

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

Manual

SITE PREPARATION AND EARTHWORKS INCLUDING TANK FOUNDATIONS AND TANK FARMS

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This revision of PTS **34.11.00.11 - Site Preparation and Earthworks Including Tank Foundations and Tank Farms (March 2009, Revision 1)** has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font.

The previous version of this PTS **34.11.00.11 (April 2003)** will be removed from PTS binder / e-repository from herein onwards.

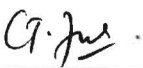
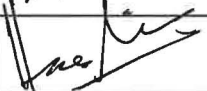
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PREFACE

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They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU/Divisions in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where PTS may not cover every requirement or diversity of condition at each locality. The system of PTS is expected to be sufficiently flexible to allow individual operating units to adapt the information set forth in PTS to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use PTS they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, it is expected of them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the PTS. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the owner.

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1. INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and gives recommendations for the design, planning, material selection, construction and maintenance for site preparation, earthworks, and shore and scour protection. It also covers the same elements for the civil works of tank farms and tank foundations.

In preparation of this PTS, the prominent and relevant points from BS 6031 have been incorporated. In the event of doubt, reference can be made to that standard.

The information contained in this PTS is supplementary to the following civil engineering PTSs:

Minimum requirements for structural design and engineering	PTS 34.00.01.30
Site investigations	PTS 34.11.00.10
Geotechnical and foundation engineering	PTS 34.11.00.12
Roads, paving, surfacing, slope protection and fencing	PTS 34.13.20.31
Drainage and primary treatment facilities	PTS 34.14.20.31

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies forming part of the PETRONAS Group or managed by a Group company.

This PTS is intended for use in oil refineries, chemical plants, gas plants and exploration and production facilities as well as distribution storage depots and installations. When PTSs are applied, a Management of Change (MOC) process should be implemented. This is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. Based on the potential impact on design, construction and maintenance costs, the Principal may decide to consult with the Authorities concerned with the object of obtaining agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

1.3.1 General

For the purposes of this PTS the following definitions shall apply:

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, installation, and commissioning or management of a project or operation of a facility. The Principal may sometimes undertake all or part of the duties of the Contractor.

The **Manufacturer** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorised to act for the Principal.

The word **shall** indicate a requirement.

The word **should** indicate a recommendation.

1.3.2 Specific definitions

Environmental engineering - engineering to protect the environment of those who may be affected by the activities

1.3.3 Definitions of materials

For the definitions of materials, see BS 6100 – 1.0 and BS 6100 – 2.2.2.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this PTS are made, the referenced section number is shown in brackets.

Other documents referenced by this PTS are listed in (8).

2. GENERAL

2.1 EXISTING SERVICES AND FACILITIES

Prior to beginning site investigations, site preparation works and earthworks, a certificate or permit shall be obtained from the Principal or the responsible body. Relevant utility companies and/or local authorities shall be contacted to establish whether they have services in the subject locations. This should normally be done by the Principal and shall confirm that services in the locality have been made safe, and any services or other facilities adjacent to the proposed work shall be described. In addition, any safety aspects and measures that are to be maintained during the work shall be specified. This shall include ensuring that all aboveground and underground services shall be maintained during the works through physical support if necessary.

The stability of all supports or excavations shall be proven by calculations based on realistic assumptions and/or available data. The nature and location of all existing aboveground and underground services, and facilities shall be determined, where necessary by hand excavation. Typically, underground services are located up to a depth of 1.50 m below ground level. Applicable excavation permits shall be adhered to for any site work.

Every precaution shall be taken, including the provision of all necessary temporary supporting, bridging, shoring and safety barriers to protect these services and facilities from damage or interference during the execution of the works. The stability of existing aboveground and underground services shall be maintained during the works in accordance with the requirements of the applicable permit or certificate to work.

If any previously unrecorded services or other objects are discovered during investigations, the Principal shall be notified in writing. An accurate description, including dimensions, levels related to reference datum and other relevant details of such services shall be prepared and supplied to the Principal.

