



RP 4-3

CIVIL ENGINEERING

December 1995

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FOREWORD

Introduction to BP Group Recommended Practices and Specifications for Engineering

The Introductory Volume contains a series of documents that provide an introduction to the BP Group Recommended Practices and Specifications for Engineering (RPSEs). In particular, the 'General Foreword' sets out the philosophy of the RPSEs. Other documents in the Introductory Volume provide general guidance on using the RPSEs and background information to Engineering Standards in BP. There are also recommendations for specific definitions and requirements.

Value of this Recommended Practice

This document distils the requirements previously included in a range of BP Group Codes and Standards on Civil Engineering into a single document. There are therefore no other BP references to foundations and general structures (with the exception of piling) that BP requires Contractors to incorporate in their work.

Application

Text in *italics* is Commentary. Commentary provides background information which supports the requirements of the Recommended Practice, and may discuss alternative options.

This document may refer to certain local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirements lies with the user. The user should adapt or supplement this document to ensure compliance for the specific application.

Principal Changes from Previous Edition

The document includes two main sections. The first part contains the bulk of the old BP Group CP 4 Foundations and General Civil Engineering while the second part includes the requirements from BP Group CP 6 Structures. The technical content of the old documents has not been substantially amended where it has been incorporated in the Recommended Practice. A number of the standard sketches that were incorporated in the old documents have been removed to permit Contractors to incorporate more modern or cost effective details.



Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application of BP Group RPSE's, to assist in the process of their continuous improvement.

For feedback and further information, please contact Standards Group, BP International or the Custodian. See Quarterly Status List for contacts.



1. INTRODUCTION

1.1 Scope

This Recommended Practice gives guidance for the design of foundations, general civil engineering works and structures in refineries, terminals, pipeline associated installations and chemical plants. It does not include buildings, structures containing fluids, offshore structures, jetties and tanker berths.

This document does not include a comprehensive listing of all regulations, codes of practice and standards applicable to detailed design. It is the responsibility of the designer to apply all relevant and appropriate standards required to achieve the standards, function, safety requirements and cost effective design intended by the Recommended Practice.

This document has been written with the aim of identifying BP's particular requirements. Contractors will be required to use best industry practice for all engineering design. Local or national codes can be used in preference to British Standards quoted, provided that they are not less stringent than design criteria and specifications required by this Recommended Practice.

It will be the Contractors responsibility to demonstrate at any later time that the facility or element provided is of equal or better standard than that described in the Recommended Practice.

The document is intended to form the 'base case' technical requirements against which Contractors bidding for design work can prepare their time and cost estimates.

1.2 Quality Assurance

Verification of the vendor's quality system is normally part of the pre-qualification procedure, and is therefore not specified in the core text of this specification. If this is not the case, clauses should be inserted to require the vendor to operate and be prepared to demonstrate the quality system to the purchaser. The quality system should ensure that the technical and QA requirements specified in the enquiry and purchase documents are applied to all materials, equipment and services provided by sub-contractors and to any free issue materials.

Further suggestions may be found in the BP Group RPSEs Introductory Volume

2. DESIGN LOADS

2.1 General

- (a) Dead and imposed loads shall generally be as stated in [BS 6399](#): Part 1 or an equivalent local national standard or code appropriate to the site of the works.



- (b) Imposed loads due to special items of maintenance equipment may be treated as transient loading where applicable.
- (c) Allowance for dynamic effects, including impact, shall be made for loads arising from machinery, runways, cranes and other plant producing periodic disturbing forces. For design requirements for machinery producing periodic disturbing forces see Clause 4.8.3.

In the UK, loads and forces on crane gantry girders shall be as stated in BS 5950, loads on road and rail bridges shall be as stated in BS 5400 and loads for lifts and passenger conveyors shall be as stated in BS 2655. For sites outside the UK, equivalent national standards appropriate to the site of the works shall be used.

2.1.1 Wind loads shall be calculated in accordance with [BS CP 3: Chapter V: Part 2](#), or equivalent local national standard or code, using the basic wind speed appropriate to the site.

2.1.2 It may be assumed that the wind loading during erection, assembly, test conditions and full hydrostatic test does not exceed 60% of the design wind load.

In the UK this is equivalent to 77% of the design wind speed in accordance with [BS CP 3: Chapter V: Part 2](#).

2.1.3 Operating and shutdown loads shall include the full dead weight of plant, vessels, insulation, fittings and piping thereon, structural framework, floors, or building carcass, together with all liquid or other material contents. The design shall also take into account any transportation loads, hydraulic test loads and other variations of load that could arise during maintenance periods.

2.2 Seismic Loads

2.2.1 All seismic loads, where appropriate, shall be calculated in accordance with the national standards or codes applicable to the site of the works.

Where such standards or codes do not exist or, with the approval of BP, are considered inappropriate, or where these do not refer to specialist and hazardous items of plant, a study shall be carried out to determine the possible risk and level of seismic activity, in order to determine the appropriate design loading.

2.2.2 The design shall take into account the effects of the following:-

- (a) Earthquake-induced liquefaction of the strata.
- (b) The hazard from tsunamis (the general term for sea-waves induced by seismic activity) in coastal regions.

- (c) Specialised structures which have their own codes of practice, and to which reference shall be made.

2.3

Thermal Loads

All thermal forces and pressure effects caused by heat exchangers, horizontal vessels and pipework, and forces caused by removal or replacement of tube bundles, shall be determined and taken into account in the design of the foundations and supporting structures. Computation of loads and forces for those items and particular design requirements should be as follows:-

- (a) Pipe racks shall be designed to cater for all calculated fixed piping and where appropriate, air cooler vertical and horizontal forces. The design shall include for a horizontal force along the piperack equal to 10% of vertical load from all unfixed pipes on the rack. For forces normal to the piperack in addition to those calculated from piping and air coolers, a minimum point load of one tonne vertically and 10% of this horizontally shall be assumed to act at the centres of horizontal tie beams to allow for pipe offtakes. For any particular crowded offtakes, the actual friction forces shall be determined. For pipe supports where few pipes are supported or in offsite areas where precast inverted tee sleepers are installed, a friction factor of 0.3 for steel to steel surfaces shall be used, provided there is no possibility of any indentation of the pipe wall occurring at the point of support.
- (b) The friction coefficient to be used for pipe supports or sliding bearings or horizontal vessels or exchangers should not exceed:-

Steel to concrete	0.6	
Steel to steel	0.3	
PTFE to PTFE	0.1	(bearing pressure shall be greater than 1.4 N/mm ²)

The above values should be used in determining the loads in the supporting structure and foundations, but when assessing resistance of the pipe or vessel to horizontal forces, an appropriately lower value may be used. (E.g. if using PTFE to PTFE bearing arrangement, the friction coefficient recommended by the manufacturers, which is often much lower than stated above, should be used to assess the resistance of a pipe to its being blown off its supporting structure.)

Where sliding bearings are used, for example at one of the two supports for horizontal vessels, heat exchangers, etc., spacers shall be provided to

prevent clamping forces being applied to the bearing plates when the holding down bolts are tightened. The design shall ensure that the sliding is correctly oriented in the direction of the anticipated movement.

Low friction bearings shall be of a fully sealed type to prevent deterioration due to ingress of wind-blown debris.

Bearing plates shall be sufficiently rigid and be arranged to prevent distortion due to uneven pressure distribution and to ensure that the complete area of support is on one truly horizontal plane.

- (c) Exchanger foundations and plinths shall be designed to withstand a horizontal pull of 1.5 times the fouled bundle weights or 5 kN whichever is the greater.

2.4 Structural Loading

2.4.1 The following imposed loads shall be used in the design of structures:-

- (a) Platforms, walkways and stairways (not supporting any equipment and not intended as working platforms):-

2.5 kN/m²

- (b) Working platforms and platforms over which heavy equipment may be transported or stored:-

5.0 kN/m²

or the actual superimposed equipment load, whichever is the heavier.

3. INFRASTRUCTURE, FOUNDATIONS, AND GENERAL CIVIL WORKS

3.1 Infrastructure

Infrastructure developments will require application of information spread across several BP Group Recommended Practices. The primary documents for reference are BP Group [RP 44-7](#) Plant Layout, BP Group [RP 4-1](#) Drainage Systems, BP Group [RP 12](#) covering electrical systems and installations and BP Group [RP 30](#) dealing with instrumentation. The following sections provide general civil engineering requirements.

3.2 Site Conditions and Investigations

3.2.1 Where available, a summary of the ground conditions, subsoil data and soil investigation reports will be provided by BP.



- 3.2.2 Where the information available is insufficient, further site investigation shall be carried out. The site investigation should be in accordance with [BS 5930](#) or an equivalent national code.

Where ground contamination has been identified as a possible concern the soil investigation should include tests to identify the extent of possible contamination and threats to the safety of workers.

3.3 Setting Out and Design Levels

- 3.3.1 For setting out and record purposes a Grid Co-ordinate System using Northings (or Southings) and Eastings (or Westings) is, or shall be, established for the site and all works shall be related to this system. The relationship between 'true North' and 'Grid North' shall be shown on all major layout drawings. Permanent monument or survey points shall be established at all sites and their locations noted on a record drawing, together with their grid references and elevations.

- 3.3.2 In establishing site 'Grade Level' the following should be considered:

- Tidal range
- Tsunamis
- River flood levels
- Groundwater level
- Drainage requirements

- 3.3.3 The 'Grade Level' datum shall match the high point of plant paving. All works shall be related to this 'Grade Level', see Clause 4.2.

- 3.3.4 On all major layout drawings, the relationship between 'Grade Level' and the local National Geographical Survey Level Datum appropriate to the site shall be shown.

3.4 Site Preparation, Grading and Infilling

- 3.4.1 The type of materials acceptable for use as site fill and method of placing those materials should be in accordance with national standards.

In the UK, earthworks should conform to [BS 6031](#).

Site infilling, where this is to be placed directly on a clay subgrade or formation, should be of sand or sandy ballast, burnt shale, graded gravel or other inert material, easily compacted and resistant to the clay squeezing into it. Stone rock, flints, hardcore and the like may be used according to availability, but these materials should not be placed directly on clay subgrades without prior blinding with sand or clinker ash or the inclusion of a geotextile mat. Infill materials with a high clay content should not be used for filling within process plot areas.

3.4.2 Spread foundations including storage tanks and process plot paving, roads or railway subgrades and any other settlement-sensitive item supported on infill material shall be designed to ensure that any settlement that may occur is tolerable.

3.4.3 Any area of made-up ground within the process plant plot limits, that is not required to be paved over, should be stabilised to prevent erosion by surfacing preferably with 75 mm of all-in ballast, gravel, stone or similar free draining material (if not already natural subgrade) and generally levelled off at 75 mm below adjacent paving grade level.

Consideration should be given to minimising excavations below grade level where ground water levels are high, particularly on soft ground sites. Large cost and time savings can be made minimising the extent of dewatering and ground disturbance. Areas on soft ground sites that are to be highly trafficked during construction such as piling mats and access routes should be protected with a geotextile membrane and built up with layers of imported fill.

3.5 Concrete

3.5.1 Concrete foundations and structures should generally be designed and constructed in accordance with national standards. Liquid retaining structures have different design requirements and may have separate design standards. The concrete shall be durable for the prevailing conditions. Particular attention is drawn to the need to assess the effects of site location and plant operations.

In the UK, [BS 5328](#) should be used for the specification of concrete mixes and [BS 8110](#) for the design of concrete structures and foundations. Liquid retaining structures should be designed using [BS 8007](#).

Use of cement replacements such as PFA, micro silica and blast-furnace slag should be considered where conditions are aggressive or where curing temperatures need to be controlled.

3.5.2 The provisions of [ACI 305-77](#) shall be followed for concreting in hot weather.

3.5.3 All exposed edges should have 25 mm chamfers.

3.6 Brickwork and Masonry

3.6.1 Brickwork shall be designed in accordance with national standards.

In the UK [BS 5628](#) is used for the design of masonry.

3.6.2 Engineering bricks Class B are preferred, but alternatives with reinforced joints as necessary may be used.

- 3.6.3 Exposed horizontal surfaces of brickwork, such as tops of bund walls, pipe trench walls and firebreaks not topped with concrete copings, plot paving, etc., should be finished with engineering bricks Class B laid on edge.

4. FOUNDATIONS

4.1 General

- 4.1.1 The design of foundations shall take account of all specified functional and testing requirements for the structures supported thereon. Structures vary widely in their capacity to accommodate movement of their foundations, and the design of both the structure and the foundation shall be considered interrelated.

The design should take account of:-

- (a) all possible relative movements between different parts of a foundation or between adjacent structures, particularly when there are interconnecting pipes or utilities etc., whether above, at or below ground level and,
- (b) movement of the supporting ground or soils due to seasonal effects, erosion, natural consolidation or vibration etc.

- 4.1.2 *In the UK, the design of foundations shall be in accordance with [BS 8004](#).*

- 4.1.3 On sites where the immediate subsoils are highly compressible, and as an alternative to the construction of deep foundations taken down to a stratum of lower compressibility, ground improvement techniques shall be considered. Improvement techniques considered should include:-

- (a) Preloading
- (b) Grouting
- (c) Vibro-compaction
- (d) Dynamic consolidation
- (e) Replacement

4.2 Design Levels

- 4.2.1 The site Grade Level shall be established for:-

- (a) The entire works, where such works are being constructed on a site of relatively level ground.

