طرح نگهداشت و افزایش تولید 27 مخزن

SPECIFICATION FOR CONCRETE WORK

نگهداشت و افزایش تولید میدان نفتی بینک

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Rev.	**Date**	**Purpose of Issue/Status**	**Prepared by:**	**Checked by:**	**Approved by:**	**CLIENT Approval**
Class:2		**CLIENT Doc. Number: F0Z-707267**				

Status:

IDC: Inter-Discipline Check
IFC: Issued For Comment
IFA: Issued For Approval
AFD: Approved For Design
AFC: Approved For Construction
AFP: Approved For Purchase
AFQ: Approved For Quotation
IFI: Issued For Information
AB-R: As-Built for CLIENT Review
AB-A: As-Built –Approved

REVISION RECORD SHEET

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1.0 INTRODUCTION

Binak oilfield in Bushehr province is a part of the southern oilfields of Iran, is located 20 km northwest of Genaveh city.

With the aim of increasing production of oil from Binak oilfield, an EPC/EPD Project has been defined by NIOC/NISOC and awarded to Petro Iran Development Company (PEDCO). Also PEDCO (as General Contractor) has assigned the EPC-packages of the Project to "Hirgan Energy - Design and Inspection" JV.

GENERAL DEFINITION

The following terms shall be used in this document.

CLIENT:	National Iranian South Oilfields Company (NISOC)
PROJECT:	Binak Oilfield Development – General Facilities
EPD/EPC CONTRACTOR(GC) :	Petro Iran Development Company (PEDCO)
EPC CONTRACTOR:	Joint Venture of : Hirgan Energy – Design & Inspection(D&I) Companies
VENDOR:	The firm or person who will fabricate the equipment or material.
EXECUTOR:	Executor is the party which carries out all or part of construction and/or commissioning for the project.
THIRD PARTY INSPECTOR (TPI):	The firm appointed by EPD/EPC CONTRACTOR(GC) and approved by CLIENT (in writing) for the inspection of goods.
SHALL:	Is used where a provision is mandatory.
SHOULD:	Is used where a provision is advisory only.
WILL:	Is normally used in connection with the action by CLIENT rather than by an EPC/EPD CONTRACTOR, supplier or VENDOR.
MAY:	Is used where a provision is completely discretionary.

2.0 SCOPE

This document covers the minimum requirements for the material, construction & testing of concrete works to be constructed for this project.

Compliance with this specification and the accompanying data does not relieve the Construction Contractor from his own responsibilities and guarantees nor from any further contract obligations. Material and workmanship not conforming to the design drawings and specifications shall be rejected at any time when such defects are found.

3.0 NORMATIVE REFERENCES

The following standards and publications are referred to and to the extent specified form a part of this specification:

1. AASHTO (American Association of State Highways and Transportation Organization)

AASHTO T260-84	"Method of Sampling and Testing for Total Chloride Ion in Concrete and Concrete Raw Materials"

2. ACI (American Concrete Institute)

2.1.	ACI 318 M-14	"Building Code Requirements for Reinforced Concrete"
2.2.	ACI 347R-14	"Guide to Formwork for Concrete"
2.3.	ACI 304R	"Guide for Measuring, Mixing, Transporting and Placing Concrete"
2.4.	ACI 305R	"Hot Weather Concreting"
2.5.	ACI 614	"Recommended Practice for Measuring, Mixing and Placing Concrete"
2.6.	ACI 214	"Evaluation of Strength Test Result of Concrete"
2.7.	ACI 212.3R	"Chemical Admixtures for Concrete"
2.8.	ACI 226.3R	"Use of Fly Ash in Concrete"
2.9.	ACI 201.2R	"Guide to Durable Concrete"
2.10.	ACI 211-1	"Standard Practice for Selecting Proportion for Normal Heavy Weight and Mass Concrete"
2.11.	ACI 221-R	"Guide for Use of Normal Weight and Heavy Weight Aggregates In Concrete"
2.12.	ACI 222-R	"Corrosion of Metals In Concrete"
2.13.	ACI 224-R	"Control of Cracking In Concrete Structures"
2.14.	ACI 224/1-R	"Cause ,Evaluation and Repair of Cracks In Concrete Structures"
2.15.	ACI 224/2-R	"Crack of Concrete Members In Direct Tension"

2.16.	ACI 301	“Specification for Structural Concrete “
2.17.	ACI 302/1 R	“Guide for Concrete Floor and Slab Construction“
2.18.	ACI 308	“Standard Practice for Curing Concrete”
2.19.	ACI 309-R	“Guide for the Consolidation of Concrete
2.20.	ACI 309-2R	“Identification and Control of Consolidation Related Surface Defects In Formed Concrete“
2.21.	ACI 311	“Manual of Concrete Inspection”
2.22.	ACI 313	“Concrete silos & stacking tubes for storing granular materials”
2.23.	ACI 315	“Details / Detailing of Reinforced Concrete“
2.24.	ACI 350R	“Environmental Engineering Concrete Structures“
2.25.	ACI 352	“Design of Beam-Column Joints / Slab-Column Connections in Monolithic Reinforced Concrete Structures”
2.26.	ACI 408	“Suggested Development, Splice, and Standard Hook Provisions for Deformed Bars in Tension “
2.27.	ACI 442	“ Response of Concrete Buildings to Lateral Forces”
2.28.	ACI 504-R	“Guide to Sealing Joints in Concrete Structures“
2.29.	ACI 214 -3R	“Simplified Version of the Recommended Practice for the Evaluation of Strength Test Results of Concrete”
2.30.	ACI 117	“Standard Tolerance of Construction and Materials”

3. ASTM (American Society for Testing and Materials)

3.1.	ASTM A307	Standard specification for carbon steel bolts and studs, 60000psi tensile strength
3.2.	ASTM A615	Standard specification for deformed and plain billet steel bars for concrete reinforcement
3.3.	ASTM A185	Standard specification for steel welded wire fabric, plain, for concrete reinforcement
3.4.	ASTM A497	Standard specification for steel welded wire fabric, deformed, for concrete reinforcement
3.5.	ASTM C109/ C 109M	“Standard Test Method for Compressive Strength of Hydraulic Cement Mortars"
3.6.	ASTM C117	Test for material finer than 75-micron (M200) sieve in mineral aggregates by washing
3.7.	ASTM C127	Test for specific gravity and absorption of coarse aggregate
3.8.	ASTM C128	Test for specific gravity and absorption of fine aggregate

3.9.	ASTM C131	Test for resistance to degradation of small size coarse aggregates by impact/abrasion of the Los Angeles machine
3.10.	ASTM C136 (Rev.A)	Test for sieve or screen analysis of fine and coarse aggregates
3.11.	ASTM C 138	Test for unit weight, yield and air content (gravimetric) of concrete
3.12.	ASTM C 142	Test for clay lumps and friable particles in aggregates
3.13.	ASTM C 150 (Rev.A)	Standard Specification for Portland Cement
3.14.	ASTM C171 (Rev.A)	"Standard Specification for Sheet Materials for Curing Concrete"
3.15.	ASTM C227 (Rev.A)	Test method for potential Alkali reactivity of cement aggregate combinations (mortar bar method)
3.16.	ASTM C260	"Standard Specification for Air-Entraining Admixtures for Concrete"
3.17.	ASTM C289	Test method for potential reactivity of aggregates (chemical method)
3.18.	ASTM C 535	Test for resistance to abrasion of large size coarse aggregate by impact/abrasion of the Los Angeles machine
3.19.	ASTM C 566	Total moisture content of aggregate by drying
3.20.	ASTM C 579	Standard test methods for compressive strength of chemical resistant mortars, grout, monolithic surfacing and polymer concretes
3.21.	ASTM D 512	Tests for chloride ion in water and wastewater
3.22.	ASTM D 516	Tests for sulfate ion in water and wastewater
3.23.	ASTM C618	"Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete"
3.24.	ASTM C 1064	Test method for temperature of freshly mixed Portland cement concrete
3.25.	ASTM C 1078	Test method for determining the cement content of freshly mixed concrete
3.26.	ASTM C 1079	Test method for determining the water content of freshly mixed concrete

4. PCA (Portland Cement Association)

   4.1. "Design and Control of Concrete Mixtures"

5. IPS (Iranian Petrolium Standard)

5.1. IPS-C-CE-200 "Construction Standard for Concrete Structure"
5.2. IPS-E-CE-200 "Engineering Standard for Concrete Structure"

6. Iranian Standards

6.1. INBC Part 9, Iranian National Building Code, Part 9 (1399)
6.2. Iranian Seismic Design Code for Oil Industries (3rd Edition) Pub.No.038-18
6.3. General Technical Specification for Construction Works, Iranian Ministry of Planning and Budget Publication , Publication No.55
6.4. Iranian Code of Practice for Seismic Resistant Design of Buildings, STD No:2800 (4th Edition)

7. British Standards Institute (BS)

7.1. B.S.812 : " Method of sampling and testing mineral aggregates, sand and fillers"

8. Other Project Document

8.1. Structural Design Criteria , Doc No: BK-GNRAL-PEDCO-000-ST-DC-0001

4.0 MATERIALS

4.1 CEMENTS

Cement shall conform to the following specifications for Portland cement:

a) "Standard Specification for Portland Cement" (ASTM C 150).

Cement type shall be considered according to geotechnical investigation report.

Cement used in the work shall correspond to that on which selection of concrete proportions was based.

Fly Ash or other pozzolans shall conform to ASTM C 618 "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete" For more information about other kinds of pozzolans see Iranian national concrete code Publication No.-120 of management and planning organization part 3-6- 4-2.

4.2 AGGREGATES

Concrete aggregates shall conform to one of the following specifications:

a) Standard Specification for Concrete Aggregates (ASTM C 33).

b) Standard Specification for Lightweight Aggregates for Structural Concrete (ASTM C 330).
c) Gradation of fine aggregates and coarse aggregates shall be within the limit mentioned in Tables 1 and 2.

Exception: Aggregates which have been shown by special test or actual service to produce concrete of adequate strength and durability and approved by the Authorized Representative*.

