SECTION 5A - Subsection 6: Earth Works, Pipe Works and Ground Improvement

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6 Earth and Pipe Works

6.1 Site Investigations

6.1.1 General

The geotechnical assessment report given with the tender documents provides an outline of the geotechnical status of the site based on measurements at the MBT Facility, if needed additional investigations should be carried out by the Contractor.

During the tender period, site may be investigated in more detail by the tenderers with the approval of the Employer.

After the commencement of the Works, the Contractor shall update the surveys according to the general layout of the MBT Facility structures in the contractor's detailed design.

The fieldwork to be carried out by the Contractor shall comprise, if deemed necessary:

- vertical test borings
- disturbed & undisturbed sampling and laboratory tests
- penetration tests (S.P.T. and/or C.P.T.)
- plate bearing tests
- permeability tests
- ground water table and ground water quality determination
- geophysical investigations (where required by Code for Infrastructure Works in Disaster Areas).

The site investigation work shall be carried out using modern methods and equipment and by fully competent staff under the supervision of a qualified Contractor’s Representative. The equipment employed shall be such as to provide the necessary data.

6.1.2 Standards and rules

The Contractor shall carry out the investigations, tests and reports according to the following codes, standards and specifications.

- Ministry of Public Works and Settlement, Code for preparation of geological and geotechnical investigation reports ,2005

- Ministry of Public Works and Settlement, Code for infrastructure works in disaster areas, Earthquake code for infrastructure

- TS 1500 Classification of soil for civil engineering purposes

- TS 1901 Methods of obtaining disturbed and undisturbed samples for civil engineering purposes

- TS 3440 Rules for making concrete exposed to aggressive effects of liquids, soils and gases

- TS 5744 In situ measurement methods of the properties of foundation soils in civil engineering

- TS 6108 Terms used in engineering geology

- TS EN 206-1 Concrete - Part 1: Specification, performance, production and conformity

6.1.3 Geotechnical report and ground improvement

For geotechnical investigations that might be needed the Contractor shall submit to the Engineer a Soil Investigation and a Geotechnical Report incorporating a record of all the investigation work carried out by him. The Report shall include boring logs, borehole coordinates, records of field and laboratory tests, records of water level observations and recommendations as to the bearing capacity and deformation properties of the soil and water inflow. The report shall be prepared in English. Two hard copies of this Report shall be submitted to the Engineer within one month of completing the field work. Laboratory tests shall be carried out in the laboratory approved by the Engineer.

The report shall cover the following for each and every structure,

- ultimate and allowable bearing capacity of foundation soil

- liquefaction analysis

- immediate and consolidation settlements, and heave at excavations

- drainage system of excavations

- single pile capacity (if necessary)

- ground improvement design (if necessary).

6.1.4 Tests on ground water

During the course of the work the Engineer may require samples of the ground water to be taken for testing to ascertain the present of harmful substances. The testing shall take place in accordance with TS 3440.

The tests shall be performed in the beginning of the execution works in the laboratory on site before starting any concrete work. The results concerning adverse effects on concrete shall be evaluated according to TS EN 206 Section 4.

6.1.5 Design of structures

The Contractor shall use the data in the documents and results of the site investigations to design in detail every aspect of the Works, permanent or temporary, which is affected by the subsoil. This stability of design shall be entirely the Contractor' responsibility, however design is subject to the approval by the Engineer.

6.2 Excavation and Fill Works

6.2.1 General

General excavation required for structures including pipes and subsoil-structures, roads or other mass excavation includes:

- excavation of any type of ground, whether this excavation has to be made by hand or by machine;
- any additional excavation to accommodate temporary supports and all working space to carry out the work;
- scarifying of the exposed surface, compaction to maximum density and protecting of formation levels;
- supporting excavations and temporary support of the sides of excavations;
- keeping free the excavation from surface and ground water;
- location, maintaining and, where required, reinstatement of other services;
- disposal of excavated material whether it shall be reused for backfilling or removed as surplus material off site including formation of all temporary spoil heaps and all double handling necessary;
- protection of the Works and all additional measures necessary to ensure that the dug is maintained in a safe and workmanlike manner.

The Contractor shall prepare a method statement of his proposal for earthworks operation for each particular part of the Works to be constructed at any one time, detailing the location, programme of excavation, temporary supports and the placing and handling of the spoil.

The Contractor shall submit for the Engineer's approval his proposed method statement at least 14 days before his intended date to commence earthworks on each particular part of the Works.

The Contractor shall give to the Engineer at least seven days written notice of his intention to commence earthworks on any part of site and shall furnish the Engineer with all ground levels site photographs showing the existing conditions and levels and other particulars he may require for the purpose of carrying out measurements.

Earthworks shall not be commenced until written approval has been received by the Contractor from the Engineer.

6.2.2 Traffic requirements

The Contractor shall comply with National laws and codes of practice in respect of this clause.

Before any work in or affecting the use of any highway is commenced, the Contractor's proposed method of working shall be agreed with and confirmed in writing to the Engineer and the Highway and Police Authorities.

Throughout the Contract, the Contractor shall co-operate with the Highway and Police Authorities concerning works in, or access to, any highway. The Contractor shall inform the Engineer of any requirements of, or arrangements made with, the Highway and Police Authorities.

Where the diversion of any existing carriageway, footway or public right of way is temporarily made necessary by the Works, the Contractor shall provide and maintain an alternative way, acceptable to the Engineer, which shall be operational before any interference with the existing way takes place.

Where ramps are required, they shall be provided and maintained to a standard suitable in all respects for the class or classes of traffic or pedestrians requiring using them.

The Contractor shall maintain emergency vehicle access to all properties at all times.

Where single line traffic operation is unavoidable, the Contractor shall provide a proper system of traffic control as agreed by the Engineer.

6.2.3 Extent of excavations

The construction of open trenches shall, at any time, be limited to lengths previously approved by the Engineer, in writing. Unless otherwise approved by the Engineer in writing work on each approved length shall be completed to the satisfaction of the Engineer before work on any new length is commenced.

6.2.4 Relocation of possible utilities and trial holes

The Contractor shall take all steps necessary to find, protect and safeguard any drains, pipes, cables and similar services encountered, already installed or to be installed, for the duration of the contract in order to keep them in good working condition. Should the services become damaged during the course of the works, then the Contractor shall be responsible for liaising with the responsible utility companies or organizations and arranging for the repair of that service and bear all costs associated with the repair of the service.

Information as may be given in the contract in relation to the present condition and character of the existing structures, roadways, embankments and the like and in relation to the dimensions of various parts of the existing structures, the position, extent and particulars of drains, pipes, cables and the like, is given without guarantee of accuracy and neither the Employer nor the Engineer will be liable for any discrepancy therein.

The absence of such information shall not relieve the Contractor of this liability for the cost of any repair work necessitated by damage caused by him to such mains and services in the course of his work and for the cost of all losses arising from their disruption.

The Contractor shall obtain all available information, assistance, full permission and approval of all relevant utility companies or organizations regarding the positions and/or relocation of mains and services, serving notices of intent to start work as may be necessary in accordance with all the local laws and regulations. He shall make this information available to the Engineer as soon as he obtains it. He shall agree with the Engineer any trial excavations, which may be necessary to confirm or establish these locations. All costs for executing trial holes shall be deemed to be included in the Contractor's quotation for the earthworks. All relocating works shall be carried out two weeks in advance of execution of the relevant work.

Any temporary or permanent diversion and/or relocation of mains and services will only be permitted after agreement with the appropriate utility companies or organizations and the approval of the Engineer.

Where a service, or obstruction is encountered along the route of a pipeline or in other excavation works which prevents the Contractor from carrying out his work, the Contractor is to inform the Engineer immediately of its presence and shall submit details, including the type of service, or obstruction, its dimensions, depth below ground level and his proposed method of overcoming the obstruction or service. Unless already detailed in the contract documents, the Engineer will then advise on the action to be taken.

The Contractor shall arrange for the refilling and reinstatement of trial holes to be carried out immediately the required information is obtained. The reinstatement of the surfaces of trial holes shall be carried out to the approval of the Engineer.

6.2.5 River crossings

Contractor shall get the necessary permissions for crossing existing infrastructure from related Authorities and provide necessary data requested by these Authorities.

Contractor shall take all necessary safety precautions before starting the Works. All intersections and parallel constructions shall be subject to the approval of the Engineer.

The Contractor shall ensure that all buried services have been located prior to commencing machine excavation in rivers, highways or footways. The Contractor shall have in place or available at the place of work, all signs, safety devices, plant and equipment necessary to progress the operation smoothly and efficiently

Where pipelines and box culverts intersect rivers or flood beds, the route shall cross the bed in perpendicular direction where possible. Finished cross section of the river crossing shall not disturb the natural flow in the river and flood water. Pipeline and box culverts shall be buried at least 1m below the river bed.

Pipes shall be protected by a reinforced concrete box and shall be secured against uplift when empty.

Where the excavation crosses streams, ditches, culverts and other watercourses the Contractor shall be deemed to have included all the additional measures and costs necessary for the proper construction of the Work at these crossings including maintaining the full flow of water.

River crossing construction shall be made under dry conditions, and where necessary trench shall be protected by sheet pile walls and drainage pumps. During every stage of construction, diversion pipes and channels shall be made available for safety of works.

6.2.6 Intersections with roads, highways and railroads

Contractor shall get the necessary permissions for crossing existing infrastructure from related Authorities and provide necessary data requested by these Authorities.

Contractor shall take all necessary safety precautions before starting the Works. All intersections and parallel constructions shall be subject to the approval of the Engineer.

After crossing the paved roads, drainage systems sidewalks and pavements shall be restored to original position by the Contractor. New pavement repair width shall be proportional with the road width.

At locations where new pipelines or culverts cross the roads, the soil cover above the pipe crest or top of box culvert shall be at least 1.50 meters.

At locations where new pipelines and culverts cross rail roads or major highways, the crossing shall be made by pipe jacking or similar method without disturbing traffic.

6.2.7 Drainage and dewatering

The Contractor shall keep all excavations for structures and pipelines clear of water from whatever source, so the works are constructed under dry conditions.

The method of keeping the excavations clear of water, dewatering and the disposal of water, shall be subject to the approval of the Engineer. The Contractor shall provide all the equipment for pumping and shall ensure that sufficient stand-by plant is on site at all times to avoid any interruption in continuity of dewatering.

For dewatering of the excavation one of the following techniques can as examples be used:

- Dewatering with pumping from wells;

- Pumping directly from the excavation;
- Pumping from drilled and filtered wells; and
- Pumping from acicular filter systems.

The usage of the above methods will depend on the soil characteristics as described in the geotechnical investigations.

6.2.8 Safety of excavation and adjacent structures

The Contractor shall provide support necessary to ensure the stability of the excavation and adjacent roads and structures. The support may be made with sheet-pile walls, holding walls, open caissons or pneumatic caissons etc. Any such support shall be deemed to be included in the relevant prices for excavations for structures, installation of pipes and cables, etc.

6.2.9 Sheeting and Bracing

The Contractor shall be responsible for the design, installation, and maintenance during construction, and where appropriate, removal of all support works needed for trenches and other excavations. The Contractor shall submit to the Engineer for approval, details of his proposal for excavation support which details shall include such Drawings, calculations or other explanatory matter as the Engineer may require, but such approval shall not relieve the Contractor of his responsibilities under the Contract. No excavation work may proceed until the Engineer’s approval has been given to the Contractor’s proposals.

The Contractor shall not remove temporary works supporting the excavations until in the opinion of the Engineer the Permanent Work is sufficiently advanced to permit such removal which shall be executed under the personal supervision of a competent foreman. Where the removal of excavation support works is considered by the Engineer to endanger existing structures thus making them liable to subsidence damage, the Contractor shall leave such support works in place, removing only the minimum necessary to allow the reinstatement of the surfaces.

Works for pit sheeting and bracing close to private or public properties, structures and utilities shall be carried out with low vibration and low concussion.

6.2.10 Slips, falls and excess excavations

The Contractor shall prevent slips and falls of materials from the sides of the excavations and embankments.

In the event of slips or falls occurring in the excavations, and where excavations are made in excess of the specified dimensions, then any unsuitable material that has entered into the excavation is to be removed from the excavation, and the additional backfilling that may be required is to be carried out with selected excavated or imported material and compacted to the approval of the Engineer.

