintained continuously damp for a minimum period of 14 days after casting, using water of the same quality as that allowed in mixing the concrete. Water used for curing purposes shall be within 5^0C of the placed concrete temperature.

D. Subject to the approval of the Engineer, curing with an approved proprietary product may be used as an alternative to curing with water except that the curing product shall not be applied to surfaces of concrete from which the shuttering has been struck, until the concrete has been inspected and approved by the Engineer's representative.

E. The concrete curing compound shall be of an approved type, which shall be readily distinguishable upon the concrete surface for at least four hours after application. The curing compound shall be compatible with subsequent surface finishes. The color, if any, shall become inconspicuous within seven days after application.

F. Provide curing and sealing compound to exposed interior slabs and to exterior slabs, walls, and curbs as follows:

1 Apply specified curing and sealing compound to concrete slabs as soon as final finishing operations are complete (within 2 hours and after surface water sheen has disappeared). Apply uniformly in continuous operation by power spray or roller in accordance with manufacturer's directions. Recoat areas subjected to heavy rainfall within 3 hours after initial application. Maintain continuity of coating and repair damage during curing period.

2 Use membrane-curing compounds that will not affect bonding of the concrete surfaces to be covered with finish materials applied directly to concrete.

3 The efficiency index E of the curing compound shall be at least 90% as calculated by:

W-W1 E = ----------(100%)

W W = average percentage loss of moisture by control specimens.

W1= average percentage loss of moisture by test

G. Curing Formed Surfaces: Cure formed concrete surfaces, including underside of beams, supported slabs, and other similar surfaces, by moist curing with forms in place for full curing period or until forms are removed. If forms are removed, continue curing by methods specified above, as applicable.

H. Curing Unformed Surfaces: Cure unformed surfaces, such as slabs, floor topping, and other flat surfaces, by application of appropriate curing method.

Within ten minutes of placing and compaction, the un-formed surfaces of the concrete shall be completely covered with reflective polythene sheeting with substantial

1 close fitting taped laps. The polythene sheeting may be raised a short distance above the concrete so that it does not mark the surface. At the edges of the pour, the polythene shall drape over the forms and it shall be securely fixed to prevent billowing due to the wind.

2 Within three hours of placing and compaction the polythene shall be quickly removed and replaced with wet hessian laid onto the concrete surface. The polythene shall then be replaced and secured as above.

I. Final cure concrete surfaces to receive liquid floor hardener or finish flooring by use of moisture retaining cover, unless otherwise directed.

3.8. EARLY LOADING

A. During the first 28 days after compaction, the concrete shall at no time be subject to loading, including its own weight, which will induce a compressive stress in it exceeding 0.25 of its compressive strength at the time of loading or of the specified 28 day strength whichever is lower. The strength of the concrete and the stresses produced by the loads shall be subject to the agreement of the Engineer.

B. No load shall be placed until the Engineer so permits, but in no case shall any

load of any kind be placed until the curing has been completed. The Contractor shall not place any temporary loads or open any section of the Works to traffic or construction equipment until permitted by the Engineer.

C. In addition to the above, the Contractor is responsible for conforming to the performance requirements for concrete in general and for the creep requirements in particular.

3.9. FIELD QUALITY CONTROL

A. Testing and Inspecting: Engage a qualified testing and inspecting agency to perform tests and inspections and to submit reports.

B. Inspections:

1 Steel reinforcement placement.

2 Waterstop placement.

3 Verification of use of required design mixture.

4 Concrete placement, including conveying and depositing.

5 Curing procedures and maintenance of curing temperature.

6 Verification of concrete strength before removal of shores and forms from beams and slabs.

C. Transporting and Curing of Samples

1 Samples shall be taken on site at the point of delivery. Test cubes shall be made, cured, stored, transported and tested to ASTM or BS 1881 Parts 108, 111 and 116.

2 The Contractor shall establish a site curing facility. Test cubes shall not to be remolded at periods of less than 24 hours and shall not transported before 48 hours have elapsed.

D. Sampling Cylinder

1 A sample of concrete shall be taken at random on eight separate occasions during the first five days of using a mix, at least one sample being taken each day.

