

## Particular Specification for Minipiles

### 1.0 Definition

A minipile is a pile consisting of a steel permanent casing with internal diameter not greater than 400 mm, with either one or a group of reinforcement bars in the middle as the load bearing element, and the remaining cavity filled with grout. The core of the minipile shall be socketed into bedrock.

### 2.0 Design Requirements

#### 2.1 Loading Capacity

The theoretical safe loading capacity of the individual pile shall not exceed 1400 KN. This safe loading capacity includes loading due to the weight and imposed loads of the structure and the negative skin friction, soil, cap and pile weight etc.

#### 2.2 Design Assumptions

The theoretical safe loading capacity of the individual pile shall be the design bond strength between the bedrock and grout times the design length and perimeter of the rock socket OR the design bond strength between the reinforcement and grout times the effective perimeter of the reinforcement and design length of the rock socket OR the allowable reinforcement bearing capacity designed in the pile, whichever is the smaller. The steel permanent casing and the grout shall not be taken into account in the calculation of pile capacity.

End bearing capacity of the pile shall be ignored.

The Contractor shall satisfy himself that the above method of calculating the theoretical safe loading capacity provides a sufficient factor of safety in his design. Should he feel that this method does not provide an adequate factor of safety in his design, he shall submit an alternative method of calculation for the approval of the SO.

Design bond strength between bedrock and grout shall not exceed 0.7 MPa for grout having minimum cube strength of 30 MPa at 28 days and 0.64 MPa for grout having minimum cube strength of 25 MPa at 28 days. Bedrock is defined in Clause 11 of this particular specification. If a different bond strength value is proposed, submit with the tender details of the design parameters, proposed testing methods of the trial piles (including loading tests) for justification of the proposed parameters and test programme, all to the satisfaction of the SO. All tests for this purpose shall be at the Contractor's own expense and no extension of time shall be granted whatsoever.

The maximum allowable compressive stress of the reinforcement shall not exceed 190 MPa for deformed high yield steel bars in Grade 460. The maximum

allowable bond stress between grout and reinforcement for deformed high yield steel bars in Grade 460 shall not exceed 0.8MPa. In calculating the allowable safe loading capacity of the pile due to bond, the effective diameter of a group of bars in contact shall be equivalent to the diameter of a bar of equal total area.

The pile shall not be designed to resist any horizontal loads unless designed as raking piles. If raking piles are used to resist lateral loads, they should only be designed to resist the lateral load. That is, no vertical load should be considered to be taken by the raking pile if it is designed to take lateral load. The sub-grade reaction of soil shall be ignored in raking pile calculations.

Group reduction factor in Clause 5.07 of the General Specification shall not be applied.

### **2.3 Reinforcement Details**

The reinforcement may be lengthened by staggering the couplers with details approved by the SO. The percentage of the total cross sectional area of reinforcement lengthened by couplers at any one section shall not be greater than 50% and the couplers should normally be arranged symmetrically with minimum spacing between couplers of 500 mm c/c along the pile. Also, couplers shall not be used within the prebored hole formed in bedrock.

Each reinforcing bar shall be separated by spacers of 16 mm minimum size at regular intervals not greater than 2000 mm. Unless agreed by the SO, the minimum length of each reinforcing bar shall be 6 m except the uppermost section. The Contractor shall submit with his tender the lapping and spacers details.

Minimum cover to reinforcement inside the prebored hole formed in bedrock shall be 35 mm. For other part of the pile, minimum cover to reinforcement shall be 40 mm or the diameter of reinforcement whichever is the greater.

### **3.0 Design Submissions**

In addition to the submissions stated in clause 5.02 of the GS, submit 2 copies of the following information with the design submissions:

- (a) details of grout mix and pressure grouting;
- (b) method of installation including equipment to be used, sequence of operations, drilling methods, casing installation and time of grouting;
- (c) pile head, reinforcement lapping, and spacers details;
- (d) minimum length of rock socket for each pile;
- (e) any other requirements specified in this particular specification.

No piling works shall commence on site unless the design submissions are approved by the SO.

