SPECIFICATION FOR DIAPHRAGM WALL

1.0 GENERAL

The specification is to be read in conjunction with the contract, the general specification and all other relevant specifications and drawings.

Where works are ordered to be performed by the Contractor, but are not specified in these specifications, the Contractor shall carry them out with full diligence and expedience as are expected for works of this nature.

1.1 Scope of Works

The work shall be carried out in accordance with the relevant British and Malaysian Standards and this specification and drawings supplied to the Contractor and any other instructions issued by the Engineer or his representative from time to time.

The contract comprises the provision of all labour, materials, tools, plant etc. necessary for the following works:-

(a) Supply and installation of diaphragm wall panels to the specified depth suitable to site condition as shown in the drawings.

(b) Supply, installation and construction of capping beam and any other permanent works as required.

(c) Prepare detailed design, calculations and drawings for all the temporary works and all specified permanent work as agreed with the Engineer. All such design and Drawings shall be fully signed and endorsed by his Registered Professional Engineer.

(d) Supply, installation, maintenance, measurement and recording of monitoring devices for diaphragm walls.

(e) Any other incidental works necessary to ensure the safety and satisfactory performance of the diaphragm wall construction.

1.2 Contractor's Responsibilities

The Contractor is responsible for satisfactory construction of all permanent works in the approved construction drawings. In addition, the Contractor is responsible for satisfactory design and construct of all temporary works, and any specified permanent work details as agreed with the Engineer. The Contractor shall also ensure that the proposed temporary work has no adverse effect on the permanent work (both in short term and long term), subject to the agreement of the Engineer.

The Contractor shall make allowance in his tender for compliance with all the specifications and other requirements necessary for the proper execution and completion of the works to the satisfaction of the Engineer inclusive of the necessary soil treatment such as grouting and underpinning through cavities.

The Contractor's attention is drawn to the presence of fill and sandy materials which may require stabilisation by bentonite. The rates for the wall panels shall include all costs necessary for the satisfactory completion of these works.

The Contractor shall be deemed to have inspected the site and geotechnical and geological conditions applicable to his work. The work shall be carried out on the basis of ground as found and no additional cost will be paid for handling hard materials or other obstructions encountered during the installation of the contract works.

The rates for diaphragm wall shall include the provision of ultrasonic 'Koden' testing or equivalent technique to determine the accuracy of the excavated trench prior to concreting. If the wall is constructed beyond the specified tolerances, hacking the protrusions and any other remedial works required by the Engineer shall be carried out at the expense of the Contractor carrying out the works for diaphragm wall. The Contractor shall allow for 30% of the panels to be tested as directed by the Engineer.

The Contractor shall be responsible for producing the detailed shop drawings and panel layouts for all the diaphragm wall contract. The drawings shall include plans, sections and elevations of all the wall panels, including the reinforcement and waterproofing details.

The Contractor shall make provision in his design, construction and costing for the provisions to be made for all recesses, anchorages, inserts and starter bars to accommodate the framing members, fixtures and penetrations as required by the Engineer.

Where boxes are required in a wall for the formation of recesses, consideration must be given to the effect of the boxes on the strength of the wall, the placing of reinforcement through the boxes, and the effect of the boxes on the flow of concrete during placing. Boxes must be positioned so as to pass into the panel excavation with clearance.

All calculations and drawings etc. shall be fully signed and certified by his Professional Engineer registered with the Board of Engineers Malaysia before being submitted to the Engineer for approval.

1.3 Other Responsibilities of Contractor

The Contractor shall carry out his own independent check to confirm that the design of the diaphragm wall is adequate during excavation to prevent excessive movements that may affect the nearby and adjacent structures and facilities. This will ensure that the contract does not face any problems during excavation and installation of ground retention system during the construction of the basement. Any modifications and additional requirements deemed necessary by the Contractor are inclusive of the rates for the wall.

The Contractor shall ensure that the panels of the diaphragm walls are properly interlocked to provide a watertight basement. Any seepage of water shall be rectified at the Contractor's expense. The Contractor shall provide a waterstop between the panel joints. The waterstop and its installation are to be approved by the Engineer prior to construction.

The Contractor shall ensure that all the site activities comply with the requirements of the relevant local authorities especially with respect to the Pollution Control Requirements governing the discharge of the bentonite and the use of ground anchor.

Where ground anchors are specified and required, it shall be the Contractor's responsibility to obtain written approval from relevant authorities or adjacent land owner prior to any installation. If temporary anchors are to be used, they shall be of those removable type and all anchors shall be properly removed to the satisfaction of the Engineer and local authorities. The anchor system to be used has to be approved by the Engineer prior to construction.

The Contractor shall ensure that the construction of diaphragm wall and the associated ground movements are properly monitored.

2.0 INFORMATION REQUIRED AT THE TIME OF TENDER

The Contractor shall at the time of tender submit the following information to assist the Engineer in assessing the Contractor’s proposals and suitability for contract works.

a) a programme for works including details of the manpower and equipment that he intends to employ.

b) staff organisation chart and curriculum vitae of key personnel to be employed on the works indicating whether they are to be part-time or full-time at site.

c) the method, sequence, size and timing of constructing the diaphragm wall panels.

d) all temporary works at each stage of construction, including proposals for the guide wall trenches and necessary grouting procedures to the existing buildings.

e) plant to be used and precautions proposed with respect to emergency backfilling should a rapid loss of bentonite slurry occur.

f) concrete mixes and minimum and maximum interval time between completion of one panel and the commencement of the adjacent panel.

g) propose method for checking for contaminated bentonite slurry at the bottom of the excavation.

h) detailed working drawings of reinforcement cages showing strengthening details and, where applicable, temporary works to form pockets, together with lifting and installation proposals.

i) calculations to show that the density of the bentonite and lowest head of slurry are sufficient to maintain the stability of the trench in the ground conditions to its entire length.

j) method statement for excavation in soil or rock (if encountered) in when excavating in front of the diaphragm wall.