If services such as drains or natural drainage of a certain area have to be interrupted or otherwise interfered with during the execution of the works, these shall be made good to the satisfaction of the Principal. Where applicable, a temporary or permanent rerouting shall be provided.

If services or facilities are accidentally cut or damaged, these shall be repaired as directed by the Principal.

2.2 SITE LEVELS

During the process of establishing finished grade levels, e.g., high point of paving, the following shall be taken into account:

- Surface water should be able to run off under gravity via the plant drainage systems, in accordance with PTS 34.14.20.31.
- Site layout/plot plan and related safety aspects, including safety distances, should be adhered to.
- Cut and fill should be economically planned so that cut and fill balancing is optimised, including allowances for earthen structures and general fill, bulking, wastage and unsuitable materials.
- Danger of flooding should be avoided (i.e. highest sea level, storm surge, wave run-up, highest river level, etc. should be determined) or alternatively the area should be adequately protected.

Prior to the commencement of work, a limited number of permanent monuments (benchmarks) shall be strategically installed on site and accurately related to the plant and/or national grid system for line and level.

2.3 SITE INVESTIGATIONS

Prior to the start of site preparation and earthworks, a site investigation shall be carried out. This investigation should include, as a minimum, soils, topographical, hydrological, hydrogeological, meteorological and rainfall intensity surveys. In certain instances, engineering geological surveys may be required.

As part of the site investigation, an environmental baseline survey is often carried out which typically comprises the installation of monitoring wells and the sampling and analysis of groundwater and soil samples to determine concentrations of contaminants. The installed monitoring wells allow an ongoing programme of sampling and testing to be carried out.

The design, materials, planning and execution of site preparation and earthworks shall be based on the results of a full scale or confirmatory site investigation; see PTS 34.11.00.10.

2.4 CLASSIFICATION OF SOILS AND ROCKS

Soil and rock classification should be carried out in accordance with BS 1377, ASTM D 2487, or ASTM D 2488.

2.5 SEISMIC ASPECTS

The design and eventual execution of site preparation and earthworks shall consider the relevant seismic conditions and relevant consequences prevalent in the area under consideration. Applicable seismic zones can be found in PTS 34.00.01.30.

Liquefaction potential shall be investigated.

If faults and or other geological disturbances exist at the site, their long-term behaviour, and where applicable, their behaviour during earthquake shall be investigated by a qualified expert. The conclusions of this investigation shall be taken into consideration for the subsequent earthworks, including foundation and structural design.

3. SITE PREPARATION

3.1 GENERAL

Site preparation activities may comprise one or more of the following activities:

- demolition and site clearance (3.2);
- stripping of topsoil (3.3);
- rerouting of existing ditches and water courses (3.4);
- treatment of underground cavities (3.5);
- treatment of subsoils (3.6);
- provision of site drainage (3.7);
- provision of temporary access (3.8)
- lay-down and stockpile areas (3.9);
- scour protection, coastal defence and river works (3.10);
- earthworks (4).

3.2 DEMOLITION AND SITE CLEARANCE

Demolition work may be required, depending on the nature of the existing area and planned usage. Typical demolition activities may include removal of buildings, structures, culverts, roads, pavements, aboveground and underground services and associated foundations.

Careful consideration shall be given to the treatment of existing piles to ensure the proposed tank foundation or in general any proposed foundation shall perform adequately and that there is no risk of contamination. The remnants of existing piles may result in unacceptable differential settlements if not accommodated in the design. Removal of some or all of existing piles may result in the creation of preferential seepage paths allowing seepage of contaminants into the backfill of the removed pile shaft and into the surrounding ground and groundwater. Guidance on the design of tank foundations is provided in (5.5.3).

Care shall also be taken to ensure the site clearance and demolition work does not adversely affect or diminish the capacity of the foundation of the existing adjacent buildings/structures.

Site clearance shall include the taking down or grubbing up and immediate removal from site, of surface obstructions and unsuitable materials such as debris, rubble, gates, fences, shrubs, hedges, trees, stumps and roots.