If any unsound material occurs in the bottom of any excavation, the Contractor shall remove it and dispose it all to the satisfaction of the Engineer. Unless otherwise specified or ordered by the Engineer, the Contractor shall fill the voids so formed with concrete grade C8/10 or with suitable granular material to the approval of the Engineer.

Unsound material shall include:

- Peat, timber and perishable material;
- Clay with a liquid limit exceeding 80 and having a plasticity index exceeding 55; and
- Materials having moisture content greater than the maximum permitted for such materials.

6.2.11 Stripping of topsoil

Topsoil is by definition the top layer of soil that can support vegetation, which shall be retained for later re-use.

Stripping of all topsoil shall be carried out in the immediate areas to be occupied by the works, including areas of excavation where material from excavation may be used in fill, areas to be occupied by temporary works, or any other areas as directed by the Engineer. Stripped topsoil shall be stored in a location agreed with the Engineer and shall not exceed 2 m in height. Stored topsoil shall be kept free of weeds and grasses.

6.2.12 Backfilling and filling

Fill materials in general

Fill material shall not contain roots, frozen material, organic or otherwise unsuitable materials.

No fill material shall be placed in any of the permanent works until its foundation has been prepared as specified.

Fill materials shall be handled, placed, spread and compacted in such a manner as to avoid segregation of the fill and to obtain a stable, homogeneous compacted structure.

When organizing his work, the Contractor shall take due account of the climatic conditions, which may be expected in the area. Should place material by any cause become unacceptable, the Contractor shall remove such material or shall process it until all specifications are met. Such work shall be performed at no additional cost to the Employer.

Backfill shall be in accordance with the TS EN 1610 while fill shall be excavated material of particle size not exceeding 75 mm.

Backfill against the permanent works shall be selected, and free from boulders, cobbles, rock fragments and the like greater than 50 mm nominal size.

Imported fill materials shall comprise the following materials all in accordance with the relevant norms:

- Sand in fraction 0.1-2 mm;
- Gravel in fraction 2-75 mm; and
- Boulders in fraction 75-100 mm.

Where fill will be used below structures and building floors, the material shall consist of durable gravel, broken stone, crushed concrete or sand with a particle size not exceeding 10 mm. The grading of the material shall be such that there is no migration of fines into the fill.

The Contractor shall prepare method statement and submit for Client approval covering all backfilling activities, outlining the sequence of work, the equipment used, etc. before commencing the backfill. The method statement shall show the different methods applied for several subsoil conditions. The Contractor shall ensure that prior to backfill; the pipeline is fully bedded in the trench to avoid any settlement during the backfill operations.”

Placing and compaction of fill and backfill
The natural ground over which filling is to be placed shall be cleared of all loose boulders, grass, productive soil, mud, bushes, trees, roots, other vegetation and other unsuitable material.

Unless otherwise specified, fill shall be spread by machine or manually in successive horizontal layers of not more than 200 mm loose depth and compacted to 95% Standard Proctor.

Operations on earthwork shall be suspended at any time when satisfactory results cannot be obtained because of rain, or other unsatisfactory field conditions. The Contractor shall drag, blade, or slope the embankment to provide proper surface drainage.

The material in the layers shall be of the proper moisture content before compaction. Wetting or drying of the material and manipulation when necessary to secure uniform moisture content throughout the layer may be required.

The Contractor shall take all necessary precautions to protect exposed faces against deterioration.

The Contractor shall compact the fill using approved compacting methods and equipment. Backfilling shall not impose uneven or excessive load on a structure.

All material used for filling shall be deposited and compacted as soon as practicable after excavation in layers of thickness appropriate to the compaction plant used. Filling of areas and embankments shall be built up evenly over the full width and shall be maintained at all times with a sufficient camber and a surface sufficiently even to enable surface water to drain readily from them.

Trial area of filling
Where required by the Engineer and before commencing filling, the Contractor shall at his own expense compact a trial area of filling of the type proposed using the equipment proposed for the works in accordance with specified standards of compaction. The area shall be of a size and depth to the approval of the Engineer sufficient for the trial to adequately represent the work involved in the general filling operations.

Variations of method or equipment will only be permitted when the Contractor demonstrates by field trials that the compaction obtained by the alternative method achieves compaction equivalent to that obtained by the approved method.

During the progress of the works the Contractor shall inform the Engineer of any factors outside his control which may adversely affect the compaction achieve so that the Engineer can give consideration to a variation of the equipment or method.

Filling adjacent to structures
Filling against the perimeter of structures shall not be carried out until the Engineer agrees that the construction is sufficiently advanced implying no risk of interferences or damage from either the compaction equipment or the backfilling material.

Filling material for excavations and for making up levels within the perimeter of structures shall be suitable material and shall contain no particular size in excess of 50 mm. The compaction of fill material within the perimeter of structures shall be carried out with equipment suited to the area being compacted.

Tolerances for filling
The fill shall be placed and compacted to a tolerance of –10 mm/+ 15 mm for a final surface. Where further works will be carried out above the fill the tolerance shall be –25 mm/+0 mm.

Within the above tolerances the surface shall have a smooth regular face all to the approval of the Engineer.

Control and testing of the fill
Control testing shall be carried out by members of the Contractor's staff competent to perform the required tests. Additional testing may be carried out at the discretion of the Engineer.

Soil compaction tests shall be carried out according to the relevant standards.

Allowance for settlement
The Contractor shall make due allowance for consolidation and settlement of fill and compacted fill such that the levels and dimensions of the finished surfaces at the end of the contract (defects notification period) are within the tolerances specified.

6.2.13 Disposal of surplus material

Deposits of surplus suitable material and unsuitable materials are in the following referred to as "soil dumps". Generally, the Contractor shall transport and dispose of all excavated material not required for the works. The locations proposed by the Contractor for disposing or storing of excavated material, whether temporarily or permanently, shall be subject to the approval of the Engineer. The Contracting Authority will assist in locating a suitable soil dump.

The surplus material, if is appropriate and in accordance with the specification for the operation of the landfill, maybe used as cover material of the waste.

The Contractor shall compact, trim and drain soil dumps as may be necessary to maintain them in a stable condition and to such levels and slopes the Engineer shall direct.

Placing materials in soil dumps shall be such that it will not contaminate or otherwise render less efficient usable lands or interfere with natural drainage or access. Where required by the Engineer, drains shall be constructed to prevent the undesirable accumulation of water in or around soil dumps.

6.2.14 Disposal of existing asbestos cement pipes

Existing asbestos cement pipes are not considered as hazardous, as long as these pipes are not broken and remain underground. Even if these pipes are broken, little amount of asbestos fibres are exposed and the pipes don't crumble easily. Therefore, existing asbestos cement pipes can be left underground in general unless any special engineering measures are needed for removing these.

Asbestos cement pipes shall be handled as follows:

- If the asbestos cement pipes need to be rehabilitated, old pipes shall be left underground.
- If the asbestos cement pipes have to be taken out for any reason, pipes shall be handled according to Turkish Health Regulations and related European Union directives.

Asbestos cement pipes are considered as hazardous waste when taken out of ground. Asbestos cement pipes are considered as products that do not produce dust during service. However, they shall be handled with care.

After being taken out of ground, asbestos cement pipes shall be transported to a suitable landfill and collected according to Turkish Regulations and EU Directives. Information about waste handling can be found in EU Directive 75/442/EEC, Framework Directive on Waste.

6.3 PIPE WORKS

6.3.1 General

The requirements covered by the present section are applicable for external, buried pipes between treatment units, to/from pumping stations to/from buildings, wastewater collectors/networks, storm water collectors/networks and pressured storm water/wastewater pipelines and applies to pipe systems for:

- Wastewater;

- Potable water;
- Technical water;
- Storm water drainage;
- Groundwater drainage (if required);

6.3.2 Standards and rules

The following standards shall apply for the pipes:

- TS 821 EN 1916 Concrete pipes and fittings, unreinforced, steel fibre and reinforced
- TS 11565 EN 969 Ductile iron pipes, fitting, accessories and their joints for gas pipelines-Requirements and test methods
- TS EN 545 Ductile iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods
- TS EN 598 Ductile iron pipes, fittings, accessories and their joints for sewerage application-Requirements and test methods
- TS EN 10216 Seamless steel tubes for pressure purposes-Technical delivery conditions
- TS EN 10217 Welded steel tubes for pressure purposes-Technical delivery conditions
- TS EN 10246 Non-destructive testing of steel tubes
- TS 9937 Polypropylene pipes general purpose
- ISO 2531 Ductile iron pipes, fittings, accessories and their joints for water or gas applications
- ISO 3183:2012 : Steel Pipe for Pipeline Transportation Systems

6.3.3 Functional requirements for pipe systems

Wastewater system

Wastewater systems for the new structures and buildings shall be connected to the inlet chamber of the existing wastewater treatment plant, as described in the pre-Feasibility Study of the Facility.

Drinking water

Adequate drinking water (both in terms of the quantity and pressure) shall be available on site.

Fire fighting water
The MBT Facility shall be covered with fire hydrants in a number and location that fulfils the requirements according to Turkish norms and standards.

Surface water drainage
The MBT Facility shall be covered with a surface water drainage system that secures the area against flooding caused by rainfall and from erosion caused by surface flows. The system may be with surface drainage supplemented with a pipe system that ensures that surface water is discharged to the adjacent water course.

Irrigation system
An irrigation system in line with the design drawings shall be established as part of the Contract. Service water shall be available at several tap locations.

6.3.4 Pipe markers

Water, wastewater and surface water pipes, manhole elements and fittings shall be marked either by carving and painting text or by thermally transferred water resistant paint.

Pipe marks shall have the following information:

- The name of the Municipality
- The name of the water and sewerage administration
- The name of the pipe factory
- The pipe class, diameter and production date.

6.3.5 Pipe materials

Generally, all pipes, valves and pipe fittings installed shall conform to the relevant international norms and standards. The Contractor shall, if required, forward to the Engineer certificates showing that the materials have been tested and comply with the requirements of this specification and the relevant standard.

Pipes shall be ordered in the maximum lengths available to minimize the number of joints. The Contractor shall be responsible for the supply of all materials in sufficient quantities and shall immediately prior to placing any order, especially for imported goods, ascertain the required quantities.

In the following is listed the pipe materials that are found appropriate and relevant for installation in the present MBT Facility depending on the media to be transported.

- Concrete
- Steel

- GRP
- HDPE (pressure)
- HDPE (corrugated)
- Stainless steel.

6.3.6 Concrete pipes

General

Unreinforced and reinforced concrete pipes and fittings with flexible joints shall comply with TS 821 EN 1916. The pipes shall be reinforced to stand the load during installation as well as in the permanent installation. Concrete pipes shall be sealed with standard rubber ring gaskets. Prior to use the jointing rings shall be stores in a cool place, protected from direct sunlight and frost.

Pipes used for wastewater or combined storm water and wastewater pipelines shall be steam cured pipes with integrated gasket type.

Pipes used for storm water pipelines shall be steam cured with separate gasket type.

Pipes shall be subject to rejection on account of failure to meet any of the testing requirements. Pipe sections also may by rejected if found to contain cracks, damaged ends and other defects due to faulty manufacture, handling, transporting or placing.

For pipe diameters of 200 mm to 400 mm, connections to the wastewater pipe can only be performed with single branch fittings produced in a factory. For pipe diameters of 500 mm and greater, saddles may be used but only saddles using direct drilling in the concrete pipe.

Pipe diameter, mm (Pipe with bell and integrated gasket)	Minimum compressive strength, kN/m (Force applied on crest)
200 mm concrete	35
300 mm. concrete	40
400 mm. concrete	60
500 mm. concrete	75
600 mm. concrete/reinforced concrete	90
800 mm. reinforced concrete	120
1000 mm. reinforced concrete	150
1200-3500 mm. reinforced concrete	According to TS-821 EN 1916

Pipe Length, joints and reinforcement

Standard pipe lengths shall not be shorter than the values specified below (excluding special and short pieces).

Diameter, mm	Minimum pipe length, m
600 and smaller	1.25
700 - 1000 and larger	2.00

Every concrete and reinforced concrete pipe joint shall be designed to withstand a load applied on joint, load being equal to the gasket pressure plus 60,000N per every 1 m of internal diameter of the pipe.

