STANDARD

FOR

MATERIALS FOR CONCRETE, MORTARS & ADMIXTURES

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1. SCOPE

This Material Standard gives minimum requirements for materials being used in concrete, mortars and admixtures as may be encountered in various civil engineering projects in the field of Petroleum Industries. The Standard deals with various constituents of the concrete but the process of mixing, placing, curing of concrete is discussed in IPS-C-CE-200, "Construction Standard for Concrete Structures".

This Standard is written in general terms and its application to any particular project may be subject to special requirements of the work under consideration.

2. REFERENCES

In this Standard the following standards and publications are referred to and to the extent specified form a part of this Standard.

2.1 Iranian Standards

IPS (IRANIAN PETROLEUM STANDARDS)

C-CE-200 "Construction Standard for Concrete Structures"

ISIRI (INSTITUTE OF STANDARDS AND INDUSTRIAL RESEARCH OF IRAN)

299-84	"Fine Sand for Cement Mortar"
300-84	"Fine Aggregate for Concrete and Reinforced Concrete"
302-84	"Sand for Concrete and Reinforced Concrete"
389 to 394	"Different Characteristics of Portland Cement"
320	"Standard for Lime"
706-82	"Mortar for Unit Masonry"
1692 to 1695	"Chemical Analysis of Portland Cement"
2761-88	"Code of Practice for Preservation and Storage of Cement in Construction Workshops"

Iranian National Building Code

Part 5	"Building Materials and Products"
Part 9	"Concrete Structures"

Iranian National Concrete Code

Publication No. 120 of Plan and Budget Organization

2.2 American Standards

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

C 33-86	"Specification for Concrete Aggregates"
C 144-87	"Specification for Aggregate for Masonry Mortar"
C 150-86	"Specification for Portland Cement"
C 494-86	"Specification for Chemical Admixtures for Concrete"

C 270-89	"Specification for Mortar for Unit Masonry"
C 260-86	"Specification for Air-Entraining Admixtures for Concrete"
C 1017-85	"Specification for Chemical Admixtures for Use in Producing Flowing Concrete"
C 109-88	"Test Method for Compressive Strength of Hydraulic Cement Mortars"
C 309-89	"Specification for Liquid Membrane-Forming Compounds for Curing Concrete"
A 416-88b	"Specification for Uncoated Seven-Wire Stress-Relieved Steel Strand for Prestressed Concrete"
A 421-80 (1985)	"Specification for Uncoated Stress-Relieved Wire for Prestressed Concrete"
A-722-88	"Specification for Uncoated High-Strength Steel Bar for Prestressing Concrete"

ACI (AMERICAN CONCRETE INSTITUTE)

ACI 318 M-89	"Building Code Requirements for Reinforced Concrete"
ACI 212.3 R-91	"Chemical Admixtures for Concrete"
ACI 116 R-89	"Cement and Concrete Terminology"

2.3 European Standards

DIN (DEUTSCHES INSTITUTE FÜR NORMUNG)

DIN 488-1984	"Reinforcing Steel", Part 1 to 7
DIN 1045-1988	"Structural Use of Concrete"

3. DEFINITIONS AND TERMINOLOGY

For general definitions refer to Chapter 2 of ACI 318M-89 and ACI 116R-89.

4. UNITS

This Standard is based on International System of Units (SI), except where otherwise specified.

5. CONCRETE MATERIALS

5.1 General

This Standard is mainly based on the instructions given in the National Iranian Concrete Code and in general the requirements of this Code should be carefully regarded. In cases where the tests or procedures mentioned in this Standard is not yet issued officially, the relevant ASTM standards should be regarded.

5.1.1 Selection and approval of materials

The materials to be used in preparation of concrete mixes should be selected in such a manner that the design regulations from the point of view of safety, structural performance, durability and appearance of the structure taking into account the environmental condition is maintained the percent of deleterious substances in concrete constituents should not exceed the admissible limits given in Tables 2, 3 and 4.

5.1.2 Material tests

In general the materials used in preparation of concrete mixes should meet the requirements of tests and specifications of ISIRI, Iranian National Concrete Code and Iranian National Building Code. If the tests or procedures are not available in Iranian standards the relevant ASTM or ACI and DIN standards (for reinforcement steel) should be regarded.

