

Particular Specification for Rock-Socketed Steel H-piles

1.0 Definition

Rock-Socketed Steel H-pile is a type of pile in which a steel H-section is installed within a prebored hole formed into bedrock and then grouted with cement grout. The prebored holes shall be large enough to facilitate the installation of H-piles and to allow sufficient cover for corrosion protection purposes.

2.0 Design Requirements

2.1 Loading Capacity

The theoretical safe loading capacity of individual pile shall not exceed 5500 kN. In no case shall this safe loading capacity be exceeded by loadings that include the dead and imposed loads of the building works, weight of soil and negative skin friction etc.

2.2 Design Assumptions

The theoretical safe loading capacity of individual pile shall be the design bond strength between bedrock and grout times the area of contact between the rock and grout below the effective rock socket top level as defined in clause 4.0 OR the design bond strength between the pile and grout times the total area of contact between the pile and grout below the effective rock socket top level as defined in clause 4.0 OR the allowable axial force of the steel H-pile section whichever is smaller. The maximum allowable axial working stress of steel H-pile sections shall be 45% of the yield stress and the combined stresses due to axial load and bending moments shall be limited to 50% of the yield stress. When the calculations of stresses are based on all loads including wind loads, the permissible stress shall be increased by 25% of the above stresses.

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 sufficient factor of safety in his design. Should he consider that this method does not provide an adequate factor of safety in his design, he shall submit an alternative method of calculations 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 shall be that defined in Clause 9 of this particular specification. If different bond strength value is proposed, submit with the tender details of the design parameters, proposed testing methods to the trial piles (including loading tests) for

justification of the proposed parameters and test programme 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 average bond stress between grout and steel H-pile shall be 0.5 MPa for grout having minimum cube strength of 30 MPa at 28 days and 0.45 MPa for grout having minimum cube strength of 25 MPa at 28 days when the shear bars details shown in Annex "A" is applied.

Unless specified otherwise, the horizontal loads given in the loading schedule shall be taken by the piles. The effect of rock socketing on the lateral stiffness of the pile may be assessed as given in "Pile Foundation Analysis and Design" by Poulos H.G. and Davis E.H. (1980).

Raking piles shall be designed to resist lateral loads only. 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 to this Particular Specification.

2.3 Pile Head Details

Provide capping plate and dowel bars in accordance with the detail as given in the GS for steel 'H' piles. The design of steel capping plates and their connections shall be in accordance with BS 5950:1990.

2.4 Cover

The minimum clearance (cover) between casing and the steel H-pile shall be 40mm. The Contractor shall submit with his tender his proposed spacer details.

2.5 Number and Minimum Length of Pile Sections Within Pile Shaft

Only one steel H-pile in an individual socket shall be accepted.

The minimum length of each pile segment forming the whole length of pile shall be 10 m except the uppermost section.

2.6 Provision of Shear Key

Provide shear bars to steel H-piles within the rock socket in accordance with the details shown in Annex "A".

3.0 Design Submissions

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

- a. Details of boring method and equipment.
- b. Details of grout mix.
- c. Sequence and details of grouting operation.
- d. Spacer details.
- e. Pile capping plate details with dimensions and size of welding.

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

4.0 Pile Details

Effective rock socket top level is the bottom level of the temporary casing.

The minimum lengths of rock socket below the effective rock socket top level shall be calculated from Clause 2.2 of this particular specification.

The entire shaft shall be filled solid with grout, without voids, honeycombing or other defects, up to a level of between 150mm and 450mm above cut-off level.

5.0 Boring Mud

Piles shall be installed without the use of bentonite slurry or other boring muds. 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 of soil in forming the pile shaft.

6.0 Temporary Casing

Temporary casing of approved quality shall be lowered at the same time when the hole is made. The embedded depth of temporary casing below the founding level (casing embedded depth) shall be 500 mm minimum or such other depths as required to avoid caving of soil at the interface of soil and bedrock during cleaning of the rock socket.

Temporary casing shall be free from distortion, internal projections and hardened grout.