The Principal may elect to leave in place certain items such as fences, shrubs, trees, or other features required for incorporation in landscaping. The Contractor shall, under such circumstances, be responsible for the care and protection of such items during the course of the works.

Demolition and site clearance works shall be planned and executed in a manner such that the safety of personnel, the work and adjacent property is guaranteed and a minimum of inconvenience is caused.

All necessary temporary works such as safety barriers, fences, safety nets, coverings and screens shall be provided to protect personnel and adjacent property from injury or damage caused by demolition operations.

All necessary dead or raking shores to support existing work shall be provided during demolition and associated operations.

All materials arising from demolition and site clearance work, except materials specified for re-use or as otherwise specified by the Principal, shall be removed from the proposed tank farm site or any site as appropriate as the work progresses and shall be disposed of in an agreed and responsible manner. Materials removed from the facility to an external

repository shall be disposed of in accordance with all applicable local and national laws and regulations. Such materials should not be permitted to accumulate and the site shall be maintained in a safe and workmanlike condition at all times.

Materials required for re-use shall be stored in a safe location and protected from damage or deterioration as agreed with the Principal.

Segregation and quantification of hazardous and non-hazardous waste material, and certified disposal of hazardous material shall be carried out in accordance with applicable legislation.

3.3 STRIPPING OF TOPSOIL

All areas to be excavated, filled or constructed upon should be stripped entirely of topsoil to a suitable depth below ground level, as indicated by the site investigation and agreed with the Principal.

Turf intended for re-use, as agreed with the Principal, shall be taken up in strips of a constant breadth with an approved turving tool. Turf intended for re-use shall be removed to a location approved by the Principal where it shall be neatly stacked and regularly watered and tended until required for relaying.

Topsoil intended for re-use, as agreed with the Principal, shall be stock-piled and/or spread at approved locations in limited heights as appropriate to the region to avoid detrimental affects to its chemical and biological composition.

The remaining topsoil and turf shall be disposed of at locations agreed by the Principal, in accordance with national and local laws and regulations.

3.4 REROUTING OF EXISTING DITCHES AND WATER COURSES

Existing drainage ditches and water courses shall be temporarily or permanently rerouted, where necessary, in order to prevent:

- unacceptable rise or fall in ground water level in, and flooding of, the site;
- unacceptable changes to the hydrological and hydrogeological regimes of the adjacent areas.

Rerouting shall be carried out in accordance with the requirements of PTS 34.13.20.31 and PTS 34.14.20.31.

3.5 TREATMENT OF UNDERGROUND CAVITIES

If naturally occurring cavities (caverns, underground watercourses, etc.) or man-made cavities (mine workings, wells, cesspools, basements, etc.) are detected under or adjacent to the construction area, they shall be suitably investigated and treated in consultation with the Principal.

Further guidance regarding ground improvement techniques may be found in BS 6031.

3.6 TREATMENT OF SUBSOILS

If the existing engineering properties of the ground may result in liquefaction, unacceptable total and/or differential settlements or bearing capacity failure, consideration shall be paid to the use of ground improvement methods rather than deep foundations.

Further guidance regarding ground improvement techniques may be found in BS 6031.

The design of the most cost-efficient ground improvement system shall be based on a thorough soil investigation and shall take into account the soil properties, distribution of loadings, particle strength, particle size and shape analysis, silt content, in-situ density, mineralogical and chemical composition and primary as well as secondary permeability of the soil.

The categorization of the ground improvement shall be as follows and the application shall be discussed thoroughly with the Principal. The combination of the following methods may be carried out to achieve the optimum and cost-efficient ground improvement:

3.6.1 *Mechanical modification (rapid densification by reducing air voids).*

- *Compaction by dynamic compaction / dynamic consolidation*
- *Compaction by vibration using vibro compaction.*
- *Deep soil mixing*
- *Cement / lime stabilization*
- *Sand / laterite replacement*
- *Jet grouting*

3.6.2 *Hydraulic modification (improvement of fine grained saturated cohesive soil).*

- *Surcharge load & prefabricated vertical drain*
- *Vacuum depressurization*

3.6.3 *Modification by inclusion*

- *Stone columns by vibro replacement process*
- *Sand / aggregate columns by dynamic replacement process*
- *Controlled modulus cement columns (cement grout mix).*

3.7 PROVISION OF SITE DRAINAGE

Adequate drainage systems shall be provided to accommodate ground water and surface water run off.