Diaphragm wall construction shall not commence until the Engineer is satisfied with the proposed method, sequence and installation procedures.

3.0 SITE CONDITIONS

The Contractor prior to the submission of the tender is required and deemed to have inspected the site and satisfied himself with regard to access, site conditions, existing buildings and structures. The work shall be carried out on the basis of ground as found.

The Contractor shall satisfy himself regarding subsoil conditions and the underground water table. No claims for extra cost or time shall be entertained on these grounds. The soil report included in this contract is based on the site investigation carried out in this site. Factual report(s) of site investigation(s) is available for the reference of the Contractor. The Contractor may at his own cost and with the written approval of the Engineer, conduct additional soil tests if he so desires.

4.0 CODES OF PRACTICE

The design and construction where relevant shall be carried out in accordance with good engineering practice and shall comply with the latest applicable Malaysian or British Standards and generally including the following:

BS 8004 : 1986	:	Code of Practice for Foundations
BS 8002 : 1994	:	Code of Practice for Earth Retaining Structures
BS 8110 : 1985	:	Structural Use of Concrete
DFCP 4	:	Drilling Fluid Material - Bentonite

BS 5950 : 1987-1995 : Structural Use of Steelwork in Building

BS 8110 and BS 5950 shall be used wherever appropriate in the design of concrete and steel reinforcement of the diaphragm walls and the design of walers and struttings in steel. No overstressing for temporary work is allowed.

5.0 PROGRAMME

The Contractor shall with his tender, submit a detailed programme showing the sequences and manner in which diaphragm wall and other works are to be executed. The construction shall be carried out in a sequence and to a programme agreed with the Engineer. Where a sequence is specified in the contract, this shall be adhered to.

6.0 SAFETY OF THE WORKS

The Contractor shall be responsible for the stability of loadings for wall panels and shall take all necessary precautions for the safety of personnel in the area of piling operations. Where rocks and hard materials are encountered during excavation requiring the use of pneumatic tools, the Contractor shall ensure that adequate equipment is available at site to handle such situations with safety.

The Contractor must ensure that no damage is caused to adjoining properties or construction works adjoining the proposed building and would be solely responsible for such consequences.

7.0 DEFECTIVE WORKS

Defective works shall be all works that, in the opinion of the Engineer, do not fully comply with this specification or the drawings. The Contractor shall make good or carry out such additional works as may be necessary at this own expense to the Engineer's satisfaction.

8.0 DESIGN

The design and construction of the works under this contract shall be carried out in accordance with good engineering practice and shall comply with the latest applicable Malaysian or British Standards.

The maximum design compressive stress in the concrete of diaphragm wall where designated to act, as a retaining structure only shall not exceed 7.0 N/mm^2. Where the wall panels are carried down to act as vertical load bearing elements, the compressive stress shall be limited to 6 N/mm^2.

The cover to the main reinforcement shall be 75mm and the minimum clear spacing between the main bars shall be 100mm.

The design of the wall shall take account of the stresses due to active and passive soil pressures, surcharges, combined horizontal and vertical forces induced by ground anchors or struts used to maintain stability of the wall, due to retained ground water where applicable, and due to the worst conditions arising in the stages of subsequent excavation, propping and anchoring and to other special conditions. The design shall take into account both the permanent and temporary stages of stress, which will arise during the life of the structure.

The assumptions made and the factors of safety which have been used in the design of the wall are to be stated. All the imposed loads including those arising from the soil taken into account in the design are to be clearly stated.

The design shall take into account the deflection of the wall. Consideration shall be given to the need for any underpinning, grouting or soil treatment required to maintain the stability of adjacent foundations during the construction and exposure of the diaphragm wall.

For the purpose of vertical load carrying capacity, friction or adhesion on that part of any wall above the related main excavation level or where the contact between the soil and the wall face could be lost as a result of deflection should not be taken as contributing to the capacity of the wall to carry imposed structural loads.

All the panels in any continuous length of wall should be designed according to compatible principles.

The Contractor shall make provision in his design, construction and costing for the provisions to be made for all recesses, anchorages, inserts and starter bars to accommodate the framing members, fixtures and penetrations as required by the Engineer. Where boxes are required in a wall for the formation of recesses, consideration must be given to the effect of the boxes on the strength of the wall, the placing of reinforcement through the boxes, and the effect of the boxes on the flow of concrete during placing. Boxes must be positioned so as to pass into the panel excavation with a clearance.

Guide walls are to be designed with continuous reinforcement and are to be constructed to comply with the drawings. They are to be cast on and against firm ground or alternatively, where it is desired to shutter both faces of the guide wall, all back-filling behind the wall is to be done using an approved lean mix concrete unless otherwise agreed by the Engineer.

(Note for guidance: The top of the guide wall should, preferably, be not less than 1.5m above existing ground level, and guide walls must be capable of being constructed in the dry).

8.1 Design Criteria for Temporary Works and Temporary Condition of Permanent Works

(i) Dimension

The dimensions of the wall shall be such that the space required as shown in the exhibited tender drawings and shall take into account of the site constraints.