- (b) Areas of the works, where such works are being constructed on a site of sloping or undulating ground.

4.2.2 Basic design levels relative to the appropriate Grade Level shall be as follows:-

4.2.2.1 High points of plant paving. Grade Level

4.2.2.2 Unpaved areas within plot limits, Grade -75 mm
maximum.

Unpaved areas within plot limits must be properly drained so as to prevent excessive build up of standing water.

4.2.2.3 Concrete base plinths for fractionating columns, towers, major vessels, structural steelwork base plates, paving-level pumping units and similar equipment, minimum including 25 mm grout. Grade +150 mm

4.2.2.4 Invert level or bottom of cable trench or basement for fully enclosed control rooms, substations and switch houses, in locations where flammable vapours heavier than air are possible, and where the cables trench is continued from the outside of the building, minimum. Grade +150 mm

Finished Floor Level (FFL) of such fully enclosed control rooms, sub-stations and switch houses shall therefore be equal to Grade plus 150 mm plus depth of cable trench or basement required. The invert level of cable trenches within buildings or basements for these buildings (and hence FFL) shall similarly apply where lighter than air flammable vapours can be present, unless an external drain pit incorporating air vents in top covers and drainage holes through the floor and immediately adjacent to the building is provided.

4.2.2.5 FFL of control buildings, sub-stations and switch houses with mesh screen filled open sided special basement/mezzanine type floors/spaces for personnel access Preferably Grade +1500 mm + floor thickness, but not less than Grade +1200 mm + depth of supporting beams/ floor thickness

Where regular access is required for monitoring of equipment or inspection then it may be necessary to increase the basement headroom to 2000mm.

4.2.2.6	Low points of floors to open sided pump and compressor shelters where these are adjacent to surrounding paving.	Grade +125 mm
4.2.2.7	Stairway and ladder bases on plant base plinths.	Plinth Level +25 mm
4.2.2.8	Stairway and ladder bases on paving.	Grade +25 mm
4.2.2.9	Drainage manhole covers, tops of sumps and hydrant pits, screeds and covers over cable and pipe trenches as follows:-	

Manhole covers which could potentially present a trip hazard in unpaved areas should be provided with suitably sloped concrete haunching.

(a) Within paved areas.	Flush with paving
(b) On unpaved areas.	Grade Level

Where feasible, plant plot perimeter roads should be constructed at a slightly higher level than the paving. This provides an extra degree of protection from flooding between units and improved compatibility with paving layout.

4.3 Types of Foundations

- 4.3.1 Single-storey administrative, stores, laboratory and amenities buildings should normally be founded on shallow foundations even above soft subsoil areas. For long buildings, suitable joints in the foundation and the building shall be provided to accommodate deflection and control possible cracking.
- 4.3.2 The foundations of buildings such as Control Buildings subject to blast loading shall be designed to withstand any dynamic loads and moments resulting from the blast overpressure. BP practice for buildings subject to blast overpressure is given in BP Group [RP 4-6](#).
- 4.3.3 Paving trenches and underground pipes should be soil supported except where they are combined with, or adequately connected to, piled or other foundation support systems. Sufficient flexible transition shall be provided for underground pipes and service trenches where these cross the joints in the paving between rigid and soil supported areas, and cable trenches shall also be provided with junction sections across these points. Such cable trench junctions should be kept to a minimum by combining minor trenches on subbase slabs.

- 4.3.4 Single or complete items of plant and equipment shall not be placed partly on piled, deep or rigid spread foundations and partly on surface foundations, or partly on compacted fill. Adjacent items within the same unit may be founded on different foundations, provided any differential settlements are not harmful and are within acceptable limits, and sufficient flexibility is incorporated into all interconnecting structures, plant, piping, drainage, service trenches, etc.

Similarly, extreme caution shall be exercised when designing foundations for new plant at the site of old demolished plant or structures, or where materials may have been stored.

- 4.3.5 Earth mound and piled foundations for vertical steel tanks are covered in Section 10.5 while requirements for process and intermediate tankage are dealt with in Section 4.12. Foundations for pressure storage vessels are discussed in Section 11.1.

4.4 Shallow Foundations

- 4.4.1 Raft foundations should be used generally where separate footings overlap or their total area exceeds 75% of the structure or building plan area.

- 4.4.2 Where surface foundations are liable to settle, their initial construction levels should be arranged above their final required levels. The levels and falls for drainage of roads or paving surrounding the foundations shall not be adversely affected by such settlements, nor cause surface water to flow into or pond around the foundation floors or slabs.

- 4.4.3 In equipment buildings and other structures where a low permissible soil bearing pressure necessitates an overall raft, this should generally be set below the surface to leave room above for cable trenches and service lines, the remaining space between raft and paving being sand filled. Otherwise, and usually in outside groups of equipment, the raft slabs may be at the surface, provided that no difficulty arises over provision of dropped sections for cable trenches, and that process lines are not buried below the slab. Provision shall be made to prevent frost heave to surface level slabs.

- 4.4.4 The design of spread foundations that are to be placed near existing units, or in the place of dismantled units, should allow for the possibility that oil or chemicals may have percolated down through loose or porous surface soils to the bearing stratum. Where the bearing stratum contains clay, foundations should be of such depth as to ensure safe bearing or penetration below any oil softened clay subsurface or chemically contaminated subsoil.

4.5 Pile Foundations

- 4.5.1 Piling is covered in BP Group [GS 104-1](#) and Section 8 of this Recommended Practice. The following relates to the design of foundations supported on piles and caissons, and also those on top of deep piers and sleeper walls.
- 4.5.2 Foundations shall be designed to suit the allowable pile loads, the minimum spacing, and lateral tolerances at pile head level, and with wind allowance to Clauses 4.13.2, 4.13.3 and 4.13.4. Capping blocks and beams, and flat slabs, shall project sufficiently in each direction beyond the pile heads to allow for driving tolerances and in order to ensure sufficient bonding and anchorage of the reinforcement and to avoid excessive shear stressing at the edge.
- 4.5.3 When pile heads are installed outside the specified tolerances or when a pile is rejected and replaced by one or more offset piles, the affected parts of the foundations shall be redesigned to suit such conditions.
- 4.5.4 Foundations on piles should in general avoid:-
- (a) Uplift on piles supporting tall columns and stacks.
 - (b) Uplift on precast reinforced concrete or shell piles when this may lead to permanent cracking or opening of joints.
 - (c) Use of raking piles, except as permitted in Clause 8.6.2.
- 4.5.5 Single structural columns, small vertical vessels and the like may be supported on only one pier or pile if lateral restraint is provided either by grade beams tied in to other piled foundations or by a sufficient depth or extent of capping block held in place by the surrounding concrete paving (see also Clause 5.6.2).
- 4.5.6 Tie beams between piles and pier foundations may be either at grade level or preferably subgrade at a depth, usually about 750 mm to 950 mm below grade, so that drainage pipes are generally supported above such beams or slabs and design of structure and drainage can proceed without interference. Where grade level tie beams are used to support paving or equipment bases, these beams should be arranged or offset so that underground piping is accessible without damage to any part of the foundation.
- 4.5.7 Both grade and subgrade tie beams should, where necessary, be designed for appropriate superimposed traffic loading.

4.6 Buoyancy Foundations

- 4.6.1 The design of buoyancy foundations shall minimise the possibility of ingress of surface and ground water, and provision shall be made for pumping out water which may collect in large voids in the foundation.

Pumping facilities should be fully accessible and if possible avoid the requirement for man entry into confined spaces.

- 4.6.2 The design shall also avoid the possibility of flammable gases and liquids collecting in large voids in the foundation.

The use of foamed concrete or other lower-density fillers can be investigated.

4.7 Plant, Pipework and Steelwork Supports

- 4.7.1 Concrete bases, plinths and piers shall be adequately anchored into the supporting spread foundation, the piled substructure, the underlying foundation slab or the supporting paving, especially where they may be subject to horizontal loads, overturning or vibrating forces. The concrete bond alone, between the lower and upper bases and at horizontal construction joints, shall not be relied upon to take shearing or tensile stresses. Reinforcement sufficiently embedded in the substructure, or sufficiently long holding-down bolts, shall be provided across such planes to ensure integral action.

- 4.7.2 Small, low, grade level bases or plinths may be unreinforced, provided that the holding-down bolts are sufficiently embedded in the foundation substructure or the paving. However, such bases should be provided with a nominal reinforcing mesh across their top surfaces to resist thermal stresses.

- 4.7.3 Bases and plinths for fractionating towers and vertical vessels supported on skirts, and the lower internal floors of stacks where sealed from flue gases, shall be drained where the enclosed space is liable to collect oil spillage or leakage, or condensation under normal operating temperatures.

- 4.7.4 Suitable slide plates or low friction support devices shall be provided for horizontal vessels, heat exchangers and pipework to allow for thermal movements, the friction factors given in Clause 2.3 may be assumed generally for sliding surfaces.

- 4.7.5 Concrete bases, plinths and piers should extend not less than 50 mm beyond the edges of plant or equipment rings, fixed base plates, or slide plates. Adequate clearance should be provided between the side of the concrete, or the reinforcement, and holding-down bolt pockets, sleeves or anchor plates.

- 4.7.6 High or slender concrete piers should be designed as load-bearing concrete walls or columns, with due allowance for horizontal loads due to thermal forces, and for tube bundle removal or replacement.
- 4.7.7 Major structural bases and all plant and equipment base-plates and rings should be grouted with a flowable 'non-shrink', non-metallic grout.
- 4.7.8 Ground level concrete pipe sleepers should be provided with steel flat bars, 100 mm wide, cast into the top surface of the concrete and projecting 10 mm. The top surface of the sleeper should slope away from the steel flat bar.

4.8 Pumps, Compressors, Engines, Turbines, etc.

- 4.8.1 In soft soil areas, when process layout considerations permit (see BP Group [RP 44-7](#)), the general run of pumps, compressors and similar equipment should be grouped on common flat slabs or simple beam and slab substructures, supported on piles, piers, or sleeper beams which extend to the founding layer. In such cases, the drainage system, cable and pipe trenches should be arranged above the structural slab in the sand-fill region which supports the equipment paving. Large pumps or compressors may however require individual foundations.

Irrespective of loading, loose sand areas should be piled or vibro-compacted before being used to support such equipment whether on a sub-base structure or on individual foundations.

- 4.8.2 Drivers and driven units should be supported on a common base block adequately stiff to limit distortion within the tolerance permitted by the unit manufacturers.
- 4.8.3 Large machines or any machine which may have large out-of-balance forces should be supported on structures and foundations which have been designed to minimise:-

- (a) Vibration of the machine.
- (b) Transmission of vibration to adjacent foundations, equipment and buildings.

- 4.8.3.1 *The following references are recommended for the design of machine bases and their foundations:-*

[BS CP 2012: Part 1](#) *Foundations for reciprocating machines.*

BS 4675: Part 1

Basis for specifying evaluation for rotating machines with operating speeds from 10 to 200 revolutions per second.

DIN 4024:

Supporting structures for rotary machines. (For loads, permissible amplitudes, frequency ratio, etc.).

VDI 2060

Standards for evaluation for the state of balance of rotating rigid bodies.

BS 8004

Code of practice for foundations

- 4.8.4 Pump and compressor bases shall be adequately reinforced in all surfaces, vertical and horizontal. Where pumps and compressor bases are integral with floors or paving slabs, the designer should ensure that adequate reinforcement is provided to prevent the propagation of cracks from the surface due to vibration.
- 4.8.5 With independent pump blocks or bases, anchor supports to the pump suction and discharge lines should, whenever possible, be integral and monolithic with the pump base.
- 4.8.6 Bases should extend beyond bedplates or any projecting bolt lugs in accordance with Clauses 4.7.5 and 4.8.9.
- 4.8.7 Large machines or any machines with large out-of-balance forces should be grouted in accordance with manufacturers' requirements, using a flowable non-metallic non-shrink grout. Special grouts shall be placed in accordance with the manufacturer's instructions. Placing should be supervised by a qualified representative of the manufacturer. Holding down bolt pockets and the space under the bedplates shall be completely filled with grout and all air expelled. Grout thickness should be within the range 25 - 50 mm.
- 4.8.8 Some large machines, particularly those which may have out-of-balance forces, e.g. reciprocating compressors, may require alternative means of mounting such as channels or rails set in the foundation block.
- 4.8.9 Holding-down bolts shall be designed to adequately resist all horizontal forces, in addition to the vertical forces, originating from the machine. The distance from any pocket or bolt to the edge of the block should be at least 100 mm in order to allow for reinforcement.

4.9 Fired Heaters

- 4.9.1 Foundations for heaters should provide for ample natural ventilation between the underside of the firing floor and the concrete foundations. Heater foundations and grade level flue gas ducts, other than piled,

should not be placed directly on clay subsoil without adequate air gap and sufficient depth of footings to prevent drying out and shrinkage of clay subsoil.

- 4.9.2 The design shall allow for the large horizontal movements and thrusts that can be applied to piers or columns supporting heaters due to the thermal expansion of the heater.
- 4.9.3 In soft soil areas, foundations for flue gas trunking should be arranged to prevent harmful differential settlements between the trunking and the heater and stack.