Permanent surface water runoff drainage systems shall be designed in accordance with the requirements of PTS 34.13.20.31 and PTS 34.14.20.31.

Further guidance regarding items including site drainage, including temporary water run-off drains and subsoil water drains, may be found in BS 6031.

3.8 PROVISION OF TEMPORARY ACCESS

Suitable temporary roads shall be laid to provide all-weather access for all construction activities. The temporary roads should preferably coincide with the planned permanent routes.

Temporary access shall be designed to suit climatic, traffic and subsoil conditions. The effects to be taken into consideration shall include heavy traffic along temporary roads, e.g., propagation of dust clouds, damage to existing structures by vibrations, disturbance of surface and subsurface drainage. Where necessary, suitable precautions shall be taken.

Traffic routing schemes should be established, especially for large-scale works.

3.9 LAY-DOWN AND STOCKPILE AREAS

Permanent lay-down areas normally located inside battery or module limits for the laying down of bundles, trays, columns, flares and other structures during shutdown or maintenance of plants shall be designed and constructed in accordance with PTS 34.13.20.31.

All temporary lay-down areas required for construction activities should be suitably levelled and provided with suitable access, temporary paving and surface drainage as necessary.

These temporary lay-down areas shall be located within the designated Contractor's area. These areas shall be drained so that stored materials remain dry at all times, and surface as well as subsurface drainage may be required (3.7). Proper access to these areas for lifting equipment and construction vehicles shall be maintained.

The method of stockpiling of materials shall take into consideration all requirements for protection from the weather and from contamination through mixing. Stockpiles shall be maintained in a stable condition and work operations shall ensure safety to operators. Further guidance regarding stockpiling materials may be found in BS 6031.

3.10 SCOUR PROTECTION, COASTAL DEFENCE AND RIVER WORKS

When a facility location is selected, consideration shall be paid to protection of the proposed site from detrimental external hydraulic processes. Potential external water related hazards to a location include flooding from hinterland run-off, storm damage from the sea, flooding from high water levels and waves from the sea and/or rivers as well as erosion of riverbanks or the coastline from rivers or the sea. Protection measures to be considered are hinterland drainage channels, coastal sea defence, and coastline and/or riverbank heightening and stabilization.

Measures shall be taken to ensure the required protection with the least disturbance to the environment and to current and future land use. Typically, an Environmental Impact Assessment should be carried out for a proposed new facility and should identify sensitive environmental areas, give recommendations on minimising the impact from construction, and identify any specific social impacts or legal requirements. Where feasible, these recommendations should be adopted.

When analysing the problem, hydraulic, morphological, geological, geotechnical coastal engineering and environmental aspects shall be considered.

The hydraulic aspects shall include waves, currents, tides, seiches, storm surges (due to changes in barometric pressure and strong winds), tsunamis, rainfall intensities, storm water run-off, river discharges, floating debris, icing, the basic bathymetry and topography of the area as well as other features and processes specific to a location.

Typical morphological aspects that shall be studied include sediment transport (rate and direction), erosion and sedimentation patterns, changes in shoreline alignment (seasonal fluctuations as well as long-term development) and changes in meander pattern and bed slope of rivers.

Rises in sea level resulting from climatic changes as well as subsidence of the land through tectonic movements (if any) and other processes shall be assessed.

The geotechnical aspects shall include the slope stability of embankments, the bearing capacity and stability of the subsoil and the likelihood of settlements and erosion.

The selection of design criteria for the design of hydraulic related earthworks and structures shall be based on an assessment of anticipated events, the risks to the facility and the total lifetime costs. The certainty with which events can be predicted will be dictated by the quantity and quality of available data. Design criteria shall be based on an analysis of this data and take into consideration combinations of hydraulic parameters that can reasonably be assumed to occur simultaneously. The critical combination that results at the structure site shall be adopted for design purposes.