TABLE 1 - GRADING REQUIREMENTS FOR FINE AGGREGATES	
SIEVE (SPECIFICATION E 11)	**PERCENT PASSING**
9.5-mm (⅜-in)	100
4.75-mm(No. 4)	95 to 100
2.36-mm(No. 8)	80 to 100
1.18-mm(No. 16)	50 to 85
600-µm (No. 30)	25 to 60
300-µm (No. 50)	5 to 30
150-µm (No.100)	0 to 10

TABLE 2 - GRADING REQUIREMENTS FOR COARSE AGGREGATES

Size Number	Nominal Size (Sieves with Square Openings)	Amounts Finer than Each Laboratory Sieve (Square-Openings), Mass Percent													
		100mm (4 in.)	90mm (3½ in.)	75mm (3 in.)	63mm (2½ in.)	50mm (2 in.)	37.5mm (1½ in.)	25.0mm (1 in.)	19.0mm (¾ in.)	12.5mm (½ in.)	9.5mm (⅜ in.)	4.75mm (No.4)	2.36mm (No.8)	1.18mm (No.16)	300µm (No.50)
1	90 to 37.5mm (3½ to 1½ in.)	100	90 to 100	....	25 to 60	....	0 to 15	....	0 to 5	....	...	....	...	...	...
2	63 to 37.5mm (2½ to 1½ in.)	....	....	100	90 to 100	35 to 70	0 to 15	....	0 to 5	.....	...	....	....	....	....
3	50 to 25.0mm (2 to 1 in.)	....	....	....	100	90 to 100	35 to 70	0 to 15	....	0 to 5	...	....	...	...	...
357	50 to 4.75mm (2 in. to No.4)	....	....	....	100	95 to 100	....	35 to 70	....	10 to 30	...	0 to 5	....	....	....
4	37.5 to 19.0mm (1½ to ¾ in.)	....	....	....	....	100	90 to 100	20 to 55	0 to 15	....	0 to 5	....	...	...	...
467	37.5 to 4.75mm (1½ in. to No. 4)	....	....	....	....	100	100	....	35 to 70	....	10 to 30	0 to 5	....	....	....
5	25.0 to 12.5mm (1 to ½ in.)	....	....	....	....	....	100	90 to 100	20 to 55	0 to 10	0 to 15	....	...	...	...
56	25.0 to 9.5mm (1 to ⅜ in.)	....	....	....	....	....	100	90 to 100	40 to 85	10 to 40	0 to 5	0 to 5		....	....

TABLE 2 - GRADING REQUIREMENTS FOR COARSE AGGREGATES

Size Number	Nominal Size (Sieves with Square Openings)	Amounts Finer than Each Laboratory Sieve (Square-Openings), Mass Percent													
		100mm (4 in.)	90mm (3½ in.)	75mm (3 in.)	63mm (2½ in.)	50mm (2 in.)	37.5mm (1½ in.)	25.0mm (1 in.)	19.0mm (¾ in.)	12.5mm (½ in.)	9.5mm (⅜ in.)	4.75mm (No.4)	2.36mm (No.8)	1.18mm (No.16)	300µm (No.50)
57	25.0 to 4.75mm (1 in. to No. 4)	....	....	....	....	....	....	95 to 100	....	25 to 60	....	0 to 10	0 to 5	...	...
6	19.0 to 9.5mm (¾ to ⅜ in.)	....	....	....	....	....	....	100	90 to 100	20 to 55	0 to 15	0 to 5	....	....	....
67	19.0 to 4.75mm (¾ in. to No. 4)	....	....	....	....	....	....	100	90 to 100	....	20 to 55	0 to 10	0 to 5	...	...
7	12.5 to 4.75mm (½ in. to No. 4)	....	....	....	....	....	....	....	100	90 to 100	40 to 70	0 to 15	0 to 5		....
8	9.5 to 2.36mm (⅜ in. to No. 8)	....	....	....	....	....	....	....	....	100	85 to 100	10 to 30	0 to 10	0 to 5	....
89	9.5 to 1.18mm (⅜ in. to No. 16)	....	....	....	....	....	....	....	....	100	90 to 100	20 to 55	5 to 30	0 to 10	0 to 5
90	4.75 to 1.18mm (No. 4 to No. 16)	....	....	....	....	....	....	....	....	...	100	85 to 100	10 to 40	0 to 10	0 to 5

[A] Size number 9 aggregate is defined in Terminology C 125 as a fine aggregate. It is included as a coarse aggregate when it is combined with a size number 8 material to create a size number 89, which is a coarse aggregate as defined by terminology.

Nominal maximum size of coarse aggregate shall be not larger than:

a) 1/5 the narrowest dimension between sides of forms, nor;
b) 1/3 the depth of slabs, nor;
c) 3/4 the minimum clear spacing between individual reinforcing bars or wires, bundles of bars, or pre stressing tendons or ducts.

These limitations shall not apply if, in the judgment of the AR, workability and methods of consolidation are such that concrete can be placed without honeycomb or voids.

Where aggregates are alkali-reactive, impose restrictions on materials to minimize deterioration.

4.3 WATER

Water used in mixing concrete shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials, or other substances that may be deleterious to concrete or reinforcement.

Mixing water for pre-stressed concrete or for concrete that will contain aluminum embedment, including that portion of mixing water contributed in the form of free moisture on aggregates, shall not contain deleterious amounts of chloride ion.

Non-potable water shall not be used in concrete unless the following are satisfied:

a) Selection of concrete proportions shall be based on concrete mixes using water from the same source.
b) Mortar test cubes made with non-potable mixing water shall have 7-day and 28-day strengths equal to at least 90 percent of strengths of similar specimens made with potable water. Strength test comparison shall be made on mortars, identical except for the mixing water, prepared and tested in accordance with "Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 50-mm Cube Specimens)" (ASTM C 109).

Sea water shall not be used as mixing water.

4.4 STEEL REINFORCEMENT

For general description and method of use of concrete reinforcement refer to Section 3.5 of ACI-318M.

Reinforcing bars shall be S400 according to: ISIRI3132 and INBC9 with minimum tensile yield strength 400 N/mm^2 .

All foundations shall be placed on minimum 100 mm lean concrete.

4.5 ADMIXTURES AND ADDITIVES

An admixture shall be capable of maintaining essentially the same composition and performance throughout the work as the product used in establishing concrete proportions in accordance with Clause 5.2 ACI 318M.

Admixtures to be used in concrete shall be subject to written approval of AR.

Air-entraining admixtures shall conform to ASTM C 260, "Standard Specification for Air-Entraining Admixtures for Concrete".

Water-reducing admixtures, retarding admixtures, accelerating admixtures; water reducing and retarding admixtures and water reducing and accelerating admixtures shall conform to ASTM C 494, "Standard Specification for Chemical Admixtures for Concrete".

Fly Ash or other pozzolans used as admixtures shall conform to ASTM C 618, "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete" For more information about other kinds of pozzolans see Iranian national concrete code publication No.-120 of management and planning organization part 3-6-4-2.

Ground granulated blast-furnace slag used as an admixture shall conform to "Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars" (ASTM C 989).

The types of admixtures suitable for use in concrete to obtain the desired effect are listed in Table 3.

TABLE 3- ADMIXTURES BY CLASSIFICATION	
Air-entraining admixtures	ASTM C 260, AASHTO M 154;
Accelerating admixtures;	ASTM C 494 Type C
Water-reducing admixtures;	ASTM C 494 Type A
Retarding admixtures	ASTM C 494 Type B
Water-reducing and retarding admixtures;	ASTM C 494 Type D
Water-reducing and accelerating admixtures	ASTM C 494 Type E
Water-reducing, high-range admixtures	ASTM C 494 Type F
Water-reducing, high-range, and retarding admixtures.	ASTM C 494 Type G
Admixtures for flowing concrete	ASTM C 1017, Type I or Type II (retarding):

TABLE 3- ADMIXTURES BY CLASSIFICATION	
Miscellaneous admixtures:	ACI 212 section 6.
Gas-forming admixtures	ACI 212 section 6.1
Grouting admixt	ACI 212 section 6.2
Extended set-control admixtures	ACI 212 section 6.3
Bonding admixtures	ACI 212 section 6.4
Pumping aids	ACI 212 section 6.5
Pigments(To produce colors)	ACI 212 section 6.6
Permeability-reducing admixtures	ACI 212 section 6.9
Chemical admixtures to reduce alkali-aggregate reaction expansion	ACI 212 section 6.10
Corrosion-inhibiting admixtures	ACI 212 section 6.11
Antiwashout admixtures	ACI 212 section 6.12
Freeze-resistant admixtures	ACI 212 section 6.13

4.6 STORAGE OF MATERIALS

Cement and aggregates shall be stored in such manner as to prevent deterioration or intrusion of foreign matter and in dry shaded and weatherproof conditions.

Any material that has deteriorated or has been contaminated shall not be used for concrete.

4.7 TEST OF MATERIALS

Tests of reinforcing materials and of concrete shall be made in accordance with standards listed in Clause 3.8 of ACI 318 M.

5.0 PROPORTIONING

5.1 STRENGTH

The following grades of concrete according to minimum compressive characteristic strength at 28 days (f'c) on cylinder specimen (ATSM C39) shall be used.

- Cast in place concrete f'c=30 Mpa
- Precast concrete f'c=30 Mpa
- Tank & reservoirs f'c=35 Mpa
- Foundation for vibrating machine f'c=30 Mpa
- Lean concrete f'c=15 Mpa
- Fire proofing concrete f'c=25 Mpa
- Cast-in-place pile f'c=35 Mpa
- Paving and ditches f'c=25 Mpa
- Catch basins and Manholes f'c=25 Mpa
- Duct Banks f'c=20 Mpa
- Plain Mass Concrete f'c=20 Mpa

5.2 SLUMP

The concrete consistency as determined by the slump concrete test (ASTM C143 or Pub No .55) shall have the following range:

RECOMMENDED SLUMPS FOR VARIOUS TYPES OF CONSTRUCTION

Types of Construction	Maximum	Minimum
	mm	mm.
Reinforced foundation wall & footing	75	25
Plain footing , caissons & substructure	75	25
Slabs , beams , & reinforced walls	100	25
Building columns	100	25
Pavements	75	25
Heavy mass construction	50	25

Note 1: In the case of hand vibrating methods, the max. Value may be increased by 25mm.