Spiral reinforcement shall be of totally circular type. Ellipsoid or partial circular reinforcement shall not be accepted. Longitudinal reinforcement shall not be less than 0.2% of the pipe cross sectional area. Longitudinal reinforcement shall be placed around the pipe in a uniform spacing.

Causes for rejection of pipes

Inspection of the pipes as may be deemed necessary by the Engineer will be made at the place of manufacture. Unless a damaged pipe can be repaired as specified below and approved by the Engineer the pipe may be rejected.

Pipes will be rejected as unsuitable for the Works for any of the following reasons:

Defects in unreinforced and reinforced concrete pipes

Pipes, which exhibit any of the following defects, shall be subject to rejection:

1 A piece of any size broken out of the pipe.

2 Defects that indicate imperfect mixing or moulding of the concrete.

3 Any crack extending through the wall of the pipe and having a longitudinal or transverse length greater than the wall thickness of the pipe.

4 Any shattering or flaking of concrete at a crack.

5 A deficiency greater than 6.5 mm from the specified wall thickness of pipes 750 mm or smaller in diameter, or a deficiency greater than 6 percent from the specified wall thickness of pipes larger than 750 mm in internal diameter, except that the deficiency may be 8 percent adjacent to the longitudinal from joint, provided that the additional deficiency does not lie closer than 20 percent of the internal diameter to the vertical axis of the pipe and does not extent along the circumference for a distance greater than 20 percent of the internal diameter of the pipe.

6 The deficiencies in wall thickness permitted herein do not apply to gasket contact surfaces in gasket jointed pipe. Dimensions and tolerances of such contact surfaces shall be submitted for approval.

7 A variation of more than 1 percent from the true circle of the specified pipe internal diameter.

8 Rock pocked and water pockets in any pipe.

9 Exposure of any reinforcement or insufficient cover to reinforcement.

10 Surface defects indicating honey-comb or open texture.

11 Separation or”blisters”.

12 Any continuous crack having surface width of 0.25 mm or more and extending for a length of 300 mm or more, regardless of depth or position in the wall of the pipe.

13 The pipe fails the strength test.

Repair of imperfections (Bonding mortar repairs with epoxy resin adhesive)

Unsound or imperfect concrete shall be removed by chipping with a sharp tool. If hand placed mortar is to be used, the edges shall be left sharp and square with the surface. The area to be repaired shall be kept dry. Loose material and concrete dust remaining after the chipping operation shall be removed by means of an air jet.

Epoxy resins previously approved for such use by the Engineer shall be used as a bonding agent in the manner prescribed by the Engineer. The prepared area shall be primed with the epoxy resin compound, care being taken to insure intimate contact with the base material. Mortar shall be applied before the epoxy resin compound sets.

The mortar used for repair shall contain the same of cement and sand as the mix from which the pipe was made and shall also incorporate an expanding additive.

This mortar shall be pre-shrunk by mixing it to a plastic consistency as far in advance of its use as possible. Trial mixes shall be made and aged to determine the longest period the mortar’s use can be delayed while retaining sufficient plasticity to permit good workmanship.

Immediately prior to the application of the mortar, the damp surface of the area to be repaired shall be scrubbed thoroughly with a small quantity of neat cement ground, using a wire brush. Remaining loose sand particles shall be swept away immediately before application of the mortar.

In applying the mortar, it shall be compacted into the space to be filled, care being taken to eliminate air pockets and to secure bond at the edges. The surfaces shall be shaped and finished to correspond with adjacent surfaces of the pipe.

Any holes and small areas of defects on the surface shall be repaired by using Dry-pack mortar as specified in the Employer's Requirements, Section 6: Concrete and Steel Works.

The newly repaired surfaces shall be kept damp for 24 hours after the repair is completed. A membrane coating of an approved white-pigmented sealing compound shall then be applied.

6.3.7 Ductile iron pipes

Ductile cast iron pipes shall be used exclusively within the fields of water supply, sewerage and waste water treatment works.

Pipes and fittings in ductile cast iron shall be in conformity with TS EN 545, DIN EN 598 and, TS 11565 EN 969, ISO 2531 and shall withstand successfully any test described therein.

Pipe connections of ductile Iron Pipes shall be tension proved sockets according to DIN 28603. All bending points have to be provided with concrete abutments or anchorage in sub grade.

All pipes, and fittings and accessories shall be made from ductile cast iron, also called nodular or spheroid graphite cast iron, characterized by the presence of graphite in the spheroid state in sufficient quantities to impart the mechanical characteristics defined in the standard TS 11565 EN 969 or ISO 2531 to the material.

Pipes for water supply

Pipes for water supply will be subjected to a maximum static head of 85 m of water column. Allowing for friction losses and water hammer conditions, the maximum working pressure shall be 16 bars.

Pipes for pumped wastewater

Pipes for pumped wastewater will be subjected to a maximum static head of 35 m of water column. Allowing for friction losses and water hammer conditions, the maximum working pressure shall be 16 bars.

Ductile iron pipes for pumped wastewater shall be lined with an inner sulphate resistant cement lining according to DIN 28610 and TS EN 545. The outer corrosion protection shall be in accordance to DIN 30674 and TS EN 598.

All pipes of ND 250 or smaller shall have an external electrolytic zinc protection. In addition, all pipes shall have an external coat of black varnish applied at the factory. Special external bitumen, having a minimum thickness of 0.3 mm, shall be sprayed onto the pipes before laying to provide protection against corrosion.

Coating of water supply pipes

Pipes for water supply shall be lined internally with spun cement mortar. The mortar shall contain no toxic element or elements soluble in water, or any elements susceptible to impart any smell or odour to the water. The characteristics of the mortar, its placing and control shall be in compliance with ISO 4179.

All pipes of ND 250 or smaller shall have an external electrolytic zinc protection. In addition, all pipes shall have an external coat of black varnish applied at the factory.

A special external bitumen-based hot applied coating, having a minimum thickness of 0.3 mm, shall be sprayed onto the pipes before laying to provide protection against corrosion.

Bends and tees
Bends and tees shall be lined inside with epoxy as specified for accessories and coated outside as specified above for pipes.

6.3.8 Polypropylene (PPRC) pipes

This kind of pipe shall be used for drinking water systems in the buildings. The installation, material and fittings shall be compatible with TS 9937 and international requirements. The Contractor shall provide the material catalogues with related standards to the Engineer's approval.

6.3.9 PVC and PP pipes

All PVC and PP pipes shall be manufactured by a quality assured manufacture in accordance with the ISO 9000 system. Un-plasticized PVC pipes and fittings for gravity drainage and sewerage shall comply with the relevant provisions of CEN Standard EN 1401, PP pipes shall comply with CEN Standard EN 1852. Un-plasticized PVC pipes and fittings for pressure pipes shall comply with the relevant provisions of CEN-standard EN 1452.

All connections to PVC and PP pipes must be performed by using single 45 branch; no saddle must be used.

Only pipes with a ring stiffness greater than 8 kN/m^2 may be used. Reference is made to ISO 9969.

6.3.10 High density polyethylene (HDPE) pipes

All HDPE pipes and fittings shall be manufactured by a quality assured manufacturer in accordance with the ISO 9000 system. HDPE pipes shall be manufactured from PE 100 material, as classified by the European Technical Committee Report CEN/TC 155. In accordance with ISO 12162 the PE 100 material shall have a minimum required strength (MRS) value of 10 MPa. The pipes and fittings shall be coloured blue (potable water), yellow (gas) or black (wastewater) and be suitable for below-ground use.

Gravity pipes shall be engineered light weight pipes with (structured wall pipe type) with ring stiffness larger than SN 8 kN/m^2. The pipes shall be manufactured so that the cavity between the inner and outer pipe can be water filled.

Pressure pipes shall be in pressure class PN6 minimum.

PE pipes and fittings shall comply with the relevant provisions of CEN-standard EN12201 (water and wastewater) and EN1555 (gas).

Generally, all buried pipes shall be jointed using either butt or electro fusion welding techniques. Small diameter pipes (diameter<63 mm), pipes within structures and pipes connecting to metal fittings shall be jointed using mechanical jointing techniques, such as compression, flanged joints or push-fit joints.

Jointing of large pipes of the light weight type shall be made by extruder welding.

All welding shall be performed by certified welders holding licences not older than 12 months, and issued by a recognised institution approved by the manufacturer and the Engineer.

6.3.11 Corrugated HDPE pipes

HDPE pipes shall comply with DIN 8074 and DIN 8075 in connection with DIN 19537 or equivalent. The pipes shall be designed for a nominal working pressure Class PN 6, have a hydrostatic design stress of 50 kg/cm² at 20 °C and be jointed with push fit couplings.

The length of coiled pipes shall be in general 100 m. The minimum diameter of the rollers for coiled pipe should be such that kinking of the pipe is prevented. The minimum internal diameter of the rollers shall not be less than 24 times the nominal outside diameter of the pipe. The ends of the pipe shall be plugged or covered.

The pipes shall be manufactured from high-density polyethylene containing only those anti-oxidants, UV stabilisers and pigments necessary for the manufacture of potable water black pipes. The Contractor shall provide an approved third party certificate to verify the above.

Mechanical couplings and fittings shall be used. The mechanical joints shall be push-on types. They shall be produced in acetyl-homo-polymer or be combined with gunmetal adaptors. The joints have to provide the system with strength in tension and water tightness. Push fit jointing type shall consist of a PVC grip ring and nitrite elastomer or equivalent O ring.

The couplings and fittings shall be designed for a nominal working pressure of 16 bars and a temperature of 40°C and shall fit the HDPE pipes in this contract.

All fittings (couplings, bends, tees, reducers) and adaptors shall be deemed to be included in the unit rates of HDPE pipes.

6.3.12 Glass fibre reinforced pipes (GRP)

GRP (Glass Fibre Reinforced Pipe) pipes and fittings shall be manufactured by quality assured manufacturer in accordance with ISO 9001. GRP pipes shall be centrifugally cast or produced with continuous filament wound technology and shall comply with DIN 19565, DIN 16858, prEN 1796 and prEN 1636. GRP pipes with a diameter greater than 200 mm shall be provided for the following principal categories:

Pressure rating, bar	Stiffness, N/mm^2
PN 6	SN 5,000
PN 10	SN 10,000

All pipes shall be jointed using collar or sleeve joints incorporating an integral full width EPDM rubber seal. All joints shall comply with DIN 19565.

Fittings including flange joints, bends, tee pieces, tapped pieces and junctions shall be standard GRP fittings and shall comply with DIN 19565.

All flanges shall be drilled and comply with EN 4504 unless otherwise specified. The nominal pressure rating for particular flanges shall be at least equal to the highest pressure rating of the pipes or fittings to which they are attached, but with a nominal pressure of PN 10. All flanges shall be provided with all necessary nuts, bolts washers and gaskets, as specified herein. After cleaning the flanges, the gasket shall be fitted smoothly to the flange and the joint made by tightening the nuts to finger pressure first. Thereafter the final tightening of the nuts shall be made by gradually and evenly tightening the bolts in diametrically opposite positions using only standard spanners of type approved by Engineer.

Gaskets and joint rings shall be manufactured from natural or approved synthetic rubber.

Flange joints gaskets shall be of the inside bolt circle type, unless specified otherwise, and shall comply with DIN 19565.

Other types of gaskets may be used with the prior approval of the Engineer

6.3.13 Steel pipes

The specification for steel pipes is given in the Employer's Requirements,: Mechanical Works.

6.4 Pile Foundations

6.4.1 General

Pile foundation may be necessary for supporting structures where the subsoil is considered to have insufficient bearing capacity. The Contractor shall carry out detailed design of these structures in accordance with the Contract Conditions and Employer’s Requirements and shall determine the type of foundation required, the number of piles and their working loads and the optimum arrangement of piles required for supporting the structures.

Excavation, concrete steel reinforcement and steel casing where applicable shall conform to the relevant sections of the Employer’s Requirements.

At least 21 days before the Contractor intends to commence piling work on the site, the Contractor shall submit for the Engineer’s approval full details of his proposed piling system including the type and dimensions of piles, reinforcement details and full details and full design and driving calculations. The details to be submitted shall include the Contractor’s proposals for equipment, temporary works and construction methods.