2 Thereafter one sample shall be taken at random for each class of concrete in accordance with Table 4 of the Specification. At least one sample shall be taken from each individual structural unit, or part of a unit, when the latter is the product of a single pour.

3 From each sample, three cylinders shall be made for testing at 28 days and three for testing at 7 days for control purposes.

4 The frequency of sampling may be required to be varied if directed by the Engineer.

5 The procedures shall be repeated when materials or design mixes are changed.

E. Test Requirements for Concrete

1. Samples shall be taken and 6 (six) cylinders made for strength testing for each

Type of Structure Critical elements		Elements within Project Walls, Columns, piles	Sampling To Represent a Volume of Concrete (m_3) Cylinder Strength Tests Durability Tests 10 50	
Normal structural elements		Generally	50	250

Class of concrete and for each particular application at a frequency.

1 Water: One 5 liter sample shall be obtained prior to use from each source for quality testing in accordance with Clause 2.4. of the Specification.

2 Samples of concrete, cement and water shall be taken and tested as described in the above Clause at least once a week during concreting operations. Concrete slump and concrete bleeding tests shall be conducted for each load or as directed by the Engineer.

F. Cylinder Strength Results

1. The results will be acceptable only if both of the conditions below are met:

-The average strength determined at the age of 28 days from any sample of four consecutive strength test results exceeds the Actual Characteristic Strength by 3N/mm^2 .

- No individual result of the sample is less than the Actual Characteristic Strength minus 3N/mm^2 or as specified in the relevant ASTM or BS 5328 Part 4, whichever critical.

2. If the above criteria are not satisfied, the unit represented by the sample is questionable and any or all of the following actions may be instructed by the Engineer at the Contractor's expense:

a. Changing the mix.

b. Improving quality control.

c. Cutting and testing cores from placed concrete.

d. Non-destructive testing of placed concrete.

e. Cutting-out and replacing defective concrete.

3. If any individual 28 day cylinder strength from a sample in less than the Target Mean Strength achieved in the trial mixes by more than 6.5N/mm^2 then any or all of the actions listed above may be instructed by the Engineer at the Contractor's expense.

4. In the event cutting and testing of cores are required, the Contractor shall cut cores from approved locations, and test them to ASTM or BS1881 as modified by BS 6089. The core tests shall be deemed to have failed if the in-situ strength is found to be less than 85% of the specified cylinder strength. In such event, the Engineer may instruct removal of the concrete represented by the core or instruct further tests.
5. Test results shall be reported in to the Engineer, within 24 hours after tests. Reports of compressive strength tests shall contain the project identification name and number, date of concrete placement, name of concrete testing service, concrete type and class, location of concrete batch in structure, design compressive strength at 28 days, concrete mix proportions and materials, compressive breaking strength, and type of break for both 7-day tests, 14 day test and 28-day tests.
6. A statistical record of the results of the cylinder tests shall be maintained by the Contractor for each mix design. This shall include calculation of the standard deviation and mean strength for the mix and plots of cylinder test results against time. Up to date results and graphs shall be forwarded to the Engineer on a weekly basis.

G. Flexural Tensile Strength Tests
1 Samples shall be taken and two beams cast to determine the tensile strength of the concrete at 7 days and 28 days, as specified in the relevant ASTM or BS 1881 Part 118.

2 The samples shall be taken in accordance with the minimum test requirements for concrete in the Specification and shall coincide with samples taken for test cubes.

H. Other Tests

1. The Contractor shall submit to the Engineer for approval his proposed methods recommended by his specialist Concrete Technologist, for complying with the creep strain performance requirements of the Specification. These shall include:

Tests to establish the strength of the concrete and the static modulus of elasticity of the concrete to the relevant ASTM or BS 1881: Part 121 at least 7 days, 28 days and 3 months.

Sufficient tests shall be undertaken to allow an accurate assessment of the creep strain also at various ages to be made prior to, and during, the concreting operations. These tests shall only cease when directed by the Engineer.