5.3 MAX SIZE OF AGGREGATES IN ANY CASE SHOULD NOT EXCEED THE VALUES BELOW:

a. 1/5 of smallest interior faces of formwork
b. 1/3 of concrete slab thickness
c. 3/4 of min interior spaced bars
d. 3/4 of concrete cover
e. 38 mm

5.4 PROPORTIONING OF INGREDIENTS

The proportioning of concrete ingredients shall conform to ACI standard 211.1 "Recommended practice for Selection proportions for Normal and Heavy weight Concrete".

Maximum water cement ratio shall not be greater than 0.48.

A part from aforementioned requirements for durability of concrete (which includes compressive strength and the ratio W/C and each grade and type of cement), the geotechnical study results shall also be considered for that if study results are more preferable.

6.0 DURABILITY REQUIREMENTS

6.1 FREEZING AND THAWING EXPOSURES

Normal density and low-density concrete exposed to freezing and thawing or deicer chemicals shall be air entrained with air content indicated in Table 4. Tolerance on air content as delivered shall be ±1.5 percent. For specified compressive strength f'c greater than 35 MPa, air content indicated in Table 4 may be reduced 1 percent.

TABLE 4 - TOTAL AIR CONTENT FOR FROST - RESISTANT CONCRETE

NOMINAL MAXIMUM AGGREGATE SIZE, mm(1)	AIR CONTENT, PERCENT	
	SEVERE EXPOSURE	MODERATE EXPOSURE
9.5	7 ½	6
12.5	7	5 ½
19.0	6	5
25.0	6	4 ½
37.5	5 ½	4 ½

TABLE 4 - TOTAL AIR CONTENT FOR FROST - RESISTANT CONCRETE		
NOMINAL MAXIMUM AGGREGATE SIZE, mm(1)	AIR CONTENT, PERCENT	
	SEVERE EXPOSURE	MODERATE EXPOSURE
50 [2]	5	4
75 [2]	4 ½	3 ½

1. See ASTM C33 for tolerances on oversize for various nominal maximum size designations.
2. These air contents apply to total mix, as for the preceding aggregate sizes. When testing these concretes, however, aggregate larger than 37.5 mm is removed by hand-picking or sieving and air content is determined on the minus 37.5 mm fraction of mix, (Tolerance on air content as delivered applies to this value) Air content of total mix is computed from value determined on the minus 37.5 mm fraction.

Concrete that will be subject to freezing and thawing in a moist condition, intended to have low permeability to water or be exposed to deicing salts, brackish water, sea water, or spray from these sources shall conform to the requirements of Table 5.

6.2 CORROSION PROTECTION

When reinforced concrete will be exposed to chloride from deicing salts, brackish water, sea water, or spray from these sources, requirements of Table 5 for water- cement ratio or concrete strength and minimum concrete cover requirements of Clause 11.7 shall be satisfied.

TABLE 5 - REQUIREMENTS FOR SPECIAL EXPOSURE CONDITIONS		
EXPOSURE CONDITION	MAXIMUM WATER-CEMENT RATIO, NORMAL WEIGHT CONCRETE	MINIMUM f'_c NORMAL-WEIGHT AND LIGHT- WEIGHT CONCRETE
Concrete intended to have low permeability when exposed to water	0.50	28
Concrete exposed to freezing and thawing in a moist condition	0.45	31
For corrosion protection for reinforced concrete exposed to deicing salts, brackish water, seawater or spray from these sources	0.40*	35*

TABLE 5 - REQUIREMENTS FOR SPECIAL EXPOSURE CONDITIONS		
EXPOSURE CONDITION	**MAXIMUM WATER-CEMENT RATIO, NORMAL WEIGHT CONCRETE**	**MINIMUM f'_c NORMAL-WEIGHT AND LIGHT- WEIGHT CONCRETE**
Frost-resistant concrete Thin sections and any concrete exposed to deicing salts All other structures	0.45 0.50	30 28
Placing concrete under water	0.45	Not less than 350 kg of cement per cubic meter

Note:

If minimum concrete cover required by Clause 11.7 is increased by l0 mm, water-cement ratio may be increased to 0.45 for normal density concrete, or f'c reduced to 30 MPa for low-density concrete.

For corrosion protection, maximum water soluble chloride ion concentrations in hardened concrete at ages from 28 to 42 days contributed from the ingredients including water, aggregates, cementitious materials and admixtures shall not exceed the limits of Table 6.

When testing is performed to determine water soluble chloride ion content, test procedures shall conform to ASTM C1218.

TABLE 6- MAXIMUM CHLORIDE IN CONTENT FOR CORROSION PROTECTION	
TYPE OF MEMBER	**MAXIMUM WATER SOLUBLE CHLORIDE ION (CI-) IN CONCRETE, PERCENT BY WEIGHT OF CEMENT**
Prestressed concrete	0.06
Reinforced concrete exposed to chloride in service	0.15
Reinforced concrete that will be dry or protected from moisture in service	1.00
Other reinforced concrete construction	0.30

6.3 SULFATE EXPOSURE

Concrete to be exposed to sulfate-containing solutions or soils shall conform to requirements of Table 7, or be made with cement that provides sulfate resistance when used in concrete with maximum water-cement ratio and minimum compressive strength from Table 7.

Calcium chloride as an admixture shall not be used in concrete to be exposed to severe or very severe sulfate containing solutions, as defined in Table 7.

TABLE 7 - REQUIREMENTS FOR CONCRETE EXPOSED TO SULFATE- CONTANING SOLUTIONS

SULFATE EXPOSURE	WATER SOLBLE SULFATE (SO4) IN SOIL , PERCENT BY WEIGHT	SULFATE (SO_4) IN WATER (ppm)	CEMENT TYPE	MAXIMUM WATER - CEMENT RATIO BY WEIGHT[1]
Negligible	< 0.20	< 300	I	0.55
Moderate [2]	0.20 < < 0.50	300 < < 1200	I - V	0.5
Severe	0.50 < < 1.00	1200 < < 2500	I - V	0.5
Very severe	1.00 < < 2.00	2500 < < 5000	II – V [3]	0.45
Extremely severe	2.00 <	5000 <		0.4

1. A lower water-cement ratio or higher strength may be required for low permeability or for protection against corrosion of embedded items or freezing and thawing.
2. Seawater.
3. Pozzolan that has been determined by test or service record to improve sulfate resistance when used in concrete containing Type V cement.

6.4 WATER-CEMENT RATIO

For place ability, finish ability, abrasion resistance, and durability in flatwork, with regard to aggregate size, the quantity of cement to be used should be not less than shown in Table 8.

TABLE 8 - MINIMUM CEMENT REQUIREMENTS FOR CONCRETE USED IN FLATWORK

MAXIMUM SIZE OF AGGREGATE, mm	CEMENT, kg/m^3
28	282
25	312
19	324
12.5	354

9.5	366

The minimum cement content of concrete mixtures exposed to freezing and thawing in the presence of deicing chemicals shall be 252 kg of cement meeting ASTM C 150 or C 595 per m3 of concrete.

The water-cement ratio required in Tables 5 and 7 shall be calculated using the mass of cement meeting ASTM C 150 or C 595 plus the weight of fly ash or pozzolan meeting ASTM C 618 and/or slag meeting ASTM C 989, if any.

6.5 CONCRETE FOR WEAR RESISTANCE

Aggregate of up to 4 mm particle size shall consist mainly of quartz or materials of at least equivalent hardness and coarser particles, of natural or artificial stone possessing high wear resistance. The aggregate grading should be such that it is as coarse as possible.

Provisions for obtaining abrasion resistance concrete surface are referred to ACI 201 chapter (3).

Concrete for exposure to service temperatures up to 250°C shall be made with aggregates which have proved suitable in accordance with relative Clause of ASTM for exposure to such temperatures. The concrete should be allowed to dry out before it is heated for the first time, the latter being performed as slowly as possible.

6.6 SHOTCRETE

Shotcrete is process, by which concrete or mortar is sprayed onto a surface to produce a compacted self-supporting and bearing Layer, depending on the addition of water to the mix, distinction as made between the dry process and the wet process.

For more information see Iranian national concrete code Publication No. 120 of management and planning organization part 7-7 and ACI 506.2(specification for shotcrete).

7.0 CONCRETE QUALITY, MIXING AND PLACING

7.1 GENERAL

Concrete shall be proportioned to provide an average compressive strength f'cr as prescribed in Section 5.3.2 of ACI 318M as well as satisfy the durability criteria of Clause 6.

.For concrete designed and constructed in accordance with the code, fc shall not be less than 17MPa.

Unless otherwise specified, fc' Shall be based on 28-day tests. If other than 28 days, test age for fc' shall be as indicated in design drawings or specifications.

Where design criteria in IPS-E-CE-200 provide for use of a splitting tensile strength value of

concrete, laboratory tests shall be made in accordance with "Specification for Lightweight Aggregates for Structural Concrete" (ASTM C 330) to establish value of f_{ct} corresponding to specified value of f c '.

Splitting tensile strength tests shall not be used as a basis for field acceptance of concrete.

7.2 SELECTION OF CONCRETE PROPORTIONS

Proportions of materials for concrete shall be established to provide:

a. Workability and consistency to permit concrete to be worked readily into forms and around reinforcement under conditions of placement to be employed, without segregation or excessive bleeding.
b. Resistance to special exposures as required by Clause 6.

Where different materials are to be used for different portions of proposed work, each combination shall be evaluated.

Concrete proportions, shall be established on the basis of field experience and/or trial mixtures specified in Section 5.3 of ACI 318M, or alternatively, Section 5.4 of the same Code and shall meet applicable requirements of Clause 6 of this Specification.