4.10 Structures and Overhead Pipe Racks

- 4.10.1 Where firm ground is at a significant depth below the surface and only very limited settlements can be accepted, the columns of light structures including overhead pipe rack gantries may be founded on single piles or piers according to depth. Grade or subgrade tie beams to connect these supports may be omitted where sufficient lateral restraint is provided by the concrete paving.
- 4.10.2 Supports for heavy structures should be suitably tied together, particularly where such supports are formed of single piles or piers, and tie beams or slabs should be designed to allow for moments caused by piles driven off centre.
- 4.10.3 Where steel structures support plant and equipment, attention shall be given to passive fire protection requirements (see BP Group [RP 24-1](#)).

4.11 Switch Houses and Transformer Bases

- 4.11.1 Cable holes through the foundation or the walls of switch houses, substations or control rooms which do not have an 'open sided' cable basement shall be in accordance with Clause 9.5, and cable trenches and entry points shall be in accordance with Clause 9.1.3, splayed to suit changes of direction of the cables and to ensure ease of installation and removal.
- 4.11.2 The space surrounding the base block and within the tray walls should be filled with open graded gravel or stone chippings so that the volume of the voids provided is not less than the volume of oil contained in each transformer. A sump should be provided consisting of a trapped gully set within brick walls with porous openings, to allow rainwater to drain off while keeping the chippings clear of the gully. The outlet from the trapped gully should be connected to the oily water drainage system if available, or provision should be made for pumping out.

4.11.3 Where justifiable by the degree of fire risk, transformer enclosures should include support for 225 mm thick brick dividing walls set between two or more transformers.

4.11.4 All transformer enclosures should include for fencing on the sides open for access in accordance with Section 13.

4.12 Process and Intermediate Tankage

4.12.1 These clauses cover foundations at or near grade level for vertical or horizontal cylindrical steel tanks or vessels, including such items as blowdown tanks and cooler boxes, which primarily form part of process units located within plot limits.

4.12.2 Foundations for process tankage should be any of the following:-

- (a) Concrete bases or rafts bearing on the surface of the ground.
- (b) Concrete bases forming part of the pile supported process plant paving or substructures, or separately as pile-supported slabs.
- (c) Earth-mound foundations, with or without brick or concrete ring walls under the tank perimeter.
- (d) Steel or concrete cradles for horizontal cylindrical tanks.
- (e) Brick or concrete sleeper walls to support a vertical steel tank bottom clear of the ground.

4.12.3 Tanks with heated or refrigerated contents should not be placed directly on clay soils without due allowance for, or protection against, shrinkage or expansion of the soil and excessive movement.

4.12.4 Foundation rafts for process tanks elevated on sleeper walls and open structural frames should be given a central super elevation, so that after settlement the central part of the raft is not below the perimeter level.

4.12.5 Sleeper walls for tanks elevated above grade should normally be of Class B engineering brick but may also be of reinforced concrete construction. In soft soil conditions where settlement, flexing and deformation of the raft may occur, brick sleeper walls should be capped with concrete lintels reinforced to prevent fracture or spalling of the concrete and the brickwork at the ends of the sleeper walls. Tank bottom plates should be insulated from the wall capping to prevent moisture absorption.

- 4.12.6 The top surface of earth-mound and concrete slab foundations to tanks should be finished with bitsand in accordance with Clause 10.6.
- 4.12.7 Cradles for horizontal cylindrical tanks should normally be of steel welded to the tank shell and bearing on low, flat topped concrete foundation plinths generally designed as in Clause 4.7. In cases where tank shells are thin and thermal forces high, overstressing of tank shells due to excessive rigidity of the foundations should be avoided. Cradles of concrete or brickwork, should be designed to take the full thrusts developed at their 'horns' and the tank shells should be insulated from fretting corrosion on the saddle by means of pads of filler board to prevent moisture absorption.
- 4.12.8 Only two supports should be provided for horizontal cylindrical tanks (or bullets) when foundations bear on weak soils. In the case of such tanks containing hazardous materials or formed from expensive alloys, e.g. copper, aluminium or stainless steel, whose support system would bear on weak soils and could be prone to differential settlement, a rigid slab and multiple supports may be used as an alternative foundation.

4.13 Bearing Pressures and Settlements

- 4.13.1 In computing the maximum pressure under a foundation, the maximum load shall be the sum of the dead load, including the self weight of the foundations, live (or imposed) load on the plant, equipment or structure, and wind loads or earthquake loads. For the purpose of comparison with the specified allowable bearing pressure, the weight of the soil displaced by a foundation may be deducted from the aforementioned maximum load.
- 4.13.2 The maximum pressure under eccentric loading on foundations, due to any cause other than those shown in (a) (b) and (c) below, should not exceed the allowable bearing pressure, nor the allowable pile loading:-
- (a) Where individual foundation loads, with the exception of loads described in Clause 4.13.3, due to wind on shallow or deep foundations, are less than 25% of the loads due to dead and live loads, the wind loads may be ignored in this assessment. Where this ratio exceeds 25%, foundations should be so proportioned that the maximum bearing pressure due to combined dead, live and wind loads does not exceed the allowable bearing pressure by more than 25%.
 - (b) In locations where the national standards or codes permit, a 30% or 33% increase in bearing pressure due to wind may be allowed in place of the 25% stated in (a).

- (c) In locations where the national standards or codes permit, certain limited increases in bearing pressures may be allowed for loads due to earthquakes.

4.13.3 However, in the case of stacks, tall columns and fractionating towers etc., due to the possibility of sway action, the maximum applied bearing pressure under eccentric loading due to wind shall not exceed the allowable bearing pressure, nor the allowable pile loading. For in-situ hydrostatic test loading of towers and vessels see Clauses 2.1.2 and 4.14.

4.13.4 In the case of piles of patented construction installed by a specialist contractor, any such excess for wind loads over the guaranteed safe working load should be subject to acceptance by the specialist contractor concerned.

4.13.5 The design of foundations should take into account all effects of possible settlement. In most cases it is necessary to limit settlements. When foundations are designed on the basis of allowable settlement rather than allowable bearing capacities, a safety factor shall be applied to the calculated settlements. This safety factor shall be consistent with the quality of the soil investigation, sensitivity of the supported structure and quality of experience with the method of settlement prediction and should generally not be less than 1.5.

4.14 Stability of Foundations

4.14.1 The stability ratio of foundations is the stabilising (or restoring) moment divided by the overturning moment and should be in accordance with the table below. The stabilising moment should be taken about the edge of the foundation and the weight of any material, such as backfill, paving, etc., directly above the foundation, may be included.

4.14.2 Allowance should be made for any buoyant effects of a high ground water table.

Foundation Stability Ratio

Loading Condition	Loading to be made up of combinations of loads below to give most adverse overturning conditions	Minimum Stability Ratio
Erection	Dead (Minimum) Wind or Seismic	1.4
Hydrostatic Test	Dead (Minimum) 60% Maximum Wind Load	1.4
Operating	Dead Live Thermal Wind or Seismic Tube Bundles	1.75
Shut Down	Dead Wind Or Seismic Thermal Tube Bundles	1.75

5. PAVING AND ACCESS

5.1 General

The need for paving, and its extent if used, should be determined for each individual site. All intended uses and loading requirements for paving, including road bridges and suspended slab paving, should be taken into consideration in the design. In general, paved surface areas should be kept to a minimum consistent generally with the requirements listed below.

5.1.1 Process Plot Areas

5.1.1.1 Concrete paving should be provided within plot limits only where necessary for vehicular and pedestrian access to process plant, equipment buildings and maintenance areas, and as a drainage surface in areas which may be subject to oil or chemical spillage during operations or maintenance.

5.1.1.2 In addition to the requirements for collection of surface water, oil or chemical spillage, paved areas should also be designed:-

- (a) So that flammable liquid spills do not collect under process equipment.
- (b) To prevent the spread of firewater to process or plant areas unaffected by fire incident. Specific drainage catchment areas within a process or plant unit should be defined. These should be related both to the layout of the component parts of the unit

and the fire fighting methods applicable as defined in BP Group [RP 24-1](#). Catchments may be generally defined by high points of the paving or in particular cases by upstand kerbs; however, trip hazards or obstruction of access-ways shall be avoided. (See BP Group [RP 4-1](#) for further information).

- 5.1.1.3 In some plants where a special fire risk has been identified additional paving may also be required to allow efficient drainage of the associated high firewater flows.
- 5.1.1.4 In some areas of the plant, paving may be required as a protective layer against erosion of certain soil types.
- 5.1.1.5 Concrete paving should generally be provided for:-
 - (a) Vehicular access ways from process plot limits into, and within, the paved areas.
 - (b) Walkways.
 - (c) Maintenance access consisting of a 1200 mm width of paving around individual equipment isolated from main paved areas.
 - (d) Tube-pulling areas for heat exchangers where oil may be spilt during extraction and removal of tube bundles, even where such areas extend beyond plot limits.
 - (e) Continuously around all groups of pumps and compressors, piping manifolds, associated with pump stations and generally under all structures supporting process plant overhead.
 - (f) Continuously around and under heaters as required by BP Group [RP 22-1](#).
 - (g) Access ramps for maintenance vehicles, trolleys, etc.
- 5.1.1.6 Concrete paving should not generally be provided for walkway access to isolated floodlight towers and manholes.
- 5.1.1.7 Bituminous paving should not be used within plot limits for any hydrocarbon process plant or in areas where fuel spillage or large amounts of water may be discharged.
- 5.1.2 Offsite Areas
 - 5.1.2.1 For roads and access-ways in offsite areas, see Section 4.2.

5.1.2.2 There are no general requirements for paving in offsites areas. However, paving may be required at particular locations such as pump areas, metering areas and manifold areas where hydrocarbon and chemical leakage or spillage could occur.

5.1.3 Tankage Areas

For paving details in tankage areas, see Section 10.

5.2 Arrangement of Paving

5.2.1 Paving should be laid to falls sloping to drainage points as required by BP Group [RP 4-1](#). The perimeter of the paving should be at Grade Level.

5.2.2 Drain points and valley lines should be located to ensure a clear flow past all bases, plinths, piers and other obstructions. High points should be located along cable trenches, expansion joints and over subgrade beams and the valleys along any pipe trenches. To ensure there are no 'dead' areas that could cause ponding, paving layout drawings should show all bases, plinths, piers and other obstructions, with paving valley lines and ridges indicated and all falls shown with arrows. Surface falls and drainage points for soil supported paving bounded by, and liable to settle between, grade beams, should be designed to ensure continued drainage in the event of differential settlement.

5.2.3 Surface drainage collection points, in accordance with BP Group [RP 4-1](#) should be provided with their top level set 25 mm below the paving surface, pipe trench bottom or other surface to be drained.

5.2.4 Paving should be kept as free as possible from all obstructions liable to cause a trip hazard. Covers for cable and pipe trenches, manholes, sockets and the like should be graded flush with the paving with hand grips sunk below. Open pits and sumps should be railed off.

5.2.5 Pipe trenches within the paved areas should be avoided wherever possible. Where pipe trenches below paving level are unavoidable, they should comply with Clause 9.2.

5.2.6 Where permanent access-ways from the plant to the surrounding roads are ramped, the slope should not exceed 1 in 15.

5.3 Pavement Edging and Kerbing

5.3.1 Protection should generally be provided to the paving formation at the perimeter or edge of all paving. The pavement edging may be formed

by inverted kerbs or downstand edge beams of minimum dimensions 150 mm width x 300 mm depth where:-

- (a) Offsite fill or natural ground beyond the plot limit is more than 100 mm below the edge of the plot paving.
- (b) Offsite pipetracks, cable trenches or draw pits, manholes or valve pits are at lower levels immediately adjacent to the plot paving limit.

Inverted kerbs or downstand edge beams are not required for the edges of concrete paving and access-ways where they:-

- (a) Terminate at unpaved areas within the plot limits with the unpaved area at an elevation of grade 75 mm (see Clause 4.2).
- (b) Directly adjoin offsite roads or paving.

5.3.2 Where concrete paved access-ways from the plot meet bituminous paving of offsites roads, a flush edge kerb should be provided. Also, where such access-ways adjoin surrounding roads, a minimum internal radius (for junctions of paved access-ways) of 9 m should be provided. Fully supported upstand kerbing to a height of 150 mm should be provided around the bend and for 1 m beyond the tangent points. The top surface of the 1 metre length beyond the tangent point should slope down to road and access-way level.

5.3.3 Where paved and unpaved plot limits adjoin offsite fill or natural ground more than 100 mm below the edge of the plot paving, provision should be made for fill to be graded down from plot limits to the lower offsite levels.

5.4 Widths of Access-ways and Clearance

5.4.1 Minimum widths of access-ways should be as follows:-

- | | |
|---|-------|
| (a) Vehicular access-ways within process plot limits | 4.0 m |
| (b) Pedestrian access-ways | 1.0 m |
| (c) Pedestrian access-ways receiving traffic from two or more routes | 1.2 m |
| (d) Maintenance access around individual equipment isolated from the main paved areas, the clearance being measured from the furthest projection on the equipment | 1.0 m |

- 5.4.2 Clearances beneath the underside of heaters and plot paving surface should be in accordance with BP Group [RP 22-1](#). Clearances of all other overhead structures and steelwork above the plot paving surface should be in accordance with BP Group [RP 42-1](#).

5.5 Structural Design of Concrete Paving

- 5.5.1 The reinforcement and thickness of paving required should be determined according to the likely usage of the paving described below.

