CONSTRUCTION STANDARD

FOR

FOUNDATIONS, PILES AND RETAINING WALLS

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1. SCOPE

This Standard deals with procedures relevant to the construction of foundations, piles and retaining walls as may be encountered in various civil engineering projects in the field of petroleum industries. The Standard covers shallow and deep foundations generally used in buildings with normal range of complexity, as well as foundations subject to dynamic loads from machinery. It also includes constructional procedures for piles and retaining walls and slope protections.

2. REFERENCES

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

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-M-CE-105	"Building Materials"
IPS-E-CE-110	"Soil Engineering"
IPS-C-CE-112	"Earthworks"
IPS-E-CE-120	"Foundations"
IPS-E-CE-130	"Piles"
IPS-M-CE-165	"Materials for Concrete, Reinforced Concrete, Mortars and Admixtures"
IPS-C-CE-200	"Concrete Structures"
IPS-E-CE-470	"Onshore Facilities"
IPS-C-CE-470	"Construction Standard for Onshore Facilities"
IPS-E-CE-210	"Steel Structures"
IPS-E-TP-220	"Electrochemical Protection"

BSI (BRITISH STANDARDS INSTITUTION)

BS 1377: 1975	"Methods of Test for Soils for Civil Engineering Purposes"
BS 3921: 1985	"Specification for Clay Bricks"
BS 5268: 1989 Part 2	"Code of Practice for Permissible Stress Design, Materials and Workmanship (Timber)"
BS 5930: 1981	"Code of Practice for Site Investigation"
BS 5606: 1978	"Code of Practice for Accuracy in Building"
BS 6031: 1981	"Code of Practice for Earthworks"
BS 6073: 1981 Part 1	"Specification for Precast Concrete Masonry Units"
BS 6349: 1984 Part 1	"Maritime Structures, General Criteria"
BS 6349: 1984 Part 2	"Maritime Structures, Design of Quay Walls, Jetties and Dolphins"

BS 8004: 1986	"Code of Practice for Foundations"
BS 2654: 1989	"Standard Specification for Manufacture of Vertical Steel Welded Non-Refrigerated Storage Tanks with Butt-Welded Shells for Petroleum Industry"
CP 2012: 1974 Part 1	"Foundations for Reciprocating Machines"

API (AMERICAN PETROLEUM INSTITUTE)

API Std. 650 8th Ed., 1988	"Welded Steel Tanks for Oil Storage"

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

C 29-78	"Test Method for Unit Weight and Voids Aggregate"
C 127-88	"Test Method for Specific Gravity and Absorption of Coarse Aggregate"
C 128-8	"Test Method for Specific Gravity and Absorption of Fine Aggregate"
C 131-87	"Test Methods for Resistance to Degradation of Small Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine"
C 88-83	"Test Methods for Soundness of Aggregates, by Use of Sodium Sulfate or Magnesium Sulfate"
C 150-86	"Specification for Portland Cements"
C 595-86	"Specification for Blended Hydraulic Cements"
C 33-86	"Specification for Concrete Aggregates"
C 330-87	"Specification for Lightweight Aggregates for Concrete Masonry Units"
A 328 M-88	"Specification for Steel Sheet Piling"
C 145-75 (1981)	"Specification for Solid Load-Bearing Concrete Masonry"
D 1559-82	"Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus"

AASHTO (THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS)

Standard Specification for Highway Bridges, 14th Ed., 1989

3. DEFINITIONS AND TERMINOLOGY

Most of terms related to construction of foundations, piles and retaining walls are defined in relevant IPS Standards, i.e., IPS-E-CE-140 "Retaining Walls", IPS-E-CE-130 "Piles", IPS-E-CE-120 "Foundations".

For detailed information reference is made to the above mentioned IPS Standards in this Standard.

4. UNITS

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

5. CONSTRUCTION MATERIALS

5.1 General

The materials covered by this clause include the basic materials generally used in the construction of foundations, pilings and retaining walls. The materials covered in this clause are as follows:

a) stone and masonry;
b) concrete;
c) structural steel;
d) timber.

In addition to the above mentioned materials, protective measures are briefly discussed in the following sub-clauses.