7.3 MIXING

All concrete shall be mixed until there is a uniform distribution of materials and shall be discharged completely before mixer is recharged.

Ready-mixed concrete shall be mixed and delivered in accordance with requirements of "Standard Specification for Ready-Mixed Concrete" (ASTM C 94) or "Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing" (ASTM C 685).

Job-mixed concrete shall be mixed in accordance with the following:

a. Mixing shall be done in a batch mixer of approved type.
b. Mixer shall be rotated at a speed recommended by the manufacturer.
c. Mixing shall be continued for at least 1-½ min after all materials are in the drum, unless a shorter time is shown to be satisfactory by the mixing uniformity tests of "Standard Specification for Ready-Mixed Concrete" (ASTM C 94).
d. Materials handling, batching, and mixing shall also conform to applicable provisions of ASTM C 94.
e. A detailed record shall be kept to identify:
   1) Number of batches produced;
   2) Proportions of materials used;
   3) approximate location of final deposit in structure;
   4) Time and date of mixing and placing.

Normally, mechanical means shall be used for concrete mixing, and hand mixing shall only be allowed for small works, if approved by the AR.

Concrete mixing equipment shall be sufficient for size of the structures to be constructed and the concreting schedules, taking also into account the need to ensure continuous concreting for each structure.

Mechanical means shall be used for measuring concrete materials, and the concrete composition shall be constant and identical with those that proved to be optimum during the trial mixing for each class of concrete.

7.4 PLACING CONCRETE

Placement of concrete shall be accomplished according to ACI 304R Chapter 5.

8.0 HANDLING, WORKING AND CURING OF CONCRETE

8.1 HANDLING OF CONCRETE ON SITE

a) The method of concrete conveyance (e.g. by skip, conveyor belt, pumping, compressed air) and the composition of the concrete shall be coordinated so as to prevent segregation.
b) Conveying equipment shall be capable of providing a supply of concrete at site of placement without separation of ingredients and without interruptions sufficient to permit loss of plasticity between successive increments
c) Segregation shall also be prevented when concrete is poured into column or wall formwork, one way of achieving this being to pour the concrete through downpipes which terminate only a short distance above the point of deposit.
d) The use of pipes made of light metal is not permitted for pumping purposes.
e) The layout of pipes for conveying pump able concrete shall be such as to ensure an uninterrupted flow of concrete through the pipes. Where concrete is conveyed by conveyor belt, scrapers and devices for holding the concrete together shall be provided at the throw-off point.
f) When placing concrete, care shall be taken that any reinforcement, fittings, or formwork surfaces, etc. in position for a later concreting phase do not become encrusted with concrete.

8.2 DEPOSITING

Concrete shall be deposited as nearly as practical in its final position to avoid segregation due to rehandling or flowing.

Concerting shall be carried on at such a rate that concrete is at all times plastic and flows readily into spaces between reinforcement.

Concrete that has partially hardened or been contaminated by foreign materials shall not be

deposited in the structure.

Retempered concrete or concrete that has been remixed after initial set shall not be used unless approved by the AR.

After concreting is started, it shall be carried on as a continuous operation until placing of a panel or section, as defined by its boundaries or predetermined joints, is completed except as permitted or prohibited by Clause 11.

Top surfaces of vertically formed lifts shall be generally level.

When construction joints are required, joints shall be made in accordance with Clause 12.

All concrete shall be thoroughly compacted by suitable means during placement and shall be thoroughly worked around reinforcement and embedded fixtures and into corners of forms.

8.3 WORKING OF CONCRETE

Working time:

Plain concrete shall be worked as soon as possible after mixing, and ready-mixed concrete as soon as possible after delivery. In any event, this shall be before it stiffens or changes in composition. The total time for mixing, transportation and puring of the concrete should generally not exceed 60 minutes under conditions that prevent segregation and maintain workability.

Compaction (Consolidation):

Reinforcing bars shall be densely embedded in concrete, which shall be thoroughly compacted (consolidated) by means of vibration, punning, tamping, rapping of formwork, etc., and particularly in corners and along the sides of the formwork.

While compacting (consolidating) by vibration methods, surface vibrators shall move slowly to enable the concrete below to soften while leaving behind them a solid mass. Where powerful surface vibrators are used, the layer of concrete after compaction should be not more than 200 mm deep. Where formwork vibrators are used, it shall be borne in mind that the depth to which they are able to compact the concrete is limited, this also depending on the design of the formwork.

Concrete with consistence range of soft to flowing properties may also be compacted (consolidated) by punning, taking care to work the concrete thoroughly to form a solid, void-free mass.

Tamping may be used for concrete of stiff consistence, the concrete after compaction being not more than 150 mm in depth. Tamping shall preferably be by mechanical means, although hand tamping is also permitted, and shall be carried out until the concrete softens whilst acquiring a closed surface structure. Individual layers should, where possible, be normal to the direction of compression, and tamping shall be in the direction of compression. Where this is not possible, the concrete shall be at least of plastic consistence in order to ensure that there are no tamping

joints parallel to the direction of compression.

If no provision is made for construction joints, the time intervals between placing individual layers shall be kept as short as possible since, to achieve an effective bond between layers, no new layer shall be placed on one which has already set. Where immersion vibrators are used, the head shall penetrate into the lower layer, in which compaction has already taken place.

8.4 CURING

8.4.1 Concrete (other than high-early-strength) shall be maintained above 10°C and in a moist condition for at least the first 7 days after placement, except when cured in accordance with 8.4.7.

8.4.2 High-early-strength concrete shall be maintained above 10°C and in a moist condition for at least the first 3 days, except when cured in accordance with 8.4.7.

8.4.3 Until it has sufficiently hardened, concrete shall be protected from harmful effects such as severe cooling or heating, premature drying out (including by wind), leaching out by rain or flowing water, chemical attack, or vibration and impact which may disrupt the concrete and interfere with its bond to the reinforcement. This shall also apply to sealing mortar and to the concrete used as a filler for joints between precast members.

8.4.4 On flat surfaces such as pavements, sidewalks and floors, curing can be accomplished by immersion of the finished concrete, called ponding, which will prevent loss of moisture and is effective for maintaining a uniform temperature in the concrete. The curing water temperature should not be more than 11°C cooler than the concrete to prevent thermal stresses that could result in cracking.

8.4.5 Plastic sheet materials such as polyethylene film used for curing concrete should conform to ASTM C 171.

8.4.6 Curing compound should conform to ASTM C 309.

8.4.7 Accelerated curing :

Curing by high pressure steam, steam at atmospheric pressure, heat and moisture, or other accepted processes, shall be permitted to accelerate strength gain and reduce time of curing.

Accelerated curing shall provide a compressive strength of the concrete at the load stage considered at least equal to required design strength at that load stage.

Members subjected to heat treatment shall be kept moist since hardening is not generally completed by the end of the treatment and the concrete dries out considerably during cooling.

Curing process shall be such as to produce concrete with durability at least equivalent to the curing method of 8.4.1 or 8.4.2.

When required by the AR, supplementary strength tests in accordance with Testing & Inspection Procedure for Concrete Works shall be performed to assure that curing is satisfactory.

8.4.8 Cold weather concreting

Cold weather is defined as that in which average daily temperature is less than 5°C, except that if temperatures above 10°C occur during at least 12 hours in any day, the concrete should no longer be regarded as winter concrete and normal curing practice should apply. For recommended concrete temperatures see Table 9.

8.4.8.1 Adequate equipment shall be provided for heating concrete materials and protecting concrete during freezing or near-freezing weather.

8.4.8.2 All concrete materials and reinforcement, forms, fillers, and ground with which concrete is to come in contact shall be free from frost.

8.4.8.3 Frozen materials or materials containing ice shall not be used.

8.4.8.4 Concrete that has been frozen just once at an early age may be restored to early normal strength by providing favorable curing conditions. Such concrete, however, is not as resistant to weathering nor is it as water tight as concrete that has not been frozen. Air-Entrained concrete is less susceptible to damage by early freezing than concrete without entrained air.

8.4.8.5 Concrete should not be cast on frozen concrete or on frozen ground. Aggregate shall be free from snow, ice and frost. If required, the water and, where necessary, the aggregate shall be preheated. Water at a temperature of above +70°C shall first be mixed with the aggregate before cement is added. Particularly for slender members it is advisable to increase the cement content or to use cement of a higher strength class, or both.

8.4.8.6 Accelerators shall not be used as a substitute for proper curing and frost protection. Also, the use of antifreeze compounds or other materials to lower the freezing point of concrete shall not be permitted.

8.4.8.7 Accelerators containing chlorides should not be used where there is an in service potential for corrosion.

8.4.8.8 During cold weather, the concrete mixing temperature should be controlled so that when the concrete is placed its temperature is not below the values shown in Line 1 of Table 10. Placement temperatures should not be higher than the minimum values by more than 11° C. The mixing temperature should not be more than 8° C above the recommended values in Lines 2, 3, and 4.

TABLE 9 - RECOMMENDED CONCRETE TEMPERATURE FOR COLD-WEATHER CONSTRUCTION; AIR-ENTRAINED CONCRETE

Line	Air temperature	Section size, minimum dimension, in. (mm)			
		< 12 in. (300 mm)	12-36 in. (300-900 mm)	36-72 in. (900-1800 mm)	> 72 in. (1800 mm)
	Minimum concrete temperature as placed and maintained				
1	-	13° C	10° C	7° C	5° C
	Minimum concrete temperature as mixed for indicated air temperature*				

2	**Above -1° C**	**16° C**	**13° C**	**10° C**	**7° C**
3	**-18 to -1° C**	**18° C**	**16° C**	**13° C**	**10° C**
4	**Below -18° C**	**21° C**	**18° C**	**16° C**	**13° C**
Maximum allowable gradual temperature drop in first 24 hr after end of protection					
5	**-**	**28° C**	**22° C**	**17° C**	**11° C**

*For colder weather a greater margin in temperature is provided between concrete as mixed and required minimum temperature of fresh concrete in place.