5.1.3 Storage and preservation of materials

All materials for concrete should be carefully stored and preserved. Cement and aggregates shall be stored in such manner as to prevent deterioration or instrusion of foreign matters. Reinforcing steel shall be protected as far as practicable from mechanical injury or surface deterioration; from rusting or other causes, from the time of shipment until it is placed. No reinforcing steel shall be exposed to rain, snow or damp weather condition. Any material that has deteriorated or contaminated shall be rejected.

5.2 Cement

5.2.1 Cement specification

Portland cement should meet the requirements of ISIRI 389 to 394 and 1692 to 1695. It is divided in 5 groups:

I - Ordinary portland cement

This type of cement should be used in ordinary concrete structures which have not any specific limitation.

II - Cement with moderate heat

This type of cement should be used in cases where moderate protection from sulfates are being considered, specially where both sulfates and chlorides are present simultaneously.

III - High strength cement

This type of cement should be used where early striking of formworks are needed.

IV - Low heat cement

This type of cement should be used where low hydration heat in concrete is necessary.

V - Sulfate-resisting cement

This type of cement should be used where severe attacks from sulfates are anticipated. It should however be noted that in environments where simultaneously sulfates and chlorides are present, use of this type of cement is not recommended, as it will aggravate the process of reinforcement corrosion. In such case usage of Type II cement may be more prudent.

5.2.2 Chemical tests

All chemical tests should meet the requirements of ISIRI Standards No. 1692 to 1695.

5.2.3 Physical and mechanical test

All physical and mechanical tests of cements should be according to ISIRI Standards No. 389 to 394.

5.2.4 Handling and storage of cement

Cement shall be delivered to the site in its original packages, containers and bundles bearing the name of manufacturer and brand. It should be stored off the ground, under cover and away from damp surfaces, to prevent caking or partial setting which would render the material ineffective or unusable. In general the requirements of ISIRI 2761 should be regarded.

5.3 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. In general nonpotable water shall not be used in concrete unless the following are satisfied:

- Selection of concrete proportions shall be based on concrete mixes using water from the same source.

- Concrete test cubes made with nonpotable mixing water shall have 7-day, and 28-day strengths equal to at least 90% of strengths of similar specimens made with potable water. These tests should be performed according to ASTM C109.

Table 1 gives the minimum requirements for water to be used in concrete mixes.

TABLE 1 - MAX. ADMISSIBLE LIMITS OF DELETERIOUS SUBSTANCES IN WATER TO BE USED FOR CONCRETE

ITEM	MAX. CONCENTRATION (ppm)
Suspended Solid Particles:	
- Reinforced concrete in severe environmental conditions and prestressed concrete.	1000
- Reinforced concrete in moderate environmental conditions and plain concrete.	2000
Soluble Substances:	
- Reinforced concrete in severe environmental conditions and prestressed concrete.	1000
- Reinforced concrete in moderate environmental conditions.	2000
- Plain concrete and concrete without embedded metallic items.	3500
Chlorides (Cl^-):	
- Reinforced concrete in severs environmental conditions, prestressed concrete, bridge decks.	500*
- Other reinforced concrete items, in humid conditions or having embedded aluminum items or permanent galvanized formworks.	1000*
- Plain concrete and concrete without embedded metallic items.	10000
Sulfates (SO_4):	
- Reinforced concrete and prestressed concrete.	1000*
- Plain concrete and concrete without embedded metallic items.	3000**
Alkalines ($Na_2O + 0.658\ K_2O$)	600

Notes:

*** The total amount of soluble chloride ions present in concrete mix should not exceed the values given in Table 2.**

**** The total amount of soluble sulfates (SO_3) in concrete mix (taking into account the SO_3 present in cement) should not exceed 4 percent of cement weight and in any case should not exceed 5 percent of cement weight (also see Table 6.3.3.3. of Iranian Concrete Code).**

TABLE 2 - MAX. ADMISSIBLE LIMIT OF SOLUBLE CHLORIDE ION IN WATER TO PREVENT CORROSION

TYPE OF CONCRETE STRUCTURE	MAX. AMOUNT OF SOLUBLE CHLORIDE IN CONCRETE, PERCENT OF THE CEMENT WEIGHT
Prestressed concrete	0.06
Reinforced concrete subject to humidity and attack of chlorides	0.15
Reinforced concrete in dry condition or protected from humidity	1.00
Other reinforced concrete structures	0.30

5.4 Aggregates

5.4.1 General

Aggregates shall conform to the requirements of ISIRI Standards No. 300 and 302. Concrete aggregates may be obtained from natural sands and gravels except when one or more of the following conditions exist, in which case crushed sand (stone crushed to fineness of sand) and crushed rock shall be used:

- When use of crushed stone is specified;

- when natural sands and gravels fail to provide the specified strengths or fall short of other specified requirements;

- when concrete with a compressive strength of 35 MPa or higher is required.