(ii) Allowable Working Stress for Concrete and Steel

The stress used will generally follow the allowable stresses specified in the codes mentioned above. However, for deformed bar, 20% of allowable bond stress is to be deducted.

(iii) Soil Parameters

The Contractor shall discuss and agreed with the Engineer his proposed design soil parameters prior to detail design of his temporary works. Soil parameters shall be based on the in-situ and laboratory testing carried out.

(iv) Loads

The typical diaphragm wall section and basement floor design prepared by the Engineer is general and any specific size of equipment used by individual tenderer have not been taken into consideration. The tenderer is to follow the size and dimension of wall, floor and column reinforcement as shown in Engineer's drawing. The tenderer is required to submit their own design together with their working drawings by a professional engineer that their designs have been allowed for all loadings imposed on to the wall and floor such as:-

(a) Soil pressure (active & passive) for temporary conditions.

(b) Surcharge load (including adjacent building) induced to wall during construction period or 20 kN/m^2 whichever is greater, unless otherwise agreed by the Engineer.

(c) Water pressure.

(d) combined horizontal and vertical force induced by the ground anchors and steel strutting system used to maintain stability of the wall in temporary condition.

If any computer programs are used, the basis of the programs shall be explained, a copy of documentation including relevant parts of user and verification manuals are to be submitted. The Contractor shall make available his computer program for checking and verification by the Engineer.

Any Contractor's design shall take into account the deflection of the wall and its influence to the nearby and adjacent structures and facilities. Consideration shall be given to the need for any underpinning, grouting or soil treatment required to maintain the stability of diaphragm wall and adjacent foundations during the construction and exposure of the diaphragm wall.

(v) **Diaphragm Wall and Adjacent Ground Movement**

The Contractor is to monitor diaphragm wall and adjacent ground movements until the permanent supports are in place. Prior to construction, the Contractor must discuss and agreed with the Engineer his analysed and predicted wall deformation and adjacent ground movement. Details of monitoring shall be discussed and agreed with the Engineer. In the event that the movements exceed the limits specified by the Engineer, the Contractor is to take corrective measures (to be agreed by the Engineer) to maintain the limits.

The limits to the movement however may be relaxed by the Engineer if the Contractor can demonstrate by field measurements to the Engineer that the relaxation of the limits will not cause damage to the diaphragm wall and nearby structures and facilities.

(vi) **Seepage**

The Contractor is to provide in his tender an estimate with calculations of the amount of seepage by flow net method or any reasonable method to be expected from this design. The diaphragm wall panel joints shall be watertight.

(vii) **Temporary and Permanent Support**

The temporary support to be designed and constructed by the Contractor for the wall has to take into account the site constraints. The points or lines of support has to take into account the positions of the floor system of the permanent basement structure.

The Contractor is to provide to the Engineer's requirements on reinforcement bars in the diaphragm wall to properly effect transfer of loads from the permanent floor system to the diaphragm wall.

The Contractor is to de-stress and remove all temporary supports in the basement side of the wall within a time frame agreed by the Engineer after the permanent supports are constructed. If temporary ground anchors are used, the Contractor shall be responsible for the total removal of all such ground anchorage.

(viii) **Excavation in Rock**

Excavation in rock for diaphragm wall is said to occur when the natural material

encountered necessitate the use of chiselling, in addition to the normal means of excavation and the natural material shall have a compressive strength greater than 20N/mm^2.

9.0 MATERIALS

9.1 Concrete

Concrete for use in diaphragm walls shall have a minimum characteristic strength of 35 N/mm^2 at 28 days and shall contain Portland Pulverized Fuels Ash(PFA) Cement complying with M.S. 1227 or Sulphate Resisting cement complying with BS 4027 if required. Aggregate shall comply with B.S. 882.

Clean water, free from acids and other impurities and in accordance with the B.S. 3148 shall be used in the making of concrete. The slump of the concrete shall normally be in accordance with the following standard:

a) Minimum slump : 150mm

b) The concrete mix shall flow easily in the tremie pipe and shall be designed to give a dense concrete when placed by the tremie method.

c) Aggregate shall be preferably be of naturally rounded gravel and sand.

Aggregate shall comply with gradings of Zones 2, 3 or 4 of B.S. 882. The shell content shall not be greater than the limits given in the table:-

Nominal Max. Size of Aggregate	Shell Content Maximum Percent
40mm	2
20mm	5
Sand	30

The maximum size of aggregate is to be suggested and limited to 20mm (3/4"). The shape of grading curve should flow evenly graded to prevent segregation.

The chloride ion content of the aggregate shall be such that the chloride ion content of the mixed concrete shall not exceed 1.2 percent for unreinforced concrete or 0.2 percent for reinforced or prestressed concrete

Unless otherwise approved by the Engineer, a minimum cement content of 400 kg/m^3 is to be employed in making concrete which is to be placed by tremie methods under a bentonite slurry, in accordance with B.S. 8004.
The concrete mix shall flow easily in the tremie pipe and shall be designed to give a dense concrete when placed by the tremie method. Water cement ratio shall not exceed 0.50.

Waterproofing Additives are to be used in the concrete for diaphragm wall. The waterproofing additives shall be SBD Aquapel Standard Integral Concrete Waterproofing Compound or equivalent and approved used at a rate of 5 litres per cubic metre of concrete in accordance to manufacturer's instructions. The manufacturer shall arrange a site supervisor for the supervision of the works.