5.2 Stone and Masonry

a) Stone

Natural stone to be used in construction of retaining walls, and foundation works should be hard and of best quality, with good durability. It should be free from laminations and weak cleavage planes, and should not disintegrate or erode due to the action of air, water, wetting and drying, freezing and thawing. Test procedures for quality of rock should comply with IPS-E-CE-110, IPS-M-CE-105 and/or the following Standards:

BS 1377: 1975	"Methods of Test for Soils for Civil Engineering Purposes"
ASTM Designation C 29-78	"Test Methods for Unit Weight and Voids in Aggregate"
ASTM Designation C 127-82	"Test Method for Specific Gravity and Absorption of Coarse Aggregate"
ASTM Designation C 88-83	"Test Methods for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate"

b) Masonry

Materials and workmanship should be of the highest quality in order to provide satisfactory durability. Clay bricks and blocks should comply with BS 3921 and IPS-M-CE-105. They should have a high frost resistance, and the soluble sulfate radical content measured according to BS 3921 should be less than 0.5%. Concrete blocks and their use should comply with BS 6073: Part 1.

5.3 Concrete

5.3.1 Constituent materials

The specification of materials and workmanship for concrete should comply with IPS-C-CE-200 and IPS-M-CE-165.

5.3.2 Chemical attack and prevention of corrosion

For durable concrete the requirements of IPS-C-CE-200 should be carefully observed. Where the quality of workmanship is in doubt, precast concrete may have advantages, as it is produced in controlled conditions. For more details refer to IPS-C-CE-200.

5.4 Structural Steel

Structural steel should conform to the specification and minimum strength level, group and class specified in IPS-E-CE-210 "Steel Structures".

Corrosion protection should comply with IPS-E-TP-720 "Electrochemical Protection".

For details of corrosion of mild steel in soils and in the case of piling refer to Clause 10.3.5 of BS 8004: 1986.

5.5 Timber

Timber has a very limited use in oil industries. In cases where use of timber is indispensable the following standards should be referred to:

BS 5268: 1989 Part 2 "Code of Practice for Permissible Stress Design, Material and Workmanship (Timber)"

BS 8004: 1986 "Code of Practice for Foundations (Clause 10.2)"

6. CONSTRUCTION PROCEDURES

6.1 General

Engineering aspects of foundations, piles and retaining walls are discussed in IPS-E-CE-120, IPS-E-CE-130 and IPS-E-CE-140 respectively. In the following clauses, constructional aspects of the same are discussed.

Foundation should be set out by establishing a series of profiles around the excavation. For additional information on setting out of foundations, refer to BS 5606: 1978.

For piles and diaphragm walls, centerlines for each base or pile group should primarily be established and then each pile position located using those setting-out reference lines.

For diaphragm walls the verticality of the wall excavation must be checked regularly. When steel reinforcement cages, steel or precast concrete members are set in the trench prior to concreting those should be suspended freely and vertically.

6.2 Foundations

6.2.1 Dewatering and drainage of foundation area

For dewatering of foundation areas refer to IPS-C-CE-112, IPS-E-CE-120 and BS 8004: 1986.

6.2.2 Concreting

6.2.2.1 Material

The material for concrete should be in accordance with IPS-M-CE-165.

6.2.2.2 Concrete quality, mixing and placing

Concrete quality, mixing and placing should be in accordance with relevant clauses of IPS-C-CE-200.

6.2.2.3 Formwork

Formwork should comply with relevant clause of IPS-C-CE-200.

6.2.2.4 Reinforcement

Bars used for concrete reinforcement shall meet the requirements stated in IPS-C-CE-200; reinforcement steel shall be executed according to drawings and plans approved by the AR*.

6.2.3 Machinery foundations

The construction of the foundations for machinery should be under the control of an experienced supervising engineer appointed by AR.

Foundation blocks should be cast preferably in a single continuous operation. In the event that an unforeseen interruption in the concreting occurs, the resulting unavoidable joint should be considered as a construction joint and treated in the same way as construction joints shown on the working drawings, or as may be directed by the AR.

The method to be employed for fixing the machine to its foundation should be determined by mutual agreement between the machine manufacturer and the civil or structural engineer responsible for the design of foundation and should be shown in detail on the working drawings, together with a clear demarcation between the limits of supply of the contractors concerned.

The work of embedding, grouting, packing and filling should be in accordance with the requirements stipulated in the design documents.

All necessary precautions should be taken to avoid the possibility that the machine will be disturbed or displaced during filling, grouting and embedding operations. For more detailed information refer to clause 4 of CP 2012: Part 1: 1974.

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

6.2.4 Oil storage tanks

6.2.4.1 Excavation

The excavation shall conform to the dimensions and elevations indicated on the approved working drawings.

6.2.4.2 Construction of tank pads

Material for tank pads shall consist of gravel or the approved excavated material.

The natural gravel or crushed stone when specified for the ring under the tank periphery shall not contain any fines and shall be in accordance with the requirements of API Standard 650.