5.4.2 Size and gradation of aggregates

The maximum size of aggregates shall not exceed any of the following values:

- 1/5 th the narrowest dimensions between sides of forms, nor;

- 1/3 rd the depth of slabs, nor;

- ¾ th the minimum clear spacing between individual reinforcing bars or wires, bundle of bars or prestressing tendons or ducts.

Note:

Use of aggregates larger than 32 mm is not recommended in reinforced concrete; in any case aggregates larger than 63 mm should not be used.

For grading of aggregates in general the requirements of ASTM C33 should be regarded, depending on the specified conditions of each project and according to the mix specimen of concrete in each job. If no special requirement is specified the following grading for fine and coarse aggregates may be used:

GRADING FOR FINE AGGREGATES

SIEVE SIZE	PERCENT PASSING
9.5 mm	100
4.75 mm	95 to 100
2.36 mm	80 to 100
1.18 mm	50 to 85
600 µm	25 to 60
300 µm	10 to 30
150 µm	2 to 10

GRADING FOR COARSE AGGREGATES

SIEVE SIZE	PERCENT PASSING
37.5 mm	100
25 mm	90 to 100
19 mm	20 to 55
12.5 mm	0 to 10
9.5 mm	0 to 5

5.4.3 Quality of aggregates

Aggregate to be used in concrete mixes should be hard and durable and the amount of deleterious materials present should not be more than values specified in Tables 3 and 4.

5.4.4 Storage

Aggregates shall be stored in a manner to prevent deterioration or the instrusion of foreign matters. Any material which has been deteriorated or damaged shall not be used for concrete. Aggregates shall be furnished and stored in sufficient separate sizes in order to prevent segregation of sizes in handling.

TABLE 3 - LIMITS FOR DELETERIOUS SUBSTANCES IN FINE AGGREGATE FOR CONCRETE

ITEM	WEIGHT (PERCENT OF TOTAL SAMPLE, MAX.)
Clay lumps and friable particles	3
Materials finer than No. 200 sieve (75 μm): - Concrete subject to abrasion. - All other concrete.	 3* 5*
Coal and lignite: - Where surface appearances of concrete is of importance. - All other concrete.	0.5 1.0
Mica	1.0
Sulfates (SO_3)	0.4**
Chlorides (Cl^-)	0.04***

Notes:

*** In the case of manufactured sand if the material finer than N0. 200 (75 μm) sieve consists of the dust of fracture, essentially free of clay or shale, these limits may be increased to 5 and 7% respectively.**

**** The total amount of soluble sulfates (SO_3) in the concrete mix (taking into account the SO_3 present in the cement), should not exceed 4% and in any case the total amount of sulfates should not exceed 5% of cement weight.**

***** The total amount of soluble chlorides in the concrete mix should not exceed the values given in Table 2.**

TABLE 4 - LIMITS FOR DELETERIOUS SUBSTANCES IN COARSE AGGREGATES FOR CONCRETE

ITEM	WEIGHT (PERCENT OF TOTAL SAMPLE, MAX.)
Clay lumps	0.25
Friable particles	5*
**Chert as impurities for concrete: Subject to environmental conditions. - Severe - Moderate - Negligible	 1 3 5
Material finer than No. 200 (75 μm) sieve	1***
Coal, lignite and other lightweight materials: - Where surface appearance of concrete is of importance. - All other concrete	 0.5 1
Friable particles including sum of clay lumps, friable particles, weathered chert, shales and laminated schists: - Exposed concrete - Concrete under abrasion - Other concrete	 3 5 7
Sulfates (SO_3)	0.4****
Chlorides (Cl^-)	0.02*****

Notes:

*** This limitations apply only where the friability of each individual grain of coarse aggregate is critical, such as floors subject to high traffic or concrete surfaces where hardness of the surface is of special importance.**

**** This type of chert will be disintegrated in 5 cycles of roundness test, or 50 cycles of thawing and freezing test (0 to 4 degree centigrade) or its density is less than 2.35. These limitations apply only to aggregates in which chert appears as an impurity; they are not applicable to gravels that are predominantly chert.**

***** In case of manufactured coarse aggregates if the materials finer than No. 200 (75 μm) sieve are essentially free from clay or shale, these limit may be increased to 1.5 percent.**