2. When instructed by the Engineer concrete shall be tested for drying shrinkage and wetting expansion, for which 75x75mm prisms shall be prepared and tested in accordance with the

relevant ASTM or BS 812 Part 120. The maximum acceptable limits shall be:
a. Drying Shrinkage: 0.04%

b. Wetting Expansion: 0.03%

1 Cylinders may be required and trials carried out to determine stripping times for formwork, the duration of curing and to check testing and sampling errors.

2 The air content of air-entrained concrete shall be determined in accordance with ASTM C231 for each batch produced until consistency has been achieved, when one in five batches may be tested. The maximum value shall not exceed 2%.

3 Compaction factor, slump, Vebe or other workability tests shall be carried out as required during concreting of permanent Works to control workability at the batching plant and at the site of the pour. For each sample the temperature of the concrete shall be measured and recorded with the time the test was performed. The degree of workability shall be as for the trial mixes; permitted tolerances shall be in accordance with the relevant ASTM or BS 5328.

3.10 DEFECTIVE WORK

A. The action to be taken in the event of non-compliance of test results with the Specification, including cylinder strength results, shall be determined by the Engineer and may range from qualified acceptance to rejection and removal of all or part of the affected works as described in Field Quality Control Cylinder Strength Results.

B. The Contractor shall provide at his own expense all records, samples, including core samples, tests and their results as may be required by the Engineer, whether the concrete be finally accepted or not.

C. Where Work exhibits any one or more of the following deficiencies, or where Work otherwise fails to conform to the requirements of the Contract Documents and to the requirements of the Building Code, for any reason or combination of reasons, such Work shall be considered deficient and not in conformance with the requirements of the Contract:

1 Low specimen strength at 28 days, as defined by this Specification.

2 Excessive or deficient cement content.

3 Excessive or deficient air content.

4 Slump not in accord with this Specification.

5 Unauthorized addition of water.

6 Spalling, honeycombing or the like.

7 Unauthorized cutting, construction joints, cold joints and so forth.

8 Workmanship not in accord with the Drawings, with this Specification, with accepted samples, or with referenced codes or standards.

9 Incorrect forming, cracking, surface defects, or improper consolidation.

10 Exceedance of tolerances.

11 Evidence of improper curing and the like.

D. Where the Engineer finds any of the above deficiencies or other Work not in accord with the Drawings or with this Specification, the Engineer may order that the affected Work be replaced or repaired at Contractor's expense. All such remedial Works shall be executed within 7 days of removal of the formwork to the Engineer's approval.

E. The cost of all other activities and procedures associated with defective Work shall be paid by Contractor.

F. The fact that the Contractor has used materials etc. to the approval of Engineer, shall in no way relieve of his responsibility of producing a concrete of the required characteristic strengths workability, shrinkage characteristic etc. for the purpose to which it is placed.

3.11 REINFORCEMENT

A. Bar Schedules and Shop Drawings

1 The Contractor shall submit plans depicting location/detail of all proposed construction joints and sequence of construction to suit his concreting program prior to construction of any level, for the Engineer's approval.

2 The Contractor shall prepare and submit full shop drawings, for the Engineer's approval of all the concrete work to a level of detail to enable the co-ordination and full incorporation of all architectural and building services items, and to enable the bending of reinforcement to be carried out. The Contractor is responsible for the co-ordination of the structure, architecture and services. No hacking shall be permitted.

3 Submit coordination drawings for approval prior to fabrication and fixing of any reinforcement for the structure based on the relevant Drawings. Submit floor layout plans with sections showing all structural members with sizes and incorporating structural and finished levels, including all openings, voids required for architectural or M&E services.

4 The Contractor shall schedule the reinforcement in accordance with ACI 315, ACI 318 and CRSI and the information on the Drawings, this Specification and subsequent instructions.

5 The Contractor shall include for all necessary chairs and spacers, and his price and rates for steel thus shown shall include for these.

6The Contractor shall prepare reinforcement detail shop drawings and other relevant shop drawings on electronic/soft copy to the following scales:

a. Walls and slabs 1:50

b. Beams and column elevations 1:20

c. Beam and column sections 1:20 or 1:10

7. Reinforcement details shop drawings shall be in accordance with ACI 315 or the Standard Method of Detailing Structural Concrete published by the Institution of Structural Engineers/Concrete Society.