The use of ready mixed concrete, as defined in B.S. 1926, will be subjected to the written approval of the Engineer, who will require to inspect the plant from which it is to be supplied.

Notwithstanding any such inspection and/or approval by the Engineer, the Contractor shall take responsibility that all ready mixed concrete complies with all the requirements for concrete as

stated in this specification.

Placing in Works : The concrete will be compacted in its final position and left undisturbed in a time as short as possible after mixing and not later than 1 1/2 hours after the time when the cement comes into contact with wetter aggregates, i.e. the time when hydration of cement commences.

Mixing : Plant mixed concrete will be agitated continuously by rotation the mixer drum during transit and while awaiting discharge. In the case of truck mixed concrete, the water may be added either at the supplier's plant or under the Contractor's supervision after arrival at site, but will not be added during transit. Any additional water added must be recorded.

Records : The Contractor will maintain full records of all supplied of ready mixed concrete placed in the work, including :-
(i) Delivery notes giving details of quality, mix proportions and time of adding cement to the aggregates.
(ii) Position in the works where the concrete is placed.

Test Cubes : Works test cubes will be made on site by the Contractor in accordance with provisions of specification, irrespective of any sampling and testing which may be carried out by the supplier. Four (4) test cubes for each of diaphragm wall panel shall be prepared and tested in accordance with B.S. 1881. Two (2) cubes shall be tested at seven (7) days and two at twenty-eight (28) days.

9.2 Reinforcement

All reinforcing steel for use in diaphragm walls shall be in accordance with British Standard B.S. 4449 hot rolled high yield steel bars unless otherwise agreed with the Engineer.

The welding of steel reinforcement required in the works shall be carried out only by techniques which can be shown to maintain the full strength of the structural reinforcement and shall be with prior agreement of the Engineer. The shopdrawings prepared by the Contractor should show all the steel reinforcement necessary including that required for lifting stiffening and splicing.

The steel reinforcement cage shall be clearly marked to indicate its correct orientation for proper insertion into the trench. The reinforcement shall be maintained in position during the casting of each panel by approved spacers. Steel reinforcement shall be positioned as shown in the drawings and the design minimum cover shall be maintained. The reinforcement shall be placed in the trench to give the minimum projection bond length required by the particular specification or relevant Code of Practice.

9.3 Bentonite

Bentonite, as supplied to the site and prior to mixing, shall be in accordance with Specification No. DFCP. 4 of the Oil Companies Materials Association, London.

A certificate is to be obtained by the Contractor from the manufacturer of the bentonite powder, stating from which manufacturer's consignment the material delivered to site has been taken and showing properties of the consignment as determined by the manufacturer. This certificate shall be made available to the Engineer.

The bentonite powder shall be mixed thoroughly with clean fresh water. The percentage of bentonite used to make the slurry shall be such as to maintain the stability of the trench excavation.

Control tests are to be carried out on the bentonite slurry using suitable apparatus, to determine

the following parameters.

9.3.1 Freshly Mixed Bentonite Slurry

The density of the freshly mixed bentonite slurry shall be measured daily as a check on the quality of the slurry being formed. The measuring device is to be calibrated to read within 0.005 g/ml.

For the average soil conditions the following tests shall be applied to the bentonite supplied to the trench and the results shall generally be within the ranges stated in the table below :

Items to be Measured	Range of Results at 20°C	Test Method
Density	Less than 1.10g/ml	Mud Density Balance
Viscosity	33-75 seconds	Marsh Cons Method
Shear Strength (10 min gel strength)	1.4 to 10 N/mm^2	Shearometer
pH	9.5 - 12	pH indicator strips
Sand Content	Less than 5%	Wet sieving though 210 BS mesh

Tests to determine density, viscosity, shear strength and pH value shall be carried out initially until a consistent working pattern has been established, taking into account the mixing process, any blending of freshly mixed bentonite slurry and previously used bentonite slurry and any process which may be employed to remove impurities from previously used bentonite slurry.

9.3.2 Bentonite Slurry Supplied to Trench Excavation

When the results show consistent behaviour, the tests for shear strength and pH value may be discontinued and tests to determine density and viscosity only shall be carried out as agreed with the Engineer. In the event of a change in the established working pattern, the additional tests for shear strength and pH value shall be reintroduced for a period if required by the Engineer.

The following test methods shall be employed in assessing the quality of Bentonite.

Parameter	Test Method
Viscosity	Marsh Cone
Rheology : (a) Plastic Viscosity (b) Apparent Viscosity (c) Bingham Yield Strength (d) 10mm Shear Strength	} Fan Viscometer
10 min. Gel Strength	Shearometer
Density	Mud Density Balance
pH	Electrical pH Meter or pH Indicator Paper Strips

Fluid Loss	Filter Press
Sand Content	Wet Sieving Through 210 BS Mesh

9.3.3 Bentonite Slurry in Trench Prior to Placing Concrete

Prior to placing concrete in any panel, the Contractor shall ensure that heavily contaminated bentonite slurry, which could impair the free flow of concrete from the tremie pipe, has not accumulated in the bottom of the trench. Samples have to be taken from the bottom of the trench for testing.

Note for guidance : One method of identifying contaminated bentonite slurry is to take a sample of the slurry from near the bottom of the trench excavation (about 0.2m above the base of trench) and to carry out a density test on this using a Mud Balance. Where this method is employed, the density determined should not be greater than 1.3 g/ml to enable satisfactory concrete placing.