****** The total amount of sulfates (SO_3) in the concrete mix (taking into account the SO_3 present in the cement) should not exceed 4% and in any case the total amount of sulfates should not exceed 5% of cement weight.**

******* The total amount of soluble chlorides in the concrete mix should not exceed the values given in Table 2.**

5.5 Reinforcement

5.5.1 General

Reinforcing steel available in Iranian markets can be classified as AI, AII, AIII and AIV which are corresponding to S220, S300, S400, and S500 steels in which the figures stated after "S" denote the characteristic yield strength of the steel f_{yk} in terms of MPa. In case of any discrepancies, DIN 1045 and DIN 488 should be consulted.

5.5.2 Mechanical characteristics

a) Factory tests

When specified by AR* it is necessary to test the reinforcing steels in the factory. In accordance with Clause 4.4 of Iranian National Concrete Code. Every shipment weighting 20 ton with equal nominal diameter should be tested.

b) Site tests

After delivery of the reinforcing steel to the site it should be tested. Only in case the total weight of required reinforcement for entire project is less than 50 ton the tests may be omitted by agreement with AR.

5.5.3 Size and form of reinforcing steel

Both plain and deformed bars may be used unless otherwise specified in the specifications and depending on the requirements of the job where use of only deformed bars are stipulated. The nominal size of reinforcing steel is categorized as follows:

6, 8, 10, 12, 14, 16, 20, 22, 24, 26, 28, 32, 40, 50 mm

5.5.4 Prestressing tendons

Tendons for prestressed reinforcement shall conform to one of the following specifications:

- ASTM A416
- ASTM A421
- ASTM A722

*** AR = Authorized Representative of the Owner.**

5.5.5 Storage

All reinforcing steel shall be protected as far as practicable from mechanical injury or surface deterioration from rusting or other causes from the time of shipment until it is placed. No reinforcing steel shall be exposed to rain, snow or damp weather condition without some acceptable protection for long periods of time.

5.6 Admixtures

5.6.1 General

Any admixture should be tested prior to its application and no claim of manufacturers' should be accepted without presentation of valid certificates of such tests. The efficiency of admixtures should be controlled prior to their usage. If more than one admixture is to be used, their compatibility should be investigated before the use. The main types of admixtures are discussed under Clause 5.6.2 to 5.6.8.

Calcium chloride as an admixture shall not be used in concrete to be exposed to severe or very severe sulfate-containing solutions and in reinforced or prestressed concrete.

5.6.2 Water-reducing admixtures and workability aids

These materials are also commonly called plasticizers and have the effect of making concrete more workable for a given water content. They can also reduce the water/cement ratio for a constant workability and can therefore be used to improve strength development.

Plasticizers for mortars are used to give plasticity or cohesion. These admixtures should meet the requirements of ASTM C494 and ASTM C1017.

5.6.3 Superplasticizers and high range water reducing admixtures

The more specialized admixture perform similar functions to normal plasticizers, but with increased effectiveness. Because of their very effective action on the fluid properties of the concrete, much closer control of the initial mix design and subsequent batching is needed to prevent excessive bleeding or segregation of the mix. This admixtures should meet the requirements of ASTM C494 and ASTM C1017.

5.6.4 Air-entraining agents

These admixtures are widely used especially for paving concrete. Their importance is related to the capacity of concrete containing a small amount of air in the form of well-distributed small bubbles to have greater resistance to destructive action of freezing and thawing when the concrete is saturated than similar concrete made without air entraining agents. These admixtures should meet the requirements of ASTM C260.

5.6.5 Accelerators and antifreezes

These are used to hasten the hardening of concrete particularly in cold weather. The term "antifreeze" is misleading because these admixtures merely lessen the period when frost damage is likely; they do not prevent concrete from freezing. These admixtures should meet the requirements of ASTM C494.

5.6.6 Retarders

These have the effect of delaying the onset of hardening and usually also of reducing the rate of the reaction when it starts. Ultimate strengths are unaffected by retardation for several hours but may reduce if the addition of retarder is

excessive. Trial mixes are essential to determine the dosage at which the retarder is to be used. These admixtures should meet the requirements of ASTM C494.

5.6.7 Mixed admixtures

Mixed admixtures containing a variety of materials are available. Examples are combinations of an air-entraining admixture with water-reducing admixture, or water-reducing admixture and retarding admixture. In case of mixed admixtures special tests should be performed on the initial samples and the results retained for reference and comparison with the instructions of the manufacturers. AR's approval shall be obtained prior to use of any mixed admixtures.