8.4.8.9. Table 10-A gives the minimum length of the protection period at the temperatures given in Line 1 of Table 9 and the service category. These minimum protection periods are recommended unless the in-place strength of the concrete has attained a previously established value. The service categories are as follows:

Category 1: No load not exposed - This category includes foundations and substructures that are not subject to early load, and, because they are buried deep within the ground or are backfilled, will undergo little or no freezing and thawing in service.

Category 2: No load exposed - This category includes massive piers and dams that have surfaces exposed to freezing and weathering in service but has no early strength requirements.

Category 3: Partial load, exposed - The third category includes structures exposed to the weather that may be subjected to small, early-age loads compared with their design strengths and will have an opportunity for additional strength development prior to the application of design loads. In such cases, the concrete should have at least the length of protection recommended for Category 3 in Table 10-A.

Category 4: Full load - This category includes structural concrete requiring temporary construction supports to safely resist construction loads.

Part B of Table 10 has been adapted from Table 6.8 of ACI 306. The values shown are approximations and will vary according to the thickness of concrete, mix proportions, etc. They are intended to represent the ages at which supporting forms can be removed. For recommended concrete temperatures, see Table 9.

8.4.8.10. The concrete carried by the ready mix truck to the site should be placed in the forms before its temperature drops below that given on line 4 of Table 9 and that temperature should be maintained for the duration of the protection period.

8.4.8.11. Columns and walls should not be cast on frozen foundations, because chilling the bottom of the column or wall will cause weak concrete.

8.4.8.12. Heat can be retained in the concrete by covering it with commercial insulating blanket or other insulating materials, which should be kept dry and in close contact with concrete or formwork for maximum efficiency.

The resistance to heat transfer (R) values for common insulation materials are given in Table 11.

8.4.8.13. Insulating blankets for construction are made of fiberglass, sponge rubber, open-cell polyurethane foam, vinyl foam, mineral wool, or cellulose fibers. The outer covers are made of canvas, woven polyethylene, or other tough fabrics that will take rough handling.

8.4.8.14.No concrete shall be placed during heavy rain, snow or when ambient temperature falls below -18°C, unless proper sheltering or heated enclosure are provided and written approval of AR is obtained.

TABLE 10 - A) LENGTH OF PROTECTION PERIOD FOR CONCRETE PLACED DURING COLD WEATHER

Line	Service category	Protection period at temperature indicated in line 1 of Table 10, days*	
		Type I or II cement	Type III cement, or accelerating admixture, or 100 lb/yd^3 (60 kg/m^3) of additional

			cement
1	1- no load, not exposed	2	1
2	2- no load, exposed	3	2
3	3- partial load, exposed	6	4
4	4- full load	See chapter 6 ACI 306 R	

***** A day is a 24 hr period

TABLE 10-B) DURATION OF RECOMMENDED PROTECTION FOR PERCENTAGE OF STANDARD-CURED 28-DAY STRENGTH*						
REQUIRED PERCENTAGE OF DESIGN STRENGTH f_c	DAYS AT 10°C			DAYS AT 21°C		
	TYPE OF PORTLAND CEMENT			TYPE OF PORTLAND CEMENT		
	ASTM I	II	III	ASTM I	II	III
50	6	9	3	4	6	3
65	11	14	5	8	10	4
85	21	28	16	16	18	12
95	29	35	26	23	24	20

* The 28-day strength for each type of cement was considered as 100 percent in determining the times to reach various percentages of this strength for curing 10° C and 21° C. These times are only approximate, and specific values should be obtained for the concrete used on the job

TABLE 11 - INSULATION VALUES OF VARIOUS MATERIALS		
INSULATING MATERIAL	THERMAL RESISTANCE, R FOR THESE THICKNESSES OF MATERIAL *	
	1 in., hr.ft ^{2}.F/Btu	10 mm, m ^{2}.K/W
Board and Slabs		

Expanded polyurethane (R-11 exp.)	6.25	0.438
Expanded polystyrene extruded (R-12 exp.)	5.00	0.347
Expanded polystyrene extruded, plain	4.00	0.277
Glass fiber, organic bonded	4.00	0.277
Expanded polystyrene, molded beads	3.57	0.247
Mineral fiber with resin binder	3.45	0.239
Mineral fiber board, wet felted	2.94	0.204
Sheathing, regular density	2.63	0.182
Cellular glass	2.63	0.182
Laminated paperboard	2.00	0.139
Particle board (low density)	1.85	0.128
Plywood	1.25	0.087
Blanket		
Mineral fiber, fibrous form processed from rock, slag, or glass	3.23	0.224 0.224
Loose Fill		
Wood fiber, soft woods	3.33	0.231
Mineral fiber (rock, slag, or glass)	2.50	0.173
Perlite (expanded)	2.70	0.187
Vermiculite (exfoliated)	2.20	0.152
Sawdust or shaving	2.22	0.154

* Values are from ASHRAE Handbook of Fundamentals, 1977, American Society of Heating, Refrigerating and Air- Conditioning Engineers, Inc., New York.

8.4.9 Hot weather concreting

8.4.9.1 During hot weather, proper attention shall be given to ingredients, production methods, handling, placing, protection, etc. For details refer to "Hot Weather Concreting" recommended by ACI committee 305. [5.1, 10.4.9.1]

8.4.9.2 At higher temperatures greater amount of water is required to hold slump constant than is needed at lower temperatures. Adding water without adding cement results in a higher water-cement ratio, thereby lowering the late-age strength and adversely affecting other desirable properties of the hardened

concrete.

8.4.9.3 Besides reducing the strength and increasing the mixing water requirement, high temperatures of fresh concrete have other harmful effects. Setting time is reduced; high temperatures increase the rate of concrete hardening and thereby shorten the length of time within which the concrete can be transported, placed, and finished.

8.4.9.4 In hot weather the tendency to crack is increased both before and after hardening. Excessively rapid evaporation of water from plastic concrete can cause plastic-shrinkage cracks before the surface has hardened.

8.4.9.5 Air entrainment is also affected in hot weather. At elevated temperatures, concrete requires an increase in the amount of air-entraining admixture to obtain a given total air content.

8.4.9.6 .4.9.6. The usual method of maintaining low concrete temperatures is to control the temperature of the concrete materials. One or more of the ingredients should be cooled before mixing. In hot weather the aggregates and water should be kept as cool as practicable.

8.4.9.7 Cold water will effect a moderate reduction in the concrete temperature. It should be stored in tanks that are not exposed to the direct rays of the sun. Tanks and pipelines carrying the mixing water should be buried, insulated, shaded or painted white to keep water at the lowest practical temperature.

8.4.9.8 Water can be cooled by refrigeration, liquid nitrogen, or crushed ice.

8.4.9.9 Aggregates have a pronounced effect on the fresh concrete temperature because they present 60% to 80% of the total weight of concrete.

8.4.9.10 "Specification for Ready Mixed Concrete" (ASTM C 94) shall be followed which states that during hot weather the time limit required for discharge of concrete shall be completed within one hour or even 45 minutes.

8.4.9.11 Plastic cracking is usually associated with hot-weather concreting; however it can occur at any time when atmospheric conditions produce rapid evaporation of moisture from the concrete surface.

8.4.9.12 In hot weather and where careful inspection is maintained, a retarding admixture is beneficial in delaying the setting time while increasing the rate of slump loss. Retarding admixtures should conform to the requirements of ASTM C 494, Type B.

8.5 CONCRETING UNDER WATER

As a rule, only plain concrete placed by means of stationary tremies is suitable as underwater concrete.

Underwater concrete shall be placed rapidly and steadily. The water in the enclosure shall be still, i.e. there shall be no flow of current. It shall be possible for the levels of water inside and outside the enclosure to reach equilibrium.

For water depths up to 1 m, the concrete may be placed by carefully causing it to advance at its natural angle of flow without segregating. Prior to this, it shall be deposited above water level.

For water depths exceeding 1 m, the concrete shall be placed so that it does not fall freely through the water, avoiding the washing out of cement and, where possible, the formation of

interlayers of cement slurry.

For secondary structural members, the concrete may be deposited in successive layers using hops or traveling tremies standing on the foundation base or on the surface of the individual layers of concrete.

Stationary tremies or closed containers which project sufficiently far into concrete which has not yet set may be used for making all types of member provided that the formwork is adequately watertight.

Tremies shall be kept sufficiently immersed in concrete which has already been placed for this to be displaced sideward and upwards by the fresh quantity of concrete discharged by the tremies. At no point shall the displaced concrete come into contact with water. Stationary tremies shall be spaced so that the lateral flow distances of the concrete are as short as possible.

During concreting, the tremie shall be carefully raised, its discharge pipe remaining in the concrete. Where several tremies are used, they shall be simultaneously and uniformly fed with concrete.

When placing the concrete into tremies or other containers, it shall be compacted using immersion vibrators for air expulsion.

Alternatively, underwater concrete may be made by injecting low-segregation grout from below into a mass of suitably graded aggregate (i.e., not containing fines or medium sized particles), the grout rising at an even rate.

The slump of the concrete should be not less than 125 mm and the cement content not less than 350 kg/m^3.

Concrete should flow without segregation, therefore the aim in proportioning the mixture should be to obtain a good plastic mix with high workability.

Rounded aggregates with higher percentage of fines and entrained air will provide the desired consistency.

About 10% to 15% more cement should be used than for a similar mixture placed in dry air.

Additional provisions are referred to ACI 304 section 7.

8.6 MORTARS AND GROUTS

For general information reference is made to IPS-M-CE-105 and for grout for bonded prestresting tendons refer to Section 18.18 of ACI 318M.

8.7 INSTALLATION OF PIPES AND HOLES IN CONCRETE STRUCTURES

For more information see Iranian national concrete code publication No. 120 of management and planning organization part 9-7.

9.0 FORMWORK

9.1 GENERAL CONSIDERATIONS

The design, engineering and construction of the formwork shall be the responsibility of the contractor but will be subject to the approval by the AR. Typical drawings showing the proposed formwork shall be submitted by the contractor for approval by the AR before starting the construction.

