SA Water

TG 10i

SOUTH AUSTRALIAN WATER CORPORATION

TECHNICAL GUIDELINE

GENERAL TECHNICAL INFORMATION FOR GEOTECHNICAL DESIGN

~ Part I ~
Pile Driving

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of South Australia

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No Changes Required In the January 2007 Edition

The following lists the major changes to the November 2004 edition of TG 10i:

1. Nil

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Referenced Documents

1. AS 1289.5.2.1

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Section 2: Sand Piling Specification

Specification for the improvement of the foundation for a proposed surge tank in the cadell irrigation district of south australia using sand piling.

The improvement of the foundation for a proposed surge tank in the cadell irrigation district of south australia using sand piling.

2.1 Project Background

A new surge tank is required as part of the rehabilitation of the Cadell Irrigation District. The tank will have an internal diameter of 7.5 metres, a footing diameter of approximately 8.8 metres, and a height of 25 metres.

A geotechnical investigation of the site for the proposed tank has indicated that the footing area is underlain by a six metre depth of relatively clean, loose to medium dense sand. Dense sands were encountered below six metres.

The loose to medium dense sands in the top six metres were judged to be unsuitable as a foundation for the tank because of their potential for excessive settlement under the high loads from the tank.

It was proposed that the foundation be improved by using (mainly) the sand piling technique to compact insitu all of the natural sands above the dense sands at about six metres.

In the sand piling technique .....

2.2 Scope of work

The work in this contract shall be:

1. The improvement of the tank foundation by compaction using the sand piling technique and any additional compaction techniques necessary.

2. The provision of test results to demonstrate that the required densities have been achieved.

3. The placement and compaction of a cement treated quarry rubble working surface over the area specified.

2.3 Geotechnical Information

The geotechnical investigation of the preferred site for the tank consisted of two hollow auger trial holes located as shown on Figure 1. Continuous SPT samples were taken in both trial holes to 7 metres depth.

Brown, fine and medium sand with some patches of carbonate fines (lime) were encountered for the full depth of both trial holes

SPT N values averaged about 12 blows per 300 mm for the first 6 m of Trial Hole 1 and 14 blows per 300 mm for the first 6 m in Trial Hole 3.

At 6 m in both trial holes N values rose abruptly to 30+ blows per 300 mm.

No groundwater was cut, and all samples were logged as humid.

The trial hole logs are appended, and the boxed samples may be inspected by appointment at the SA Water Soils Laboratory at Ottoway.

2.4 Performance Requirements

The Contractor shall achieve a compacted cylinder of ground with a diameter of not less than ten metres.

The compacted cylinder of ground shall extend down from EL 21.55 (150 mm below the proposed underside of tank floor level) to the top of the naturally dense sands at a depth of approximately six metres. The Contractor shall determine when the naturally dense sand has been reached when driving the casing at each sand pile location.

The ground within this cylinder shall be compacted to a density of not less than 30 blows per 300 mm (N=30) as measured by the Standard Penetration Test (AS 1289.6.3.1), or a density of not less than 100% of the maximum dry density of the material as determined by the standard method (AS 1289.5.1.1).

It is recognised that, in order to achieve the specified densities within the specified cylinder of ground, it will be necessary for the Contractor to remove and recompact, in layers, the sand in the top metre or so within the specified diameter, and also possibly to install sand piles outside of the specified diameter.

2.5 Testing of Compacted Ground (1 M to 6 M)

The Contractor shall be responsible for arranging for insitu density testing to be carried out to demonstrate that the ground between the sand piles has been compacted to the required minimum density, and for presenting the results to the Superintendent’s Representative.

The insitu density testing shall consist of not less than four continuous SPT tests done from within hollow augers. The augers shall be advanced between each test. The tests shall begin 1 m below the surface and end at 6 m below the surface.

The test holes will be located between the sand piles at positions selected by the Superintendent’s Representative.

The Contractor shall give the Superintendent’s Representative notice of not less than two working days when site will be ready for SPT testing.

2.6 Testing of Compacted Ground (Surface to 1m)

The Contractor shall be responsible for arranging for insitu density testing to be carried out to demonstrate that the top one metre of the compacted ground has been compacted to the required minimum density, and for presenting the results to the Superintendent’s Representative.