No work on piling shall commence on the site until the Engineer’s approval to the Contractor’s proposal has been received.

6.4.2 Types of piles

Bearing piles shall be driven reinforced concrete, precast concrete or cast in-situ concrete piles. All concrete shall be in sulphate resisting cement Type V.

6.4.3 Design of piles

Piles shall be generally designed in accordance with appropriate DIN standard and the materials and work shall conform to the requirements of the Employer’s Requirements. Piles shall be designed to sustain the specified loads with settlements not exceeding those specified. Allowance shall be made in the design for the incidence of negative skin friction where appropriate and for resisting the necessary tensile forces due to the swelling and heave of any soil stratum. Piles shall be designed to have a bearing capacity of at least 2.5 times the working load. In extreme cases (such as Earthquake loading case), piles shall be designed to have a bearing capacity of at least 2.0 times the extreme load.

If pile tests are carried out, capacity of the piles shall be calculated according to the safety factors given in Section 6.4.15 instead. In this case, working load bearing capacity and extreme load bearing capacity shall be the taken the same value.

The permissible load of piles shall be modified where necessary to allow for particular conditions: piles in close proximity or in groups, soil strength, groundwater level, and other relevant factors.

For earthquake loading (lateral loadings), the reactions and displacement of the pile group supporting a structure shall be analyzed in 3-dimensions and the displacements in horizontal direction shall be checked. The lateral bearing capacity should be assessed by treating the soil around as ultimate limit state (limit equilibrium) and/or elasto-plastic (p-y curves).

The piles shall be of sufficient cross-section and length to sustain loads specified without settlement exceeding the following:

Working load	Allowable settlement 8 mm
1.5 x working load	Allowable settlement 10 mm
2 x working load	Allowable settlement 12 mm

These settlements shall include both permanent and elastic deflections. Measurement of the settlement shall be made on first achieving the specified load. Measurement of the settlement shall be made at the point of application of the load.

Where piles in place are subjected to handling, stacking and pitching or bending moments and/or shear forces, these shall be combined with the vertical loads (either in compression or tension) to satisfy the design requirements.

The average compressive stress in the concrete of bearing piles under working load shall not exceed 25% of the characteristic cube strength at 28 days, calculated on the total cross sectional area of the pile shaft.

Pile spacing shall be limited to a minimum value of 3*D (D is maximum pile dimension). Otherwise, the group effect shall be considered to reduce the bearing capacity and increase in settlement by considering type of soil.

6.4.4 Preliminary test piles

After the Engineer has approved the Contractor's proposals and calculations for the proposed piling system preliminary test piles shall be constructed as instructed by the Engineer. These shall be loaded to 2.0 times the working load to prove the design and system and to demonstrate that the safe load requirements can be achieved by the piling method proposed.

The preliminary test piles shall be located in places proposed by the Contractor and approved by the Engineer. The Engineer shall be given at least 48 hours notice of commencement of construction of the preliminary pile which is to be test-loaded.

The preliminary test piles shall be constructed/installed in a manner similar to that to be used for the construction of the working piles by the use of similar equipment and materials. Any variation will only be permitted with the prior approval of the Engineer.

The pile shafts shall be extended where necessary above the cut-off level or working piles so that gauges and other apparatus to be used in the testing process will not be damaged by water or failing debris and to permit exposure of the reinforcement.

Where the pile shaft is extended above the cut-off level of the working piles in soils which would influence the load bearing capacity of the pile a sleeve shall be left in place during testing to eliminate friction which would not arise in working piles.

If the cut-off level is below ground level and the shaft is not extended and there is a risk of the borehole collapsing, a sleeve shall be left in place or inserted above the pile shaft or other means satisfactory to the Engineer shall be employed. Adequate clearance shall be given between the top of the pile shaft and the bottom of the sleeve to permit unrestricted movement of the pile.

For piles that are tested in compression the pile head or cap shall be formed to give a plane surface which is normal to the axis of the pile sufficiently large to accommodate the loading and settlement measuring equipment and shall be adequately reinforced or protected to prevent damage due to the concentrated application of load from the loading equipment.

The pile cap shall be concentric with the test pile and the joint between the cap and the pile shall have a structural strength equivalent to that of the pile.

A sufficient clear space shall be made under any part of the cap projecting beyond the section of the pile so that at the maximum anticipated settlement load is not transmitted to the ground expect through the pile.

The connection between the pile and the loading equipment shall be constructed in such a manner as to provide strength equal to the maximum load which is to be applied to the pile during the test with an appropriate factor of safety on the structural design.

If the preliminary test pile fails to meet the requirements of the Employer's Requirements, the piling system proposed will be considered unsatisfactory. The Contractor shall then submit revised proposals and calculations for the approval of the Engineer. Unless otherwise agreed by the Engineer any test pile which has failed the preliminary test will be rejected and the Engineer may instruct the Contractor to provide one or further test piles and tests to prove his modified system at no additional cost to the Employer.

6.4.5 Lengths and tolerances

The Contractor shall determine the approximate lengths of piles by examination of the available geotechnical information including information obtained from any additional site investigations under the Contractor. The final length of piles shall be decided by constructing the piles to a minimum depth on the basis of the geotechnical information.

Piles shall be constructed within the following tolerances:

1 in plan, at the working level of the piling rig 0.15 x B in any direction from the designed position: B= pile dimension (diameter or side)

2 in section, 1horizontal:75vertical for a vertical pile

The cross-sectional dimensions of the pile shall not be less than those proposed by the Contractor nor should they exceed them by more than 0.015 x B (B = pile dimension, diameter or side). No face of a precast pile shall deviate by more than 6 mm from a straight edge 3 m long laid on the face. The centroid of any cross section of the pile shall not deviate by more than 12 mm from the straight line connecting the centroids of the ends.

6.4.6 Sequence for construction

The sequence of construction of piles shall be to the approval of the Engineer and shall be arranged so as to minimise the vertical and lateral displacement of piles already installed. Levels of the tops of adjacent piles or the structures founded upon them or any other structure shall be measured at intervals while a pile is being installed. Driven piles driven which have risen, shall be re-driven or forced down to the original resistance.

6.4.7 Driving piles

The Contractor shall submit for the Engineer's approval details regarding the suitability efficiency and energy of his driving equipment.

Precast concrete piles shall not be driven until the concrete has achieved the specified characteristic strength.

Cast-in-situ driven piles with steel casing shall be bottom driven by using a casing which shall not distort or buckle during driving. Concrete casing shall be driven on the pile shoe using a mandrel.

Each pile shall be driven continuously until the approved set and/or depth has been reached except that the Engineer may permit the suspension of driving will be substantially re-established on its resumption or if he is satisfied that the suspension of driving was beyond the control of the Contractor.

A follower (long dolly) shall not be used except with the approval of the Engineer who will then require the set to be revised to take into account the reduction in the effectiveness of the hammer blow.

The final set of each pile shall be recorded either as the penetration in millimetres per 10 blows or as the number of blows required to produce a penetration of 25 mm. When a final set is being measured the following requirements shall be met:

a) The exposed part of the pile shall be in good condition without damage or distortion.

b) The dolly and packing if any shall be in sound condition.

c) The hammer blow shall be in line with the pile axis and the impact surfaces shall be flat and at right angles to the pile and hammer axis.

The Contractor shall give adequate notice and provide all facilities to enable the Engineer to check driving resistances. A set for the purposes of the Contractor shall only be taken in the presence of the Engineer unless otherwise agreed.

At the start of the work and in new areas or sections, sets shall be taken at intervals during the last 3 m of driving to establish the behaviour of piles.

The Contractor shall inform the Engineer without delay if an unexpected change in driving characteristics is noted. A detailed record of driving resistance over the full length of the nearest available pile shall be taken.

Redrive checks if required shall be carried out by a procedure to be agreed by the Engineer.

Piles shall be driven in an approved sequence to minimize the detrimental effects of heave and lateral displacement of the ground.

Measurements shall be taken to determine the movement of ground or any pile resulting from the driving process when required by the Engineer.

Where piles have risen or moved out of plumb as a result of driving adjacent piles the Contractor shall submit to the Engineer his proposals for correcting such faults and their avoidance in subsequent work.

Where preboring is required by the Contractor each pile shall be pitched into a hole prebored before driving to the required depth.

Jetting may be carried out only when approved by the Engineer and the Contractor shall submit detailed proposals and it shall not normally be undertaken over the last 3 m of penetration.

Pile driving shall be refused at the point where driving resistance exceeds either 300 blows per 0.3 meter (roughly 1 mm per blow) for five consecutive 0.3 meters (1.5 meters); or 800 blows for 0.3 meter of penetration.

If there has been a delay in pile driving operations for one hour or longer, the refusal criteria stated above shall not apply until the pile has been advanced at least 0.3meter following the resumption of pile driving. However, in no case shall the blow count exceed 800 blows for 152 mm of penetrations. Detail criteria is given in API 2A-WSD (2000) clause 12.5.6, for steel driving piles

For concrete piles, driving stresses shall be checked and shall not exceed the following values:

- 0.85 f'c (compression)
- 0.7 fy of steel reinforcement (tension)

Driving stresses may be estimated by performing wave equation analyses or by dynamic monitoring of force and acceleration at the pile head during pile driving.

6.4.8 Repair and lengthening of piles

In preparation for repairing the head of a pile the concrete shall be cut off square at sound concrete to expose the reinforcement and all loose particles shall be removed by wire brushing followed by washing with water.

If the pile is to be subjected to further driving the head shall be replaced with concrete of an approved class.

If the pile has been completely driven but the sound concrete is below cut-off level the pile shall be made good to cut-off level with concrete of a class not inferior to that of the concrete of the pile.

In preparation for lengthening a normal reinforced pile the concrete shall be cut off square to expose a sufficient length to ensure that the full strength of the bars will be developed across the joint.

Welded joints shall be made in accordance with DIN 1910 and before welding the main longitudinal reinforcing bars in the head of the pile shall be exposed for at least 300 mm below the position of the weld.

For lap or splice joints sufficient link bars shall be provided to resist eccentric forces.

If the pile is to be subjected to further driving the additional length shall be of an approved grade of concrete. Piles shall not be driven until the added concrete has reached the specified characteristic strength of the concrete of the pile.

6.4.9 Reinforcement

Unless otherwise dictated by the design, cast in situ piles shall be reinforced over the whole of their length. The minimum longitudinal reinforcement shall be 1.0% of the gross concrete area in the top 3m of the pile and 0.8% of the gross concrete area in the remainder of the pile. Lateral ties shall be provided to maintain the alignment of the longitudinal reinforcement at centres not closer than 150 mm.

Unless otherwise dictated by the design, reinforcement in precast concrete piles shall comply with the following minimum requirements:

- Areas of longitudinal reinforcement of 12 mm diameter minimum shall be at least 1% of the gross concrete area (cast in-situ and precast concrete piles) :

- Lateral reinforcement shall be in the form of hoops or links not less than 6 mm diameter. Over a distance of 3 times the width of the pile measured from each end of the pile the volume of lateral reinforcement shall be not less than 0.6 % of the gross volume. In the body of the pile, lateral reinforcement shall be not less than 0.4% spaced at not more than half the width of the pile. The transition between the close spacing near the ends and the maximum spacing shall be made gradually over a length equal to 3 times the width.

Piles of rectangular cross section shall have a minimum of 4 No. longitudinal reinforcement bars and piles of circular cross section shall have a minimum of 6 No. longitudinal reinforcement bars. Bars shall be 12 mm diameter minimum. The main longitudinal bars shall be level at the top of the pile and fit tightly into the shoe if one is used.

Hoops and links shall fit tightly against longitudinal bars and be bound to them by welding or soft iron wire with the free ends turned inwards. The longitudinal bars shall be held apart by spreader forks not more than 1.5m apart.

The main longitudinal reinforcing bars in piles not exceeding 12 m length shall be in one continuous length unless otherwise specified elsewhere. In piles exceeding 12 m in length joints will be permitted in main longitudinal bars at 12 m nominal intervals. Joints in adjacent bars shall be staggered at least 1 m apart along the length of the pile. Joints shall be such that the full strength of the bar is effective across the joint.