#### **4.0 Piling Details**

The minimum lengths of rock socket shall be provided and calculated using Clause 2.2 of this particular specification. All piles shall be grouted to a minimum level of 300 mm above the specified pile cut-off level.

#### **5.0 Drilling Mud**

Pile shall be installed without use of bentonite slurry or other drilling muds.

#### **6.0 Flushing Medium**

Air shall be used as the flushing medium during the drilling operation. Water shall not be used as the flushing medium. The Contractor's attention is drawn to the formation process of the pile shaft using air flushing where special care shall be taken to avoid caving in of soil during forming of the pile shaft.

#### **7.0 Casing to Pile Shaft**

Permanent casings for piles shall be provided and shall meet the following requirements:-

- (a) Pile shafts shall be cased for their entire length against soil plus a projection of at least 500 mm into bedrock or such other depth as required avoiding caving in of soil at the interface of soil and bedrock during cleaning of the rock socket.
- (b) The casings shall be formed of steel of 5 mm minimum thickness with an internal diameter not less than the specified pile diameter. The casings shall be joined where necessary with watertight joints. The casings shall be clean and free of any material adhering to them when first inserted into the pile position
- (c) Permanent casings shall be Grade S275J0H or S275J2H structural steel complying with GS. The casings shall be free from significant distortion and shall be of uniform cross-section throughout the whole length and be free from internal projections, which might prevent the proper formation of the piles. Dents in the casing shall not exceed 5 mm in depth.

#### **8.0 Drilling System**

The Symmetrix system (either with the pilot bit set back from or advanced ahead of the ring bit during drilling), Odex system or other drilling systems approved by the SO can be used to form the pile hole of the minipiles. Unless the Symmetrix system with special arrangement in which the pilot bit is set back from the ring bit (i.e. the pilot bit is covered by the ring bit) during drilling is adopted, the Contractor shall properly fill the

gap between the casing and soil with grout or other means. The Contractor shall submit a method statement detailing the proposed procedures and materials to be used for filling the gap between the casing and soil for the approval of the SO before the commencement of works.

## **9.0 Tolerances**

Drillholes for pile shall not be oversized by more than 20 mm.

The maximum deviation of the centre of the head of each finished pile from the designed centre point shall not be more than 15 mm in any direction. The maximum deviation from the vertical axis of the pile through the centroid of the cross section at the cut off level at any level of the finished pile shall not be more than 1 in 100.

## **10.0 Founding Level**

Founding Level of piles shall be taken as the top level of bedrock.

Before commencement of piling, take N size cores to either 5m depth or 1.5 times the rock socket length, whichever is the greater, into bedrock to establish the bedrock level. This predrilling shall be carried out by an independent Ground Investigation Contractor and in sufficient number such that any pile tip shall not be more than 5 m away from the nearest drill hole. Allow sufficient time for additional drill holes when in the opinion of the SO that the bedrock profile cannot be reasonably established from the data of the completed drill holes. Submit two copies of the bedrock levels to the SO within 3 days of the predrilling.

When the founding level has been reached, collect rock samples at the top and bottom of the rock socket for inspection. The rock samples shall be stored in plastic bags with labels showing the pile number and retrieval levels. The Contractor's Construction Engineer shall sign on the plastic bags after inspecting the samples. The actual founding level of piles shall be agreed with the SO before the commencement of rock socket boring. The method of measuring the founding level and pile toe level of piles shall be agreed with the SO before the measurements are taken.

Proof drilling shall be carried out by an independent Ground Investigation Contractor to verify the adequacy of the socketed length of piles at locations instructed by the SO. The number of proof drilling shall be at least 2 or 1% of the number of piles rounded up to the next higher whole number, whichever is the greater. The depths of the proof drill holes shall be at least 5 metres or 1.5 times the rock socket length below the founding levels of the adjoining selected piles.