The proposed method for checking this item is to be agreed with the Engineer prior to the commencement of the contract. If the bentonite slurry is found to exhibit properties outside the agreed appropriate range, then it shall be modified or replaced until the required agreed condition is achieved.

During construction the level of the bentonite slurry in the trench shall be maintained within the depth of the guide walls and at a level not less than 1.0m above the level of external standing ground water.

In the event of a sudden loss of bentonite slurry, the trench shall be backfilled without delay and inform the Engineer.

Where saline or chemically contaminated ground water occurs, special measures shall be taken as required by the Engineer to modify the bentonite slurry. The modification required depends on the nature of the contamination. In saline conditions, it is frequently necessary to ensure that the bentonite is fully hydrated in fresh water before supplying into the trench.

All reasonable steps shall be taken to prevent spillage of bentonite slurry on the site away from the immediate vicinity of the wall. Discarded bentonite slurry which has been pumped from the trench is to be removed promptly from the site.

10.0 DIAPHRAGM WALL CONSTRUCTION

10.1 General

This section specifies certain materials and workmanship required for diaphragm wall construction. The materials and workmanship specified in other sections of this volume apply to diaphragm wall construction except where modified, amended or excluded herewith. The construction of the diaphragm walls all as indicated in the Drawings and as specified shall be carried out to the satisfaction of the Engineer and the Local Authorities.

10.2 Method Statement

The Contractor shall submit for the Engineer's approval a method statement giving full details of the materials, plant and operations he intends to adopt for construction of the diaphragm walls. It shall include details of:-

(a) dimensions of walls and lengths of panels.

(b) dimension and details of guide wall.

(c) the sequence of excavation and concreting of panels.

(d) the formation of the joints between panels, including sealing the joints.

(e) the type, source, chemical and physical properties of the bentonite to be used.

(f) the mixing, transporting and placing equipment for the bentonite slurry.

(g) the cleaning and re-use of bentonite slurry.

(h) calculations to show that the density of the bentonite and lowest head of slurry are sufficient to maintain the stability of the trench, in the ground conditions envisaged, to its entire length.

(i) the methods of monitoring and checking the stability of the diaphragm wall trench; to be substantiated with relevant calculations.

(j) the methods of monitoring and checking the stability of neighbouring properties, highways, services and other underground structures.

(k) the methods of monitoring and checking the tolerances associated with the diaphragm wall panels.

(l) the method of disposal of contaminated bentonite slurry.

(m) the record sheet for construction and installation of diaphragm wall.

Construction of diaphragm walls shall not commence until the Contractor's method statement has been accepted in writing by the Engineer.

10.3 Submittals

After award of the Contract, the Contractor shall submit for approval by the Engineer his proposed schedule of shop drawings in Autocad format where possible and design calculations submission for the entire project.

Before commencement of the work, the Contractor shall submit to the Engineer for his approval three legible prints of each shop drawing and design calculations.

The shop drawings submitted shall contain the following information and other details that may be required by the Engineer from time to time :-

(a) The design criteria.

(b) Assumptions made.

(c) Factors of safety used.

(d) All imposed loads including those arising from the soil.

(e) Deflection of wall and movement of ground behind the wall.

(f) Layout, setting out, dimensions and reinforcement details of the diaphragm walls and guide walls, including sections and elevations.

(g) Layout, lengths and sequence of construction of the wall panels, including sections.

(h) Sizes, details and locations of blockouts for penetrations, recesses, inserts, vertical steel tubes, tremie pipes, etc.

(i) Layout, size and details of stop ends.

(j) Details of spacers, steel chairs, steel bracings etc. providing support and restraint to the steel cages.

(k) Details of struts and walers.

(l) Sequence of removal of struts and walers in relation to the construction of basement substructure.

(m) Details of surface waterproofing treatment to exposed faces of diaphragm walls.

Such drawings shall be submitted as soon as possible after the award of the Contract and in any case in sufficient time to permit review and consideration to be made by the Engineer and modifications to be made by the Contractor as deemed necessary by the Engineer so that any undue delay to the delivery or installation of the Works could be avoided. The drawings submitted shall be modified as and when necessary and, if directed by the Engineer, resubmitted for further review. The Contractor shall provide the Engineer with six copies of each approved shop drawing and design calculation within 2 weeks of receipt of approval from the Engineer.

For each submission of shop drawings, a minimum initial time period of 3 weeks shall be allowed for the first review thereof by the Engineer. Delays caused by late submission of such drawings or modifications thereto arising from repeated errors, unacceptable details, unclear or insufficient information will under no circumstances be construed as reasons for a request for an extension of time to the Contract. The Engineer's review of such drawings or approval accorded thereto shall not exonerate the Contractor from any of his primary responsibilities and obligations under the Contract. The Contractor shall be responsible for all financial and time consequences arising out of errors, omissions or non-clarity in such drawings or delays in the submission thereof.

10.4 As-Built Drawings

The Contractor shall make accurate records of the actual works constructed. For those parts of the works that will become hidden by further progress, such records shall be checked and verified by the Engineer while those parts of the works are open for inspection.

All drawings submitted by the Contractor shall be in Autocad format and shall have relevant particulars at the bottom right-hand corner including the project title, Contractor's name, title of drawing, scale, date, drawing number and notes identifying revisions made thereto.

The Contractor shall submit within two weeks of completion of diaphragm wall a reproducible copy and 6 numbers of prints of as-built drawings together with one set of drawings in Autocad files to the Engineer showing the following:-

(a) Verticality of diaphragm walls at face and ends of panels.

(b) Position of diaphragm walls installed horizontally in relation to grid line or centre of wall.