For the design of coastal structures, the following references may be used:

- BS 6349 - Code of practice for marine structures;
- CUR Report 154 - "Manual on the use of rock in coastal and shoreline engineering";
- "Coastal Engineering Manual", of the US Army Coastal Engineering Research Center.

Ways of minimising the life cycle cost shall be considered, including an assessment of the availability and cost of construction materials, construction methods, availability and cost of the Contractor's equipment, and the lifetime maintenance costs. The assessment of the

lifetime maintenance cost shall consider the frequency of occurrence of adopted design events with other reasonable combinations and the resulting damage potential to the proposed facility. The impact on the temporary and long-term functionality of the facility and the reparability of the hydraulic structures and damaged parts of the facility resulting from the considered combinations should be assessed in order to determine the optimal economic, technical and safe solution. If an economic evaluation is not carried out, the critical combination having a return period of 100 years may be adopted for design purposes, subject to the approval of the Principal.

4. EARTHWORKS

4.1 GENERAL

Earthworks are required to establish the general shape of the site on which the facility is to be constructed. They comprise the formation of on-plot and off-plot areas, road alignments, flood protection bunds and drainage channels. Where suitable material is not available on site, material shall be imported. Unsuitable material arising from site works shall either be stored at a designated location on site, or shall be disposed of in a responsible manner in accordance with all applicable local and national laws and regulations. In some area, the final grade or level may not be formed as finishing work may be scheduled at a later date.

To minimise the import and export of material to and from a site, materials identified in the site investigation shall be considered for re-use. The approximate quantities of materials shall be determined and laboratory testing shall be carried out to determine the engineering properties and mineralogical composition of potential sources of fill. Site construction trials shall be carried out to satisfactorily demonstrate that the proposed equipment, compaction methods and compliance testing programme fulfil the design requirements.

BS 6031 extensively describes the design of cuttings, excavations, embankments and general fill, execution of excavation, filling and compaction. Also, the design and construction of trenches and pits is covered in this standard. Earthworks shall therefore be designed, planned and executed in accordance with BS 6031. However, suggested procedures and indicative compaction methods are provided in (Appendix 1) and (Appendix 2).

Protection of all earthworks and the control of storm water run-off and groundwater shall be included in the design as specified in PTS 34.13.20.31. Appropriate temporary and permanent drainage systems shall be installed and any erosion of earthworks shall be controlled. The design shall ensure the avoidance of separation of fill materials (e.g. migration of fines), and geotextiles may be considered for this purpose.

At locations where uncommon materials are considered for use, e.g., crushed rockfill, specialist advice shall be sought and construction trials may be required to ensure an adequate design and performance of the fill.

4.2 CONTROL OF EARTHWORKS

The earthworks design shall address the functional requirements, which may include the permitted allowable total and differential settlements, minimum or maximum permeability, minimum factor of safety for stability, special measures to control erosion, etc. The specification shall define the physical characteristics of the suitable materials (grading, angle of friction, etc.) and describe the work on the basis of either an end product or a method specification.

An end product specification defines the properties of the completed earthworks, but does not define the process to achieve the final product. A method specification is prescriptive, stating amongst others the moisture content of the material as placed, the maximum thickness of each placed layer, the type of compaction equipment which shall be used, as well as the number of passes of the equipment, etc.

The specification shall include a defined compliance testing programme stating the type of testing required and the frequency of each test. It shall also provide the ranges of acceptability. Compliance testing typically comprises the sampling and testing of stockpiled material for use as fill and testing of the placed and compacted material. The properties to be tested of the stockpiled material shall be appropriate for the type of fill material and may include grading, plasticity, shear strength, angle of friction and moisture content. Testing of the placed material shall include the moisture content, bulk density and dry density, and possibly other properties.