Fills shall be placed in layers not exceeding 200 mm loose thickness. Each layer shall be compacted by suitable equipment to at least 95 percent of maximum dry density according to AASHTO Standard T 180, Method D.

6.2.4.3 Asphalt concrete for tank foundations

a) Priming

Tank pads to be asphalted shall be cleaned of rubbish and when perfectly dry shall be evenly primed by means of a mechanical sprayer with cut-back asphalt MC-250 (MC2) at the rate of 2 kg (2.5 litres) per square meter of the pad surface and permitted to remain undisturbed for a period of not less than 24 hours. The cut-back shall be applied at temperatures between 40°C and 80°C.

b) Aggregate

Aggregate shall consist of crushed stone, sand and mineral filler. The crushed stone shall be tough and rough surfaced, free from excessive dust and free from flat or clongated pieces. The sand shall consist of clean river, dune or quarry sand and shall be composed of non-absorbent sharp particles. The mineral filler shall consist of dry stone dust.

c) Bitumen

Bitumen shall have a penetration of 60 to 70 at 25°C according to the ASTM test method D5. The asphalt content shall be between 5 to 7.5% by weight of total mix. The actual percentage shall be determined by Marshall Method as outlined in ASTM D 1559.

d) Mixing

Mixing shall be done in a suitable pug mill or continuous mixer. Minimum time of mixing shall be 30 seconds and mixing shall be sufficient to coat all particles. The temperature of the mixture when spread shall be between 115°C and 150°C.

e) Transporting

Transporting shall be done in trucks having insulated tight, clean oiled bodies. Each truck load shall be tarpaulin covered whenever the weather conditions necessitate the use such cover.

f) Placing

Placing shall be done only when the surface is dry and atmospheric temperature is above 5°C. The contact surfaces of all structures shall be painted with hot bitminous material as used in the mixture. The mixture shall be spread by mechanical spreaders and only in inaccessible locations shall the mixture be spread by hand using hot shovels. The placing must be discontinued in rainy weather and/or dusty wind.

g) Joints

When new mixture is to be placed next to previously placed asphalt, the joint shall be cut back to a clean vertical surface and painted with hot asphalt.

h) Compaction

As soon after spreading as the mixture can bear the roller without undue displacement or hair cracking it shall be rolled in two stages, first with a 3 ton roller and then with a 6 ton roller to a finished thickness of not less than 300 mm.

Rolling shall start at the sides and proceed towards the center. Each trip of the roller shall overlap the previous trip by at least 300 mm. Alternate trips of the roller shall be slightly different lengths. The speed of the roller shall not exceed 5 kilometres per hour.

i) Surface Finish

Finished surface shall be smooth, free from any imperfection and shall be of uniform texture and appearance. The finished surface under the tank shell shall not vary by more than 3 mm in any 10 meter circumferential length and shall not vary by more than ±6 mm from the elevation given at any one point on the circumference. Any two points on a circle drawn from the center of tank shall not vary more than 25 mm in elevation.

j) Protection

After final rolling, no vehicular traffic of any kind shall be permitted on the pavement until it has cooled and hardened and in no case in less than 12 hours from the time of final rolling.

6.3 Piles

6.3.1 General

Design aspects of piles are covered in IPS-E-CE-130, only constructional aspects of pilings are discussed in this Standard.

In general, piles should be installed to the prescribed depth, resistance or set per blow without damage to the pile shafts or the bearing stratum and records of the installation process should be maintained.

6.3.2 Sheet piles

The most common material used in sheet piling is steel, although in some occasions, timber and precast concrete sheet piles may be used. In situ concrete diaphragm walls are covered in Clause 7.4 of this Standard.

Steel sheet piles shall be of the type and weight indicated on the plans or designated in the specifications. The piles when in place in the completed structure shall be practically watertight at joints. Unless otherwise provided, when steel sheet piles extend above the ground or water surface shall be protected by three coats of paints as specified in the specifications.

This protection shall extend from an elevation 0.6 m below the water or ground surface to top of the exposed steel. Steel sheet piles shall conform to the requirements of ASTM A 328 grade 50.

6.3.3 Bearing piles

6.3.3.1 Piling materials

Piling materials consist of steel, timber and concrete. Concrete is used either for prefabricated piles or may be used as cast-in-situ concrete piles, which is covered under Clause 6.3.3.4 of this Standard.

Steel piles shall conform to requirements of Clauses 4.2.1 and 4.2.2 of IPS-E-CE-130.

Concrete for precast pile elements should be in accordance with those for main members in BS 8110.

Where sulfates are found in soils or groundwater, concrete having a water/cement ratio of 0.55 or less should be used and recommendations of Clause 6.3.2 of this Standard should be followed.