5.6.8 Other admixtures

These include waterproofers, viscosity modifiers, resin bonding agents, fungicides etc. They may be useful for specific application but the claims made for them by the manufacturers should be supported by impartial test results. This applies particularly to the permanence of the effects claimed. For more detailed information refer to ACI 212.3R-91.

5.6.9 Storage

The admixture shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a weathertight store that will protect the admixture from dampness and freezing.

6. MORTARS

6.1 General

In this clause mortars for unit masonry are discussed. They consist mainly of cement lime and mixed (cementlime) mortars. In addition to regarding ISIRI Standards and "Iranian National Building Code", Part 5 in this respect, where necessary ASTM C270 also should be considered.

6.1.1 Cementitious materials

Cementitious materials to be used in mortars consist of cement and lime.

6.1.1.1 Cement

Different types of cements are available; they are described in Clause 5.2 of this Standard. Unless otherwise specified the cement used shall be Type I ordinary Portland cement conforming to ISIRI No. 389 through 394 and produced by recognized manufacturers.

6.1.1.2 Lime

Lime shall meet the requirements of ISIRI No. 370. Lime shall be either in powder form (pulverized hydrated lime) or putty (quicklime). When mixed with water to form a plastic paste, it shall be used within 24 hours.

6.1.2 Water

Water to be used in preparation of mortars shall be from an approved source. It shall be clean, free from deleterious organic and inorganic matters, oil and dissolved salts. In case of doubt AR may require an analysis of the water. Seawater, tidal estuary or brackish water shall not be used. In general, water suitable for drinking is normally good for mortars.

6.1.3 Aggregates

Fine aggregate shall consist of natural silica sand or manufactured sand or a combination of both or other approved inert material with similar characteristics. The sand shall be well graded conforming to the following gradation limits:

PARTICLE SIZE (mm)	PERCENTAGE PASSED
3.0	100
1.0	35 to 60
0.5	10 to 30
0.2	0 to 6

Fine aggregates should meet the requirements of ISIRI No. 299 and should be free from deleterious materials. The amount of deleterious substances in aggregate for masonry mortar shall not exceed the following:

DESCRIPTION	MAXIMUM PERMISSIBLE WEIGHT (PERCENT)
Friable particles	1.0
Lightweight particles floating on liquid having a specific gravity of 2.0	0.5

The aggregate shall be free from injurious amounts of organic impurities.

6.1.4 Admixtures

Admixtures such as coloring pigments, air-entraining agents, accelerators, retarders, water-repellent agents, antifreeze compounds and other admixtures shall not be added to mortars, unless specified by AR. Calcium chloride when explicitly mentioned in specifications may be used as an accelerator in amounts not exceeding 2% by weight of the Portland cement content or 1% by weight of the masonry cement content. If calcium chloride is allowed it should be used with caution, as it may have a detrimental effect on metals embedded in the mortar.

6.2 Cement Mortars

Cement mortars should be prepared in amounts needed for immediate application and mortars which have been kept for more then 1 hour should be discarded. For ordinary walls a ratio of 1:4 by volume of cement and washed sand should be used. For tuck-pointing this ratio should be 1:2 to 1:3. For plastering 1:3 to 1:4 and for plastering water retaining structures 1:3. The cement mortar shall be kept wet at least for one week to prevent shrinkage and cracking.

6.3 Lime Mortar

This mortar may be used for surfaces which are in contact with moisture. It consist of 1:3 by volume of lime and fine sand.

6.4 Mixed (Cement-lime) Mortar

To reduce the amount of cement, mixed mortars may be used. It consists of 1 part Portland cement, 8 parts fine sand and 3 parts lime putty (by volume). After placement of such mortar it should be kept damp for at least 48 hours.

6.5 Grouts

Grout is a mixture of cement and sand with sufficient pouring consistency; its use shall be limited only to such pumps or machine bed plates and small compressors without significant out of balance forces. The grout should be poured under a suitable head and tamped sufficiently until all the spaces under the base plate is completely filled.

An approved grout admixture should be added to the cement-sand mix. The use of a grouting pump for injecting underneath large spaces is strongly recommended. The mix shall consist of one part Portland cement and two parts sand by volume, thoroughly mixed.

Large machines or any machine with larger out of balance forces should be grouted in accordance with the manufacturer's requirements using a non-shrinkable epoxy grout comforming to ASTM C309.