Prior to commencement of earthworks, a method statement shall be produced and submitted to the Principal for comment. The method statement shall describe the proposed equipment, and a compaction trial covering the proposed methods of excavation (for

cuttings), placement and compaction (for embankments). The compliance testing programme shall be clearly defined in an inspection and test plan, identifying methods and equipment that shall be used to determine the specified physical and engineering properties, and provide sample Quality Control Record (QCR) sheets stating the information which shall be recorded for each compliance test. If the nuclear density probe test (NDP) is proposed (ASTM D 5195, BS 1377), a trial shall be conducted to demonstrate that the test is appropriate for the materials and to calibrate the NDP test results against conventional testing methods (e.g. sand replacement, or core cutter methods (BS 1377)). The acceptable ranges for each test result shall be identified in the inspection and test plan.

The compaction trial shall not be incorporated into the final earthworks. The results of the compaction trial shall be reported to the Principal prior to commencement of the earthworks. If any part of the compaction trial fails to comply with the requirements of the specification, the method statement shall be revised and additional trials conducted until satisfactory results are achieved.

During execution of the earthworks, compliance testing shall be carried out as specified in the inspection and test plan, and the results shall be reviewed against the specified allowable ranges. If results are noncompliant, the Contractor shall propose corrective actions to the Principal that are appropriate for the specific non-compliance.

The compliance test results shall be stored either electronically or in paper records as appropriate to the work scope and location. A summary report shall be produced identifying the areas on a plan in which controlled engineered fill has been placed. For each area, the summary report shall reference the exact specification to which the work was carried out and present a summary of the compliance test results.

4.3 PREPARATION OF SOIL BEARING FOUNDATIONS

If calculations show that ground conditions may produce unacceptable settlements, many well established methods are available to improve the situation, some of which are described in (3). In principle, consideration shall be given to the simplest and most cost effective methods of improving the ground conditions. However, where time constraints preclude the least expensive solution, more sophisticated and expensive methods may be required. The design of ground improvement works is a specialist area that requires a thorough understanding of the ground conditions and capabilities of appropriate ground improvement techniques to ensure the appropriate solution is adopted. In some instances, ground conditions and/or time constraints will result in a piled foundation.

Preloading of compressible areas through the construction of temporary embankments is a simple and cost effective method of achieving consolidation. Further economies can be achieved if the material used to form the preload embankment comprises suitable materials that can be re-used in construction upon removal. During construction of the preload embankment and the subsequent settlement period, a monitoring system shall be installed. At least three settlement beacons shall be installed along the future axis of each foundation. Survey data shall be recorded on a regular basis in accordance with a predefined programme to determine settlement. In addition, for more sensitive soils, or at proposed locations of critical structures, other parameters may require to be measured which may include pore water pressures, settlements at depth and surface settlement profiles.

The recorded data shall be analysed and reference shall be made to the predicted consolidation rate. If results indicate the consolidation rate is slower, or the settlements are larger than predicted, measures shall be taken to gain a better understanding of the ground conditions and settlement characteristics so that modifications can be implemented if necessary. The foundation design can be verified by monitoring settlements and other specified parameters during the construction and preload period.

The duration of the preload period depends on the subsoil condition that will dictate the duration of the hydrodynamic period. In some cases, where the calculated preload period is too long, methods of accelerating the settlement by installing of vertical drains may be considered. However, this is only permitted at locations where there is no risk of

groundwater and soil contaminations, with the vertical drains providing a preferential drainage path.

Other alternative solutions to treat poor ground include the use of special fills, e.g., lime or cement stabilisation, ground replacement (excavation of poor material and replacement with compacted suitable material, see (Appendix 11)), soil mixing, dynamic compaction, vibro compaction, vibro replacement and pressure grouting. In all cases, the main principles shall apply:

- design of ground improvement system;
- production of detailed method statement;
- controlled work including construction trials with quality records produced;
- monitoring and post treatment compliance testing to verify design.

4.4 MOUNDS FOR BURIED VESSELS

Mounds for buried liquid or gas-containing vessels shall be constructed in accordance with PTS 34.51.11.30.