The cover to the outermost reinforcement, including binding wire shall not be less than 75 mm measured to the inside of the casing. Lap or splice joints shall be provided with sufficient link bars or other elements to resist eccentric forces. Laps shall have a minimum length of 50 times the diameter of the main longitudinal reinforcement.

Main longitudinal reinforcement shall project a minimum of 50 times the bar diameter above the cut-off level of the pile. For precast piles, compliance with this requirement will necessitate breaking down of the pile head after driving.

6.4.10 Pile shoes

Driven piles shall be provided with flat or pointed co-axial shoes of cast iron if driving is liable to damage the concrete at the tip of the pile.

Cast iron pile shoes shall be made from"chill hardened" iron of the grade used for making grey iron castings. The chilled iron point shall be free from major blow holes and other surface defects.

6.4.11 Records

The Contractor shall maintain a complete record of all piling works which shall include the following where relevant:

- Pile type and number
- Nominal diameter or dimension and pile length
- Date concreted and date driven
- Depth from ground level to toe of pile
- Depth from ground level bearing stratum
- Final set, weight and drops of hammer
- Details of any obstructions observed

All records shall be accurately kept in duplicate as the work proceeds and one copy shall be handed to the Engineer at the completion of each day's work.

6.4.12 Precast reinforced concrete piles

Precast reinforced concrete piles shall be designed cast and cured to develop the strength necessary to withstand the transporting, handling and driving stresses without damage. Square piles shall have chamfered corners. Manufacturing and curing shall be in accordance with the Employer's Requirements: Concrete and Steel Works.

Any precast concrete pile section shall be checked against handling, stacking and storing stresses. In computing stresses due to handling, the static loads shall be increased by 50% as an allowance for impact and shock.

6.4.13 Cast in situ piles

Driven or bored cast in situ piles

Driven or bored cast-in-situ piles shall comprise a temporary or permanent casing of steel, or a permanent casing of precast concrete, augured or driven to a set and completely filled with dense concrete reinforced with steel bars.

All joints in the casing and between the casing and shoes where applicable shall be watertight during driving and completion of driven cast-in-situ piles. Permanent casing shall be inspected, e.g. by using a light lowered from the top after installation to ensure that the casing is neither damaged nor deformed and that all loose soil has been removed from the bottom of bored piles.

Drilling mud shall not be used unless otherwise approved by the Engineer.

Casing for cast in situ piles

The casing shall be suitable for the method of installation and for the purpose of jointing piles. The casing shall either be permanent or temporary.

Steel casing shall be delivered to site in lengths as long as can be conveniently handled. Ends shall be prepared for butt welding and designed to maintain true alignment of the pile.

Joints between steel casings shall be made by butt welding to DIN 1910 The specification for steel pipes is given in the Employer's Requirements, Section 7: Mechanical Works.

Pile foundation may be necessary for supporting structures where the subsoil is considered to have insufficient bearing capacity. The Contractor shall carry out detailed design of these structures in accordance with the Contract Conditions and Employer’s Requirements and shall determine the type of foundation required, the number of piles and their working loads and the optimum arrangement of piles required for supporting the structures.

Excavation, concrete steel reinforcement and steel casing where applicable shall conform to the relevant sections of the Employer’s Requirements.

At least 21 days before the Contractor intends to commence piling work on the site, the Contractor shall submit for the Engineer’s approval full details of his proposed piling system including the type and dimensions of piles, reinforcement details and full details and full design and driving calculations. The details to be submitted shall include the Contractor’s proposals for equipment, temporary works and construction methods.

No work on piling shall commence on the site until the Engineer’s approval to the Contractor’s proposal has been received.

Bearing piles shall be driven reinforced concrete, precast concrete or cast in-situ concrete piles. All concrete shall be in sulphate resisting cement Type V.

Piles shall be generally designed in accordance with appropriate DIN standard and the materials and work shall conform to the requirements of the Employer’s Requirements. Piles shall be designed to sustain the specified loads with settlements not exceeding those specified. Allowance shall be made in the design for the incidence of negative skin friction where appropriate and for resisting the necessary tensile forces due to the swelling and heave of any soil stratum. Piles shall be designed to have a bearing capacity of at least 2.5 times the working load. In extreme cases (such as Earthquake loading case), piles shall be designed to have a bearing capacity of at least 2.0 times the extreme load.

If pile tests are carried out, capacity of the piles shall be calculated according to the safety factors given in Section 6.4.15 instead. In this case, working load bearing capacity and extreme load bearing capacity shall be the taken the same value.

The permissible load of piles shall be modified where necessary to allow for particular conditions: piles in close proximity or in groups, soil strength, groundwater level, and other relevant factors.

For earthquake loading (lateral loadings), the reactions and displacement of the pile group supporting a structure shall be analyzed in 3-dimensions and the displacements in horizontal direction shall be checked. The lateral bearing capacity should be assessed by treating the soil around as ultimate limit state (limit equilibrium) and/or elasto-plastic (p-y curves).

The piles shall be of sufficient cross-section and length to sustain loads specified without settlement exceeding the following:

Working load Allowable settlement 8 mm

1.5 x working load Allowable settlement 10 mm

2 x working load Allowable settlement 12 mm

These settlements shall include both permanent and elastic deflections. Measurement of the settlement shall be made on first achieving the specified load. Measurement of the settlement shall be made at the point of application of the load.

Where piles in place are subjected to handling, stacking and pitching or bending moments and/or shear forces, these shall be combined with the vertical loads (either in compression or tension) to satisfy the design requirements.

The average compressive stress in the concrete of bearing piles under working load shall not exceed 25% of the characteristic cube strength at 28 days, calculated on the total cross sectional area of the pile shaft.

Pile spacing shall be limited to a minimum value of 3*D (D is maximum pile dimension). Otherwise, the group effect shall be considered to reduce the bearing capacity and increase in settlement by considering type of soil.

After the Engineer has approved the Contractor’s proposals and calculations for the proposed piling system preliminary test piles shall be constructed as instructed by the Engineer. These shall be loaded to 2.0 times the working load to prove the design and system and to demonstrate that the safe load requirements can be achieved by the piling method proposed.

The preliminary test piles shall be located in places proposed by the Contractor and approved by the Engineer. The Engineer shall be given at least 48 hours notice of commencement of construction of the preliminary pile which is to be test-loaded.

The preliminary test piles shall be constructed/installed in a manner similar to that to be used for the construction of the working piles by the use of similar equipment and materials. Any variation will only be permitted with the prior approval of the Engineer.

The pile shafts shall be extended where necessary above the cut-off level or working piles so that gauges and other apparatus to be used in the testing process will not be damaged by water or failing debris and to permit exposure of the reinforcement.

Where the pile shaft is extended above the cut-off level of the working piles in soils which would influence the load bearing capacity of the pile a sleeve shall be left in place during testing to eliminate friction which would not arise in working piles.

If the cut-off level is below ground level and the shaft is not extended and there is a risk of the borehole collapsing, a sleeve shall be left in place or inserted above the pile shaft or other means satisfactory to the Engineer shall be employed. Adequate clearance shall be given between the top of the pile shaft and the bottom of the sleeve to permit unrestricted movement of the pile.

For piles that are tested in compression the pile head or cap shall be formed to give a plane surface which is normal to the axis of the pile sufficiently large to accommodate the loading and settlement measuring equipment and shall be adequately reinforced or protected to prevent damage due to the concentrated application of load from the loading equipment.

The pile cap shall be concentric with the test pile and the joint between the cap and the pile shall have a structural strength equivalent to that of the pile.

A sufficient clear space shall be made under any part of the cap projecting beyond the section of the pile so that at the maximum anticipated settlement load is not transmitted to the ground expect through the pile.

The connection between the pile and the loading equipment shall be constructed in such a manner as to provide strength equal to the maximum load which is to be applied to the pile during the test with an appropriate factor of safety on the structural design.

If the preliminary test pile fails to meet the requirements of the Employer's Requirements, the piling system proposed will be considered unsatisfactory. The Contractor shall then submit revised proposals and calculations for the approval of the Engineer. Unless otherwise agreed by the Engineer any test pile which has failed the preliminary test will be rejected and the Engineer may instruct the Contractor to provide one or further test piles and tests to prove his modified system at no additional cost to the Employer.

The Contractor shall determine the approximate lengths of piles by examination of the available geotechnical information including information obtained from any additional site investigations under the Contractor. The final length of piles shall be decided by constructing the piles to a minimum depth on the basis of the geotechnical information.

Piles shall be constructed within the following tolerances:

3 in plan, at the working level of the piling rig 0.15 x B in any direction from the designed position: B= pile dimension (diameter or side)

4 in section, 1 horizontal: 75 vertical for a vertical pile

The cross-sectional dimensions of the pile shall not be less than those proposed by the Contractor nor should they exceed them by more than 0.015 x B (B = pile dimension, diameter or side). No face of a precast pile shall deviate by more than 6 mm from a straight edge 3 m long laid on the face. The centroid of any cross section of the pile shall not deviate by more than 12 mm from the straight line connecting the centroids of the ends.

The sequence of construction of piles shall be to the approval of the Engineer and shall be arranged so as to minimise the vertical and lateral displacement of piles already installed. Levels of the tops of adjacent piles or the structures founded upon them or any other structure shall be measured at intervals while a pile is being installed. Driven piles driven which have risen, shall be re-driven or forced down to the original resistance.

The Contractor shall submit for the Engineer’s approval details regarding the suitability efficiency and energy of his driving equipment.

Precast concrete piles shall not be driven until the concrete has achieved the specified characteristic strength.

Cast-in-situ driven piles with steel casing shall be bottom driven by using a casing which shall not distort or buckle during driving. Concrete casing shall be driven on the pile shoe using a mandrel.

Each pile shall be driven continuously until the approved set and/or depth has been reached except that the Engineer may permit the suspension of driving will be substantially re-established on its resumption or if he is satisfied that the suspension of driving was beyond the control of the Contractor.

A follower (long dolly) shall not be used except with the approval of the Engineer who will then require the set to be revised to take into account the reduction in the effectiveness of the hammer blow.

The final set of each pile shall be recorded either as the penetration in millimetres per 10 blows or as the number of blows required to produce a penetration of 25 mm. When a final set is being measured the following requirements shall be met:

a) The exposed part of the pile shall be in good condition without damage or distortion.

b) The dolly and packing if any shall be in sound condition.

c) The hammer blow shall be in line with the pile axis and the impact surfaces shall be flat and at right angles to the pile and hammer axis.

The Contractor shall give adequate notice and provide all facilities to enable the Engineer to check driving resistances. A set for the purposes of the Contractor shall only be taken in the presence of the Engineer unless otherwise agreed.

At the start of the work and in new areas or sections, sets shall be taken at intervals during the last 3 m of driving to establish the behaviour of piles.

The Contractor shall inform the Engineer without delay if an unexpected change in driving characteristics is noted. A detailed record of driving resistance over the full length of the nearest available pile shall be taken.

Redrive checks if required shall be carried out by a procedure to be agreed by the Engineer.

Piles shall be driven in an approved sequence to minimize the detrimental effects of heave and lateral displacement of the ground.

Measurements shall be taken to determine the movement of ground or any pile resulting from the driving process when required by the Engineer.

Where piles have risen or moved out of plumb as a result of driving adjacent piles the Contractor shall submit to the Engineer his proposals for correcting such faults and their avoidance in subsequent work.

Where preboring is required by the Contractor each pile shall be pitched into a hole prebored before driving to the required depth.

Jetting may be carried out only when approved by the Engineer and the Contractor shall submit detailed proposals and it shall not normally be undertaken over the last 3 m of penetration.

Pile driving shall be refused at the point where driving resistance exceeds either 300 blows per 0.3 meter (roughly 1 mm per blow) for five consecutive 0.3 meters (1.5 meters); or 800 blows for 0.3 meter of penetration .

If there has been a delay in pile driving operations for one hour or longer, the refusal criteria stated above shall not apply until the pile has been advanced at least 0.3 meter following the resumption of pile driving. However, in no case shall the blow count exceed 800 blows for 152 mm of penetrations. Detail criteria is given in API 2A-WSD (2000) clause 12.5.6, for steel driving piles

For concrete piles, driving stresses shall be checked and shall not exceed the following values:

- 0.85 f'c (compression)
- 0.7 fy of steel reinforcement (tension)

Driving stresses may be estimated by performing wave equation analyses or by dynamic monitoring of force and acceleration at the pile head during pile driving.