## 11.0 Bedrock

Bedrock is defined as rock mass of at least 5m thick or 1.5 times the rock socket length, whichever is greater and being Grade III or better rock (as defined in GEOGUIDE 3, “Guide to Rock and Soil Descriptions” prepared by Geotechnical Engineering Office and published by GIS, Hong Kong) with a total core recovery greater than 85% for any one metre within the rock mass. When directed by the SO, a bedrock proving hole shall be carried out, which penetrates at least 5m below the founding level or 1.5 times the rock socket, whichever is the greater. Records of drilling time and penetration shall be forwarded to the SO.

## 12.0 Grout for Piling Work

### 12.1 Grout Material

Grout shall consist of ordinary Portland cement and water with an approved non-shrinkage additive. Where PFA is used, the maximum PFA content shall not exceed 25% of the total cementitious content in the grout. Other admixtures can be used when approved by the SO. The manufacturer’s guidance shall be strictly followed. Cement sand mix is not allowed.

Grout shall have minimum cube strength of 25 MPa or 30 MPa at 28 days. Grout having minimum cube strength less than 25 MPa shall not be accepted.

Measurements for bleeding shall be taken at 15-minute intervals. The amount of bleeding shall not exceed 2% at the end of the first 3 hours and no interim readings shall exceed 4%. In addition the water must be reabsorbed by the grout within 24 hours after mixing.

Free expansion of grout when measured at the end of 24 hours after mixing shall have a figure between 0% and 5%. A negative percentage figure shall not be accepted.

Any approved admixtures shall be chloride-free and comply with BS EN 934.

The maximum total chloride content, expressed as a percentage relationship between the chloride ion and the cementitious content by mass in the grout shall be 0.1%.

Water for grout shall be clean fresh water having a temperature not exceeding 30°C nor less than 5°C.

### 12.2 Grout Mixing

Grout material shall be mixed by weight batching. The amount of water used shall be measured by a calibrated flowmeter or a measuring tank.

The mixing time in high-speed mixers shall be appropriate for the type of mixer used.

After mixing, the grout shall be continuously agitated in a holding tank and screened before injection. The grout shall be placed within the time limits specified by the manufacturers of the additives.

### **12.3 Pressure Grouting**

Before grouting, the bottom of the hole shall be cleaned by airlifting or an alternative method approved by the SO.

Grouting shall be carried out in such a way that the lowest part of the grout pipes shall be as close to the pile toe as possible and, unless agreed by the SO, the grout pipes shall not be lifted up before the completion of grouting.

Agree with the SO the method to measure the grout intake volume.

Grouting of the pile shall be in one continuous operation and under no circumstances shall a pile be left partially grouted.

No un-grouted rock sockets shall be closer than 3m from a pile being grouted.

Newly grouted piles shall be properly covered and fenced off.

### **12.4 Testing of Grout**

The Contractor shall employ an approved laboratory to carry out the tests for Bleeding, Free Expansion and Flow Cone Efflux of grout.

#### **12.4.1 Definition of Batch**

A 'batch' of grout is any quantity of grout used for grouting in one continuous operation in one day.

#### **12.4.2 Test for Bleeding and Free Expansion**

Provide one sample of the grout from each pile after mixing and protect from changes in moisture content before tests are carried out.

Each sample shall be divided into 3 specimens. Each specimen is to be placed in a covered cylinder with a diameter of  $100 \pm 10$ mm to a depth of  $100 \pm 5$  mm and the amount of bleeding and free expansion is measured by a scale fixed to the outside of the cylinder.

$$\text{Bleeding} = 100\% \times \frac{H_2 - H_g}{H_1}$$

$$\text{Free Expansion} = 100\% \times \frac{H_2 - H_1}{H_1}$$

where  $H_1$  - initial height of grout sample

$H_2$  - height of sample measured at upper surface of water layer or hardened grout surface if water is fully absorbed

$H_g$  - height of grout portion of sample at upper surface of grout

Submit preliminary test results to the SO within 48 hours after the mixing of grout.

If the result of the bleeding test of the grout for any pile does not comply with the specified requirements or the free expansion of the grout for any pile is greater than the specified upper limit, the Contractor shall propose changes to improve the materials, grout mix or method of production, though the failure does not constitute a failure of the pile.