- 5.5.2 Soil-supported access-ways and paving accessible to vehicles of wheel loads equal or greater than those specified in Clause 5.6.1, and 'drop out' areas where heavy loads may be placed or handled during construction or later maintenance, should have:-

Minimum Thickness	150 mm
Reinforcement	Adequately reinforced in top and bottom to suit loading and ground conditions.

- 5.5.3 Soil-supported paving not accessible to vehicles should be reinforced and have a minimum thickness of 100 mm.

- 5.5.4 Paving supported at grade level by piles and grade beams should be designed as suspended slabs and beams in accordance with Clause 3.5.1 for the loads described in Clause 5.6

- 5.5.5 Paving supported on rock or directly over equipment bases or piled or rafted substructure, and with no intermediate fill, should be 100 mm thick. Joints should be provided as stated in Clause 5.8.

- 5.5.6 Paving to cable trenches not subject to vehicular loading and supported on sand-fill should be 50 mm thick concrete screed of characteristic strength 10 N/mm², generally unreinforced and distinctively coloured. Where cable trenches are subject to vehicular loads, cover slabs in accordance with Clause 5.6 should be installed in place of in-situ paving.

- 5.5.7 Paved walkways of the main paved areas should be of 50 mm thick precast concrete paving flags.

In the UK, paving flags should meet the requirement of [BS 7263](#).

5.6 Loads

5.6.1 The following superimposed loads should be allowed for in the design of road bridges, suspended slab paving and removable cover slabs to service trenches. Reference should also be made to Clause 5.1.1.

Reference is made below to [BS 5400](#) and [DTp BD37/88](#) for use in the UK. Elsewhere, the appropriate national standards should be used if available.

- | | | |
|-----|---|--|
| (a) | Bridges and suspended paving in main roads and vehicle access-ways. | 45 units of HB loading together with associated loading in accordance with BS 5400 Parts 3,6, 10 and 10c and DTp Departmental Standard BD37/88 . |
| (b) | Suspended paving accessible to vehicles but not in main roads or access-ways. | HA loading in accordance with BS 5400 Parts 3,6,10 and 10c and DTp Departmental Standard BD37/88 . |
| (c) | Suspended paving not accessible to vehicles. | 10 kN point load on an area 300 mm square and 5 kN/m ² distributed load. |
| (d) | Removable cover slabs to service trenches in main roadways. | 125 kN wheel loads (100 kN plus 25% impact) being at 900 mm centres with a maximum of 4 wheels per axle. |
| (e) | Removable cover slabs to service trenches in paved areas accessible to vehicles but not in main roadways. | 50 kN wheel loads (40 kN plus 25% impact) arranged as in (d) above. |
| (f) | Removable cover slabs to service trenches in paved areas not accessible to vehicles. | 10 kN point load on area 300 mm square. |
| (g) | Removable cover slabs to service trenches in unpaved areas. | 5 kN/m ² distributed load. |

The design of cover slabs should ensure that they cannot be placed upside down in their final position or on their sides; alternatively, they should be provided with adequate reinforcement in all faces.

Where it is impractical to provide removable cover slabs due to the total width of service trench required, it is acceptable to provide a reinforced concrete slab. Such trenches should be located in areas that are generally not accessible to heavy vehicles, e.g. under overhead pipe tracks. In these cases, the sand filling to the trenches should be well tamped and a 100 mm reinforced concrete pavement topping laid. The slabs should be laid in maximum 5 m lengths and a maximum width of 5 m. Such trenches should also incorporate three 100 mm dia. PVC pipeducts per metre width of trench, embedded in the tamped sand filling for possible future cables.

5.6.2 Where soil-supported paving is used to provide horizontal restraint around pile or pier supports for structures the thickness and reinforcement of the paving should be designed to suit the stresses developed in providing horizontal restraint.

5.6.3 Where sockets or anchor rings are installed in paving for tube bundle pulling, the paving shall be designed and reinforced for the expected applied loads and moments.

5.6.4 Concrete paving may be used to support small isolated pipe runs, low level manifolds, etc., in accordance with the requirements of Clause 5.7.1 below.

5.7 Supports for Manifolds and Stairways

5.7.1 Low level manifolds and any pipe runs when not overhead, may be placed on soil supported paving within plot limits, provided that the piping system is sufficiently flexible to follow the associated settlements, is tolerant of backfalls, and that the design loading of the paving is not exceeded.

5.7.2 When the effects of ground settlements cannot be tolerated, or paving design loads would otherwise be exceeded, these manifolds and pipe runs should be supported on deeper spread foundations or grade beams and piles.

5.7.3 When gangways and platforms are attached to structures and plant on piles or spread foundations to firm subsoil, the access stairways should themselves be founded on extensions of the corresponding main foundations. Otherwise, these stairways and ladders should be designed to allow for settlement with soil-supported paving.

5.7.4 Permanent ladders from ground level should, wherever possible, be directly supported from the plant or its supporting structure and kept clear of the paving to avoid effects of settlement and corrosion at ground level. If ladder bases bear on soil supported paving, allowance should be made for settlement of the paving.

5.8 Joints

5.8.1 Spacing and Arrangement of Joints

Joints should be arranged at those locations where cracking may be expected. In addition, contraction and expansion joints should be provided to suit the ambient temperature range for the location. Hydrocarbon-resistant mastic sealing compounds are to be used for joint sealants. Steel reinforcement should be continuous through contraction joints.

5.8.2 Joints Around Bases, Plinths and Columns

Except when paving is required to provide some horizontal restraint as stated in Clause 5.6.2, it should be stopped clear from bases, plinths, piers, grade beams and manholes.

5.8.3 Joints in Unreinforced Screeds

Cable trench screeds should be poured in-situ against the adjacent paving edges without jointing or sealing, and poured in maximum lengths of 5 m.

6. ROADS

6.1 Public, Offsite and Plot Perimeter Roads

Roads which are open to the public must be designed in accordance with the appropriate national or local regulations and practices.

In the UK the authoritative references for road design are the Department of Transport 'Design Manual for Roads and Bridges' and 'Manual of Contract Documents for Highway Works'. Road Note 29 is concerned with the structural design of pavements. LR460 revises the reinforcement requirements for concrete roads. The latest edition of Road Note 29 is the 3rd Edition dated 1970. This has been supplemented by TRRL Laboratory Report 1132 'The Structural Design of Bituminous Roads 1984'.

6.1.1 Pavement Construction

Unless specified otherwise (see Clause 5.1.1.7), offsite and plot perimeter roads should be of bituminous construction. Paved areas adjoining roadways may be of bituminous construction if not subject to contamination by spillage or leakage of hydrocarbons, or alternatively of concrete.

6.1.2 Duty

Permanent roads should generally be sealed and surfaced unless required solely for fire access or infrequent maintenance access.

Temporary roads may remain unsurfaced depending on the degree of maintenance.

6.1.3 Loads

The road should be designed for the maximum vehicle load expected. This load should generally be as specified in Clause 5.6.1.

6.1.4 Design Life

The design life of the road should be compatible with that used for the plant or works. Where loads are to be adopted by local authorities then the design life should be in accordance with these requirements.

6.1.5 Existing Roads

The performance and details of existing road construction should be taken into account.

6.1.6 Road Bridges

6.1.6.1

Where road bridges are required to cross over pipetracks, streams, etc., the width between parapets, alignment of centre line and the profile of the flexible surface layer should be fully compatible with the adjoining roads. It is permissible to have gentle ramps (maximum slope 1 in 15) from top of road to top bridge level, but not at road junctions. Crash barriers are recommended where uncontrolled manoeuvring may damage adjacent facilities (see Clause 6.4).

6.1.6.2

All road bridges should be designed to withstand the appropriate vertical loading described in Clause 5.6.1.

6.1.7 Handrailing

Handrailing should be installed on the bridge parapet.

6.2 Geometry

6.2.1 General

Attention should be paid to construction or maintenance requirements, particularly where large plant items or pre-assembled units form part of the development.

6.2.2 Widths

In general, major permanent surfaced roads should not be less than 6 m wide. Minor roads should not be less than 4 m wide.

6.2.3 Hard Shoulder

Permanent roads should be provided with a 1 m wide hard shoulder at each side.

6.2.4 Gradients

Sustained gradients should not be steeper than 1 in 20, although short straight sections of road and local ramps adjacent to road and pipe bridges may be at maximum gradients of 1 in 15.

6.2.5 Junction Roads

Road junctions or bends shall provide for the safe movement of traffic without undue restrictions. The design should allow for the type of vehicles to be used and the limitations of space at such locations, but generally the internal radius to the kerbing should not be less than 10 m. Crash barriers are recommended for all junctions where there is potential for damage by uncontrolled manoeuvring (see Clause 6.4).

6.3 Drainage

6.3.1 Sub-Soil Drainage

The maximum height of the ground water table should be established to determine whether subsoil drainage is required to maintain a stable condition during the rainy period.

6.3.2 Surface Water Drainage

The road surface should be drained to run off to ditches at the sides of the road and thence by percolation into the adjacent ground. Where this is not feasible due to ground impermeability or where such practice would contravene local or national regulations, drainage should be via an open ditch and piped system in accordance with BP Group [RP 4-1](#).

6.4 Crash Barriers, Protection Bollards

6.4.1 Crash barriers and protection bollards are not generally required. However, where the horizontal alignment of any type of road changes abruptly, and conceivably any out-of-control vehicle could cause damage to pipework, cabling or items of the installation, a safety barrier shall be provided. If, for any reason, pipework or an item of the installation is located immediately adjacent to a road, the erection of a protective barrier should be considered.

6.4.2 Where required, protective barriers should generally be located at the outer edge of the hard shoulder and not less than 1 m from the road edge.

6.5 Kerbing

Kerbing of roads is not generally required except at road or road and vehicle access-way junctions, where there is a specific requirement to contain contaminated runoff or spillages and as in Clause 5.3.

7. RAILWAY WORKS

Installation and testing of railway lines and sidings are subject to the approval of the rail network authority to which the facility is connected.

In the UK, British Rail practice will be specified together with appropriate national standards.

8. PILING

8.1 General

8.1.1 This Section covers the use of piles generally for:-

- (a) Foundations for buildings, structures, tanks, etc.
- (b) Horizontal anchorage or restraint.
- (c) Retention of soil filling in sheet piled retaining walls.
- (d) Temporary construction.

It is not applicable to marine piles for jetties, moorings or other offshore structures.

8.1.2 The design of all foundations should meet the requirements of the local national standards.

In the UK, the design, manufacture, installation and testing of piles should comply generally with the recommendations given in:-

- (a) [*BS 8004.*](#)
- (b) *The ICE Model Procedure and Specification for Piling. (Only clauses relating to the satisfactory design and testing of piles are relevant and any references relating to conditions of contract or other contractual arrangements are not applicable.)*
- (c) *The Civil Engineering Code of Practice No. 2 Earth Retaining Structures, issued by the Institution of Structural Engineers.*

8.2 Site Conditions and Investigations

8.2.1 Where information for existing sites summarising ground conditions, subsoil data and soil investigation reports is available, an assessment as to whether or not such information is adequate should be made.

8.2.2 Where adequate information is not available for the design of piled foundations, a site investigation should be carried out to [BS 5930](#) or equivalent. This may consist of any or all of the following stages:-

- (a) Preliminary soils investigation to determine the general nature and characteristic of underlying soils of the site. This stage is usually required only on sites for which no data or previous reports are available.
- (b) Main soils investigation to provide information for detailed pile design.
- (c) Preliminary or pre-contract test piles to confirm the pile design in (b) or where the information in (b) is insufficient, for complete pile design.

8.2.3 Where test piles are to be used to obtain data for piled foundations, these piles should be sited close to selected boreholes representative of the general subsoil profile. On new sites, where possible, such locations should be selected with a view to their ultimate use as bench marks for the site.

8.3 Bearing Piles

8.3.1 Piling for plant, structures and tankage foundations, should generally be driven piles where the integrity and driven length can be checked after driving.

8.3.2 Where precast concrete piles are adopted and hard driving is expected, consideration should be given to providing at least 10% of the test piles with a cast-in 40 mm i.d. inspection duct through the centre to enable the integrity and deviation of the pile to be checked after driving.

8.3.3 Where precast concrete shell rings with in-situ hearting are adopted in soft soils and such piles are closely spaced consideration should be given to casting such piles with a 40 mm i.d. inspection duct through the centre to enable the vertical uplift and lateral displacement of the individual pile to be checked after driving of adjacent piles.

8.4 Pile Loads and Factors of Safety

The factor of safety applied to pile capacity at each site will be considered on its own merit with regard to the quality of site investigation information, the subsoil variability, the type of structure or any other particular prevailing condition.

8.5 Design of Bearing Piles

8.5.1 The type of pile to be used on a particular site should be selected with due regard to subsoil conditions such as depth to founding level, difficulties in driving to that level, possibilities of necking or other distortion while driving or constructing, heave, ground water attack, and should be formed in such a manner that the pile integrity is ensured.

8.5.2 The size, length and penetration in the founding layer and the group spacing, should be determined to develop the design load with appropriate factors of safety to suit the soil conditions.

8.5.3 Piles for any one heavy or critical piece of equipment or structure should not bear partly in one stratum and partly in another, at a different level, and in soils of widely different characteristics.

8.6 Design of Piles to Resist Lateral Loading

8.6.1 Pile foundations subject to lateral loads should be designed such that any resulting deflections may be accommodated within the supported structure and such that any differential lateral movement between adjacent structures is tolerable and acceptable.