In preparation for repairing the head of a pile the concrete shall be cut off square at sound concrete to expose the reinforcement and all loose particles shall be removed by wire brushing followed by washing with water.

If the pile is to be subjected to further driving the head shall be replaced with concrete of an approved class.

If the pile has been completely driven but the sound concrete is below cut-off level the pile shall be made good to cut-off level with concrete of a class not inferior to that of the concrete of the pile.

In preparation for lengthening a normal reinforced pile the concrete shall be cut off square to expose a sufficient length to ensure that the full strength of the bars will be developed across the joint.

Welded joints shall be made in accordance with DIN 1910 and before welding the main longitudinal reinforcing bars in the head of the pile shall be exposed for at least 300 mm below the position of the weld.

For lap or splice joints sufficient link bars shall be provided to resist eccentric forces.

If the pile is to be subjected to further driving the additional length shall be of an approved grade of concrete. Piles shall not be driven until the added concrete has reached the specified characteristic strength of the concrete of the pile.

Unless otherwise dictated by the design, cast in situ piles shall be reinforced over the whole of their length. The minimum longitudinal reinforcement shall be 1.0% of the gross concrete area in the top 3m of the pile and 0.8% of the gross concrete area in the remainder of the pile. Lateral ties shall be provided to maintain the alignment of the longitudinal reinforcement at centres not closer than 150 mm.

Unless otherwise dictated by the design, reinforcement in precast concrete piles shall comply with the following minimum requirements:

- Areas of longitudinal reinforcement of 12 mm diameter minimum shall be at least 1% of the gross concrete area (cast in-situ and precast concrete piles) :

- Lateral reinforcement shall be in the form of hoops or links not less than 6 mm diameter. Over a distance of 3 times the width of the pile measured from each end of the pile the volume of lateral reinforcement shall be not less than 0.6 % of the gross volume. In the body of the pile, lateral reinforcement shall be not less than 0.4% spaced at not more than half the width of the pile. The transition between the close spacing near the ends and the maximum spacing shall be made gradually over a length equal to 3 times the width.

Piles of rectangular cross section shall have a minimum of 4 No. longitudinal reinforcement bars and piles of circular cross section shall have a minimum of 6 No. longitudinal reinforcement bars. Bars shall be 12 mm diameter minimum. The main longitudinal bars shall be level at the top of the pile and fit tightly into the shoe if one is used.

Hoops and links shall fit tightly against longitudinal bars and be bound to them by welding or soft iron wire with the free ends turned inwards. The longitudinal bars shall be held apart by spreader forks not more than 1.5m apart.

The main longitudinal reinforcing bars in piles not exceeding 12 m length shall be in one continuous length unless otherwise specified elsewhere. In piles exceeding 12 m in length joints will be permitted in main longitudinal bars at 12 m nominal intervals. Joints in adjacent bars shall be staggered at least 1 m apart along the length of the pile. Joints shall be such that the full strength of the bar is effective across the joint.

The cover to the outermost reinforcement, including binding wire shall not be less than 75 mm measured to the inside of the casing. Lap or splice joints shall be provided with sufficient link bars or other elements to resist eccentric forces. Laps shall have a minimum length of 50 times the diameter of the main longitudinal reinforcement.

Main longitudinal reinforcement shall project a minimum of 50 times the bar diameter above the cut-off level of the pile. For precast piles, compliance with this requirement will necessitate breaking down of the pile head after driving.

Driven piles shall be provided with flat or pointed co-axial shoes of cast iron if driving is liable to damage the concrete at the tip of the pile.

Cast iron pile shoes shall be made from ”chill hardened” iron of the grade used for making grey iron castings. The chilled iron point shall be free from major blow holes and other surface defects.

The Contractor shall maintain a complete record of all piling works which shall include the following where relevant:

- Pile type and number
- Nominal diameter or dimension and pile length
- Date concreted and date driven
- Depth from ground level to toe of pile
- Depth from ground level bearing stratum
- Final set, weight and drops of hammer
- Details of any obstructions observed

All records shall be accurately kept in duplicate as the work proceeds and one copy shall be handed to the Engineer at the completion of each day’s work.

Precast reinforced concrete piles shall be designed cast and cured to develop the strength necessary to withstand the transporting, handling and driving stresses without damage. Square piles shall have chamfered corners. Manufacturing and curing shall be in accordance with the Employer's Requirements,: Concrete and Steel Works.

Any precast concrete pile section shall be checked against handling, stacking and storing stresses. In computing stresses due to handling, the static loads shall be increased by 50% as an allowance for impact and shock.

Driven or bored cast-in-situ piles shall comprise a temporary or permanent casing of steel, or a permanent casing of precast concrete, augured or driven to a set and completely filled with dense concrete reinforced with steel bars.

All joints in the casing and between the casing and shoes where applicable shall be watertight during driving and completion of driven cast-in-situ piles. Permanent casing shall be inspected, e.g. by using a light lowered from the top after installation to ensure that the casing is neither damaged nor deformed and that all loose soil has been removed from the bottom of bored piles.

Drilling mud shall not be used unless otherwise approved by the Engineer.

The casing shall be suitable for the method of installation and for the purpose of jointing piles. The casing shall either be permanent or temporary.

Steel casing shall be delivered to site in lengths as long as can be conveniently handled. Ends shall be prepared for butt welding and designed to maintain true alignment of the pile.

Joints between steel casings shall be made by butt welding to DIN 1910 so that the full strength of the original section is developed. Welded joints shall be watertight.

6.4.14 Pile load tests

General

Pile load tests shall be carried out in the following situations:

- When using a type of pile or installation method that is outside comparable experience and which has not been tested under comparable soil and loading conditions
- When using a piling system which is outside the experience of the operatives carrying out the work
- When the piles will be subject to loading for which theory and experience do not provide sufficient confidence in the design. The pile testing procedure should then provide loading similar to the anticipated loading
- When observations during the process of installation indicate pile behaviour that deviates strongly and unfavourably from the behaviour anticipated on the basis of the site investigation or experience when additional ground investigations do not clarify the reasons for this deviation

Load test can be statically or dynamical.

If a load test is carried out, it shall normally be located where the most adverse ground conditions are believed to occur. If this is not possible, an allowance shall be made when deriving the characteristic value of the bearing resistance.

If load tests are carried out on two or more test piles, the test location shall be representative of the site of the pile foundations, and one of the test piles shall be located where the most adverse ground conditions are believed to occur.

Between the installation of the test pile and the beginning of the load test, adequate time shall be allowed to ensure that the required strength of the pile material is achieved and the pore pressures have regained their initial values.

Static Load Tests

a) Loading Procedure

The pile load test procedure, particularly with respect to the number of loading steps, the duration of the loading steps and the application of load cycles, shall be such that conclusions can be drawn about the deformation behaviour, creep and rebound of a pile foundation from the measurements on the pile. For trial piles, the ultimate loading shall be such that conclusions can also be drawn about the ultimate failure load.

Static load tests shall be carried out in accordance with the ISSMFE Subcommittee on Field and Laboratory Testing recommended procedure, ”Axial Pile Loading Test, Suggested Method”, published in the ASTM Geotechnical Testing Journal, June 1985, pp 79-90.

In case of different wording the text in this Employer’s Requirements shall be valid prior to the above mentioned recommended procedure.

Devices for the determination of forces, stresses or strains and displacements shall be calibrated prior to the test.

In general, pile load tests for the purpose of designing a tensile pile foundation should be carried out to failure. Extrapolation of the load-displacement graph for tension tests should normally not be used, especially in the case of transient loading.

b) Trial Piles (Test Piles)

The number of trial piles required to verify the design shall be selected on the following aspects:

- the ground conditions and their variability across the site
- type of structure
- documented evidence of the performance of the same type of pile in similar ground conditions
- the total number and types of piles in the foundation design

The number of test piles shall be minimum 2 , with different lengths or diameters. In determination of test loads and test pile length, designer shall consider the estimated load amount that each working pile will carry as well as the capacity of the hydraulic jacks and pumps that will be used in the tests.

The ground conditions at the test site shall be investigated, preparation for lengthening a normal reinforced pile the concrete shall be cut off square to expose a sufficient length to ensure that the full strength of the bars will be developed across the joint.

Welded joints shall be made in accordance with DIN 1910 and before welding the main longitudinal reinforcing bars in the head of the pile shall be exposed for at least 300 mm below the position of the weld.

For lap or splice joints sufficient link bars shall be provided to resist eccentric forces.

If the pile is to be subjected to further driving the additional length shall be of an approved grade of concrete. Piles shall not be driven until the added concrete has reached the specified characteristic strength of the concrete of the pile.

Unless otherwise dictated by the design, cast in situ piles shall be reinforced over the whole of their length. The minimum longitudinal reinforcement shall be 1.0% of the gross concrete area in the top 3m of the pile and 0.8% of the gross concrete area in the remainder of the pile. Lateral ties shall be provided to maintain the alignment of the longitudinal reinforcement at centres not closer than 150 mm.

Unless otherwise dictated by the design, reinforcement in precast concrete piles shall comply with the following minimum requirements:

- Areas of longitudinal reinforcement of 12 mm diameter minimum shall be at least 1% of the gross concrete area (cast in-situ and precast concrete piles) :

- Lateral reinforcement shall be in the form of hoops or links not less than 6 mm diameter. Over a distance of 3 times the width of the pile measured from each end of the pile the volume of lateral reinforcement shall be not less than 0.6 % of the gross volume. In the body of the pile, lateral reinforcement shall be not less than 0.4% spaced at not more than half the width of the pile. The transition between the close spacing near the ends and the maximum spacing shall be made gradually over a length equal to 3 times the width.

Piles of rectangular cross section shall have a minimum of 4 No. longitudinal reinforcement bars and piles of circular cross section shall have a minimum of 6 No. longitudinal reinforcement bars. Bars shall be 12 mm diameter minimum. The main longitudinal bars shall be level at the top of the pile and fit tightly into the shoe if one is used.

Hoops and links shall fit tightly against longitudinal bars and be bound to them by welding or soft iron wire with the free ends turned inwards. The longitudinal bars shall be held apart by spreader forks not more than 1.5m apart.

The main longitudinal reinforcing bars in piles not exceeding 12 m length shall be in one continuous length unless otherwise specified elsewhere. In piles exceeding 12 m in length joints will be permitted in main longitudinal bars at 12 m nominal intervals. Joints in adjacent bars shall be staggered at least 1 m apart along the length of the pile. Joints shall be such that the full strength of the bar is effective across the joint.

The cover to the outermost reinforcement, including binding wire shall not be less than 75 mm measured to the inside of the casing. Lap or splice joints shall be provided with sufficient link bars or other elements to resist eccentric forces. Laps shall have a minimum length of 50 times the diameter of the main longitudinal reinforcement.

Main longitudinal reinforcement shall project a minimum of 50 times the bar diameter above the cut-off level of the pile. For precast piles, compliance with this requirement will necessitate breaking down of the pile head after driving.

Driven piles shall be provided with flat or pointed co-axial shoes of cast iron if driving is liable to damage the concrete at the tip of the pile.

Cast iron pile shoes shall be made from ”chill hardened” iron of the grade used for making grey iron castings. The chilled iron point shall be free from major blow holes and other surface defects.

The Contractor shall maintain a complete record of all piling works which shall include the following where relevant:

- Pile type and number
- Nominal diameter or dimension and pile length
- Date concreted and date driven
- Depth from ground level to toe of pile
- Depth from ground level bearing stratum
- Final set, weight and drops of hammer
- Details of any obstructions observed

All records shall be accurately kept in duplicate as the work proceeds and one copy shall be handed to the Engineer at the completion of each day’s work.

Precast reinforced concrete piles shall be designed cast and cured to develop the strength necessary to withstand the transporting, handling and driving stresses without damage. Square piles shall have chamfered corners. Manufacturing and curing shall be in accordance with the Employer's Requirements,: Concrete and Steel Works.

Any precast concrete pile section shall be checked against handling, stacking and storing stresses. In computing stresses due to handling, the static loads shall be increased by 50% as an allowance for impact and shock.