Formwork should be designed so that concrete slabs, walls and other members will be of correct dimensions, shape, alignment, elevation and position within established tolerances. Vertical and lateral loads must be carried to the ground by the formwork system or by the in-place construction that has adequate strength for that purpose.

A design analysis should be made for all formwork, stability and buckling should be investigated in all cases.

9.2 FORMWORK DESIGN CONSIDERATIONS

9.2.1 Loads and unit stresses

Formwork and its supporting structure shall be designed to resist all vertical and horizontal forces. The design also should consider the effect of rate-of-discharge and the method of compaction. For supports and walls higher than 3 m, the rate at which the concrete is discharged shall be adjusted to the load bearing capacity of the formwork. Unit stresses for use in the design of formwork shall be in accordance with Section 2.3 of ACI 347.

When fabricated formwork, shoring, or scaffolding units are used, manufacturer's recommendations for allowable loads may be followed.

9.2.2 Shores and bracing

Shores are vertical or inclined support members which should be designed in such a manner to carry the weight of formwork, concrete and construction loads. Bracing should be provided in vertical and horizontal planes were required to provide stiffness and to prevent buckling of individual members. A rational analysis should be used to determine the number of floors to be shored, reshored and backshored and to determine the loads transmitted to the floors, shores and reshores or backshores as a result of the construction sequence. For detailed information refer to Chapter 2 of ACI 347R.

9.2.3 Foundations for formwork

Proper foundations on ground such as mudsills, spread footing, or pile footings should be provided. If soil under mudsills is or may become incapable of supporting superimposed loads without appreciable settlement, it should be stabilized or other means of support should be provided. No concrete should be placed on formwork supported on frozen ground.

9.2.4 Settlement

Formwork should be so designed and constructed that vertical adjustments can be made to compensate for take-up and settlements. In addition to the Design Considerations specified above, requirements of Section 6.1 of ACI 318Mshall be satisfied.

9.3 MATERIALS FOR FORMWORK

9.3.1 GENERAL

The selection of materials suitable for formwork should be based on maximum economy to the project, consistent with safety and the quality required in the finished work, subject to approval by the AR.

9.3.2 PROPERTIES

The formwork materials commonly used consists of timber, plywood, steel, concrete, brick, plastics, fiberglass, etc. For more details refer to Chapter 4 of ACI 347.

9.3.2.1 FORM SHEATHING

Sheathing is the supporting layer of formwork closest to the concrete. It may be in direct contact with the concrete or be separated from it by a form liner.

In selection and use of materials important considerations are: strength, stiffness, release, reuse and cost per use, surface characteristics, resistance to mechanical damage, workability for cutting, drilling and attaching fasteners, adaptability to weather and extreme field conditions, temperature and moisture, weight and ease of handling.

9.3.2.2 STRUCTURAL SUPPORTS

Structural support systems carry the sheathing for which important considerations are: strength, stiffness, dimensional accuracy and stability, workability for cutting, drilling and attaching fasteners, weight, cost and durability.

9.3.2.3 ACCESSORIES

Accessories consist of: form ties, form anchors, form hangers and side form spacers. For more details of accessories refer to Section 4.3 of ACI 347.

9.3.3 FORM COATINGS OR RELEASE AGENTS

Form coatings or sealers are usually applied in liquid form to contact surface either during manufacturer or in the field to serve one or more of the following purposes:

a. Alter the texture of the contact surface.
b. Improve the durability of the contact surface.
c. Facilitate release from concrete during stripping.
d. Seal the contact surface from intrusion of moisture.

Form release agents are applied to the form contact surfaces to prevent bond and thus facilitate stripping. They can be applied permanently to form materials during manufacture or applied to the form before each use. When applying in the field, be careful to avoid coating adjacent construction joint surfaces or reinforcing steel.

Generally manufacturer's recommendations should be followed in the use of coatings, sealers, and release agents, but independent investigation of the performance by specialized organizations is recommended before use.

9.4 CONSTRUCTIONAL ASPECT

9.4.1 SAFETY PRECAUTIONS

Construction procedures must be planned in advance to insure the safety of personnel and the integrity of the finished structure. Some of the safety provisions which should be considered are:

- Erection of safety signs and barricades to keep unauthorized personnel clear of areas in which erection, concrete placing, or stripping is underway.
- Providing experienced foremen during concrete placement to assure early recognition of possible form displacement or failure.

- A supply of extra shores or other material and equipment that might be needed in an emergency case.
- Provision for adequate illumination of the formwork;
- Provision of a program of field safety inspections of formwork, etc.

9.4.2 CONSTRUCTION PRACTICES AND WORKMANSHIP

Generally the following should be considered:

- Joints or splices in sheathing, plywood panels and bracing should be staggered.
- Forms should be sufficiently tight to prevent loss of mortar from the concrete.
- Forms should be inspected and checked before the reinforcing steel is placed to insure that the dimensions and location of the concrete members conform to the working drawings.

- Forms should be checked for camber when specified.
- Control joints, construction joints, and expansion joints should be installed as specified.
- Forms should be thoroughly cleaned of all dirt, mortar, and foreign matter and coated with a release agent before each use.
- Building materials, including concrete, must not be dropped or piled on the formwork in such manner as to damage or overload it.

For other provisions refer to ACI 347 section 3.2.

9.4.3 TOLERANCES FOR STRUCTURES AND IRREGULARITIES IN FORMED SURFACES

Tolerance is a specified permissible variation from lines, grades, or dimensions given in contract documents. Tolerances for concrete structures should comply with the requirements of ACI 117 and Section 3.3 of ACI 347. Where tolerances are not stated in the specifications or drawings for any individual structure permissible deviations from established lines, grades, and dimensions shall follow the recommendations stated under Section 3.3 of ACI 347. The contractor is expected to set and maintain concrete forms so as to insure execution of works within the tolerance limits.

9.4.4 SHORING AND CENTERING

Shoring must be supported on satisfactory foundations such as spread footing, mudsills or piling. All members must be straight and true without twists or bends.

Vertical shores must be erected so that they cannot tilt and must have firm bearing. Inclined shores must be braced securely against slipping or sliding. Centering is the highly specialized temporary support system used in the construction of any continuous structure, where the entire temporary support is lowered as a unit. The lowering of the centering is generally accomplished by the use of sand boxes, jacks or wedges beneath the supporting members.

9.4.5 REMOVAL OF FORMS AND SUPPORTS

When the contract documents do not specify the minimum strength required of concrete at the time of stripping, the following elapsed times (period before removal of formwork) which are adopted from ACI 347 (sec.3.7.2.3) can be used. The times represent a cumulative number of days, or hours, not necessarily consecutive, during which is the temperature of the air surrounding the concrete above 10 °C. If high early-strength concrete is used, these periods can be reduced as approved by the AR. Conversely, if ambient temperatures remain below 10 °C, or if retarding agents are used, then these periods should be increased at the discretion of the AR. Shorter stripping times listed for live load to dead load ratios greater than 1.0 are the result of more reserve strength being available for dead load in absence of live load at time of stripping.

Walls..... 12 h

Columns..... 12 h

Sides of beams and girders... ..... 12 h

Pan joist forms

760 mm wide or less .....3 days

Over 760 mm wide.....4 days

structural live load less than structural dead load	structural live load more than structural dead load
Arch cent. 14 days	7 days

Joist, beam or girder soffits:

Under 3 m clear span between structural supports	7 days 4 days
3 to 6 m clear span between structural supports…….....14 days	7 days
Over 6 m clear span between structural supports…….....21 days	14 days

One-way floor slabs

Under 3 m clear span between structural supports……..4 days	3 days
3 to 6 m clear span between structural supports…….....7 days	4 days
Over 6 m clear span between structural supports……...10 days	7 days

For other members elapsed times and more detailed information see section 3.7 of ACI 347.

9.5 FORMWORK FOR SPECIAL METHODS OF CONSTRUCTION

9.5.1 GENERAL

Special formworks like slip forms, permanent forms, etc. are often encountered in the construction of Petroleum Industry's different projects. In the following clauses short description is presented for such instances. For more detailed information refer to Chapter 7 of ACI 347.

9.5.2 SLIP FORMS

Horizontal and vertical slip forms should be designed and constructed and the sliding

operation should be carried out under the supervision of a person or persons experienced in slip form work.

Maximum rate of slide should be limited by the rate for which the forms are designed. The level of the hardened concrete in the form must be checked frequently by the use of a probe to establish safe lifting rates.

Care must be taken to prevent drifting of the forms from alignment or designed dimensions, and to prevent torsional movement.

Detailed records of both vertical and lateral form movements should be maintained throughout the slipform operation.

For more detailed information refer to Section 7.3 of ACI 347.

9.5.3 PERMANENT FORMS

Permanent forms are forms left in place that may or may not become and integral part of the structural frame. Particular care should be taken in the design of such forms to minimize distortion or deformation of the form or supporting members under the construction loads.

The contractors should submit fully detailed shop drawings for all permanent forms to AR for review and approval. For more detailed information refer to Section 7.4 of ACI 347.

9.5.4 FORMS FOR PRECAST CONCRETE

This type of forms is used for precast concrete items that may be either load bearing or non load-bearing members for structural or architectural use.

To assure uniformity of appearance in the cast members, care should be taken that the contact surfaces are of uniform quality and texture. Where required to allow early reuse of forms, provisions should be made to use accelerated curing processes, such as steam curing, or other approved methods. Methods of lifting precast units from forms should be approved by the AR.

9.5.5 OTHER TYPES OF SPECIAL METHODS

For detailed information on forms for pre stressed and precast concrete and concrete placed underwater refer to Sections 7.5, 7.6 and 7.8 of ACI 347.

9.6 ACCEPTANCE OF FINISHING FORMED SURFACES

When a specific finish is not specified in Contract Documents for a concrete surface, apply the following finishes:

- Rough-Form Finish on Concrete Surfaces not exposed to Public View:
- Patch tie holes and defects. Chip or rub off fins exceeding 1/2 in. in height. Leave

surfaces with the texture imparted by the forms.