(c) Length and depth of each panel of wall.

(d) Complete details of diaphragm wall including reinforcement, box-up and other relevant details.

(e) Details of walers , steel strutting and anchors system where applicable.

10.5 Guide Walls

The design and construction of the guide walls shall be the responsibility of the Contractor and to the approval of the Engineer and shall take into account the actual site and ground conditions and the equipment to be used on the site. Guide walls shall be constructed of sufficient suze, height and shape to suit the excavation plant used and site condition. They shall be high enough to maintain the required head of bentonite slurry and deep enough to prevent erosion of the soil by disturbance of bentonite.

The guide walls shall be raised above ground level as necessary to permit the slurry level in the trench to be maintained at a level not lower than 0.3 metre of the top of the trench at all times during panel excavation and construction and at such higher level as the Contractor may deem necessary for maintaining stability of the trench and controlling ground movements.

After completion of the works the guide walls shall be removed by the Contractor.

10.6 Diaphragm Wall Panels

Construction of diaphragm panels shall be within a bentonite slurry which shall be sufficient depth and consistency to ensure the stability of the surrounding ground during excavation and concreting.

The level of bentonite slurry in the excavation shall be maintained within the depth of the guide walls, and at a level not less than 1.5m above the level of external ground water level.

10.6.1 Wall Panels Layout and Lengths

The Contractor is to propose the layout of the panels to be used in the Works subject to the constraints and construction sequence described by the Engineer. The sesuence of panel construction shall be arranged to avoid damage to panels which have already been cast. Two adjacent panels shall not be excavated or constructed concurrently.

The Contractor shall specify in his method statement the lengths of all panels to be concreted taking account of the ground conditions at the site and the need to maintain stability of the trench and limit movements in the adjacent ground. The Engineer may specify a trial panel prior to actual construction.

The Contractor shall not alter his accepted layout and lengths of the panels without the prior written approval of the Engineer.

10.6.2 Levels of Walls

All diaphragm walls shall be concreted to the following top level :-

(a) to the top of the guide wall; or

(b) to the levels shown upon the Drawings.

A tolerance of +0.3m deeper / -0m shallower shall be allowed for in respect of the levels for case (b). Furthermore, the remaining bentonite within the trench shall be displaced using lean mix concrete, which shall be poured to the top of the guide walls. Concrete shall be cast to such level that only sound concrete remains below specified levels. The minimum overcast shall be 300mm.

11.0 CONSTRUCTION CONTROL

11.1 Method of Wall Excavation

Trench excavation are to be performed by using a propose designed trenching tool working in dry or through a bentonite suspension.

In soil conditions susceptible to collapse, bentonite shall be used. The level of the bentonite suspension shall be maintained at a level sufficient to ensure the stabilities of the trench.

A guide wall shall be used to ensure the stability of the strata near ground level.

11.2 Sequence of Excavation

Panel excavation shall be arranged in a sequence such that panels which have recently cast will not be damaged.

11.3 Reinforcement Cages

The reinforcement cages shall be maintained in position during concreting by a method approved by the Engineer.

11.4 Concrete Placing

The Contractor shall ensure that an adequate supply of concrete to the tremie is available at all times so that placement is continuous. Concrete shall be placed continuously by one or more tremie pipes and care shall be taken during placing to avoid contamination of the concrete. Where two or more pipes are used in the same panel simultaneously, care shall be taken to ensure that the concrete level at each pipe position is maintained nearly equal.

The tremie pipe shall be clean, watertight and with a minimum internal diameter of 250mm to allow the free flow of concrete.

The tremie tube shall extend to the bottom of the trench excavation prior to the commencement of concrete pouring and care shall be taken to ensure that all bentonite slurry is expelled from the tube during the initial charging process. The tremie pipe shall be maintained with a minimum embedment of 3.0m into concrete to prevent the re-entry of bentonite slurry into the pipe.

The concrete pour for any diaphragm wall panel shall be completed in such a manner and within such time that the concrete above the foot of the tremie remains workable until the casting of the panel is completed.

The effective trimmed final wall level shall generally be taken as 250mm below the top of the guide wall when concrete is cast to the top of the trench.

For trimmed final wall levels below this level the tolerance of the cast concrete profile shall be a minimum of 150mm and a maximum of 300mm above the specified wall level plus an additional allowance of 150mm over the maximum tolerance for each one metre of final wall depth specified below the top of the guide wall.

Defects like bulging of concrete, voids, honeycomb, contaminated concrete shall be made good by the Contractor at his own expense and time, and to the satisfaction of the Engineer.

11.5 Stop Ends

Stop ends, inserted prior to placing concrete in a panel shall be clean and have a smooth

regular surface. They shall be adequately restrained to prevent horizontal movement during concreting, or to the adjacent soil and structures.

The extraction of stop ends shall be carried out as such a time and in such a manner as to avoid damage to concrete placed against it.

11.6 Steel Strutting

Steel strutting is required where no ground anchors are allowed due to space constraint. Strutting shown in the Engineers' drawings is for Contractor's information only. Contractors shall submit detailed drawings and calculations or he may propose an alternative and subject to approval from the Engineer. All steel strutting works shall be performed by skilled craftsman related to welding and connection work.

11.7 Joints and Leakage

The method of forming joints and the equipment used shall be such that all solids are removed from the end of the adjacent panel by the excavating equipment. The Contractor shall be responsible for the repair by pressure grouting of any joint where, on full exposure of the wall, visible water leaks resulting from faulty materials or workmanship are found. The walls formed shall be substantially watertight.