Driven or bored cast-in-situ piles shall comprise a temporary or permanent casing of steel, or a permanent casing of precast concrete, augured or driven to a set and completely filled with dense concrete reinforced with steel bars.

All joints in the casing and between the casing and shoes where applicable shall be watertight during driving and completion of driven cast-in-situ piles. Permanent casing shall be inspected, e.g. by using a light lowered from the top after installation to ensure that the casing is neither damaged nor deformed and that all loose soil has been removed from the bottom of bored piles.

Drilling mud shall not be used unless otherwise approved by the Engineer.

The casing shall be suitable for the method of installation and for the purpose of jointing piles. The casing shall either be permanent or temporary.

Steel casing shall be delivered to site in lengths as long as can be conveniently handled. Ends shall be prepared for butt welding and designed to maintain true alignment of the pile.

Joints between steel casings shall be made by butt welding to DIN 1910 so that the full strength of the original section is developed. Welded joints shall be watertight.

Concrete filling cast in situ piles

Concrete in cast-in-situ piles shall be in accordance with the requirements of Section 6.14 of the Employer’s Requirements. The slump for the concrete shall be agreed with the Engineer prior to concreting preliminary test piles. Concrete filling in cast-in-situ piles shall be placed continuously. Removal of temporary casings must be completed before the placed concrete loses its workability, but placing of concrete shall keep in advance of withdrawal of casing to prevent ‘necking’.

Static Load Tests

a) Loading Procedure

The pile load test procedure, particularly with respect to the number of loading steps, the duration of the loading steps and the application of load cycles, shall be such that conclusions can be drawn about the deformation behaviour, creep and rebound of a pile foundation from the measurements on the pile. For trial piles, the ultimate loading shall be such that conclusions can also be drawn about the ultimate failure load.

Static load tests shall be carried out in accordance with the ISSMFE Subcommittee on Field and Laboratory Testing recommended procedure, ”Axial Pile Loading Test, Suggested Method”, published in the ASTM Geotechnical Testing Journal, June 1985, pp 79-90.

In case of different wording the text in this Employer’s Requirements shall be valid prior to the above mentioned recommended procedure.

Devices for the determination of forces, stresses or strains and displacements shall be calibrated prior to the test.

In general, pile load tests for the purpose of designing a tensile pile foundation should be carried out to failure. Extrapolation of the load-displacement graph for tension tests should normally not be used, especially in the case of transient loading.

b) Trial Piles (Test Piles)
The number of trial piles required to verify the design shall be selected on the following aspects:

- the ground conditions and their variability across the site
- type of structure
- documented evidence of the performance of the same type of pile in similar ground conditions
- the total number and types of piles in the foundation design

The number of test piles shall be minimum 2 , with different lengths or diameters. In determination of test loads and test pile length, designer shall consider the estimated load amount that each working pile will carry as well as the capacity of the hydraulic jacks and pumps that will be used in the tests.

The method used for installation of the trial piles shall be fully documented in accordance with 6.2.14.4.

c) Working Piles
The number of working pile load tests shall be selected on the basis of the recorded findings during construction.

The selection of the working test piles should be prescribed in the contract documents.

The load applied to the working test piles shall be at least equal to the design load governing the design of two foundations.

Dynamic Load Tests
a) General
Dynamic load tests shall be carried out in accordance with ASTM D 4945-89 ”Standard Test Method for High-Strain Dynamic of Piles”.

The results of dynamic load tests may be used for design provided an adequate site investigation has been carried out and the method has been calibrated against static load tests on the same type of pile, of similar length and cross-section, and under comparable soil conditions.

Dynamic load tests may be used as an indicator of the consistency of the piles and to detect weak piles.

In a dynamic load test the pile is instrumented with accelerometers and strain gauges. The gauges are connected to a recording and data processing device. During blows on the pile signals from the gauges are recorded and processed for assessment of pile bearing capacity. The data processing will be one of two kinds, either simple or signal matching (CASE or similar program).The simple method gives instant results while signal matching is more time consuming (hours).

In the CASE method or similar the following data shall be registered and reported:

- bearing capacity
- toe resistance and skin friction
- maximum compression stress, acceleration, velocity and displacement
- maximum tension stress in pile
- pile structural integrity; extent and location of damage
- maximum energy transferred to the pile
- blows per minute for hammer check
- blow number
- input and reflection of force, velocity, upward and downward force waves
- load versus deflection of cushions and of pile toe bearing

CAPWAP or similar programs determines that set for soil resistance parameters which produces the best match between measured and computed pile top force and velocity. After CAPWAP analysis additional information than above for CASE is accomplished as:

- deformation properties, ultimate capacities and soil damping parameters for each soil segment of normally 1 m length
- unit skin friction for each segment and end bearing
- maximum of tension and compression forces and stresses
- pile structural damping
- dynamic pile toe displacement
- graph on bearing capacity and pile stresses versus blow count

An introductory program (WEAP) can be utilised before pile driving to assess preliminary combinations of sets and bearing capacities for specified pile, driving equipment and soil conditions.

The data processing shall be carried out by well experienced experts.

The piles to be tested are selected as in 6.2.14.2.

b) Dynamic Load Test Procedure
The Contractor shall notify the Engineer at least two weeks prior to dynamic testing.

The Contractor shall submit a qualified testing Consultant and his experience to the Engineer for approval.

The Engineer shall determine if the test is to be performed or if some pile waiting periods at the proposed site is required before a decision will be made.

The Engineer will establish a date for the tests and will also determine the location of all piles to be dynamically load tested.

c) Dynamic Load Test Procedure on Driven Piles
The Contractor shall supply all personnel and equipment needed to strike the test pile with the hammer.

The Contractor shall provide the hammer (drop, diesel, etc.) or the mobile crane to lift a steel ram weight by a single non-twisting cable and be able to strike to the pile top by mean of full-gravity-fail.

The instrument for the dynamic load test shall conform to ASTM D 4945.

Approximately two driven piles will be tested in one day. The testing Consultant personnel will drill holes into the pile to be tested so that transducers (two accelerometers and two strain gauges) can be attached. Testing procedures shall be conformed to ASTM D 4945.

When the transducers have been placed in position and the recording and processing equipment has been made ready to receive the acceleration and strain measurements, the Engineer will instruct the Contractor regarding the drop height and the Contractor shall strike the driven pile with the hammer as many times as is required to obtain adequate measurements as determined by the Engineer.

The Engineer may ask the Contractor to provide surveying instrument to monitor the pile set after each strike.

After the dynamic testing measurements have been obtained and analysed and a report has been submitted, the Engineer will provide instructions for the results.

d) Dynamic Load Test Procedure on Bored Piles
The Contractor shall prepare the pile top and if necessary improve the structural integrity of the pile top to resist a sharp impact force. All loose concrete at the pile top shall be removed. The top portion of the bored pile shall be extended to a length of at least two times the diameter of the bored pile with the same diameter as the bored pile. The extended portion of the bored pile shall be cast with concrete having a minimum compressive strength of 40 Mpa.

Additional shear reinforcement such as spiral hoop at the pile top is recommended for the impact force. The Contractor shall provide the windows for the installation of instrument by burning an opening 0.35 x 0.35 m^2 to the steel casing using a cutting torch.

On top of the bored pile a timber cushion under steel plate as a hammer cushion shall be mounted. Adhesive material may be applied between the pile top and the timber.

The Contractor shall provide an additional steel casing inserted into the pile top. This casing is acting as a guide for the steel ram weight, having the length not less than the summation of the drop height and the length of the steel ram weight. It is important to secure and stabilise the steel casing by means of a vibratory hammer.

The Contractor shall supply all personnel and equipment needed to strike the test pile with the steel ram weight. The Contractor shall provide a mobile crane which has the ability to lift the steel ram weight by a single non-twisting cable and be able to strike to the pile top by mean of full-gravity-fail.

The instrument for the dynamic load test shall conform to ASTM D 4945.

Approximately one bored pile will be tested in one day. The testing Consultant personnel will drill holes in the windows of the left-in-place steel casing into the pile to be tested so that transducers (two accelerometers and two strain gauges) can be attached.

Testing procedures shall be conformed to ASTM D 4945.

The Engineer may ask the Contractor to provide surveying instrument to monitor the pile set after each strike.

After the dynamic testing measurements have been obtained and analysed and the report has been submitted, the Engineer will provide instructions for the results.

Load Test Report

The Contractor shall submit a complete record of each pile test to the Engineer 24 hours after completion of the tests. Where appropriate, this report shall include:

- a description of the site
- the ground conditions with reference to ground investigations
- the pile type
- a description of the loading and measuring apparatus and the reaction system
- calibration documents of the load cells, the jacks and the gauges
- the installation record of the test piles
- photographic records of the pile and the test site
- test results in numerical form
- time settlement plots for each applied load when a step loading procedure is used

- the measured load-settlement behaviour
- justification of the reasons for any departures from the recommendations

6.4.15 Piles in compression

Ultimate Bearing Resistance from Static Pile Load Tests

The manner in which load tests are carried out shall be in accordance with 6.2.14.

Trial piles to be tested shall be installed in the same manner as the piles which will form the foundation and shall be founded in the same stratum.

In the case of a very large diameter pile, it is often impractical to carry out a load test on a full size trial pile. Load tests on smaller diameter trial piles may be considered provided that:

- the ratio of the trial pile/ working pile diameter is not less than 0.5
- the trial pile is instrumented in such a manner that the base and shaft resistance can be derived separately from the measurements

When deriving the ultimate characteristic bearing resistance Rcc from values Rcms measured in one or several static pile load tests, an allowance shall be made for the variability of the ground and the variability of the effect of pile installations a minimum, both conditions (a) and (b) of the table below shall be satisfied using the equation:

- Rcc = Rcms/γns

Factors γns to Derive Rcc

Number of load tests	1	2	>2
γns on average Rcms	1.5	1.35	1.3
γns on lowest Rcms	1.5	1.25	1.1

In order to derive the ultimate design bearing resistance, the characteristic value Rcc should be divided into components of base resistance Rcbc and shaft resistance Rcsc such that

- Rcc = R cbc + Rcsc

The design bearing resistance Rd shall be derived from

- Rcd = Rcbc/ γbs + Rcsc/γss

where γbs and γss are taken from the table below.

Values of γbs, γss and γts

Component actors	γbs	γss	γts
Driven piles	1.3	1.3	1.3
Bored piles	1.6	1.3	1.5
CFA piles	1.45	1.3	1.4

Normally the load test only provides the pile load test versus settlement and time versus settlement diagrams without distinction between point and shaft resistance. Therefore, it is often not possible to distinguish between partial factors for the assessment of the design value of base resistance and shaft resistance. Instead a partial factor on the ultimate characteristic pile resistance, Rcc may be taken as the γts values given in the table above.

Ultimate Bearing Resistance from Pile Driving Formulas
If pile formulae are used to assess the ultimate bearing resistance of individual compression piles in a foundation, the validity of the formulae shall have been demonstrated by previous experimental evidence of good performance or static load tests on the same type of pile, of similar length and cross-section, and in similar ground conditions.

Pile driving formulae shall only be used if the stratification of the ground has been determined.

In the design, the number of piles to be redriven shall be specified. If redriving gives lower results, these shall be used as basis for ultimate bearing resistance assessment. If redriving gives higher results, these may be taken into consideration.

Redriving should usually be carried out in silty soils, unless local comparable experience has shown this to be unnecessary.

Ultimate Bearing Resistance from Dynamic Load Tests
Dynamic load tests and their evaluation can be used to assess pile bearing resistance of individual compression piles. The validity of the evaluation shall have been demonstrated by previous evidence of acceptable performance or static load tests on the same pile type of similar length and cross-section and in similar soil conditions. The input energy level during the dynamic load testing shall be high enough to allow for an appropriate interpretation of the pile capacity at a correspondingly high enough strain level.