Extraction of temporary casing shall be carried out only after the completion of grouting. Partial extraction of temporary casing before the completion of grouting shall only be carried out with the approval of the SO. Refer to Clause 19.0 regarding the safety of casing extraction.

The temporary casing of raking pile shall not be extracted.

In case the temporary casing, other than that of raking pile, cannot be extracted for whatever reasons, pressure grouting shall be carried out at the peripheral of the temporary casing to fill up the gaps between the pile and surrounding soils, otherwise the horizontal load carrying capacity of the pile shall be ignored and the Contractor shall revise the design accordingly. Submit method statement of pressure grouting for the approval of the SO.

7.0 Tolerances

The maximum deviation of the centre of the head of each pile from the designed centre point shall not be more than 75mm in any direction. The maximum deviation from the vertical axis of the pile through the centroid of the cross section at cut off level of the finished pile shall not be more than 1 in 75.

8.0 Founding Level

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

Before commencement of piling, take cores of N size to 5m deep 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 top and bottom of the rock socket for inspection. The rock samples shall be stored in plastic bags with labels showing the pile numbers and levels of retrieval. 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 levels and pile toe levels 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 socket length of piles at locations as instructed by the SO. The number of proof drillings 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.

9.0 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 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 greater. Records of drilling time and penetration shall be forwarded to the SO.

10.0 Grout for Piling Work

10.1 Grout Material

Grout shall consist of ordinary Portland cement and water with 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 admixture 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 every 15 minutes. 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.

10.2 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 suitable 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 put in place within the time limits as specified by the manufacturers of the additives.

10.3 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 with two non-flexible grout pipes, one at each side of the web of the steel H-pile. 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 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.

10.4 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.

10.4.1 Definition of Batch

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

10.4.2 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 ± 10 mm to a depth of 100 ± 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.

10.4.3 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 the SO's prior agreement for grout mixes containing additives, grout having an efflux time of less than 15 seconds shall be rejected.

10.4.4 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.

10.4.5 Core Testing

10% of the total no. of piles shall be subject to core testing on the hardened grout. Take a 84 mm nominal diameter core down to the bottom of the pile in the hardened grout for examination and testing. To facilitate such coring, one mild steel tube terminated at 0.6 m above the founding level and of 150 mm internal diameter sufficient for coring shall be fixed to every pile in the manner as specified in GS Clause 5.35 (i) to (vii). The tube shall be filled with water before grouting. All tubes shall be filled up by pressure grouting upon completion of all testing.

The pile shall be deemed to have failed the coring test if :-

- (i) The concrete core exhibits honeycombing which means interconnected voids arising from, for example, inadequate compaction or lack of mortar.

OR

- (ii) When any sample section of the core with length/diameter ratio of 1.2 is taken for compressive testing, the sample has an estimated in-situ cube strength converted in accordance with CS1 from the compressive strength of the grout core, less than 75% of the specified cube strength.

10.4.6 Failure of Coring Test

When a pile fails a coring test, the following procedures shall be followed:

- (i) The Contractor shall carry out remedial measures in accordance with clause 5.30 of the GS. In addition, further coring tests shall be carried out on two other piles. The cost of the additional coring tests shall be borne by the Contractor.

OR

- (ii) The Contractor shall carry out a loading test on that pile in accordance with clause 5.28 of the GS to test for acceptance. The cost of the loading test shall be borne by the Contractor. The pile would be accepted if it passes the loading test, otherwise, the pile shall be deemed a failure and remedial measures shall then be carried out in accordance with clause 5.30 of the GS. In either case, further coring tests shall be carried out on two other piles and the cost of the additional coring tests shall be borne by the Contractor. In addition, if a pile fails a coring test in accordance with Clause 10.4.5(i) of this Particular Specification, pressure grouting of pile to fill up the honeycombing shall be carried out before the acceptance of the pile.

11.0 Steel H-Pile

Clause 5.18 (i), (ii), (iii), (v), (vi), (vii) of the GS shall apply to Rock-Socketed Steel H-piles.