8.6.2 When vertical and raking piles form bents, or trestles, subject to permanent or transient lateral loading the pile groups should be designed to ensure that their lateral deflections remain within acceptable limits.

8.7 Piles to Resist Uplift

Shaft and binder reinforcement shall be designed to resist the tensile forces and should be continued into the toe of the pile or any enlarged bases where these are deemed to provide the anchorage. In steel-cased piles, tension may be taken by the casing, provided 3 mm corrosion all round allowance is deducted from the steel section in tension.

8.8 Underpinning

8.8.1 Bored and jacked piles should be used for underpinning or for installation of new piles close to existing spread or pile foundations,

where it is necessary to avoid disturbance to such foundations by soil heave or vibration.

- 8.8.2 Bored and jacked piles should be taken down to at least the full penetrations of the existing adjacent piles to develop equal bearing capacities.

8.9 Sheet Piles

- 8.9.1 Steel sheet piles of approved section may be used for both permanent and temporary works.

- 8.9.2 Design, material and installation requirements, and earth pressure and stability calculations should comply with local national standards.

In the UK the codes given in Clause 8.1.2 (a) and (b) should be used.

8.10 Pile Testing

- 8.10.1 At new sites where piles are likely to be required and at existing sites where variations in strata conditions occur in the pile supporting strata or when a new type of pile is being used, test piles should be installed as close as possible to any existing borings (see Clause 3.2 and 8.2.3).

- 8.10.2 Pile testing includes the installation of test piles to determine the bearing capacity of the subsoil at various depths from full-scale loading tests, and the load testing of working piles which are to become part of a foundation. Test piles should, wherever practicable, be loaded to failure but test piles which will subsequently be working piles should be tested to 1.5 x design working load.

- 8.10.3 Test piles should be of the same type and size as the proposed working piles.

- 8.10.4 Load testing should be carried out generally in accordance with the procedure in [BS 8004](#) and the [ICE Model Procedure and Specification for Piling](#).

9. CIVIL WORKS FOR SERVICES AND PIPELINES

9.1 Power, Light and Instrument Cable Trenches

- 9.1.1 Paved Areas

Where cable trenches inside process plant paved areas are required in accordance with BP Group [RP 12](#) and BP Group [RP 30](#), they should generally be constructed with a reinforced concrete base with walls



constructed from either brickwork, precast concrete blockwork or reinforced concrete.

9.1.1.1 Trench fill

- Cable installation and sand fill as necessary should be in accordance with BP Group [RP 12](#).

9.1.1.2 Paving over trenches

- Paving over cable trenches should be in accordance with Clauses 5.5.6 or 5.6.

9.1.1.3 Partition walls

- In a multipurpose cable trench, instrument and telecommunication cables should be separated from power and light cables by means of a division wall extending the full depth of the trench.
- Slots with removable lintels or beams, adequately supported and located, should be provided in such walls where cables pass through them and support is required to cover slabs above.
- Nominal 100 mm x 100 mm weep holes at 5 m centres should be provided at the junction of the base slab and walls for the passage of moisture.
- Cable entry through the trench walls should be via built in ducts.
- In the design of such trenches the effects of the following should be taken into consideration:-
 - Soil conditions and loads,
 - Vehicular loads,
 - Wall heights,
 - Cover slab spans or trench surfacing,
 - Constructional requirements (both from a civil and cable laying viewpoint).

9.1.1.4 Unpaved Areas

- In unpaved areas within, adjacent to, or remote from plot limits, power, light and instrument cables may be direct buried or laid in trench units in accordance with the requirements of BP Group [RP 12](#) and BP Group [RP 30](#).

9.1.1.5 Where cables are direct buried, they should be a minimum of 450 mm below the unpaved surface, surrounded with 75 mm of uncontaminated sand in accordance with BP Group [RP 12](#) and BP Group [RP 30](#) and protected by identifiable cable tiles or plastic cable marker tape as appropriate. Concrete route markers should be installed at surface level.

9.1.2 Precast Concrete Cable Trench Units

- (a) At road and rail crossings, cables should be ducted, see 9.4, but where large numbers of ducts are involved, a reinforced concrete in-situ trench with removable precast cover slabs designed to carry the appropriate loads as in Clause 5.6, may be used as an alternative.
- (b) The top level of covers to trenches abutting or within paved areas, should be at plot paving level. In unpaved areas adjacent to plot paving, covers should generally be 150 mm above adjacent open ground level (but with suitable transition levels where necessary to connect with trenches within paved areas). In unpaved areas remote from plot limits, precast cable trenches and covers, when used, should be set at a level to suit local surface-water run-off drainage requirements. Lifting slots should be incorporated in every fifth cover.
- (c) Precast trench units should be laid directly abutting one another without jointing and the covers laid thereon without sealing the joints.

9.1.3 Trench Support

9.1.3.1 Trenches should be supported directly on, and constructed in-situ with, foundation substructures. In other locations, trenches should be supported on the subsoil, which should be levelled and compacted such that differential settlements between the trench, paving and adjacent foundations are minimised.

9.1.3.2 Provision should be made to accommodate relative movement where the support to a trench changes from subsoil to foundation substructure. To avoid the possibility of cables being sheared at such locations, a short hinged transition length of trench devoid of sand filling and with precast cover slabs, or equivalent arrangement, should be provided.

9.2 Pipe Trenches

- 9.2.1 Trenches for process plant piping should generally be avoided. However, if considered necessary they should comply with BP Group RP 4-1 and BP Group [RP 42-1](#) regarding clearance to pipework, falls for drainage, provision of trapped gullies (offset if necessary for access, rodding and cleaning), spacing of firebreaks and trench flooring. Paving around the trenches should be arranged as in Clause 5.2.
- 9.2.2 Trenches in plot paving should have walls and floors constructed of reinforced concrete. Alternatively, walls may be of precast concrete blockwork or brickwork. Where there is risk of hydrocarbon contamination of the trench, the blockwork or brickwork should be laid on a minimum 150 mm high concrete upstand cast monolithically with the trench base slab, the top of this upstand being horizontal. The floor slab should be channelled to pass surface water below pipe bearers.
- 9.2.3 Trench covers should be either galvanised open steel grate or concrete wherever practical:-
- (a) Inside industrial buildings:-

8 mm thick chequer plate flooring may be considered.
 - (b) In open areas within plot limits:-

Open grating of rectangular pattern, galvanised or suitably protected against corrosion. Angle kerbing is to be connected into the reinforced concrete and will ensure that covers are flush fitting.
- 9.2.4 Trench firebreaks are to be provided as required.
- Large pipes and all pipes subject to thermal movement should be sleeved, and the annulus plugged and then sealed with a hydrocarbon-resistant mastic seal. All piping or sleeving in contact with the fill material contained within the firebreak should be protected against corrosion.
- 9.2.5 The filling to firebreaks between brickwork should be of clayey sand or sandy soil, compacted around the pipes in as dry a state as practicable. In paved areas, trench firebreaks should be topped with a 50 mm concrete screed.

9.3 Telephone Cable Trenches

In general, telephone cables should be run underground within the plot limits, from a point opposite the nearest offsite junction box. Within the plot paved area, telephone cables may be run with power and lighting cables in a common trench.

In the UK, requirements for buried telephone cables are covered in [BS 6701](#). Generally these recommend a depth of 350-450 mm and between 25-500 mm separation from power cables depending on the voltage of the power cable.

9.4 Ducts

9.4.1 Cable Ducts

9.4.1.1 Cable crossings, under offsite roads and under vehicle access-ways not part of the plot paving, should be formed of ducts encased in reinforced concrete. Ducting should extend a sufficient distance beyond the road or hard shoulder edge to ensure that there is no damage or undermining of the road or hard shoulder during any subsequent excavation to duct invert level. Spare ducting should be included for possible future requirements.

9.4.1.2 The design of such ducts, their bedding, concrete surround and reinforcement shall withstand the appropriate traffic loading as in Clause 5.6. The top level of the concrete duct shall be a minimum of 450 mm below the crown level of the road or access-way concerned. If at the end of the duct, cables continue in a pre-formed trench, a suitable transition pit should be provided with floor sloping at an angle not greater than 30 degrees and with removable concrete covers and sand filling above the cables.

9.4.2 Ducts for Instrumentation Lines

Ducts for instrumentation lines crossing under roads from process units to adjoining or centralised control buildings may be formed as in Clause 9.4.1 above. After installation, the instrumentation lines in the ducts should be surrounded with mastic sealant, and access pits at either end filled with sand with a 50 mm concrete screed over.

9.5 Ducts and Cable Trenches at Buildings

9.5.1 Provision should be made to prevent any accumulation of flammable liquids and gases in buildings, due to entry via service ducts, cable trenches or drains.

9.5.2 On all sites, irrespective of water table level or substrata conditions, the bottom level of cable trenches required within control room,

substation and switch house buildings, and invert level of any entry holes or ducts thereto, should be in accordance with Clause 4.2.

9.6 Pipe Sleeves

9.6.1 Road and Rail Crossings

Load bearing sleeves should be provided to pipes crossing under roads, access-ways or rail tracks, where provision of a bridge would be uneconomical and where:-

- (a) The strength of the pipe is inadequate for the anticipated loading.
- (b) The pipe is subject to excessive thermal movement.
- (c) For operational convenience or safety, it is desired to be able to replace the pipe without excavation.

Flexible end seals, resistant to hydrocarbons where appropriate, should be fitted between pipes and sleeves at both sides of the crossing.

9.6.2 Pipes Through Structural Elements

Large-diameter pipes and all pipes subject to thermal movement should be sleeved when passing through walls or other structural elements or firebreaks. Such sleeves should normally be of steel, except that in any exposed position above grade they should be of non-corroding material in order to obviate unsightly rusting and spalling of the adjoining concrete or mortar. Where necessary, flexible end seals resistant to hydrocarbon, should be fitted between the pipe and its sleeve.

9.6.3 Pipes through Earth Bunds

All pipes subject to thermal movement should be sleeved when passing through earth bunds. End seals, resistant to hydrocarbon where appropriate, should be fitted between the pipe and its sleeve, and such seals should be capable of withstanding the hydrostatic pressure appropriate for the height of the bund. Where pipes come into contact with soil they must be properly protected against corrosion.

9.7 Fire Hydrant Pits

The use of fire hydrant pits should be discouraged.

9.8 Valve Pits

9.8.1 Pits for small underground lines should be constructed with precast concrete blockwork or brick walls, where there is no necessity to anchor the pipes in the walls. Where there is risk of hydrocarbon contamination of the pit, the blockwork should be laid on a concrete upstand cast monolithically with the pit base slab, a minimum of 150 mm high, the top of this upstand being horizontal.

9.8.2 For lines where restraint is required against thermal movement, and for larger pits where earth and hydrostatic pressures become design criteria, construction should be wholly of reinforced concrete in accordance with the requirements of liquid retaining structures. Where pipes penetrate walls at a level below the highest expected water table, the pipes should be fitted with puddle flanges located in the centre of the wall and the walls local to the pipe should be at least 250 mm thick.

9.8.3 Valve pits should be finished 150 mm above adjacent paving or ground level, left open, and provided with handrailing. Pit floors should be sloped to a shallow sump, to allow for pumping out of liquids, and where necessary the pit walls should be provided with step irons.

9.9 Floodlight Masts

Floodlights, where they are not mounted on plant structures, should be mounted on masts, with foundations either spread or integral with the plot paving, thickened and reinforced as required.

9.10 Earthing

Earthing electrodes shall be installed through the paving and elsewhere in the ground, in accordance with BP Group [RP 12](#).

10. STORAGE TANKS

10.1 General

This Section covers foundations for vertical steel storage tanks designed and constructed in accordance with BP Group [RP 58-1](#) and BP Group [GS 158-2](#). It also covers the civil engineering design of the bunded areas.

10.2 Tankage Layout and Grade Levels

10.2.1 The layout and spacing of tanks shall be in accordance with BP Group [RP 44-7](#). The stated minimum spacing between tank shells should be

increased as necessary where tank stability and/or settlement due to interaction of foundations is the governing factor.

10.2.2 The design levels must be dependent on local or national authority regulations, and should take account of pumping requirements, tie-in points, foundation conditions, drainage requirements, ground water table and any earthwork requirements elsewhere on the site.

10.2.3 Wherever possible, grade levels inside and outside bunded areas and the associated levels for roads, pipetracks and tank pads should be determined to balance the cut and fill earthwork requirements.

10.3 Tank Foundation Design

10.3.1 Foundation design should be compatible with the type of tank, design life and the degree of integrity required for storage of the product. The selection of foundation type should aim at minimising total tankage cost, taking into account:-

- (a) Cost of construction.
- (b) Cost of land.
- (c) Time period to commissioning.
- (d) Maintenance costs.

In the UK, tank foundation design should generally be in accordance with [BS 2654](#) and [BS 8004](#).

10.3.2 Types of foundations for vertical steel storage tankage are broadly classified as follows:-

- (a) Earth Mound Foundations

Earth mound foundations to support steel vertical storage tanks of low height to diameter ratio basically consist of a well compacted mound. At sites where existing soil or subsoil conditions are poor, ground improvement works may be necessary.

- (b) Piled Foundations

Piled or other deep foundations may be required where subsoils are soft, where tanks of large height: diameter ratio are required and when the resultant differential settlements of the earth-

mound or even concrete raft foundations, are expected to be excessive.