The insitu density testing shall consist of not less than four sand replacement or nuclear densometer tests at each of the following depths below the surface: 100 to 250 mm, 450 to 600 mm, and 850 to 1000 mm.

2.7 Placement of Quarry Rubble Working Surface

When the compacted foundation has been accepted by the Superintendent’s Representative, the Contractor shall place and compact a cement treated quarry rubble (CTQR) working surface not less than 150 mm thick over the 10 metre diameter area.

The finished level of the top of the CTQR working surface shall be the proposed underside of tank floor level (EL 21.70) to within a tolerance of + 0 mm and - 20 mm. The CTQR shall consist of 20 mm quarry rubble with 3% cement complying with TSA standard specification PM21, C3. The CTQR shall be compacted to a density of not less than 100% of its modified maximum dry density (AS 1289.5.2.1).

2.8 Testing of Quarry Rubble Working Surface

The Contractor shall be responsible for arranging for insitu density testing to be carried out to demonstrate that CTQR working surface has been compacted to the required minimum density and for presenting the results to the Superintendent’s Representative.

The insitu density testing of the CTQR shall consist of not less than five sand replacement or nuclear densometer tests from the surface of the CTQR to a depth of 150 mm.

This “Technical Note” was prepared by Ed Collingham, 16/10/1997
(Ex Principal Engineer Geotechnical)

Section 3: Pile Driving Notes and Formulae

Specification, hammers, sets, and the application of dynamic formulae

With specific reference to the "adjusted gates formula" for steel piles in sand

These notes apply only to single, axially loaded, steel piles driven using an impact hammer

These notes were originally prepared by Ed Collingham, Supervising Engineer Geotechnical, SA Water in 1992. They were intended to provide basic background information only, and it was strongly recommended that all piling jobs be referred to a geotechnical specialist for specification and design. Despite the release of the piling code (AS 2159-1995) and the availability of more modern equipment, they are still considered to have general relevance.

3.1 Records

Complete and accurate records are essential. A typical specification clause might read: The Contractor shall provide a driving record for each pile showing

a. The number and location of the pile.
b. The date and time at the beginning and end of each driving run, and of any pauses in the driving.
c. The make, model number and type of hammer used.
d. The manufacturers rated energy, stroke and blow rate for the hammer, the total mass of the hammer, and the mass of the piston.
e. The type of helmet used.
f. The type of material and thickness of the cushion blocks on the pile head (the main job of the cushion blocks is to shape the impact pulse for the most effective driving).
g. For each 250 mm increment of penetration (see note 4), a log of: the depth of penetration of the pile toe the elevation of the pile toe the number of hammer blows for the specified increment of penetration.
h. The speed of operation, stroke or drop of the hammer (as appropriate for the type of hammer being used) while the final set is being taken.
i. Any unusual phenomena observed during driving.

3.2 Adequacy of Hammer – The Hammer Must Be Big Enough!

The mass of the "ram" must be not less than 0.4 times the mass of the driven components. The "ram" referred to here is the dropweight itself for a drop hammer, or the piston or ram for a diesel or air hammer. The driven components include the hammer itself (less the mass of the ram), plus the helmet and the pile. If the hammer is too small most of the blow energy is dissipated within the hammer/helmet/cushion-block/pile system and not in advancing the pile into the ground.

Dynamic pile driving formulae will be invalidated if too light a hammer is used.

3.3 Correct Operation of the Hammer

Make sure that the hammer is operating at its energy when taking the final set. This is usually indicated by the stroke of the piston for a diesel hammer and the blow rate for a double acting air hammer. (Refer to the manufacturer’s specs.) If it is lower than specified, the energy per blow may be well down and give a false impression that the required set has been reached. (A trick which has sometimes been used by less than scrupulous contractors!)

3.4 The “Set”

The "driving set" is the depth driven per blow of the hammer when the pile is deemed to be able to carry the design load with an adequate factor of safety (ie at least 3).

The driving set may range from say 5 mm or less up to 100 mm or more per blow. In practise the set must be specified and measured over a depth range encompassing several blows to ensure that the pile toe has not hit just a thin hard layer or isolated boulder.