The Contractor shall employ an approved specialist firm to carry out and interpret the inspection and testing of welds, and provide any necessary labour and attendance. Submit evidence proving that operators carrying out the inspection and testing have been trained and assessed for competence in the inspection and testing of welds. In addition, submit certificates of competence from a recognised authority for operators carrying out ultrasonic examination.

The welded joints of piles shall not be lowered into the pile shaft within one hour after they are completed.

The maximum length of spliced pile sections in horizontal or inclined positions shall be 24 m.

12.0 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.

13.0 Static Loading Tests

Loading tests shall be required as instructed by the SO in accordance with clause 5.28 of the GS.

The net length of pile, L , in clause 5.28 (iv) of the GS shall be taken as the length from the top to the middle of the socket length. The cross sectional area of pile, A , shall be the cross sectional area of the steel H-pile. The dimension D shall be taken as the diagonal of the rectangle enclosing the H section.

14.0 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 survey of the settlement markers once a fortnight during the entire piling construction period. Submit 3 copies of the survey results within 3 days of the surveying to the SO.

15.0 Piling Records

The Contractor shall keep record of the installation of each pile and submit two signed copies of the record 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 of grouting.
- g. Position of pile in the works and ground level at pile position.
- h. Working level.
- i. Boring rates and material encountered.
- j. Samples of rock cutting flushing in the rock socket
- k. Depth from working level to pile toe.
- l. Toe level.
- m. Depth from working level to pile head level.
- n. Depth and level of top of rock socket.
- o. Length and toe level of temporary casing.

- p. Length of steel H-pile.
- q. Grout mix.
- r. Volume of grout in pile (actual and theoretical).
- s. Details of obstructions, delays and other interruptions to sequence of work.
- t. Flow rate and total time required for the grouting operation.
- u. Grouting pressure used.
- v. Contours of rockhead inferred from drill hole logs
- w. Any other data requested by the SO.

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

16.0 Environmental Control

The Contractor shall keep the Site clean and tidy during the construction period. He shall submit a method statement in reducing the nuisance such as noise, dust, waste water, and deposition of excavated material on public roads by dump truck during haulage to meet EPD's latest environmental requirements for the SO approval before the commencement of works.

The Contractor shall carry out Daily Cleaning in accordance with the Particular Specification for Daily Cleaning and Weekly Tidying. For the purpose of this clause, "waste materials" stated in the above particular specification shall also mean the material retrieved from the pile shaft during the course of boring. Attention is drawn to the prevention and removal of water ponds, and clearing of stockpiling and waste arising from the Works.

The Contractor shall apply for a Wastewater Disposal Licence under the Water Pollution Control Ordinance and no wastewater shall be discharged into communal sewers, storm drains, river courses or waterbodies until the said Licence is granted by EPD. Provide, operate and maintain suitable works for the treatment and disposal of the wastewater to meet the requirements stated in the said Licence.

The Contractor shall submit to the SO for approval the temporary site drainage to keep the site clear of water and prevent nuisance due to run-off onto adjacent land.

Store cement in bags in a dry, weatherproof store with a raised floor. The storage area for more than 20 bags of cement shall be covered entirely by impervious sheeting or sheltered on the top and the 3 sides.

The set up of grout batching plant shall be properly designed to minimise dust emission and provide sufficient ventilation for workers.

In addition to the use of hung tarpaulin or similar fabric sheets, provide suitable device to the satisfaction of the SO near the top of the temporary casing at all times during the

boring of pile shaft to mitigate the scattering of the excavated material from the pile shaft.

During the course of boring, the retrieved material shall be wetted before being flushed out from the pile shaft.

17.0 Safety of Air Receiver, Compressor and Hoses.

The use of air receiver and compressor shall be in accordance with the Boiler and Pressure Vessels Ordinance (The Ordinance) and Regulations, and the Code of Practice for Pressure Equipment Owners published by the Boiler and Pressure Vessels Authority, Labour Department. For the purpose of this clause, the “appointed examiner” shall be the person defined in the Ordinance.