11.8 Cleaning

Where diaphragm wall panels are exposed within the excavation the exposed surfaces shall be thoroughly cleaned to remove all traces of bentonite, soil, or other contaminating material so as to leave exposed only sound concrete material.

This requirement shall apply irrespective of whether or not the exposed panel is to be subsequently covered by in-situ concrete.

11.9 Safety Precaution and Emergency Procedures

Safety precaution shall be taken throughout the construction of diaphragm walls in accordance with the relevant statutory requirements and suggestions given in B.S. 8004: Code of Pratice for Foundation.

The Contractor shall take all necessary precautions to ensure stability of his excavations and guide walls and shall take all necessary precautions and be responsible for safety of personnel in the area of operation.

The Contractor shall maintain, available for immediate use, a sufficient quantity of slurry to allow for any sudden loss. Should the loss continue despite the additional of the slurry and the stability of the trench be placed at risk, the Contractor shall immediate remedial advise the Engineer and take such immediate remedial action as is necessary to preserve the stability of the trench and for ensure the safety of neighbouring structures and facilities.

11.10 Setting Out

The setting out of wall must be carried out by a Chartered Land Surveyor employed by the Contractor, to the Engineer's approval and the Contractor is to ensure that all lines and levels are in accordance to the working drawings.

11.11 Watertightness

The Contractor is responsible for providing a watertight wall. Should the wall be not watertight,

the Contractor shall, at his own expense carry out all remedial measures required to render the wall watertight.

11.12 Blasting

Blasting shall not be permitted without the written approval of the Engineer and the relevant Authorities. The Contractor shall comply with all regulations of the relevant Authorities and take all precautions necessary to avoid damage. Should any damage be caused this shall immediately be made good at the Contractor's own expense.

The Contractor shall be responsible for obtaining any necessary permits for the use of and storage of explosives.

Details of all proposed blasting operations shall be submitted to the Engineer with as much advance notice as possible and at least 24 hours prior to blasting. These shall include charge calculations and expected ground vibration levels.

11.13 Disposal of Spoil

Spoil removed from the excavation shall be separated from the slurry employed in the excavation process. It shall be disposed of in accordance with the current statutory requirements and as quickly as possible to an approved dump site and in such a manner that spillage and annoyance be minimised and as agreed with the Engineer.

11.14 Disposal of Slurry

Used bentonite or contaminated slurry, not suitable for re-use shall be disposed of by mixing it with sufficient granular soil or similar approved material in such properties as will neutralize its characteristic properties and produce a material that is, in the opinion of the Engineer and local authorities, suitable for placing in public dumps to form usable areas of reclaimed land.

11.15 Slurry Spillage

The Contractor shall ensure that the site be cleared of slurry to the satisfaction of the Engineer, and that his operations be conducted in such a manner as to minimise any spillage of slurry over the site.

12.0 TOLERANCES

Construction shall be carried out in accordance with the following normal tolerances :-

(a) The minimum clear distance between the faces of guide walls shall be the specified diaphragm wall thickness plus 25mm and the maximum distance shall be the diaphragm wall thickness plus 50mm. The guide walls shall be propped, as necessary, to maintain these tolerances during the course of construction of the Works. The face of the guide wall towards the trench and on the side of the trench nearest to the subsequent excavation shall be vertical and shall represent the reference line. This reference line shall not vary from a straight line or specified profile by more than ± 6mm in any 5 metres wall length and it shall be so maintained that there is no abrupt change.

(b) The plane of the diaphragm wall face to be exposed shall be vertical to within a tolerance of 1 in 200. For the purpose of measuring the verticality of the wall at a particular location, the reference point shall be at the top of the wall on the exposed face at that location.

(c) In addition to the tolerance under (b) above, a tolerance shall be allowed for local protrusions beyond the wall face (as determined above) resulting from irregularities in the ground excavated, subject to the following requirements :-

(i) over a basement storey height the maximum allowable protrusion beyond the plate of the diaphragm wall face shall be 75mm and on any vertical section only one bulge will be permitted within a basement storey height.

(ii) over any horizontal distance of 4m the maximum allowable protrusion beyond the plane of the diaphragm wall face shall be 75mm and along any horizontal line of 4m length only one bulge will be permitted.

(iii) undulations in the exposed surface of the wall shall not exceed 25mm over any 3m distance on the face.

(iv) lumps and sharp local projections in the wall face will not be accepted by the Engineer regardless of whether they meet the requirements of items (i) to (iii) above.

All defects shall be made good by the Contractor at his own expense and time, and to the satisfaction of the Engineer.

(d) Where blockouts for penetrations, recesses and inserts are formed within the wall, they shall be positioned within the following tolerances. Horizontal and vertical tolerance of plus and minus 50mm for recesses located at a depth of up to 15 metres from the top of the guide walls; for recesses located at depths in excess of 15 metres, the tolerance shall be ± 100mm.

(e) The tolerances in positioning reinforcement shall be as follows :

(i) Longitudinal tolerance at cage head measured along trench is ± 50mm and vertical tolerance at cage head in relation to top of guide wall is ± 50mm.

(ii) Lateral tolerance of reinforcement position in the direction across the width of the wall can be 50mm but must still maintain minimum cover to reinforcement of 75mm.

(iii) Horizontal tolerance at cage head in relation to top of guide wall is ± 10mm.

(iv) Vertical location of starter bars into basement slabs shall be ± 50mm from designated levels.