Smooth-Form Finish on Concrete Surfaces Exposed to Public View:

Patch tie holes and defects. Remove fins exceeding 1/8 in. in height.

9.7 CRACK CONTROL

Regarding construction aspects for control of cracking refer to section 8 of ACI 224R (control of cracking by proper construction practice).

10.0 CONSTRUCTION AND CONTRACTION (CONTROL) JOINTS

10.1 CONSTRUCTION JOINTS

Construction joints are merely stopping places in the process of construction. A true construction joint should bond new concrete to existing concrete and permit neither horizontal nor vertical movement.

Surface of concrete construction joints shall be cleaned and laitance removed. Immediately before new concrete is placed, all construction joints shall be wetted and standing water removed.

Construction joints shall be so made and located as not to impair the strength of the structure. Provision shall be made for transfer of shear and other forces through construction joints.

Construction joints in floors shall be located within the middle third of spans of slabs, beams, and girders. Joints in girders shall be offset a minimum distance of two times the width of intersecting beams.

Beams, girders, or slabs supported by columns or walls shall not be cast or erected until concrete in the vertical support members is no longer plastic.

Beams, girders, haunches, drop panels and capitals shall be placed monolithically as part of a slab system, unless otherwise shown in design drawings or specifications.

More detailed information are referred to ACI 224-3R

10.2 CONTRACTION (CONTROL) JOINTS

Control joints should be constructed to permit transfer of loads perpendicular to the plane of the slab or wall.

The spacing of control joints in floors on ground depend on (1) slab thickness, (2) shrinkage

potential of the concrete and (3) curing environment.

Control joints in walls should be spaced not more than about 6 m apart. In addition control joints should be placed where abrupt changes in thickness or height occurs, and near corners-if possible as close as 1500 mm.

More detailed information are referred to ACI 224-3R

11.0 DETAILS OF REINFORCEMENT

11.1 STANDARD HOOKS

The term "standard hook" as used in this Standard shall mean one of the following:

180-deg bend plus $4d_b$ extension, but not less than 60 mm at free end of bar.

90-deg bend plus 12 d_b extension at free end of bar.

For stirrups and tie hooks:

a. Φ16 bar and smaller, 90-deg bend plus 6 d_b extension at free end of bar, or
b. Φ20 and Φ25 bar, 90-deg bend plus 12 d_b extension at free end of bar, or
c. Φ25 bar and smaller, 135-deg bend plus 6 d_b extension at free end of bar.

11.2 MINIMUM BEND DIAMETERS

Diameter of bend measured on the inside of the bar, other than for stirrups and ties in sizes No. 10 through No. 16 shall not be less than the values in Table 12.

Inside diameter of bend for stirrups and ties shall not be less than 4 db for Φ15 bar and smaller. For bars larger than Φ16, diameter of bend shall be in accordance with Table 12.

Inside diameter of bend in welded wire fabric (plain or deformed) for stirrups and ties shall not be less than 4 db for deformed wire larger than D6 and 2 db for all other wires. Bends with inside diameter of less than 8 db shall not be less than 4 db from nearest welded intersection.

TABLE 12 - MINIMUM DIAMETERS OF BEND	
BAR SIZE	**MINIMUM DIAMETER**
No.10 through No.25	6 d_b

No.30, 32, 36	8 d_b
No.45 and No.55	10 d_b

11.3 BENDING

All reinforcement shall be bent cold, unless otherwise permitted by the AR.

Reinforcement partially embedded in concrete shall not be field bent, except as shown on the design drawings or permitted by the AR.

11.4 SURFACE CONDITIONS OF REINFORCEMENT

At time concrete is placed, metal reinforcement shall be free from mud, oil, or other nonmetallic coatings that adversely affect bonding capacity.

Metal reinforcement, except per stressing tendons, with rust, mill scale, or a combination of both shall be considered satisfactory, provided the minimum dimensions (including height of deformations) and weight of a hand-wire brushed test specimen are not less than applicable ASTM specification requirements.

Pre stressing tendons shall be clean and free of oil, dirt, scale, pitting and excessive rust. A light oxide is permissible.

11.5 PLACING REINFORCEMENT

Reinforcement, prestressing tendons, and ducts shall be accurately placed and adequately supported before concrete is placed, and shall be secured against displacement within tolerances permitted in sub clause 13.5.2.

Unless otherwise specified by the AR, reinforcement, prestressing tendons, and prestressing ducts shall be placed within the following tolerances:

Tolerance for depth d and minimum concrete cover in flexural members, walls and compression members shall be as follows:

TABLE 13 – TOLERANCE FOR DEPTH AND CONCRETE COVER

DEPTH	TOLERANCE ON d	TOLERANCE ON MINIMUM CONCRETE
d ≤ 200 mm	±10 mm	-10 mm
d >200 mm	±12 mm	-12 mm

Except that tolerance for the clear distance to formed soffits shall be minus 6 mm, and tolerance for cover shall not exceed minus 1/3 the minimum concrete cover required in the design drawings or specifications.

Tolerance for longitudinal location of bends and ends of reinforcement shall be ±50 mm except at discontinuous ends of members where tolerance shall be ±25 mm.

Welded wire fabric (with wire size not greater than W5 or D5) used in slabs not exceeding 3 m in span may be curved from a point near the top of slab over the support to a point near the bottom of slab at mid span, provided such reinforcement is either continuous over, or securely anchored at support.

Welding of crossing bars shall not be permitted for assembly of reinforcement unless authorized by the AR.

11.6 SPACING LIMITS FOR REINFORCEMENT

11.6.1 Clear distance between parallel bars in a layer shall be not less than db but not less than 25 mm.

11.6.2 Where parallel reinforcement is placed in two or more layers, bars in the upper layers shall be placed directly above bars in the bottom layer with clear distance between layers not less than 25 mm.

11.6.3 In spirally reinforced or tied reinforced compression members, clear distance between longitudinal bars shall be not less than 1.5 db nor 40 mm.

11.6.4 Clear distance limitation between bars shall apply also to the clear distance between a contact lap splice and adjacent splices or bars.

11.6.5 In walls and slabs other than concrete joist construction, primary flexural reinforcement shall be spaced not farther apart than three times the wall or slab thickness, nor 500 mm.

11.6.6 Bundled bars:
Groups of parallel reinforcing bars bundled in contact to act as a unit shall be limited to four in any one bundle.

Bundled bars shall be enclosed within stirrups or ties.
Bars larger than Φ36 shall not be bundled in beams.

Individual bars within a bundle terminated within the span of flexural members shall terminate at different points with at least 40 db stagger.

Where spacing limitations and minimum concrete cover are based on bar diameter db, a unit of bundled bars shall be treated as a single bar of a diameter derived from the equivalent total area.

11.6.7 Prestressing tendons and ducts:

Clear distance between pretensioning tendons at each end of a member shall be not less than 5db for wire, or 4db for strands. Closer vertical spacing and bundling of tendons may be permitted in the middle portion of a span.

Post-tensioning ducts may be bundled if shown that concrete can be satisfactorily placed and if provision is made to prevent the tendons, when tensioned, from breaking through the duct.

11.7 CONCRETE PROTECTION FOR REINFORCEMENT

11.7.1 CAST-IN-PLACE CONCRETE (NONPRESTRESSED) :

The following minimum concrete cover shall be provided for reinforcement:

TABLE 14 – MINIMUM CONCRETE COVER – CAST IN PLACE	
Description	**Minimum Cover. mm**
Concrete cast against and permanently exposed to earth	75
Concrete exposed to earth or weather : No. 20 through No. 55 bars No. 16 bar, MW200 or MD200 wire and smaller	 50 40
Concrete not exposed to weather or contact with ground Slabs, walls, joists: No. 45 and No. 55 bars، No. 36 bar and smaller Beams, columns: Primary reinforcement, ties, stirrups, spirals Shells, folded plate members: : No. 20 bar and larger	 40 20 20 13
In contact with or above sea water: underside and sides of slabs top side of slab Beams	75 50 75

11.7.2 Precast concrete (manufactured under plant control conditions)

The following minimum concrete cover shall be provided for reinforcement

TABLE 15 – MINIMUM CONCRETE COVER – PRECAST CONCRETE	
Description	**Minimum Cover. mm**
Concrete exposed to earth or weather:	
Wall Panels:	
No. 45 and No. 55 bars, prestressing tendons larger than 40 mm Diameter	40
No. 36 bar and smaller, prestressing tendons 40 mm diameter and smaller, MW 200 and MD 200 wire and smaller	20
MD 200 و MW 200	50
Other members:	
No. 45 and No.55 bars, prestressing tendons larger than 40 mm diameter	40
No. 20 through No.36 bars, prestressing tendons larger than 16 mm diameter through 40 mm diameter	30
No. 16 bar and smaller, prestressing tendons	
Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists	30
No.45 and No.55 bars, prestressing tendons larger than 40 mm diameter	20
Prestressing tendons 40 mm diameter and smaller	10
No.36 bar and smaller, MW200 or MD200 wire and smaller	

Description	**Minimum Cover. mm**
Beams, columns	
Primary reinforcement… d_b but not less than 16 and need not exceed	40 10
Ties, stirrups, spirals	20
Shells, folded plate members	16
Prestressing tendons	10
No.20 bar and larger	

Description	Minimum Cover. mm
In contact with or above sea water: underside and sides of slab top side of slab beams	 75 50 75

11.7.3 Pre stressed concrete-cast in place

The following minimum concrete cover shall be provided for pre stressed and non pre stressed reinforcement, ducts, and end fittings, except as provided in Sections 13.7.3.2 and 13.7.2.

For pre stressed concrete members exposed to earth, weather, or corrosive environments, minimum cover shall be increased 50 percent.