A typical specification clause for the "set" might read:

“The Contractor shall drive the piles (specify which) to a set of 25 mm per blow, measured as ten blows over the last 250 mm of driving. If there has been a pause during driving the pile shall be re-started by attempting to drive it 500 mm before considering that the blow counts recorded are an indication that the final set has been achieved.”

It is obvious that the specification for the "set" and for the penetration increment over which it is measured must be adapted in each case to suit the hammer and the required pile capacity.

Other less obvious factors should also be considered such as whether the pile is sensitive to over-driving; will it be end-bearing on a dense stratum, or will it terminate within a deep sand profile. The penetration increment over which data is logged during normal driving may also need to be adjusted (see 1(g) above).

3.5 Dynamic Pile Driving Formulae – General Comments

There are several dynamic pile driving formulae around. All are empirical - even those that appear to consider a range of subtle parameters such as did the old Hiley Formula.

Some work well in some soils for some pile types some are atrocious and give almost no correlation between set and load carrying capacity.

“Dynamic” means measured during continuous driving - NOT on restart after a period of no driving. The ground can tighten up during a break in driving (particularly in clays) and give a false impression that the required set has been reached.

(This is another trick sometimes used by less than scrupulous contractors – hence 1(b) above and the final sentence of the suggested specification clause in section 4 above.)

3.6 The “Adjusted Gates Formula” for Piles in Sand

At the time of writing, the "Adjusted Gates Formula" is the recommended "dynamic" formula for the calculating the load carrying capacity of a pile from the observed driving set, or for computing the required set for a given hammer and design axial pile load.

The formula applies only to piles in sand.

Versions are available for steel, concrete and timber piles.

Reference: Pile Driving Formulas for Friction Piles in Sand
Olson, Kaare and Flaate
ASCE Journal of the Soil Mech and Foundations Div
Volume 93 No SM6 November 1967.

3.7 Set for Steel Piles in Sand (Adjusted Gates Formula)

$$\mathbf{s = 250 \div 10^{**} ((Q_c + 740) / 120(e_h.E_n)^{0.5})}$$

where:

"s"	is the set in mm per blow
"Q_c"	is the pile capacity in kN (3 x design load) (see Note 1)
"e "	is the efficiency of the hammer (see Note 2)
"E "	is the nominal energy of the hammer in inch.tons per blow (see Note 3)

Notes:

1. A factor of safety of at least 3 between design load and pile capacity Q is required to cover inaccuracies in the calculation procedure, uncertainties in loading, and to ensure relatively small settlements under load.
2. For values of e_h (a dimensionless ratio) see Table 1.
3. For conversion factors for E see Table 2.

3.8 Capacity of Steel Piles In Sand (Adjusted Gates Formula)

$$\mathbf{Q_c = 120 \times \log(250/s) \times (e_h.E_n)^{0.5} - 740}$$

kN mm inch.ton units
(3 x design load)

Table 3.1 - Values of e_h.

Type of Hammer	$\mathbf{e_h}$	**Comments**
Winch operated DROP HAMMER	0.8	–
Trigger release DROP HAMMER	1.0	–
Single acting hammer	0.9	–
Double acting STEAM or AIR HAMMER	1.0	Use the manufacturers rated energy per blow at the actual speed of operation of the hammer. The speed of operation must be checked when taking the final set.
DIESEL HAMMERS	1.0	Use the manufacturers rated energy per blow corresponding to the stroke of the hammer at the final set.

Table 3.2 - Conversion Factors for e_n.

Unit in which the rated energy of the hammer is quoted by the manufacturer	**Multiply the rated energy by the factor below to convert to the inch and (US) ton units required by the formulae**
inch.(US)ton (1(US)ton = 2000 lb)	1.0
inch.(Imp)ton (1 Imperial ton = 2240 lb)	1.1
ft.lb	0.006
Joules (N.m)	0.0044
drop hammer (metric tonnes and metres)	43.0
drop hammer (Imperial tons and metres)	44.0

This “Technical Note” was prepared by Ed Collingham, 14/03/2002
(Ex Principal Engineer Geotechnical)