If the free expansion of the grout for any pile has a negative figure, the Contractor shall carry out test(s) at their own expense to demonstrate that the pile can fulfil the original design requirements.

#### **12.4.3 Flow Cone Efflux Test**

At least one sample from each pile shall be taken and tested in accordance with ASTM C939 to determine the Flow Cone Efflux time. Agree with the SO the frequency of the test.

Except with SO's prior agreement for grout mixes containing additives, grout having an efflux time of less than 15 seconds will be rejected.

#### **12.4.4 Test for Crushing Strength**

Provide one sample of the grout for each pile after mixing and protect it from changes in moisture content before making test cubes.

Cubes shall be prepared using 100mm cube moulds.

Make two cubes from the sample. Strength compliance requirements shall follow GS clause 6.55.

## 13.0 Reinforcement and Mechanical Coupler

Steel reinforcement shall comply with Section 6 of GS.

### 13.1 Mechanical Coupler

#### 13.1.1 General

Mechanical coupler shall be of an approved proprietary type comprising threaded or cold swaged metal sleeve that can transfer full compression and/or tension strength of the connecting reinforcement bars by means of mechanical interlocking between the sleeve and the connecting bar.

#### 13.1.2 Submission

The following documents and particulars shall be submitted to the SO for approval prior to use:

- a) Name of the manufacturer of the mechanical coupler.
- b) Technical information on the construction details, material composition, mode of load transfer action and designed strength of the mechanical coupler.
- c) Full specification of the mechanical coupler.
- d) Identification system for the mechanical coupler. Each mechanical coupler shall be legibly and durably marked, e.g. hard stamped, with the identification of the manufacturer, the nominal diameter and the batch reference.
- e) The manufacturer's quality system on traceability of production record for the mechanical coupler and threaded reinforcement bars.
- f) Installation method including factory and site operations, particularly the special equipments and technical skills that have to be engaged on site, and means of checking the completeness of installation. The installation process on site shall be workable under the particular site circumstances of the Contract.
- g) Local job reference.

#### 13.1.3 Sampling for Testing

(a) Both mechanical couplers and reinforcement bars shall be divided into matching batches for connecting in final fixing position. Mechanical couplers may be grouped in the same batch if they are of the same steel grade, the same diameter and the same batch reference. Reinforcement bars may be grouped in the same batch if they are of the same steel grade, the same diameter, the same mill certificate and if threaded, being cut by the same thread cutter. For reinforcement bars threaded in the coupler manufacturer's factory, identification statement on the thread cutter used shall be obtained from the manufacturer and be submitted to the SO upon delivery of the threaded reinforcement bars on site. Agree with the SO on the batch representation and

size before selecting test specimen. The maximum batch size for mechanical coupler is 1000.

(b) Reinforcement bars for coupling shall be tested to Clause 6.17 of the General Specification prior to threading and testing of the matching batch for the mechanical coupler.

(c) Each test specimen shall consist of one mechanical coupler connected to two reinforcement bars of the matching batch. Test specimen shall be selected by the SO. The installation process of the mechanical coupler shall strictly follow the manufacturer's installation method and be witnessed by the SO.(d) The number of test specimens for each batch of mechanical coupler shall be in accordance with Table 1:

Table 1

Size of batch of mechanical coupler	For tensile strength and elongation testing to COP2004
Below 100 Nos.	3
101 – 500 Nos.	6
501 - 1000 Nos.	9

#### 13.1.4 Testing Requirements

Test specimen as per Table 1 shall be prepared and tested for tensile strength and elongation in accordance with Clause 3.2.8.2 of the Code of Practice for Structural Use of Concrete 2004 (COP2004). The testing regime shall be in accordance with that for reinforcement bar under CS2.

#### 13.1.5 Acceptance Criteria

(a) The acceptance criteria for the testing of the mechanical couplers are in accordance with Clause 3.2.8.2 of the COP2004.