8. Sketches will not be acceptable.

9. These drawings shall show all openings for services, up stands or plinths for equipment and cast-in items.

10. Bending schedules and reinforcement detail drawings shall be submitted for the Engineer's approval. Four weeks shall be allowed for the Engineer's consideration of this initial submission.

11. The Contractor shall correct these schedules incorporating the Engineer's comments and resubmit as reasonably required to ensure a high standard of work. He shall program his work and submit schedules for approval allowing time for such verification, rectification and resubmission as necessary. Such approval shall not relieve the Contractor of his responsibility for the accuracy of such schedules.

12. No concreting shall be allowed to proceed until such a time that the drawings and bending schedules for that particular section of works are approved. Any delay incurred in obtaining approval shall be the Contractor's responsibility.

B. Bar Cutting and Bending

1 Reinforcement shall be cut and bent in accordance with ACI 318, CRSI or BS 8666. Cutting or bending by the application of heat is not permitted. Welding of reinforcement will not be allowed. The Contractor shall submit full technical details of his proposed procedures prior to seeking approval.

2 Hot rolled high yield bars shall not be straightened or bent again, having once been bent. If the Engineer gives approval to bend mild steel reinforcement projecting from the concrete, the internal radius of bend shall not be less than four times the nominal size of the bar.

C. Placing and Fixing Reinforcement

1 Clean reinforcement of loose rust and mill scale, earth, ice, and other materials that reduce or destroy bond with concrete.

2 Accurately position, support, and secure reinforcement against displacement. Locate and support reinforcing by metal chairs, runners, bolsters, spacers, and hangers, as approved by Engineer.

3 Place reinforcement to obtain at least minimum coverage for concrete protection. Arrange, space, and securely tie bars and bar supports to hold reinforcement in position during concrete placement operations. Set wire ties so ends are directed into concrete, not toward exposed concrete surfaces.

4 Reinforcement shall be placed and maintained in the position shown in the Contract Drawings. Unless otherwise permitted by the Engineer, all bar intersections

shall be tied together using 1.2mm diameter steel wire and the ends of the tying wire shall be turned into the main body of the concrete.

5 Spacer blocks or other supports approved by the Engineer shall be provided and used to retain the reinforcement at proper distances from the forms. Supports under horizontal bars at the bottom of base slabs shall be spaced at not more than eighty

(80) diameters of the bar. All reinforcement shall be so rigidly supported and fastened that displacement will not occur during construction. Reinforcing steel shall be inspected in place and must be approved by the Engineer before any concrete is deposited.

1 No splices shall be made in the reinforcement except where described in the Contract Drawings or where approved by the Engineer.

2 Reinforcement temporarily left projecting from the concrete at construction or other joints shall not be bent out of position during the periods in which concreting is suspended, except with the approval of the Engineer.

3 Install welded wire fabric in as long lengths as practicable. Lap adjoining pieces at least two full mesh and lace splices with wire. Offset laps of adjoining widths to prevent continuous laps in either direction.

4 Welding of Reinforcing bars is not permitted.

5 Specification for Mechanical Coupler Joints

a. Tensile Failure

1) Actual performance of coupler joint must be at least equivalent to the characteristic strength of the parent bar i.e. tensile failure must occur in the bar clear from the joint.

2) Elongation after failure must be equivalent to the parent bar.

b. Thread Profile

c. Permanent Elongation

d. Coupler Traceability

1) No reduction of the nominal cross section area of the parent bar after threading is permitted.

1) After loading to 0.6 x Fy it cannot exceed 0.1mm.

1) Coupler must be marked to allow full traceability of material and manufacturing process.

e. Site Installation

1) A coupler system based on a parallel metric thread is preferred to ease installation on site, thus avoiding the use of special torque equipment.

2) Mechanical splices are to be so arranged that no more than 50% of bars are spliced at anyone point.