Every air receiver together with its fitting, attachments and hoses once delivered to site shall be examined by an appointed examiner prior to its operation on site. During the examination, the hoses shall be connected to the maximum length intended to be used. The air receiver shall not be used until:

- i. the appointed examiner is satisfied that the air receiver and its associated fitting, attachments and hoses are of sufficient strength to withstand the maximum permissible working pressure to which they may be subjected; and,
- ii. a certificate of fitness for the air receiver as stipulated in the Ordinance is issued accordingly by the appointed examiner and submitted to the SO.
- iii. A written report is issued for the fitness of the hoses.

Every air compressor on site shall have a valid certificate of fitness (for its internal air receiver).

The air receiver and compressor shall not be operated at a pressure greater than their maximum permissible working pressures specified in the latest certificates of fitness.

A copy of the certificate of fitness shall be attached to the air receiver and compressor.

The air receiver shall not be used until it is re-examined by the appointed examiner if:

- i. the seal attached to a safety valve has been broken, or the setting of a safety valve has been altered,
- ii. the air receiver has been repaired extensively,
- iii. the certificate of fitness has expired.

Where appropriate, the whip-checks shall be properly installed at hose connection points. The first whip-check shall be directly attached to the main body of the air receiver/compressor.

Every shut-off valve connected to the air receiver shall be fitted with a non-return valve, and shall be closed when the piling plants are idling. The use of elbow connectors to connect hoses to air receiver or compressor are not allowed.

During the course of piling works, every compressor, air receiver and their auxiliary equipment, including the connecting hoses, shall be properly inspected and recorded daily for the integrity of the system before the commencement of works by a designated competent person who shall be assigned by the Contractor and shall have at least 3 years' experience in the maintenance of similar systems. The daily inspection records shall be kept by the Contractor for the examination of the SO. The appointed examiner shall be consulted whenever necessary. If any defect is found, it shall be rectified immediately prior to operating the air receiver system.

Attendants shall be present to look after the compressed air system during the operation of the air receiver and compressor. The system shall be shut down after the work.

The routings of hoses shall not present a hazard or obstruct access and shall be routed away from any areas where they may be vulnerable to mechanical damage.

Include in the Safety Plan a maintenance programme for the compressed air system. Tool-box Talk and Job Specific Training on the potential hazards and safe use of the compressed air system shall be conducted to all relevant site personnel and workers.

The Contractor shall prepare risk assessment for the use of the compressed air system, and review the safety procedures and control measures for the operation of the compressed air system periodically or after there is a material change in connection with the plant, process, material and environment.

18.0 Safety Requirements of Cranes on Casing Extraction

Unless otherwise agreed by the SO, casing extraction shall be carried out by a vibrating pile extractor. The Contractor shall submit method statement of casing extraction for the agreement of the SO.