6.3.3.2 Driving of piles

Piles may be driven with gravity hammer, a steam hammer, or a combination of water jets and hammer, but a steam hammer is preferred. Precast concrete piles, preferably shall be driven by means of a combination of hammer and jet. Hammers shall deliver proper energy to drive the piles without injury to the piles.

The AR shall be notified 24 hours before the commencement of driving. Piles shall be driven to the set or depth and in sequence of driving approved by the AR. Any length of pile surplus to that required for incorporation in the substructure shall be cut out and removed. Piles which have rised as a result of driving adjacent piles shall be redriven to the requirement of specification and relevant drawings. For more details refer to Clause 3.4 of reference 2.5.

6.3.3.3 Determination of bearing values; test loads

When required, the size and number of piles shall be determined by actual loading tests. In general these tests shall consist of the application of a test placed upon a suitable platform supported by the pile with suitable apparatus for accurately measuring the test load and the settlement of the pile under each increment of load. Also in some occasions, hydraulic jacks with suitable yokes and pressure gages may be used.

The safe allowable load shall be considered as 50 percent of that load which after a continuous application of 48 hours produces a permanent settlement not greater than 6 mm, measured at the top of the pile.

This maximum settlement shall not be increased by a continuous application of the test load for a period of 60 hours or longer. At least one pile for each group of 100 piles preferably should be tested.

6.3.3.4 Cast-in-situ concrete piles

Cast-in-situ concrete piles are formed by boring or grabbing and subsequently filling the hole with concrete. There are several methods of constructing bored piles; many features of their construction are similar and not proprietary. Continuous supervision on site by the engineer, and the contractor is always necessary to ensure that the piles are properly formed.

In general the concrete used in this Clause should be in accordance with IPS-C-CE-200. The concrete should be supplied in sufficient quantity to ensure that the concreting of each pile proceeds without interruption. In a pile casing which contains water the concrete shall, unless otherwise agreed by the AR, be placed by means of tremie tube.

In addition to meeting the strength requirements specified in IPS-C-CE-200, the concrete will need to have adequate workability so that it can flow against the walls of the shaft and into every cavity.

Cast-in-situ concrete piles shall be constructed in accordance with details shown on the approved working drawings. Prior to the placing of concrete in the driven shells, it should be inspected throughout its entire length. Any improperly driven, broken, or otherwise defective shell shall be corrected by removal and replacement, or the driving of an additional pile. Reinforcement placed in accordance with the plans or special provisions shall be maintained in its correct position during concreting of the pile. Where it is made up into cages they shall be sufficiently rigid to enable them to be handled without damage.

No concrete shall be placed until all driving within a radius of 0.45 m has been completed. If this cannot be done, all driving within the above limits shall be discontinued until the concrete in the last pile cast has set at least 7 days. Concrete shall be placed as specified for piles precast in the vertical position. Accumulation of water in shells shall be removed before concrete is placed. After concrete has hardened, the top of pile shall be brought above the required finished level and any defective concrete removed to ensure satisfactory bonding of the pile head to the sub-structure. For more details refer to Clause 7.4.5 of BS 8004: 1986.

For other details about caps, collars, splicing piles, water jets, storage and handling of precast concrete piles refer to Clauses 3.5 to 3.15 of reference No. 2.5.

6.4 Retaining Walls

6.4.1 General

Types of retaining walls and brief discussion of them are made in Clause 5 of IPS-E-CE-140.

In this part of the Standard some constructional aspects of retaining walls are discussed.

6.4.2 Gravity walls

Gravity walls consist of mass concrete, masonry, etc.

6.4.2.1 Concrete walls (plain)

The construction of concrete gravity walls should comply with general requirements of IPS-C-CE-200. Weep-holes should be provided according to approved working drawings or as directed by AR.

6.4.2.2 Masonry walls

The dimensions, lines and grades of masonry walls shall be in accordance with approved drawings. Generally the requirements of Clause 5.2 of this Standard should be carefully regarded for stone and masonry.

The stones used in facades should be of regular size and dimensions. As each course of stones is placed, it shall be surrounded by fresh mortar and then all the surface joints should be pointed for protection and aesthetic reasons.

Weep holes shall be provided through the wall as shown on the drawings or as directed by the AR for drainage purposes.

6.4.2.3 Gabion walls

A gabion can be described as a box made of metal or plastic mesh which is filled in situ with coarse granular material such as crushed rock or cobbles and used as a basic building unit. The mesh will be transported to the site and local labor and materials will be used to construct the structure.