5. BUNDED AREAS AND FOUNDATIONS FOR TANKS

5.1 BUNDED AREAS FOR TANKS

5.1.1 General

The material and type of the banded area shall be assessed in relation to the function of the tank, with due account being taken of geotechnical aspects. The main factors to take into consideration are the potential environmental and economic risks that may result from a tank spillage. If water and non-toxic fluids are stored, and there is no potential risk to surrounding areas in the event of a spillage, the requirements for the bund may be less demanding than if hydrocarbons or toxic chemicals are stored, or where process equipment or other sensitive assets may be placed at risk.

A finishing layer that shall be appropriate for the location shall cover the banded area. If contaminants are being stored, impermeable membranes shall be required to prevent egress from the banded area in the event of a tank leak. In all cases, erosion control on both sides of the bund shall be accommodated in the design to prevent deterioration in the bund resulting from anticipated heavy rainfalls, or during a leakage of the tank.

5.1.2 Functions and requirements

The function of a banded area for tanks and its associated drainage system is to contain potential spillages from any tank in the banded area so that subsequent damage to adjacent tanks, their contents and the surrounding areas is minimized.

Tanks containing water, e.g., fire-, boiler feed-, condensate-, blow down-, raw water, etc., do not require a banded area unless they are located adjacent to areas where the economic or safety impact resulting from a spillage would be unacceptable.

Layout sketches for various tank farm configurations are shown in (Appendix 7). The European Model Code of Safe Practice, Part II may also be used for determining layouts and safety distances for marketing and distribution facilities.

The net capacity of a tank bund (banded area) formed within the main fire wall should be sufficient to provide reasonable protection against possible escape of products beyond those walls. Reasonable protection in terms of volume is considered to be when the bund has a net volume capacity equal to the volume of the largest tank in the banded area. The total volume of the bund should be calculated by adding to this net volume capacity the following volumes insofar as these volumes are below the top level of the surrounding bund wall:

- the volume of the tanks except that of the largest tank in that bund;
- the volume of all tank pads;
- the volume of all intermediate fire walls and the low level piping.

In larger banded areas, intermediate firewalls may be designed (normally not higher than 0.6 m) to act as firebreaks and to divide the tankage into groups of a convenient size.

Guidance for the design of tank farms is provided in API STD 620. However, bund walls shall be designed in accordance with BS 8007 unless otherwise indicated by the Principal or otherwise stated in this PTS.

Drainage systems shall be designed and constructed in accordance with PTS 34.14.20.31.

5.2 IMPOUNDING BASIN

If land availability and space restrictions do not permit the banded area design to satisfy the requirements of (5.1), a suitable depression or a purpose-made impounding basin may be used conveniently situated elsewhere within the installation. This impounding basin shall be connected to the tank farm(s) by an adequately sized underground drain line, with open catch basins at both ends.

The need to incorporate pumping facilities or discharge valves to empty the contents of the impounding basin shall be assessed.

5.3 BUNDS AND BUNDWALLS

5.3.1 Design of bunds

Bunds should be designed and constructed as a liquid-tight or essentially impermeable earthen or clay structure with a slope not steeper than 1:1. For details, see Standard Drawing S 12.002. In some instances, reinforced concrete or steel retaining walls may be more economic or practical especially where embedded cut-off walls are required to prevent seepage. Examples of typical retaining walls are presented in (Appendix 8).

For operational and maintenance access, at least two stairways (preferably made of concrete) shall be provided for each bunded area. These stairways should be located at opposite sides of the bunded area.

The crest elevation of the earthen bund wall shall have a minimum width of 0.60 m. The height of the bund wall above the bund floor shall be determined from the summation of the following heights:

- a) required net capacity of the bund;
- b) maximum determined bund settlements with respect to the tank foundation during the design life;
- c) a freeboard of 0.30 m.

The freeboard is included to allow for the following affects that may or may not occur:

- a) storm surge (0.30 m);
- b) foam containment;
- c) collection of rainwater;
- d) standing water in bunded area (0.15 m);
- e) sloshing resulting from sudden collapse of a storage tank.