3) The position of splices shall be shown on the drawings. The splices shall be staggered so that not more than half the bars are coupled at any location and the distance between staggered splices shall be not less than 30 times the diameter of the bar.

f. Specification

1) Only a system complying with the above and meeting all the relevant standards is to be used.

g. A sample of each type of mechanical coupler shall be submitted to the Engineer for testing and approval prior to the use of any coupler in the Works. Coupler shall be tested at the Contractor's expense for tensile strength for each coupler diameter. Frequencies shall be at least three (3) tests per size per delivery.

h. Mechanical couplers shall be used for all bars equal or bigger than 32mm diameter.

Technical Conditions

EXCAVATION

PART 1 – GENERAL

1.1. RELATED DOCUMENTS:
1.2. SCOPE
1.3. DEFINITIONS
1.4. REGULATORY REQUIREMENTS
1.5. DELIVERY AND STORAGE
1.6. SITE CONDITIONS

PART 2 – PRODUCTS

2.1. MATERIALS

PART 3 – EXECUTION

3.1. PROTECTION
3.2. SURFACE PREPARATION
3.3. EXCAVATION
3.4. FILLING AND BACKFILLING
3.5. FINISH OPERATIONS
3.6. ON SITE GROUND CONDITION

PART 1 – GENERAL

1.1. RELATED DOCUMENTS:

A. Section 03300: Cast-In-Place Concrete

1.2. SCOPE

A. The Contractor shall be solely responsible for the protection, installation of any temporary retention system, installation of instruments and monitoring as necessary, completion of excavation to the final formation level, application of lean concrete and shall comply with other requirements indicated on the drawings.

B. The temporary retention system, if necessary, shall be designed by the Contractor and shall be solely responsible for the same. The retention system should be relatively independent to the permanent structure.

C. Any approval from the Engineer of submittals, materials and workmanship etc. shall not relieve the Contractor of his sole responsibility and obligations to comply with all requirements under the Contract.

1.3. DEFINITIONS

A. Backfill: A specified material used in refilling a cut, trench, or other excavation, placed at a specified degree of compaction.

B. Cohesive Materials: Cohesive materials include materials classified by ASTM D2487 as GC, SC, ML, CL, MH, and CH. Materials classified as GM and SM will be identified as cohesive only when the fines have a plasticity index greater than zero.

C. Cohesion less Materials: Cohesion less material includes materials classified by ASTM D2487 as GW, GP, SW, and SP. Materials classified as GM and SM will be identified as Cohesion less only when the fines have a plasticity index of zero.

D. Compaction: The process of mechanically stabilizing a material by increasing its density at a controlled moisture condition. "Degree of Compaction" is expressed as a percentage of the maximum density obtained by the test procedure described in Test 12 of BS 1377 for general soil types.

E. Embankment: A "fill" having a top that is higher than adjoining ground.

F. Excavation: The removal of soil, rock, or hard material to obtain a specified depth or elevation.

G. Fill: Specified material placed at a specified degree of compaction to obtain an indicated grade or elevation.

H. In-Situ Soil: Existing in place soil.

J. Lift: A layer (or course) of soil placed on top of a previously prepared or placed soil.

K. Rock: Solid, homogeneous, interlocking crystalline material with firmly cemented, laminated, or foliated masses or conglomerate deposits, neither of which can be removed without systematic drilling and blasting, drilling and the use of expansion jacks or feather wedges, or the use of backhoe-mounted pneumatic hole punchers or rock breakers; also large boulders, buried masonry, or concrete other than pavement, exceeding 0.40 cubic meter in volume. Removal of "hard material" will not be considered rock excavation because of intermittent drilling and blasting that is performed merely to increase production.

L. Soil: The surface material of the earth's crust resulting from the chemical and mechanical weathering of rock and organic material.

M. Topsoil: In natural or undisturbed soil formations, the fine-grained, weathered material on the surface or directly below any loose or partially decomposed organic matter. Topsoil may be a dark-colored, fine, silty, or sandy material with a high content of well decomposed organic matter, often containing traces of the parent rock material. Gradation and material requirements specified herein apply to all topsoil references in this contract. The material shall be representative of productive soils in the vicinity.