- 10.3.3 A site investigation is required to identify the ground conditions under the complete area of each tank to a depth over which significant settlements may occur. The position of any existing foundations should be plotted and the existence of any land drainage established. In reclaimed areas, the position of original watercourses and filling dikes should also be established.

In the UK, site investigations are carried out in accordance with [BS 5930](#).

- 10.3.4 Where the founding material is sound or weathered rock, the site investigation should be supplemented by a geotechnical mapping of the tank pad formation. The maps should be prepared by an experienced engineering geologist or geotechnical engineer in the format proposed in 'The preparation of maps and plans in terms of engineering geology' - a Report of the Geological Society Engineering Group Working Party, published in the Quarterly Journal of Engineering Geology, Vol. 5, 1972.

- 10.3.5 This mapping should be carried out concurrently with the site investigation. However, in some cases it may be necessary to undertake the mapping on completion of the primary excavation works. It should be recognised that an examination of the exposed material at this stage may result in variations to the tank location or foundation design.

- 10.3.6 The ultimate bearing capacity of the foundation should be determined by a comprehensive stability analysis, and an adequate factor of safety against failure under the worst loading conditions is to be applied.

- 10.3.7 Where a piled foundation design is required, particular attention should be paid to the group action of the piles in assessing overall stability and settlement of the foundation. The design should take into account the possible installation difficulties of high density piling such as uplift, lateral heave and densification of granular layers leading to increased driving resistance.

- 10.3.8 Settlement criteria for the immediate and long term conditions should be determined at an early stage in the design in respect of:-

- (a) Total settlement.
- (b) Edge-to-centre differential settlement and localised rotation of the floor plates.

(c) Peripheral differential settlement.

- 10.3.9 Settlement criteria are to be defined to ensure that settlements will not result in the tank and its fittings being overstressed, and in the case of floating roof tanks, to limit deformation of the shell so that the roof remains free to move and the seals retain their integrity. Even with detailed investigation and analysis, settlement calculations are of limited accuracy. Tanks shall not be designed to depend for their integrity on precise settlement predictions.
- 10.3.10 Where the site is located in an area that may be influenced by earthquakes, the design should include for seismic loading in accordance with Clause 2.2.
- 10.3.11 The design of earth mounds for heated tanks should ensure that the temperature at formation level does not cause significant shrinkage to underlying soils. Temperature monitors should be installed in the soil for all foundation types where a cooling system is required.
- 10.3.12 Restraint against uplift should be designed in accordance with Appendix R of [API Standard 620](#) for tanks with internal pressures less than 1050 mbar.
- 10.3.13 The effect of differential settlement across concrete base slabs supported on piles and any thermal movement should be considered in the design. In locations where the soil is liable to settle significantly around the piles, a downstand may be required around the periphery of the slab to prevent any gap between slab and soil being open to the atmosphere, and thus allowing gases to collect under the slab.

In the UK, [BS 8110](#) is used for the design of concrete structures. The equivalent US Standard is [ACI 318](#).

10.4 Associated Foundations

Foundations and bases for tank access ladders, support towers, pipe supports, etc., should be designed to allow for anticipated settlement of the tank. It may be necessary to grout the bases after completion of the water test and make provision for subsequent adjustments. The method of excavation for these foundations should be closely specified and supervised by the designer to ensure that the integrity of the tank foundations is not affected. Reference should also be made to Clause 10.5.5.

10.5 Earth Mound Foundations

- 10.5.1 Earth mound foundations are preferred for large vertical storage tanks where the subsoil conditions are suitable or where ground improvement techniques such as dynamic compaction are proposed.

BP recent experience has been that ground improvement for tank bases using stone columns has been unsatisfactory. Use of this technique should be fully justified before acceptance.

In the UK, BS 2654 provides guidance on the construction of foundations and the testing of vertical, steel storage tanks. Alternatives to this code may be used where they satisfy the same level of requirement. In order to minimise entry of water under the tank base the mound should slope away from the outside edge of the annular plate. BP experience would suggest that the slope should be 20 mm over the first 150 mm and at 1 vertical to 10 horizontal thereafter.

- 10.5.2 The core of the mound may be constructed from any highly-compactable, chemically inert, locally-available material that is not susceptible to frost heave, is non-corrosive and is of low compressibility and sufficient strength. In order to prevent undertank corrosion a capillary break is required within the mound. This can be achieved by installation of an underbase membrane or a free draining permeable layer of material. An annular ring of coarse granular material may be required to provide high edge load resistance when the locally-available material has low strength except when confined (e.g. fine sands). The top surface of the mound should be provided with a permeable granular drainage layer and should be covered with bitsand in accordance with Clause 10.5.

The top surface of the mound should be provided with a permeable granular drainage layer and should be covered with bitsand in accordance with Clause 10.6.

- 10.5.3 Depending on the product stored an impermeable membrane is usually required below the drainage layer. The form of undertank lining will depend on the soil characteristics, permeability of the material used in the mound and bund and the potential for ground contamination. Specialist advice should be sought to balance the most cost effective solutions against any potential environmental damage. Local authority and national regulations need to be consulted as in some countries these will determine the solution adopted in respect of impermeability of the bunded area. The membrane may also be required to minimise the possibility of wash-out of the mound in the event of a bottom plate leakage. The design should be checked to ensure that the introduction of an impermeable membrane or clay layer does not weaken the foundation.

- 10.5.4 Concrete structures should not be incorporated in earth mound foundations. Where this cannot be avoided, e.g. where a concrete ring beam is required to resist uplift or a bottom entry pipe is needed surrounded by a concrete collar, detailed attention should be given to the consequences of differential settlement between the soil and concrete. The design and construction of the foundations and the tank

should be such as to reduce as far as possible the differential settlement and its consequences, the most serious of which is the risk of overstressing the bottom plates. In order to minimise this risk, particular attention should be given to:-

- (a) Avoidance of sudden changes in the condition of support.
- (b) The positions of potential sudden change in support in relation to the bottom plate welds, particularly the sketch to annular plate lap.
- (c) Compaction of the fill adjacent to concrete structures.

10.5.5 A hinged transition slab may be required to minimise the local effect of consolidation and differential settlement.

10.6 Bitsand Surfacing

10.6.1 The surface of the tank foundation and the side slopes of an earth mound foundation should be covered with a 50 mm compacted thickness of bitsand in accordance with the detail in BS 2654 Appendix A. The bitsand layer should be maintained over any concrete structures incorporated in the foundation and should be extended beyond the annular plate even if holding-down bolts are installed to resist any uplift of the tank. If the foundation includes or consists of a complete concrete raft, the bitsand thickness may be reduced to 25 mm.

10.6.2 In addition to the tolerances stated in [BS 2654](#) Appendix A, the surface level of the finished bitsand along any radial should not deviate by more than 15 mm from the design levels and the difference in level of any two points 10 m apart, should not vary by more than 10 mm.

10.6.3 If necessary, the slope away from the tank annular plates should be reinstated on completion of the water test.

10.7 Tank Testing

10.7.1 The test procedure is an integral part of the design and construction of the tanks. A hydrostatic test should normally be carried out in accordance with [BS 2654](#). The test fluid is generally water and the foundations should therefore be designed for a full-height water test unless otherwise instructed by a Plant Specification. The settlement results should be interpreted as the test proceeds, in order to control the rate of filling, to prevent overstress of fine-grained soils and to confirm whether the tank can be commissioned for its design duty.

It is stressed that the hydrotest results on their own are not sufficient to justify the long term serviceability of the tank. The design of the tank foundations must take into account all factors relating to the short and long term settlement and bearing capacity.

- 10.7.2 The water test procedure should give the following information:-
- (a) Number and details of reference points for level measurement externally and internally.
 - (b) Method of levelling.
 - (c) Bench mark details.
 - (d) Source of water.
 - (e) Procedures for emergency disposal of water if off loading becomes necessary.
 - (f) Rate of filling of tank.
 - (g) Stages of loading and unloading.
 - (h) Hold periods at each stage in terms of acceptable increases in settlement with time.
 - (i) Minimum hold period at maximum load.
 - (j) Disposal of water and clean out and freshwater wash-down procedure if necessary.
 - (k) Anticipated overall programme for test.
 - (l) Supervision.
- 10.7.3 Settlement gauges and inclinometers of various types may be required to be installed in the tank foundations. It may also be necessary to install piezometers to monitor pore-water pressures during the water test for tanks formed on weak clayey soils.
- 10.8 Bunds**
- 10.8.1 The height and location of the bunds should be decided in accordance with the tank layout (see Clause 10.2.1), and the strength of the subsoil.
- 10.8.2 Earthwork bunds should be designed with stable side slopes appropriate to the conditions and have a minimum top width of 920 mm.

- 10.8.3 Normally, earthwork bunds are preferred. These should be constructed whenever possible of site-excavated material with the most impermeable material being used on the inner face. Highly permeable material such as sand should be used only with the approval of local or national regulating authorities. It may be permissible to use the material if clay or another suitable impermeable material is used to cover the profile.
- 10.8.4 Care should be exercised in the use of frost-susceptible materials in areas of low ambient temperatures.
- 10.8.5 The crest and sloping sides of bunds may be stabilised by planting grass, spraying with bitumen or other approved methods, depending on local conditions and materials.
- 10.8.6 Concrete bunds should be designed to resist full-height hydrostatic pressures.
- 10.8.7 The extent and form of bund lining may be required to meet local or national authority regulations. Specialist advice should be sought to balance the most cost effective solution against any potential environmental damage.
- 10.8.8 Temporary openings left in bunds for construction access and any openings subsequently cut for pipelines, should be benched in 300 mm steps at 45 degrees before backfilling to form a 'key' and prevent local slipping. These should be filled with material similar to that used for the bunds, placed and compacted in the same manner as the rest of the bund. Any softened material in the benched portions of the bund should be removed before backfilling and compaction commence.
- 10.8.9 Steps, normally 600 mm wide, together with handrail, should be provided for access over the bund.
- 10.8.10 Clear access to tank valves, stairways and manifolds on both sides of bunds should be provided by footpaths with a minimum width of 600 mm.

It may prove necessary to elevate walkways within the bunded area to permit dry access between the bund and tank in all weather.

10.9 Grading and Drainage within Bunded Areas

- 10.9.1 The drainage from the bunded areas shall be in accordance with the requirements of BP Group [RP 4-1](#).

11. PRESSURE STORAGE VESSELS

11.1 Vessel Foundation Design

- 11.1.1 Only two supports should be provided for horizontal cylindrical tanks. Where foundations bear on weak soils, and could be prone to differential settlement, an alternative support system may be considered.
- 11.1.2 The design of foundations for spheres shall accommodate the limitations on differential settlement between adjacent supports which may be required by the sphere designer. In exceptional cases a means for jacking may be provided.
- 11.1.3 Permanent load monitoring points should be installed on vessel foundations. Levels should be recorded during hydrostatic testing, and then at regular intervals thereafter, to ensure that pre-determined differential settlement criteria are not exceeded.

11.2 Vessel Spacing, Bunding and Area Grading

- 11.2.1 The layout and spacing of vessels should be in accordance with BP Group [RP 44-7](#).
- 11.2.2 Bunding is not required but dwarf walls should be provided to prevent spillages reaching nearby equipment or pipetracks and to direct any spillages to a collection area.
- 11.2.3 The area under vessels should be graded to drainage channels, and in such a way that spillage from any one vessel will not flow towards any of the other vessels. For further details of drainage requirements reference should be made to BP Group [RP 4-1](#).
- 11.2.4 The graded areas under vessels should be covered with a concrete apron extending for 4.5 m to 6 m outside the periphery of the vessels, or to the extent of any area enclosed by dwarf walls.

12. CHEMICAL-RESISTANT FLOORING

12.1 General

- 12.1.1 In plants where frequent spillage of corrosive chemicals may occur, a suitable chemical-resistant surfacing should be provided in order to protect the yard paving or subfloor of a structure or building, bases and wall faces from attack. Although some plants may require extensive treatment, limited and localised treatment may be adequate on other plants.



12.1.2 The following should be considered in the design of chemical-resistant flooring:-

- (a) The nature and concentration of all materials which may come into contact with the flooring as a result of process operations or malfunction of equipment.
- (b) The nature and concentration of all cleaning agents which will come into contact with the flooring.
- (c) The temperature of all materials likely to be spilt on the flooring, including possible exothermic or endothermic reactions with wash-down water.
- (d) The location of the floor (e.g. ground floor or suspended floor).
- (e) The construction of the subfloor.
- (f) The loading characteristics of the floor, including details of pedestrian and wheeled traffic.
- (g) Details of any vibration resulting from plant located in the building.
- (h) Details of any specified foreseeable process changes which would involve the use of materials or conditions not listed above.
- (i) Non-skid acid resisting bricks or tiles are preferred in process working areas subject to acidic corrosion.

12.1.3 The installation should be carried out by a specialist firm having experience of the materials specified.

12.2 Chemical-Resistant Surfacing Materials

12.2.1 All chemical-resistant brick or tile surfacing should consist of two layers. The top layer is the actual wearing surface, which should be anti-slip and resistant to the chemical and mechanical conditions specified. The bottom layer is a substantial membrane or impervious underlay, which should protect the subfloor in the event of the top layer being damaged.

12.2.2 Chemical-resistant surfacing may be divided generally into the following categories:-

- (a) Jointless surfacing such as acid resisting asphalt, polyester and epoxy resin flooring and other proprietary floor surfacings.
- (b) Brick or tile surfacing such as acid-resisting bricks or tiles bedded and jointed in chemical-resistant mortar.