When deriving the ultimate characteristic bearing resistance Rcc from values Rcmd measured in two or several dynamic pile load tests, an allowance shall be made for the variability of the ground and the variability of the effect of pile installations a minimum, both conditions (a) and (b) of the table below shall be satisfied using the equation:

- Rcc = Rcmd /γnd

Factors γnd to Derive Rcc

Number of load tests	2	4	>4
γnd on average Rcmd	1.5	1.35	1.3
γnd on lowest Rcmd	1.5	1.25	1.1

In order to derive the ultimate design bearing resistance, the characteristic value Rcc should be divided into components of base resistance Rcbc and shaft resistance Rcsc such that

- Rcc= Rcbc + Rcsc

The design bearing resistance Rcd shall be derived from

- Rcd = Rcbc/γbd + Rcsc/γsd

where γbd and γsd are taken from the table below

Values of γbd, γsd and γtd

Component factors	γbd	γsd	γtd
Driven piles	1.4	1.4	1.4
Bored piles	1.7	1.4	1.6

In case Rcbc and Rcsc are not known, the design bearing resistance Rcd is derived from

- Rcd = Rcc/γtd

6.4.16 Piles in tension

Ultimate Tensile Resistance from Static Pile Load Tests

Pile load tests to determine the ultimate tensile resistance Rtc of an isolated pile shall be carried out in accordance with 6.2.14.

When deriving the ultimate characteristic resistance Rtc from values Rtm measured in one or several static pile load tests, an allowance shall be made for the variability of the ground and the variability of the effect of pile installation. As a minimum, both conditions (a) and (b) of the table below shall be satisfied using the equation:

- Rtc = Rtms/γnt

Load test number	1	2	2
γnt on average Rtms	1.5	1.35	1.3
γnt on lowest Rtms	1.5	1.25	1.1

Normally when piles are loaded in tension, more than one pile shall be tested. In the case of a larger number of tension piles, at least 2% shall be tested.

The design tensile resistance, Rtd, shall be derived from

- $Rtd = Rtc/\gamma m$

  where $\gamma m = 1.6$

6.4.17 Supervision of construction

A pile installation plan shall be the basis for the construction work.

The plan should give the following design information:

- the pile type with designation if standardised or technical approval otherwise
- the location and inclination of each pile and tolerances on position
- pile cross-section
- pile length
- number of piles
- required pile load carrying capacity
- pile toe level or the required penetration resistance
- installation sequence
- any other constraints on piling activities

The installation of all piles shall be monitored and records shall be made at site and as the piles are installed. A record signed by the supervisor of the work and the pile manufacturer shall be kept for each pile.

The record for each pile shall include the following, where appropriate:

- pile type and installation equipment
- pile number
- pile cross-section, length and (for concrete piles) reinforcement
- data and time of installation (including interruptions to the construction process)
- concrete mix, volume of concrete used and method of placing for cast-in situ piles

- pumping pressures of the grout or concrete, internal and external diameters, pitch of screw and penetration per revolution (for continuous flight auger piles or other injection piles)

- for driven piles, the values of driving resistance measurements such as weight and drop or power rating of hammer, blow frequency and number of blows for at least the last 0.25 m penetration

- the power take-off of vibrators (where used)

- the torque applied to the drilling motor (where used)

- for bored piles, the strata encountered in the borings and the condition of the base, if performance of the base is critical

- obstructions encountered during piling

- deviations of positions and directions and as-built elevations

Records shall be kept for a period of at least five years after completion of the works. As built record plans shall be compiled after completion of the piling and kept with the Drawings.

If site observations or inspection of records reveal uncertainties with respect to the quality of installed piles, additional investigations shall be carried out the determine the as-built conditions of the piles and whether remedial measures are necessary. These investigations shall include either re-driving or pile integrity tests, in combination with soil mechanics field tests adjoining the suspected piles, or static pile load tests.

Tests shall be used to examine the integrity of piles for which the quality is sensitive in a reliable way.

Dynamic low strain integrity tests can be used for a global evaluation of piles that might have severe defects or that may have caused a serious loss of strength in the soil during construction. Since defects like insufficient quality of concrete and thickness of concrete cover, affecting the long term performance of a pile, often cannot be found by dynamic tests, other tests such as sonic tests, vibration tests or coring may be needed in supervising the execution.

6.5 Ground Improvement

6.5.1 General

Any ground treatment proposed by the Contractor to improve the bearing capacity and/or settlement characteristic of the soil must be supported by a full method statement -including design calculations and design drawings- with a statement of the minimum performance to be achieved.

In the selection of ground improvement method, the time limitations of the Contract shall be taken into consideration. The methods listed in the Employer's Requirements may be used and all methods are subject to the approval of the Engineer. Where directed by the Engineer the Contractor shall carry out a field trial of the proposed treatment to demonstrate that it meets the stated performance criteria.

All in-situ verification of ground improvement shall be made by CPT or SPT test after ground improvement works.

6.5.2 Soil replacement

Soil replacement involves excavating the soil that needs to be improved and replacing it. Excavated soil shall be replaced with compacted granular soil (Sand & gravel) with more suitable properties for the proposed application.

Method and material or soil replacement shall be approved by the Engineer.

6.5.3 Admixture stabilization

Admixture stabilization consists of mixing or injecting admixtures such as cement, lime, fly ash or bentonite into a soil to improve its properties. Admixtures can be used to increase the strength, decrease the permeability or improve the workability of a soil. Admixtures can fill voids, bind particles, or break down soil particles and form cement. The general process of admixture stabilization consists of (1) excavating and breaking up the soil, (2) adding the stabilizer and water, if necessary, (3) mixing thoroughly, and (4) compacting the soil and allowing it to cure.

During stabilization of soils with admixtures, the most important observations are the amount of admixture and water mixed into the soil, the amount of mixing performed, and the amount of compactive effort used on the fill. The moisture content and density of the fill can be determined in the field. The curing time and conditions should also be recorded. Samples should be taken for laboratory testing.

Method of admixture stabilization shall be approved by the Engineer.

6.5.4 Jet grout columns

The Contractor is required to test several jet grout column sections prior to construction to determine the geometry and quality of treated material that can be obtained.

For assessing the geometry, excavation or coring shall be made. Wet grab samples shall be taken for strength and permeability testing. If piezometers are installed for later hydraulic conductivity measurements, the construction details of the piezometers shall be recorded.

During construction, it shall be monitored and the Contractor is required to note if the grouting parameters and materials are consistent with the approved test section. The ability to erode the soil with the jets is an important factor in successful jet grouting. There shall be a continuous flow of spoils to the ground surface during jetting. If there is no spoil return, it is possible that hydrofracturing is occurring. The rate of rotation and removal of the grout pipe and the rate of material consumption shall be monitored.

Method of jet grouting shall be approved by the Engineer.

6.5.5 Prefabricated vertical drains (Wick drains - strip drains)

The Contractor is required to prepare a method statement for preloading with wick drains, based on the geotechnical report. This method statement shall include the following data:

1 materials

2 monitoring equipment

3 spacing and depth of wick drains (drain layout drawings)

4 spacing and depth of settlement gauges (monitoring system layout drawings)

5 height of preloading fill

6 time required for achieving design settlements

7 record keeping

8 expected vertical displacements (swell/settlements) during trial loading, preloading, excavation for foundations and in long term (for centres and edges of foundations).

First stage in the application of the prefabricated drain, shall be removing the topsoil, installing surface settlement plates, laying the separation geotextile and placing the drainage layer according to the thickness stated in the Method Statement and extend this drainage layer to the drainage trenches around.

Later, the vertical drain locations shall be marked. Prefabricated wick drains shall be installed down to the depth stated in the Method Statement using a special steel mandrel mounted on the service crane. The mandrel shall be pushed into the soil using a vibratory hammer.

Wick drains shall be placed at constant load and high speed in order to avoid disturbance of soil. Vertical misalignments shall be avoided by checking with a water balance.

A drainage ditch shall be excavated around the perimeter of the wick drain field. This drainage trench will collect the discharge coming from the granular drainage layer over the wick drain field.

Finally, another separation geotextile shall be laid over the granular drainage layer over the wick drain field. Before any preloading fill material is placed, settlement columns and magnetic extensometer shall be installed according to the Method Statement, in order to find out the future settlements. The settlements shall be measured and recorded until the displacements have reached the desired level.

Preloading fill materials shall be laid around the perimeter of the large structures and the base of the fill shall be extended at least 4 meter outside the structure's borders as shown on the drawings. Then the fill will be placed with 1H:1V side slope, to a maximum height of 4 meters.

Fill material will be laid uniformly in 200-300mm thick layers and spread uniformly. No compaction tests are required and compaction will be achieved by the truck traffic over the fill construction. Therefore it is mandatory to place the fill homogeneously and uniformly.

Surface settlement measuring plates will be buried in natural ground at the preloading area and these will be protected and extended as described.

A working platform shall be formed to support drain installation equipment. Drainage layer may be used for this purpose; however, thickness of the drainage layer may need to be increased to support the equipment as required.

The drain capacity could be the limiting factor in cases where PV drains are designed for sites where there are deep compressible layers with surcharge loading. When PV drains are designed to function near their maximum capacity, the installations shall be monitored carefully. Before using wick drains below a depth of 45m, a specialist shall be consulted.

Wick drains shall be composed of two parts: inner core and filter material. These may be manufactured as a single material or the filter may be wrapped around the core, and overlapped to keep the core closed inside.

Wick drains shall be, 100 mm wide, 6 mm thick polyester (PES) or polypropylene (PP), or similar, with the approval of the Engineer.

Wick drains shall be flexible, capable of being rolled to a 300mm diameter drum without damage. The wick drain must be strong enough so it will not break, tear or lose its drainage properties during installation. The core of the drain shall resist crushing or formation of kinks when bent.

The positions of the wick drains shall be at most 100 mm away from the coordinates shown on the drain layout drawings.

Vertical deviation of the drains shall be at most 1 Horizontal in 50 Vertical.

Wick drains shall be cut at least at least 150 mm above the working platform.

Daily reports shall be written for the drains installed. A copy of these reports shall be presented to the Engineer within two days after installation. The records shall include:

1 date

2 reference area and grid for each drain

3 depth of installation for each drain

4 obstacles and delays

5 readings of the installed instruments.

Any unexpected conditions experienced and reported will be briefly mentioned in these records.

After all field works are completed, two (2) copies of the Final Report will be presented to the Engineer within two (2) weeks after removing the preloading fill.

Method of preloading with wick drains shall be approved by the Engineer.

6.6 Flood Protection

6.6.1 General

The main aims of the flood protection works are:

- To avoid the inflow of storm water into the facility, protecting in this way its structural stability
- To protect the buildings and the roads of the landfill site from storm water erosion

The flood protection works of the site consist of the following:

- Ditches for the protection of facilities
- Ditches for the protection of internal road network
- Well for the drainage of the ditches and sewers

The ditches aim at collection and transporting the rainwater from the outside basins and the internal sub-basins. The flooding protection will be succeeded via perimetric insulated ditches outflow wells through which the water will be lead to the natural recipient.

The hydrological calculations should be made for a return period of 20 years. A safety factor has to be adopted for the maximum discharge that the ditches can convey.

It is clearly stated that rainwater that will occur throughout the facility will be collected separately from washing and similar waste waters.

If new construction of structures or facilities are to be located in a floodplain, accepted flood proofing and other flood protection measures shall be applied to new construction or rehabilitation. To achieve flood protection, Contractors shall, wherever practicable, elevate structures above the base flood level rather than filling in land.

6.6.2 Earth dikes

Dikes shall be high enough to prevent the 100-year flood from overtopping. Existing dikes at the plant area shall also be investigated. These shall be reshaped or rebuilt where necessary, and repaired in areas of the dikes where erosion had occurred.

Design requirements for earth dikes:

- Preconstruction surveys required for design
- Soil sampling and soil tests for dike embankment fill borrow areas
- Design of local drainage improvements (including culverts with flap gates and/or manual control gates).

6.6.3 Mortared stone walls and slabs

Mortared stone walls and slabs shall be built at locations shown on Drawings, with the sections and stone sizes shown on the details.

Before the stones are placed, ground surface shall be arranged smooth and parallel to the finished surface considering the stone thickness and wall slope. Wall thickness shown on the Drawings or specified by the Engineer must be achieved with a single stone layer, and two stone layers on top of each other will not be accepted.

The void between the stones shall be filled completely with mortar, and stones shall be hammered after laying to get a strong bond between stones.

Larger stones shall be used at the edges of the stone surfaces, especially at the skirts of sloped surfaces. Stoned shall be laid from bottom to the top. Mortar, cement and water shall be in accordance with the Employer's Requirements, Concrete and Steel Works.