N. Unsatisfactory Material: Existing, in-situ soil or other material which can be identified as having insufficient strength characteristics or stability to carry intended loads in fill or embankment without excessive consolidation or loss of stability. Materials classified as PT, OH, or OL by ASTM D2487 are unsatisfactory. Unsatisfactory materials also include man- made fills, refuse, uncompacted backfills from previous construction, unsound rock or soil lenses, or other deleterious or objectionable material.

O. Working Platform: A layer of compacted crushed rock or natural stone that replaces the in-situ soil to provide a stable, uniform bearing foundation for construction equipment to facilitate further site construction.

P. Refill: Material placed in excavation to correct over-cut in depth.

Q. Unyielding Material: Rock rib, ridge, rock protrusion or soil with cobbles in the trench bottom requiring a covering of finer grain material or special bedding to avoid bridging in the pipe or conduit.

R. Unstable Material: Material in the trench bottom, which lacks firmness to maintain alignment and prevent joints from separating in the pipe, conduit, or appurtenance structure during backfilling. This may be material otherwise identified as satisfactory which has been disturbed or saturated.

1.4. REGULATORY REQUIREMENTS

A. Materials and workmanship specified herein with reference to Standard Specifications of BS or ASTM and Local Municipality shall be in

accordance with the applicable requirements of the referenced articles, sections and paragraphs of the standard.

1.5. DELIVERY AND STORAGE

A. Deliver and store materials in a manner to prevent contamination or segregation. Store synthetic fiber filter cloth to prevent exposure to direct sunlight in accordance with the manufacturer's recommendations.

1.6. SITE CONDITIONS

A. Dewatering Plan
Base on site surface and subsurface conditions and available soils and hydrological data.

PART 2 – PRODUCTS

2.1. MATERIALS

A. Soil Materials: Provide materials free from debris, roots, wood, scrap materials, vegetable matter, or refuse material. Use excavated material from the site for the work indicated when material falls within the requirements specified herein.

1 General Site Fill, Backfill and Embankment Material Provide a soil material from the site or borrow that can be readily compacted to the specified densities. Materials shall be in accordance with ASTM D2487. Test on Borrow pit material shall be one (1) per material type per source.

2 Working Platform Material and thicknesses of working platform for support of construction equipment shall be at the discretion of the construction Contractor. The gradation and placement of such material shall not create large void spaces upon which overlying work is indicated to be placed.

3 Topsoil Provide salvaged topsoil from stockpile. Provide additional topsoil from approved sources off the site meeting the requirement described in BS 1377, if stockpiled material is not sufficient to complete all indicated work. Borrow Provide materials meeting requirements for general site fill, general backfill, and topsoil. Obtain borrow materials in excess of those furnished from excavations described herein from sources within Employer’s property or from sources provided by the Contractor.

PART 3 – EXECUTION

3.1. PROTECTION

A. Integrity of the Excavation The contractor shall design as necessary, an earth retention system, to stabilize the vertical/slope faces of the excavation. A licensed Geotechnical Engineer, at the expense of the Contractor, shall undertake the design of the stabilization system, if necessary. Calculations shall be made available to the Engineer to verify the design. Include provisions that will accomplish the following:

1 Prevent undermining of pavements, foundations and slabs.

2 Prevent excessive movements or collapse of the excavation.

3 Prevent water entering the excavation. The Contractor's attention is drawn to any Soil Erosion and Sediment Control Ordinances in force at the site and shall comply with the same.

B. Protection and Restoration of Surfaces

1. Protect newly graded areas from traffic, erosion, and settlements. Repair and re-establish damaged or eroded slopes, elevations or grades and restore surface construction prior to acceptance.

a. Disposal of Excavated Material

Dispose of excavated material in such a manner that it will not obstruct the flow of runoff, streams, endanger a partly finished structure, impair the efficiency or appearance of facilities, or be detrimental to the completed work.

3.2. SURFACE PREPARATION

A. Unsatisfactory Material Remove organic matter, sod, muck, rubbish, and unsuitable soils under embankments, which are less than 400 mm in thickness and under pavements or slabs on grade.