The stability of the bund and its foundation (i.e. its horizontal stability against sliding, as well as the stability of slopes and subsoil) shall be analysed by taking as a design basis the bunded area being completely filled with water (i.e. to bund crest). The analysis shall assume long-term design parameters (i.e. effective shear strength parameters ϕ' , c'). The influence of possible liquid flow through and/or under the bund wall on the stability shall be investigated. Reference is made to PTS 34.11.00.12. for the stability analysis and the soil deformation aspects of bund wall design.

Design safety factors shall not be less than 1.3.

The penetration of earthen bund walls and the underlying soil with service line (i.e. pipes, cables, etc.) should be avoided. If penetrations are unavoidable, protective pipe sleeves with sealed, flexible collars at the upstream end shall be used. Free space shall be provided between the protective pipe sleeve and the service line to allow for the expected settlement. The sealing material between the pipe and sleeve shall be malleable to remain functional in the event of movements.

Filter cloth shall be placed around rigid elements where there is a danger of bund wall materials being washed out; see Standard Drawing S 12.002. If more than one service line penetrates the earthen bund walls, structural elements forming an integral part of the bund wall should be used.

The proposed design of these subsurface or penetrating service lines and the protection measures is subject to the approval of the Principal.

Bunds constructed from materials susceptible to erosion, and covered by a sand, bitumen and cement mix or a clay cover, shall be provided with toe drainage and a toe filter in order to prevent damage to the cover by build-up of pore water pressure within the bund wall; see

Standard Drawing S 12.002. Care shall be taken to ensure that this toe drainage does not create a seepage path in the event of a spill.

5.3.2 Bund materials

To ensure the liquid tightness of the bund, it shall be constructed partly or wholly of impermeable or low-permeable materials. A bund constructed entirely with clay is normally preferred. In locations where clay is scarce or not available, the following may be considered:

- a sand body with a clay cover of at least 300 mm thick;
- a sand body covered by a durable mix of sand, bitumen and cement, at least 75 mm thick.

5.3.3 Construction of bunds

Site preparation for bunds shall be carried out in accordance with (3).

Placing and compaction of materials shall be carried out in accordance with (4).

The surface protection measures required for earth bunds are described in (5.3.4).

5.3.4 Bund covering (erosion protection)

If the climate permits, solid clay or clay-covered bund walls should be covered with a layer of topsoil 150 mm thick and grassed. Topsoil shall be lightly compacted and raked prior to the sowing of grass. If necessary, turf shall be laid and pegged in place. The grass type should be a locally available variety and shall provide strong dense roots and growth. It shall require minimal maintenance. The use of fertilisers and mulching, as well as requirements for watering and cutting of grass, shall be agreed with the Principal. Grass that grows tall and dries out, forming a fire hazard, is not acceptable.

The covering comprising a mix of sand, bitumen and cement shall be well compacted and given a smooth finish. The durability of these covers shall be proven through a trial mix and application. Cracks shall be repaired by removing the cover back to sound material and filling the cracks with molten bitumen. Larger rejected areas shall be trimmed back to original base and repaired with a minimum of a 75 mm thick layer of the sand, bitumen and cement mix.

Rigid coverings (e.g., concrete) shall not be used for earthen bunds because of the increased risk of uncontrolled cracking followed by washout of bund material from under the cover and subsequent loss of integrity.

For bunds designed to contain chemical or light products, linings (Low Density Polyethylene (LDPE) or High Density Polyethylene (HDPE)) shall be introduced both on the surface of the bunded area and in the bund itself.

5.3.5 Structural elements

Structural elements such as reinforced concrete retaining walls or steel sheet piles may be used where many pipes cross the bund or where there are space restrictions. However, if this type of bund is adopted, special attention shall be paid to the following:

- stability of the wall;
- panel joints (water stops) e.g. by means of hydrocarbon resistant sealant or a flexible polyurethane joint filler;
- pipe penetrations;
- subsurface drainage of the tank bund;
- flow and void formation under the structural retaining elements;
- consequences of settlements and the effect of the relative rigidity of the structures and bunds;
- deflection or deformation of the structure during the containment of liquids;