(b) For every test specimen for tensile strength and elongation testing at Clause 13.1.4 that fails to comply with the requirements of Clause 13.1.5(a), two additional specimens shall be taken from the same batch of mechanical coupler, and the matching batch of reinforcement bar, for additional tensile strength and elongation testing.

(c) If the result of any additional test at Clause 13.1.5(b) fails to comply with the requirements of Clause 13.1.5(a), both the batch of the mechanical coupler and the reinforcement bar shall be considered as not complying with this Particular Specification. The failed batch of mechanical coupler and

reinforcement bar shall be rejected and the action shall be taken in accordance with the modes of failure as per Table 2:

Table 2

Mode of failure	Action
Reinforcement bar fracture (inside or outside the coupler sleeve portion).	The batch of mechanical coupler may be re-tested to this Particular Specification with new matching batch of reinforcement bar.  The batch of reinforcement bar shall be rejected and removed from Site.
Fracture at the coupler sleeve.	The batch of mechanical coupler shall be rejected and removed from Site.  The batch of reinforcement bar may be re-tested to this Particular Specification with new batch of mechanical coupler.
Slippage out before reaching the required tensile strength or Exceeded the permanent elongation limit	The batch of mechanical coupler shall be rejected and removed from Site.  The batch of reinforcement bar shall be rejected for use with mechanical coupler. The threaded or prepared ends of the reinforcement bars shall be removed from Site.

#### 13.1.6 Workmanship

(a) Splicing joint using mechanical coupler shall be installed strictly in accordance with the approved installation method as per Clause 2.3 and Clause 13.1.2.

(b) Mechanical couplers from each batch, and the reinforcement bars of the matching batch, shall not be installed in position until testing has been completed and the results complied with the relevant clause of this Particular Specification.

(c) Mechanical couplers and threaded end of the reinforcement bars shall be adequately protected from damage during transportation and storage.

## 14.0 Pile Spacing

Notwithstanding clause 5.08 (ii) of the GS, the minimum centre to centre spacing of piles shall be the perimeter of the drill hole formed in bedrock.

## 15.0 Static Loading Tests

Loading tests shall be required as instructed by SO in accordance with Clause 5.28 of the General Specification. In determining the cross sectional area (A) of pile, the transformed section, comprising the casing, grout and rebars shall be used in the case of compression tests whereas only the total area of rebars shall be used for tension tests. In determining the diameter (D) of pile, the outer diameter of the steel casing shall be used.

The Young's modulus of grout shall be taken as that of concrete of the same strength as given in the GS.

## 16.0 Monitoring of Ground and Building Settlement

Install and maintain ground settlement and building settlement markers on site. The numbers and locations of these markers shall be determined by the SO. The Contractor shall employ an approved independent registered professional surveyor to carry out bi-weekly surveys of the settlement markers during the entire piling construction period. Submit 3 copies of the survey results to the SO within 3 days of the surveying.

## 17.0 Piling Records

The Contractor shall keep records of the installation of each pile and submit two signed copies of these records to the SO not later than noon of the next working day after the pile was installed.

The record shall give the following information in an approved format:-

- a. Pile reference number.
- b. Date and time of boring
- c. Soil samples taken and insitu test carried out if any
- d. Date pile installed.
- e. Pile type and size.
- f. Date and time of drilling.
- g. Date of grouting.
- h. Position of pile in the works and ground level at pile position.
- i. Working level.
- j. Drilling rates and material encountered.
- k. Samples of rock cutting flushing in the rock socket
- l. Depth from working level to pile toe.
- m. Toe level.

- n. Depth from working level to pile head level.
- o. Depth and level of top of rock socket.
- p. Length and toe level of casing.
- q. Length of reinforcement and lapping details.
- r. Grout mix.
- s. Volume of grout in pile (actual and theoretical).
- t. Details of obstructions, delays and other interruptions to sequence of work.
- u. Flow rate and total time required for the grouting operation.
- v. Grouting pressure used.
- w. Contours of rockhead inferred from drill hole logs
- x Any other data requested by SO.

On completion of all piling, submit to the SO two copies of the record piling plans showing, as appropriate, the position, identity number, size and top and bottom levels of each pile installed.