TABLE 16- MINIMUM CONCRETE COVER – PRESTRESSED CAST IN PLACE

Description	Minimum Cover. mm
Concrete cast against and permanently exposed to earth	75
Concrete exposed to earth or weather: Wall panels, slabs, joists Other members	 25 40
Concrete not exposed to weather or in contact with ground: Slabs, walls, joists Beams, columns Primary reinforcement Ties, stirrups, spirals Shells, folded plate members: No.16 bar, MW200 or MD200 wire, and smaller Other reinforcement	 20 40 25 10 d_b but not less than 20

In contact with or above sea water: underside and sides of slab top side of slab beams	 75 50 75

11.8 BUNDLED BARS

For bundled bars, minimum concrete cover shall be equal to the equivalent diameter of the bundle, but need not be greater than 50 mm, except for concrete cast against and permanently exposed to earth, minimum cover shall be 75 mm.

11.9 CORROSIVE ENVIRONMENTS

In corrosive environments or other severe exposure conditions, amount of concrete protection shall be suitably increased, and denseness and nonporosity of protecting concrete shall be considered, or other protection shall be provided.

11.10 FUTURE EXTENSIONS

Exposed reinforcement, inserts, and plates intended for bonding with future extensions shall be protected from corrosion.

11.11 FIRE PROTECTION

When the general building standard requires a thickness of cover for fire protection greater than the minimum concrete cover specified in Clause 13.7, such greater thicknesses shall be according to IPS-E-CE-260.

For additional information regarding reinforcement details for columns, connections, lateral reinforcement for compression and flexural members, shrinkage and temperature reinforcements and requirements for structural integrity, reference is made to Chapter 7 of ACI 318M.

12.0 T-BEAM CONSTRUCTION

In T-beam construction, the flange and web shall be built integrally or otherwise effectively bonded together.

Width of slab effective as a T-beam flange shall not exceed one-quarter of the span length of the beam, and the effective overhanging flange width on each side of the web shall not exceed:

a) Eight times the slab thickness, and
b) One-half the clear distance to the next web.

For beams with a slab on one side only, the effective overhanging flange width shall not exceed:

a) one-twelfth the span length of the beam,
b) Six times the slab thickness, and
c) One-half the clear distance to the next web.

Isolated beams, in which the T-shape is used to provide a flange for additional compression area, shall have a flange thickness not less than one-half the width of web and an effective flange width not more than four times the width of web.

Where primary flexural reinforcement in a slab that is considered as a T-beam flange (excluding joist construction) is parallel to the beam, reinforcement perpendicular to the beam shall be provided in the top of the slab in accordance with the following:

Transverse reinforcement shall be designed to carry the factored load on the overhanging slab width assumed to act as a cantilever. For isolated beams, the full width of overhanging flange shall be considered. For other T-beams, only the effective overhanging slab width need be considered.

Transverse reinforcement shall be spaced not farther apart than five times the slab thickness, or 450 mm.

13.0 JOIST CONSTRUCTION

Joist construction consists of a monolithic combination of regularly spaced ribs and a top slab arranged to span in one direction or two orthogonal directions.

Ribs shall be not less than 100 mm in width; and shall have a depth of not more than 3-½ times the minimum width of rib.

Clear spacing between ribs shall not exceed 750 mm.

Joist construction not meeting the limitations of 15.1 through 15.3 shall be designed as slabs and beams.

When permanent burned clay or concrete tile fillers of material having a unit compressive strength at least equal to that of the specified strength of concrete in the joists are used:

For shear and negative-moment strength computations, it is permitted to include the vertical shells of fillers in contact with the ribs. Other portions of fillers shall not be included in strength computations.

Slab thickness over permanent fillers shall be not less than one-twelfth the clear distance between ribs, nor less than 40 mm.

In one-way joists, reinforcement normal to the ribs shall be provided in the slab as required by Clause 8.7 of IPS-E-CE-200.

When removable forms or fillers not complying with 15.5 are used:

Slab thickness shall be not less than one-twelfth the clear distance between ribs, nor less than 50 mm.

Reinforcement normal to the ribs shall be provided in the slab as required for flexure, considering load concentrations, if any, but not less than required by Clause 8.7 of IPS-E-CE-200.

Where conduits or pipes as permitted by Section 6.3 of ACI 318 M-89 are embedded within the slab, slab thickness shall be at least 25 mm greater than the total overall depth of the conduits or pipes at any point. Conduits or pipes shall not impair significantly the strength of the construction.

For joist construction, contribution of concrete to shear strength Vc is permitted to be 10 percent more than that specified in Clause 9. It is permitted to increase shear strength using shear reinforcement or by widening the ends of ribs.

14.0 EMBEDDED ITEMS

Anchor bolts 25mm dia. and larger shall be provided with a sleeve located near the top of the bolt and long enough to provide some flexibility for equipment setting. The sleeve length shall be ignored for bond length calculations and the space filled with a stiff or expanding grout prior to equipment base plate grouting. All sleeves, inserts anchors, and embedded items required for adjoining work or for its support shall be placed and securely located prior to concreting.
All anchor bolts shall be set with substantial templates locating the bolts with a tolerance in relation to the plant coordinate system of ±1mm for bolts up to 25 mm diameter and ±1.5mm. For anchor bolts larger than 25mm diameter. The axial alignment tolerance for anchor bolts shall not exceed ±1mm in the radial direction. (The more than this tolerance should be seen in design and detailing of structure and equipment)

"The tolerance for bolt projection shall be plus 3mm and minus 0"

Anchor bolts shall have a minimum clearance for 2.5 bolts diameter from the center line of bolts to edge of concrete, but not less than 100mm minimum distances between edge of sleeves and concrete shall be 75mm.

Contractor shall furnished and place embedded items before the concrete is placed.

Anchor bolts shall not be heated to facilities equipment installation.

Exposed bolt threads shall be protected by wrapping with prior to placing concrete.

14.1 PLACING EMBEDDED ITEMS

Expansion joints material, water-stops, and embedded items shall be positioned accurately and supported against displacement. Voids in sleeves, inserts, and anchor bolts shall be filled temporarily with readily removable material to prevent the entry of concrete into the voids. The resident engineer shall be given at least 24 hours check- out time after placement of embedded items and before depositing concrete.

15.0 FINISHING

15.1 FLAT WORK

Floor slabs, unless otherwise noted, shall be screened level, tamped with a grid tamper until a thin bed of grout forms on the surface, and then power – floated and finished as specified on the drawings.
Floor slabs scheduled to receive ceramic tile, Terrazzo or other grouted finished shall be screened to required elevations, boomed and left rough
.
Floor slabs of machine rooms, control rooms compressor and boiler rooms where no floor covering is required shall be finished to the given levels of falls and in addition shall be steel toweled by hand to a hard dense burnished finish.

All finished concrete surfaces of the same classification shall have the same texture throughout the project.

Where spillage of corrosive chemicals may occur, a suitable chemical resistant surfacing should be provided in order to protect the concrete paving and / or the structure.

Immediately after the forms have been removed, all exposed concrete surfaces shall be inspected for defects, and all fins, bulges, projections, honeycombing, and other defects repaired before the concrete is fully matured. Defective areas, such as honeycombed concrete, shall be cut back to solid concrete for repair, if before or during this operation any reinforcing bar is exposed the cutting out shall continue right round the bar to form a key. When reinforcing bars are so exposed, care should be taken to ensure that the bars or any other insets are not damaged by the tools used for cutting out the concrete.

Top surfaces of all exposed slabs and beams shall be given a steel toweled finish.

Top surface of foundation bases and plinths shall be finished with a wooden float and laitance removed by mechanical scabbing at a later date where required.

15.2 PAVING

Paving should be kept free from all obstructions liable to cause a trip hazard. Covers for cables and pipe trenches etc should be graded flush with the paving with hand grips sunk below. Open pits and sumps should be railed off. Paving should be finished generally at grade level around

the outer edges of plot limits falling inwards to drainage points with falls not exceeding 150mm and slope not greater than 1:80. All falls should be shown on drawings. Ridges should preferably be located along cable trenches, expansion joints and valleys along any pipe trenches. Pipe trenches should be drained.

After floating and before the concrete has set hard it shall be broomed using a stiff wire brush. This brooming operation should be carefully timed so that drag-up of soft concrete is avoided.

Ragged shrinkage cracks forming at the corners of large openings (2.5m X 2.5m and larger) also at the corner of re-entrant shapes shall be avoided by the installation of contraction joints placed along the line bisecting the angle formed by the corner.

16.0 PRECAST CONCRETE (IF NECESSARY)

The requirements of the clauses relating to concrete and reinforcement shall be observed in the case of pre-cast concrete in so far as they are applicable, as well as the following requirements relating to pre-cast work in particular.

All pre-cast concrete shall, unless particularly specified to the contrary, be mechanically vibrated.

The yard in which pre-casting work is to be undertaken shall be clean and shall have firm level beds, preferably of concrete, with drainage channels between the beds.

Where pre-cast units have projecting reinforcement, the moulds shall, if necessary, be raised on stools above the general level of the pre-casting yard.

The moulds shall be strongly constructed, closely jointed and true to the required shape with edges, corners and surfaces which comply with the particular specification moulds that can be taken apart and reassembled with ease.

All units are to be marked on a face, which shall not be exposed in the permanent works, with the date of manufacture and such distinguishing letters or numbers as the Resident Engineer may direct.

The maturing of pre-cast concrete shall be carried out as required by the Resident Engineer. Generally the procedure shall be as follows:

The sides of the moulds may be removed after not less than 12 hours provided the concrete has thoroughly set to the satisfaction of the Resident Engineer. All concrete surfaces shall be kept thoroughly wet for at least seven days during which time the surfaces shall be kept covered with hessian or other approved materials.

Slinging, transporting and stacking may take place ten days after casting, or as particularly specified. Building or setting in the work shall not be permitted until 28 days after casting. The time periods for above may be reduced where special techniques adopted such as vacuum or pressed concrete, steam curing or when rapid hardening cement is used, all as approved by the Resident Engineer.

Each pre-cast unit shall be constructed in one operation. No construction joints are to be formed unless shown on the drawings.

The faces of all units which are required to form a joint with in-situ construction shall be left well-roughened to ensure that an adequate key will be obtained.