The stone to be used in gabions should, in general, meet the requirements of Clause 5.2(a) of this Standard, only it should not be laminar or stretched in form, in order to prevent its passage through the openings of wire mesh. To guarantee this requirement, the minimum dimension of the stone should be 1.5 times greater than the maximum dimension of the wire mesh openings.

6.4.3 Reinforced concrete walls

The classification of reinforced concrete walls is given in Clause 5 of IPS-E-CE-140. In the following paragraphs a brief discussion about the constructional aspects of such walls are given.

6.4.3.1 Reinforced concrete cantilever wall

The various types of such walls are described in Clauses 5 of IPS-E-CE-140. In general the requirements of reinforced concrete construction as concreting, shuttering, and reinforcement should comply with Clause 6.2.2 of this Standard and IPS-C-CE-200.

6.4.3.2 Reinforced concrete diaphragm walls

The first stage of construction of a diaphragm wall is to construct a pair of guide walls along the line of the future trench in which the diaphragm wall is to be constructed. The distance between parallel guide walls should be about 100 mm greater than the design width of the permanent wall.

Excavation for the trench should be performed in alternate panels. Throughout the excavation process the walls of the trench are supported by a bentonite slurry that is circulated by pumping from the trench to remove the contaminated and diluted slurry.

Concrete mixes should be designed to displace the slurry and any sediment remaining at the bottom of the trench. Slumps in the range of 150 mm to 200 mm are desirable and they should be checked at frequent intervals during the placing operations.

A reinforcement cage that has been prefabricated at ground level is lowered into the trench and suspended from the guide walls. The spacing of the bars should permit easy flow of concrete between the bars and into the space between the bottom of the cage and the base of the trench. For more detailed information refer to Clause 6.5.3 of BS 8004: 1986.

6.4.4 Steel sheet piling

Straight-web sheet piles are not able to resist high driving stresses, therefore, where a substantial thickness of soil lies above the required toe level, it is preferable to remove some of the soil. Typical maximum driving depths are 3.0 m in dense sand and 1.5 m in hard clay. Hard driving should be avoided since it will damage the ends of piles and cause splitting.

6.4.5 Slope protection

6.4.5.1 General

The areas to receive slope protection shall be dressed smooth according to the slopes or shapes called for on the drawings and shall be free from stumps, organic matter, or waste material. A filter blanket should be provided where it is anticipated that there may be migration of fines through the protection layer.

6.4.5.2 Rip-rap protection

Stone for rip-rap shall be placed on the prepared slope surface in a manner to produce a reasonably well graded mass of stone with the minimum practicable percentage of voids, and shall be constructed to the lines, grades, and thicknesses shown on the drawings or as directed by AR. Rip-rap protection shall be placed to its full course thickness at one operation and in such a manner as to avoid displacing the underlying material.

Unless otherwise authorized by the AR, the rip-rap protection shall be placed in conjunction with the construction of the embankment with only sufficient lag in construction of the rip-rap protection as may be necessary to prevent mixture of embankment and rip-rap material.

6.4.5.3 Precast concrete elements

Precast concrete elements may be manufactured on the job or at a regular masonry unit manufacturing plant. If reinforcement is required, it shall be furnished and placed as shown on the drawings. All blocks shall be of the limiting dimensions shown on the drawings.

Plant manufactured slabs shall be uniform in texture with true sharp edges. Plant manufactured blocks shall comply with ASTM specification C 145. Blocks shall be laid in horizontal course and successive courses shall break joints with preceding courses. Weep holes shall be provided through the protection cover as shown on the working drawings or as directed by the AR.

6.4.5.4 Masonry (mortar rip-rap for slopes)

Stone for this purpose shall, as far as practicable, be selected as to size and shape in order to secure fairly large, flat surfaced stone which will lay up with a true and even surface and a minimum of voids. Spaces between the larger stones shall be filled with stones of suitable size, leaving the surface smooth, reasonably tight, and conforming to the contour required.

As each of the larger stones is placed, it shall be surrounded by fresh mortar and adjacent stones shall be shoved into contact. After the larger stones are in place all of the spaces or openings between them shall be filled with mortar and the smaller stones then placed by shoving them into position, forcing excess mortar to the surface and ensuring that each stone is carefully and firmly bedded laterally. After the work has been completed all excess mortar forced up shall be spread uniformly to completely fill all surface voids. All surface joints shall then be roughly pointed.

Weep holes shall be provided through the protection cover as shown on the drawings or as directed by the AR.

Mortar shall not be placed in freezing weather. During hot, dry weather the work shall be protected from the sun and kept moist for a minimum of 3 days after placement. Rock shall be kept wet during placing of the mortar.