12.2.2.1 Jointless surfacings are normally proprietary brands and should be designed, and applied strictly in accordance with the manufacturers written instructions by a specialist firm having experience of the particular material specified and preferably under the site supervision of the manufacturer's representative.

12.2.2.2 Jointless surfacings are not recommended for floors subject to large temperature variations.

12.2.3 Tile and brick surfacing should be laid in bonded formation, and bedded and jointed in chemical-resistant mortar. The mortar bed should be restricted to 5 mm thick and the joints should not exceed 3 mm wide.

12.3 Jointing Materials for Brick or Tile Surfacings

Jointing materials should consist of chemical-resistant mortars and should have a resistance at least equal to that of the floor surfacing to suit the chemical conditions.

12.4 Membranes

12.4.1 All membranes should have the following properties:-

- (a) The material should be resistant to corrosion by the chemicals with which it may come into contact.
- (b) The material should be completely impervious to all liquids which may be spilled on the floor.
- (c) The material should, wherever possible, possess some flexible properties.
- (d) The membrane should be completely continuous and all joints should be sealed, i.e. it should be dressed into walls at comings, carried under drainage channels, carried over plinths, dressed through holes in floors, dressed into sockets or drain outlets and sealed around machinery holding-down bolts.
- (e) The material should be sufficiently strong to support the loads it may be required to carry and robust enough to allow the top

surfacing to be broken out for repair work without damaging the membrane.

- 12.4.2 Where a solid ground floor is not subject to excessive thermal movement or vibration, the bottom layer may consist of an applied skin of material in the form of a sealing coat to suit the chemical conditions specified.

12.5 Expansion Joints

- 12.5.1 Expansion joints should be incorporated in chemical-resistant floor surfacing only when absolutely necessary, i.e. where the surfacing may be subjected to excessive temperature or thermal shock.
- 12.5.2 When expansion joints are provided, they should coincide with expansion joints in the subfloor and wherever possible be located at the high points of the floor surfacing.
- 12.5.3 Expansion joints in chemical-resistant floor surfacing should be filled with a flexible compound as recommended by a specialist manufacturer and having a chemical resistance at least equal to that of the floor surfacing.

12.6 Floor Drainage

- 12.6.1 Floor drainage should be provided as in BP Group [RP 4-1](#). Stainless steel gratings and covers should be provided as necessary.
- 12.6.2 The slope of the falls in floor surfacing and drainage channels should not be flatter than 1 in 60, and wherever possible this slope should be increased to 1 in 40.

12.7 Machine Plinths on Chemical-Resistant Floors

- 12.7.1 Machine plinths should normally be a minimum of 150 mm above finished floor level and the protective system should be continued over the plinth top and under the machine base.
- 12.7.2 Where jointless surfacing is used:-
- (a) The surfacing material should be sealed to the holding-down bolt stems after locating the machine by bedding the base plate in a further layer of the surfacing material.
 - (b) The surfacing material should then be finished off around the extremities of the base plate with a small neat fillet.

- 12.7.3 Where brick or tile surfacing are used:-
- (a) The membrane should be sealed to the holding-down bolt stems and the surfacing around the bolts made good with the same chemical-resistant mortar as that used for jointing the floor.
 - (b) Where the chemical conditions are highly corrosive, the machine base plate should be bedded in the same chemical-resistant mortar and finished off around the extremities of the base plate with a small neat fillet.
- 12.7.4 On installations for large rotating machinery, etc., where a rigid foundation is essential, it is preferable to mount the machinery on a steel bed, raised above general floor level as stated in Clause 12.7.1 above, and located directly on the concrete foundations. The chemical-resistant membrane and tiles should be suitably terminated around the steel bed.
- 12.7.5 Stainless steel holding-down bolts may be required.
- 12.7.6 Soffits of manhole cover slabs should receive a chemical resistant treatment consistent with that applied to adjacent grade surfaces.

13. FENCING

13.1 General

- 13.1.1 This Section covers general requirements for fencing, both permanent and temporary, for construction and other purposes.
- 13.1.2 For the purpose of this Section, fencing should include gates, barriers, stiles, turnstiles and cattle grids.

13.2 Safety, Security and Legal Requirements

- 13.2.1 Where necessary, the location, type of fencing and appropriate design details should be subject to approval by the Client. These details should include the wording of notices attached to the fencing. In cases where risk of intruders attempting to enter the site is known to exist, specialist advice on security is available within BP and this advice should be requested.
- 13.2.2 The rights of adjacent owners, including any rights of light and air, should be ascertained and respected. Boundaries and party fences shall be checked with them, and, in the case of disputes arising in UK, with the Land Registry.

13.2.3 Note that local legislation may affect the siting of fences

In the UK, the [Highways Act 1971](#) and the [Petroleum Consolidation Act 1928](#), apply.

13.3 Type of Fencing

13.3.1 Permanent Fencing

13.3.1.1 Whenever possible, in the interests of standardisation, the choice of permanent fencing should be made from the following chain link types:-

- (a) General-purpose fencing (1.400 m high).
- (b) Electrical transformer compound fencing (1.800 m high).
- (c) Industrial security fencing (2.130 m high).
- (d) Anti-intruder fencing (2.900 m high).

13.3.1.2 Types of chain link fencing should comply with national standards.

In the UK, chain link fencing should comply with [BS 1722: Parts 1 and 10](#) as applicable. Where these types are not permitted, or are not appropriate, selection should be made from other types covered by other parts of [BS 1722](#).

13.3.1.3 In some circumstances fencing will be insufficient deterrent against intruders. In such cases details of design and material requirements will be agreed with the Client.

13.3.2 Fencing to Transformer Compounds

Adequate provision of frame-mounted and bolted-in-position removable sections of fencing should be provided to ensure maximum choice of access for, and removal of, transformers. Also, an outward-opening lockable access gate should be provided to each separate transformer compound.

13.3.3 Temporary Fencing

Although temporary fencing need not have the durability of permanent fencing, it should provide the safety and security commensurate with its duty. Provided that these requirements are met, departures may be made from the materials and workmanship requirements of permanent fencing. In particular, steel posts of tubular or rolled section or timber posts are acceptable.

13.4 Notices

13.4.1 Notices for permanent attachment to fencing should be fixed with bolts which pass through stretcher bars on the inside face of the fencing.

13.4.2 Notices should be subject to approval by BP in their style and content.

13.5 Locks

Locks and padlocks or permanent gates, wickets and barriers should conform to the master or pass key system, where this exists.

13.6 Stiles & Cattle Grids

Stiles and cattle grids should comply with national standards.

In the UK, Stiles should comply with [BS 5709](#) and Cattle grids with [BS 4008](#).

14. STRUCTURES

14.1 Structural Form

The number of structures should be kept to a minimum by locating equipment at ground level.

Proposals should take cognisance of local conditions, locally available materials, availability of the necessary fabrication and construction facilities and skills locally, also fire protection, programme requirements and costs.

Steel structures may be constructed piecemeal and/or pre- assembled in a fabrication yard remote from the site.

Concrete structures may be cast in-situ or precast on site or at a remote location.

14.2 Standards and Statutory Requirements

14.2.1 Plant steel structures should be designed and constructed in accordance with national standards.

In the UK, where a particular British Standard does not exist, plant steel structures should be designed and constructed in accordance with [BS 5950](#).

14.2.2 Structural concrete should comply with Section 3.5.

14.2.3 Structural steel and concrete composite construction should comply with specific national codes for composite construction if these are available.

In the UK, structural steel and concrete composite construction should comply with [BS 5400: Part 5](#) and [BS 5959: Section 3](#).

- 14.2.4 Permanent mechanical lifting equipment, including overhead cranes, trolleys with hoist block, pull beams and lifting eye fixtures, should comply with the requirements of the UK Factories Act or other national legislation as appropriate.

The equipment and supports should be tested in position and a certificate of satisfactory test issued by the authority concerned.

14.3 Loading

- 14.3.1 A structure or part of a structure should be designed to resist all applicable dead and live loading as outlined in Section 2 and Clause 5.6.

- 14.3.2 Bridge structures subject to vehicular loading should comply with the loads given in Section 5.6.

14.4 Stress Levels

- 14.4.1 For special structures such as tall free-standing towers, guyed masts and structures prone to fatigue arising from cyclic loading, specialist advice should be sought when deciding safety factors and stress levels.

- 14.4.2 For fatigue-prone structures, details which give rise to high local stress should be avoided.

14.5 Design Details

- 14.5.1 As far as is practicable, all members and connections should be readily accessible for maintenance. Pockets and crevices likely to entrap water, dirt or condensation should be avoided.

- 14.5.2 Special attention should be given to possible future extensions of pipe racks and, when necessary, structural and detailed provision should be made.

- 14.5.3 All cross beams of reinforced concrete pipe racks should be provided with steel flat bars as Clause 4.7.8.

- 14.5.4 Specific attention should be given to provide, in concrete construction rack beams and columns, for the support of power and instrument cables, control and junction boxes.

14.6 Clearances

- 14.6.1 For clearances over railways, offsite roads, on-plot accessways, walkways and platforms reference should be made to the appropriate section of BP Group [RP 42-1](#).
- 14.6.2 For road bridges over pipe tracks or piping slung from underside of bridges, the clearance between bridge soffit and top of pipe, bolted flange or insulation should be at least 150 mm.
- 14.6.3 Where main pipe bridges cross offsite roads, protection should be provided to the overhead lines against impact from cranes by the installation of sacrificial goal posts or equivalent, positioned either side of the bridge and approximately 7 m distant.
- 14.6.4 No structural member should be located closer than 1.5 m to the edge or kerb of an offsite road.
- 14.6.5 If structural members have to be sited within 1.5 m of main on-plot access ways, they should be protected, (see Clause 6.4.1); alternatively they should be designed for impact loading.

14.7 Passive Fire Protection

The passive fire protection of steel structures shall be as specified in BP Group [RP 24-1](#).

14.8 Earthing

Where required, provision should be made for the earthing of steel and concrete structures in accordance with BP Group [RP 12.-16](#).

14.9 Preparation and Painting of Steel Structures

- 14.9.1 All metal surfaces should be prepared and painted unless galvanised or otherwise noted.
- 14.9.2 Preparation and Painting shall be to [GS 106-2](#).

14.10 Connections for Steelwork

- 14.10.1 Welded connections should be carried out using the manual metallic arc process. A welding procedure for each class of work should be submitted for approval prior to commencement of work.

In the UK, [BS 5135](#) is used for the specification of arc welding of carbon steels.

- 14.10.2 Bolted connections shall be made with high strength friction grip (HSFG) bolts or grade 8.8 high tensile structural bolts, except in the following minor connections where black bolts may be used:-

Removable handrail and ladder cage assemblies, removable floor plates.

Purlins and sheeting rails.

Platforms and walkways attached to vessels not more than 4 m high.

- 14.10.3 The use of HSFG bolts for structural steelwork shall be in accordance with [BS 4604](#).

- 14.10.4 All bolted connections should have a minimum of two 20 mm dia. bolts per connection, except in the case of horizontal and vertical bracing for lightweight structures, e.g. floodlight towers, where single bolted connections may be acceptable.

- 14.10.5 The variety of forms of connections should be minimised.

14.11 In-Service Inspection and Maintenance

- 14.11.1 The design of a structure should take due account of the need for in-service inspection and maintenance at appropriate time intervals.

- 14.11.2 Access to all parts of the structure for inspection and maintenance should be accommodated in the design by the provision of permanent platforms and ladders or anchor points for the attachment of temporary facilities.

15. MATERIALS

Material requirements are dealt with here only in so far as they are required for adequate design and detailing of structures.

15.1 Cladding on Steel Structures

- 15.1.1 Cladding materials may be selected from:-

- (a) zinc coated profile sheet with lightly bonded plastic finish both sides,
- (b) aluminium sheet,
- (c) profiled aluminium sheet.

In the UK, aluminium sheet is specified to [BS 1470](#) and profiled aluminium sheet to [BS 4868](#).

- 15.1.2 Aluminium cladding shall not be used in process areas or other similarly hazardous areas.

15.2 Steel Flooring

- 15.2.1 Steel flooring should conform to national standards.

Flooring should normally be of open-type metal (either rectangular pattern or pressed steel) although chequer plate flooring may be permitted where there is a danger of petroleum liquids or liquefied petroleum gases falling from high level onto lower platforms or equipment.

Ideally, steel flooring should conform to the requirements of [BS 4592](#). Chequer plate is very susceptible to corrosion and is a slip hazard in wet or icy conditions. Its use therefore should be minimised.

Open-type metal flooring should be hot dip galvanised.

- 15.2.2 Rectangular pattern, open-type, metal flooring is normally preferred with main bearing bars approximately 5 mm thick and with an anti-slip serrated top surface. The width of the opening between load-bearing bars should not exceed 25 mm.

The minimum thickness requirements of [BS 4592](#) for load bearing and transverse bars should be increased in highly corrosive environments.

- 15.2.3 Deflections of flooring should not exceed maximum permissible limits given in the standards.

- 15.2.4 Removable panels should not exceed 75 kg in weight.

- 15.2.5 Stair treads should be open-type metal, similar in pattern to main flooring, with visible slip resistant front edges and hot dipped galvanised finish.