3.3. EXCAVATION

Excavations for Structures Structure excavations shall be in accordance with Local Municipality Construction Specification and its implementing ordinances, rules and regulations. Excavate to depth indicated. If excavation is deeper than indicated, then fill with Concrete of Grade as specified and shown on structural drawings to the Engineer's requirement prior to placement of foundations. Excavations for foundations may not begin until after completion of the indicated filling operation.

3.4. FILLING AND BACKFILLING

A. Sub grade Preparation Where necessary, scarify the underlying sub-grade surface to a depth of 150 mm before the fill is started. Step, bench, or break up

sloped surfaces steeper than one vertical to 4 horizontal so that the fill material will bond with or be securely keyed to the existing material. Scarify existing surface to a minimum depth of 150 mm if sub-grade density is less than the degree of compaction specified and recompact. When the sub-grade is part fill and part excavation or natural ground, scarify the excavated or natural ground portion to a depth of 150 mm and recompact as specified for the adjacent or overlying fill. Compact with equipment well suited to the soil being compacted. Moisten or aerate material as necessary to provide the moisture content that will readily facilitate obtaining the specified compaction with the equipment used.

B. General Fill and General Backfill Construct fill, backfill and embankment at the locations and to lines and grades indicated. Use only approved materials in constructing fill on the prepared sub-grade. Place satisfactory material in horizontal lifts not exceeding 200 mm in loose depth. Do not place material on surfaces that are muddy. Compact with equipment well suited to the soil being compacted. Moisten or aerate material as necessary to provide the moisture content that will readily facilitate obtaining the specified compaction with the equipment used. Compact each lift as specified before placing the overlaying lift.

C. Final Backfill for Utilities Construct backfill (final backfill) for utility lines, and other utility appurtenances using the material and compaction requirements specified herein for the adjacent or overlying work. Bedding and initial backfill requirements shall be of competent suitable material to the Engineer’s approval. Backfilling against concrete will be done only after approval has been obtained from the Engineer.

D. Weather Limitations Fill and backfill shall not be constructed when weather conditions detrimentally affect the quality of the finished course. Do not construct fill and backfill in the rain or on saturated sub-grades. If weather conditions are windy, hot or arid, with high rate of evaporation, schedule the placement in cooler portions of the day and furnish equipment to add moisture to the fill or backfill during and after placement.

3.5. FINISH OPERATIONS

A. Site Grading
Grade to finished grades indicated within 30 mm. Grade areas to drain water away from structures, and to provide suitable surfaces for mowing machines. Existing grades which are to remain but are disturbed by the Contractor's operations shall be restored as specified herein.

B. Finishing Sub-grades under Structures and Roads Finish surface of top lift of fill or top of sub-grade to the elevation and cross section indicated. Finished surface shall be smooth and of uniform texture.

C. Spreading Topsoil Clear areas indicated or specified to receive topsoil of materials

interfering with planting and maintenance operations. Do not place topsoil when sub-grade is extremely wet or dry, or in other conditions detrimental to seeding, planting, or grading. Spread topsoil to a uniform depth of 100 mm over the designated area.

D. Disposition of Surplus Material Surplus or other soil material not required or suitable for filling, backfilling, or embankment shall be the property of the Employer. The Contractor should remove waste material including unacceptable excavated material and dispose off Employer's property.

E. Protection of Surface Protect newly graded areas from traffic, erosion, and settlements that may occur and as required. Repair or re-establish damaged grades, elevations, or slopes prior to specified tolerances.

3.6. ON SITE GROUND CONDITION

A. The geotechnical report enclosed to Tender Documents is for guidance only, the Contractor should study this report and visit the site and check all relevant conditions. If the contractor found it is necessary to carry out any other soil investigations he should carry out the same as specified at his own cost . B. The recommendation to be derived from the new soil investigation shall be followed in all aspects concerning Soil allowable bearing pressure, appropriate level for foundations, depth and diameters of piles, type of cement to be used in substructures, etc.

C. If the Contractor decided to accept the enclosed geotechnical report then he will be full responsible for it as being carried out by him. In all cases the Contractor will be full responsible for the geotechnical investigation for the project. Neither the Engineer nor the Employer assumes responsibilities for completeness or accuracy of data contained therein and no claims for extra cost or time will be entertained on this account.

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