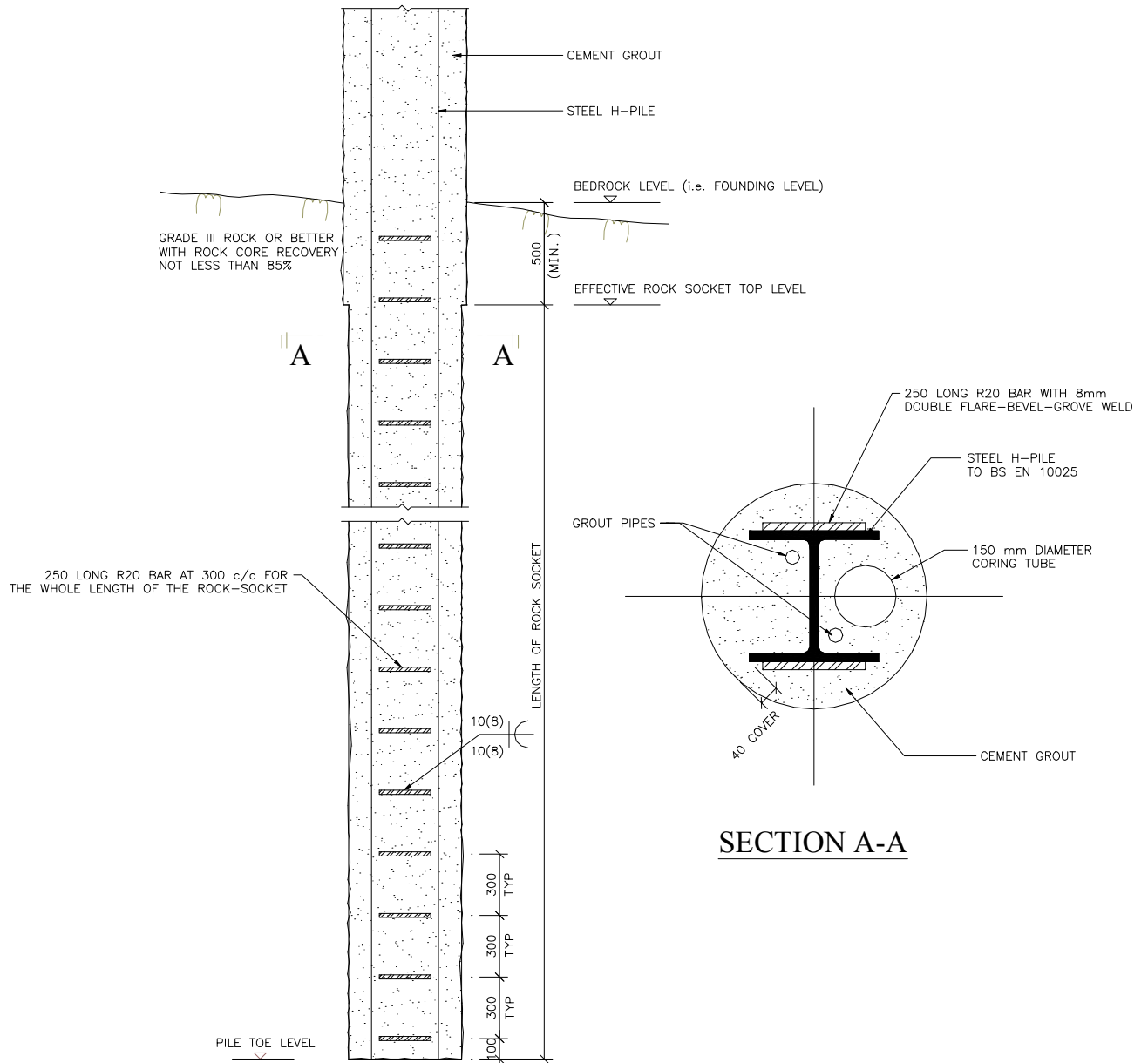
The test, examination, use and maintenance of a mobile crane suspending a vibrating pile extractor for casing extraction, together with the associated lifting gear, shall be in accordance with the Factories and Industrial Undertakings (Lifting Appliances and Lifting Gear) Regulations.

The maximum safe working load (SWL) at the specified operating radius of the crane shall be ample enough to take the weight of the extractor and its vibrating load transmitted through the absorber to the crane, the weight of the casing to be extracted and the frictional force between the soil and the casing during the extraction.

The maximum SWL shall be taken from the data specified in the Form 3 of the Factories and Industrial Undertakings (Lifting Appliances and Lifting Gear) Regulations, not necessarily the original capacity of the crane. A copy of the Form 3 shall be kept in the cabinet of the crane for operation use and for inspection upon requested.

The operator of the crane shall possess a valid crane operator certificate. Prior to the casing extraction, the operator shall be briefed by the Contractor's Construction Engineer on the weight and depth of the casing to be extracted. The crane shall be operated with great care. The extractor shall be effected by a smooth pull on the hoist line and under no circumstances shall the hoist rope be jerked, boom swung or the machine tipped to free entanglement and achieve faster results.

The crane for the pile extraction should be seated on solid level ground in order to prevent toppling. Under no circumstances shall the pile extraction be performed over the side of the crane.



**TYPICAL SHEAR BARS DETAILS FOR
ROCK-SOCKETED STEEL H-PILE**