- 15.2.6 Where chequer plate flooring is used it should be 8 mm thick over the chequers, and should be fixed using screws countersunk flush with the top of the plate. A membrane strip should be placed between the underside of the chequer plate and the supporting steelwork.

If chequer plate flooring is used to fulfil a structural task, thereby stabilising the compression flange of beams, the fixing should meet the structural requirements. Corrosion should be allowed for when developing such a detail.

15.3 Structural Steelwork

15.3.1 Structural steel should comply with national standards for materials and fabrication.

In the UK, general structural steel should comply with [BS 4360](#) or [BS EN 10025](#) as applicable. The selection of the various grades should be in accordance with [BS 5950](#).

15.3.2 When selecting the grade of steel, the resistance of the material to brittle fracture should be considered if any of the following situations exist:-

- (a) when any important element of the structure is used in circumstances where its temperature may fall below -5°C (23°F),
- (b) when a single failure may result in the collapse of a major part of the structure,
- (c) where the joint details cause areas of high restraint to welding contraction,
- (d) where tension is developed due to dynamic or shock loading.

15.3.3 Structural steelwork for use on road bridges should comply with the relevant national codes.

In the UK, the code for the design of steel bridges is [BS 5400](#): Part 6.

15.4 Concrete

Concrete should comply with national standards as stated in Clause 3.5.

15.5 Grouts

Bed plates of equipment and structures with holding-down bolts should be grouted in position using a proprietary pre-mixed flowable, non-shrink, non-metallic grout (also see Clause 4.8.7).

16. PLATFORMS, STAIRWAYS AND LADDERS

16.1 Platforms

16.1.1 A platform shall be provided at any item of equipment which requires regular attention for operation or servicing while the plant or

equipment is in commission and which is located more than 2 m above grade level or another platform.

Platforms should therefore be provided for access to:-

- (a) elevated manways on process equipment,
- (b) high level fixed fire monitors,
- (c) instrument locations,
- (d) manifold locations.

16.1.2 Where platforms at different levels and around different items can be interconnected by walkways, stairs or ladders, specific attention should be given to providing alternative escape routes in the event of fire.

16.1.3 Where pipes or fittings encroach on a walkway, a minimum clearway of 450 mm is required.

Platforms for servicing the heads of shell/tube exchangers mounted on a structure should provide a work space 1.2 m wide.

Platforms opposite manways should have a minimum clear width of 900 mm and be located at an elevation of 1.5 m below the centre line of the manway.

Connecting walkways and access platforms used for servicing purposes should have a minimum clear width of 900 mm in maintenance, main access and operating areas; elsewhere they should be 750 mm wide.

Where walkways converge, specific attention should be given to increasing the minimum width to 1.2 m.

16.1.4 When not accessible from main operating platforms or walkways, all inspection and clean out openings, instruments, control valves, orifices, relief valves and other minor items of equipment which require attention and servicing should be made accessible by permanent ladders, portable ladders, stairways or temporary platforms supported on permanent brackets.

16.1.5 Openings in the floor for piping or equipment should be sized to avoid fouling of insulation or other ancillaries. The flooring should split on the centre of the opening to permit removal and should be banded around the opening to provide a toe plate.

16.1.6 Self closing gates should be provided at platform exits to all vertical ladders. The gate should open inwards towards the platform and hinge from the outer edge of the platform. Attention can be given to the use of self-closing safety bars in lieu of gates, but safety chains shall not be permitted.

- 16.1.7 Toe plates shall be provided along all edges protected by handrailing, at openings in flooring around equipment but not across the entrance to platforms served by a side step or step through ladder. Toe plate upstand should be 100 mm.

16.2 Stairways and Ladders

- 16.2.1 Stairways shall be provided for access to platforms serving equipment which requires regular and frequent operational attendance or rapid escape or access in the event of an emergency.

In the UK, permanent ladders for industrial use should conform to [BS 5395](#), and stairway treads should conform to [BS 4592](#). The [EEMUA Publication 105](#) gives recommendations and typical details for the design and general construction of stairways, ladders, access platforms, ramps and handrails.

- 16.2.2 Stairways should be arranged with the angle of slope between 34 degrees and 38 degrees to the horizontal. Only in exceptional circumstances should slopes up to 45 degrees be provided.
- 16.2.3 The maximum rise in a single flight of stairs shall be 4.6 m. The minimum length of landing shall be 1.2 m.
- 16.2.4 Stairway tread width shall be at least 800 mm and should comply with local national standards for industrial flooring.
- 16.2.5 The lesser plan dimension of any opening in the upper surface of floors or stairways used for escape should not exceed 20 mm.
- 16.2.6 Fixed ladders shall be provided:-
- (a) for access to all platforms not served by a stairway,
 - (b) as an emergency escape from a platform which is already served by a stairway,
 - (c) for access to locations where no platform is necessary but where observation of a process condition is required involving no manual effort and which will not create a hazardous situation, e.g. checking a level indicator,
 - (d) for access to platforms provided at high level monitors or corrosion monitoring points.
- 16.2.7 Ladders, and intermediate platforms where appropriate, should comply with national standards. Rungs shall be fitted into holes in the

stringers and secured by welding. Stand-off distances for ladders should be those given in [EEMUA 105](#).

- 16.2.8 Changes of inclination should be avoided. If this is impracticable, intermediate platforms should be provided to avoid change of inclination within a "flight".
- 16.2.9 Additional safety rails shall be provided where ladders start close to the edge of an elevated platform. The safety rails shall prevent personnel falling from the platform when starting to climb up.
- 16.2.10 Safety cages shall be of circular shape in plan.
- 16.2.11 A building or structure to be equipped with a crane carrying a driver's cab shall be provided with a ladder and platform for access to the cab.

16.3 Access to Roofs

- 16.3.1 For buildings which are 6 m high or more to eaves, a ladder or ladders shall be provided to give roof access.

The ladder shall be provided with a platform not less than 500 mm wide.

The top hoop of the ladder shall be extended to form a handrail to the sides of the platform.

- 16.3.2 Duck boards or crawling ladders should be fixed to the roofs of industrial buildings where necessary to give access to roof ventilators, and to facilitate in-situ maintenance, or cleaning of the roof.

16.4 Handrails

- 16.4.1 Stairways, platforms and walkways shall be provided with handrailing.

In the UK, handrailing shall conform to [BS 6180](#)

- 16.4.2 Walkways over pipe tracks or similar low level accessways not exceeding 2 m above grade level, may be provided with handrailing on one side only. Any platforms accessways, etc., above this height shall have handrailing on both sides.
- 16.4.3 Stanchions shall be forged steel and galvanised. On stairways, stanchions should be at 1.2 m centres; on walkways, they should be at 2 m centres.

17. MAINTENANCE FACILITIES

17.1 Handling Facilities

Maximum use should be made of mobile lifting equipment, but the following permanent facilities should be provided:-

- (a) Equipment for handling parts of heat exchangers, pumps, compressors, drivers and relief valves not accessible to mobile lifting equipment.
- (b) Anchor points for pulling tubulars.
- (c) Facilities for handling special equipment and materials, e.g. catalysts.

17.2 Lifts

Use of lifts is to be restricted to a minimum.

DEFINITIONS AND ABBREVIATIONS

Definitions

Standardised definitions may be found in the BP Group RPSEs Introductory Volume.

Abbreviations

i.d. Internal diameter

LIST OF REFERENCED DOCUMENTS

A reference invokes the latest published issue or amendment unless stated otherwise.

Referenced standards may be replaced by equivalent standards that are internationally or otherwise recognised provided that it can be shown to the satisfaction of the purchaser's professional engineer that they meet or exceed the requirements of the referenced standards.

UK General

The Civil Engineering Code of Practice No. 2 - Earth retaining structures, issued by the Institution of Structural Engineers, UK.

The preparation of maps and plans in terms of engineering geology - a report of the Geological Society Engineering Group Working Party, UK.

[ICE Model Procedure and Specification for Piling, Institution of Civil Engineers, UK.](#)

[DTp Departmental Standard BD 37/88, Department of Transport, UK.](#)

[Highways Act 1971, UK.](#)

[Petroleum Consolidation Act 1928, UK.](#)

[TRRL](#) *Transport and Road Research Laboratory, Thickness design of concrete roads Report RR 87, TRRL. The structural design of bituminous roads, Report LR 1132.*

[EEMUA 105](#) *Factory Stairways, Ladders and Handrails (including access platforms and ramps).*

British Standards

BS 1470	<i>Specification for wrought aluminium and aluminium alloys for general engineering purposes - plate, sheet and strip</i>
BS 1722	<i>Fences</i>
BS 2654	<i>Specification for manufacture of vertical steel welded non refrigerated storage tanks with butt-welded shells for the petroleum industry</i>
BS 2655	<i>Specification for lifts, escalators, passenger conveyors and paternosters</i>
BS 4008	<i>Specification for cattle grids</i>
BS 4211	<i>Specification for ladders for permanent access to chimneys, other high structures, silos and bins</i>
BS 4360	<i>Specification for weldable structural steels</i>
BS 4592	<i>Industrial type metal flooring, walkways and stair treads</i>
BS 4604	<i>Specification for the use of high strength friction grip bolts in structural steelwork. Metric series</i>

<i>BS 4675 : Part 1</i>	<i>Basis for specifying evaluation standards for rotating machines with operating speeds from 10 to 200 revolutions per second.</i>
<i>BS 4868</i>	<i>Specification for profiled aluminium sheet for building</i>
<i>BS 5135</i>	<i>Specification for arc welding of carbon and carbon manganese steels</i>
<i>BS 5328</i>	<i>Concrete</i>
<i>BS 5400</i>	<i>Steel, concrete and composite bridges</i>
<i>BS 5628</i>	<i>Code of practice for use of masonry</i>
<i>BS 5709</i>	<i>Specification for stiles, bridle gates and kissing gates</i>
<i>BS 5950</i>	<i>Structural use of steelwork in building</i>
<i>BS 6031</i>	<i>Code of practice for earthworks</i>
<i>BS 6180</i>	<i>Code of practice for protective barriers in and about buildings</i>
<i>BS 6399 : Part 1</i>	<i>Loading for buildings: Part 1 Code of practice for dead and imposed loads</i>
<i>BS 6701</i>	<i>Code of practice for installation of apparatus intended for connection to certain telecommunication systems</i>
<i>BS 8004</i>	<i>Code of practice for foundations</i>
<i>BS 8007</i>	<i>Code of practice for design of concrete structures for retaining aqueous liquids</i>
<i>BS 8110</i>	<i>Structural use of concrete</i>

British Codes of Practice

<i>BS CP 3: Ch V: Pt 2</i>	<i>Code of basic data for the design of buildings: Chapter V Loading: Part 2 Wind loads</i>
<i>BS CP 2012: Part 1</i>	<i>Code of practice for foundations for machinery: Part 1 Foundation for reciprocating machines</i>

American

<i>API 620</i>	<i>Recommended rules for design and construction of large, welded, low-pressure storage tanks</i>
<i>ACI 305</i>	<i>Recommended practice for hot weather concreting</i>
<i>ACI 318</i>	<i>Building Code requirements for reinforced concrete.</i>

German

<i>DIN 4024</i>	<i>Supporting structures for rotary machines(especially pier foundations for steam turbines) VDI 2060 Standards of evaluation for the state of balance of rotating rigid bodies.</i>
<i>VDI 2060</i>	<i>Standards for evaluation for the state of balance of rotating rigid bodies</i>



BP Group Documents

BP Group RP 4-1	Drainage Systems (replaces BP CP 5)
BP Group RP 4-6	Procedure for the Design of Blast Resistant Buildings (replaces BP CP 19 Appendix B)
BP Group RP 12 series	Electrical Systems and Installations (replaces BP CP 17)
BP Group RP 22-1	Fired Heaters (replaces BP CP 7)
BP Group RP 24-1	Active Fire Protection (replaces BP CP 15)
BP Group RP 30	Instrumentation (replaces BP CP 18)
BP Group RP 42-1	Piping Systems (replaces BP CP 12)
BP Group RP 44-7	Plant Layout (replaces BP CP 3)
BP Group RP 58-1	Non-Refrigerated Petroleum and Petrochemical Storage (replaces BP CP 21)
BP Group GS 104-1	Onshore Piling
BP Group GS 158-2	Tanks to BS 2654
BP Group GS 106-2	Painting of Metal Surfaces



LIST OF RELATED DOCUMENTS

BS 594	Hot rolled asphalt for roads and other paved areas
BS 1200	Specification for building sands from natural sources
BS 1247	Manhole steps
BS 1768	Specification for Unified precision hexagon bolts, screws and nuts, (UNC & UNF threads) Normal series.
BS 1881	Testing concrete
BS 3139	Specification for high strength friction grip bolts for structural engineering
BS 3382	Specification for electroplated coatings on threaded components
BS 3692	Specification for ISO metric precision hexagonal bolts, screws and nuts. Metric units
BS 4027	Specification for sulphate resisting Portland cement
BS 4190	Specification for ISO metric black hexagonal bolts, screws and nuts
BS 4320	Specification for metal washers for general engineering
BS 4395	Specification for high strength friction grip bolts and associated nuts and washers for structural engineering
BS 4987	Coated macadam for roads and other paved areas
BS 5750	Quality Systems
BS 5930	Code of practice for site investigations
BS 7263	Precast concrete flags, kerbs, channels, edgings and quadrants
Paper No. 25	Building Research Station Research Paper