(v) The reinforcement shall be maintained in position during the casting of each panel.

(f) A minimum cover to reinforcement of 75mm shall be maintained.

(g) Notwithstanding the requirements of (a) to (f) of this item, the tolerances may be aggregated only to the extent that they do not exceed 125mm.

(h) Stop ends, inserted prior to placing concrete in a panel shall be cleaned and have a smooth regular surface. They shall be adequately restrained to prevent horizontal movement during concreting.

(i) Where the final trimmed level of the diaphragm wall is up to 1.0m below the top of the guide wall, the casting tolerance will be 600mm above the trimmed level. For each additional 1m depth of the final trimmed level or part thereof, a further 150mm addition to the tolerance will be allowed.

(j) Cast-ins for services penetration shall be within 50mm from designated levels. Any rectification works required as a result of no complying with above tolerances shall be

rectified by the Contractor at his own expense and time.

If during the general excavation it is detected that the above stated tolerances have been exceeded, the Contractor shall submit for the approval of the Engineer, his proposals for remedying the defects.

13.0 PUMPING

Should pumping be required during construction, the Contractor shall work out the drawn-down curve so that no foundations of the adjacent buildings and any permanent work installed may be affected by the drawn-down. The Contractor shall submit this to the Engineer for approval before pumping starts.

14.0 RECORDS

The following records shall be kept for each panel completed and such records shall be available for inspection by the Engineer at any time : -

(a) Panel number

(b) Top of guide wall level

(c) Bottom of guide wall level

(d) Top level of wall as cast in relation to top of guide wall

(e) Depth of base of panel from top of guide wall

(f) Date and time of start of panel excavation

(g) Date and time of finish of panel excavation

(h) Date and time of start and of completion of panel concreting

(i) Length of panel

(j) Thickness of wall

(k) A log of soil type encountered from start to finish of excavation and water level

(l) Cubes taken, markings, date and results obtained on testing

(m) Actual volume of concrete used and method of calculating the volume

(n) A graph of theoretical and placed concrete volumes with depth and depth of tremie to be included.

(o) Quantity of slurry removed from Site and spoiled removed from Site recorded by date

(p) Details of cage type for reinforcement

(q) Date and time of completion of cage placement

(r) Details of any obstructions encountered and time spent in dealing with obstructions.

The details of the construction record sheel shall be discussed and agreed with the Engineer prior to construction.

15.0 MONITORING DEVICES FOR DIAPHRAGM WALL

The following clauses shall apply to the supply, installation, maintenance, measurement and recording of monitoring devices. The Contractor shall submit the monitored results and the predicted/analysed results to the Engineer for review. The results shall be submitted to the Engineer in hardcopy and diskette. The Contractor shall also plot the results in the format agreed by the Engineer. The plot should include the Contractor's prediction and monitored results at site. The specific locations of monitoring devices will be directed by the Engineer.

15.1 Inclinometers

The Contractor shall supply and install at least six inclinometer measurement tubes in the diaphragm wall.

The tubes shall be secured to the steel reinforcement cage before the cage is lowered into the trench. The bottom end of the tube shall be sealed against intrusion of concrete or grout.

The tube shall be filled with water and the top end adequately covered prior to tremie concreting of the wall panel.

The Contractor shall provide the read-out equipment to assist the Engineer in recording any movement of inclinometer tubes daily or at such intervals as may be agreed.

15.2 Strain Gauges

The Contractor shall provide the read-out unit and assist the Engineer in taking readings at predetermined time interval.

15.2.1 Steel Strain Gauges

The Contractor shall supply and install vibrating wire strain gauges for measuring strain in the reinforcement. The strain gauge may be incorporated in a piece of reinforcement bar. This piece of reinforcement bar will take the place of equivalent steel reinforcement provided for the steel cage.

15.2.2 Concrete Strain Gauges

The Contractor shall supply and install proper concrete strain gauges or gauges for measuring strain in the concrete. The gauges shall be installed by securing to the steel reinforcement cage.

15.2.3 Calibration and Measurement

The Contractor shall calibrate and take frequent readings of the strain gauges prior to installation and supply proof that the installation has no significant effect on the calibration.

15.3 Piezometers

The Contractor shall supply and install standpipe piezometers. The installation shall incorporate a lockable protective cover and will extend to depths required for proper monitoring of the water table.

The Contractor shall provide the read-out unit and assist the Engineer in taking the reading daily

or at such interval as may be agreed.

15.4 Pressure Cells

The Contractor shall supply if required and install pneumatic/hydraulic pressure cells in the internal and external faces of diaphragm walls to record the water and soil pressure acting on the structural elements.

The Contractor shall provide the read-out unit and assist the Engineer in readings and recording the data provided by this instrumentation.

15.5 Settlement Monitoring Points

The Contractor shall supply and install settlement markers at locations to be determined by the Engineer. Where markers on existing building has to be installed, this shall be approved by the Engineer.

Markers in the ground shall be steel rods at least 12mm in diameter. They shall be driven at least 1m into the ground. The Contractor shall provide precise level and staff to assist the Engineer to take level readings on these monitoring points.

16.0 ADJACENT PROPERTIES

The Contractor's site procedures and method of working shall at all times be such as to limit to a practical minimum settlement and lateral movement of the ground and buildings around the site. Contractor shall send to the Engineer the estimated ground movement behind the wall during each stage of construction.

The Contractor shall be responsible for any damage or movement in adjacent properties including roads, paved areas, drains, services, buildings, street furniture, underground structures of any type, etc.

Allowance shall be made for all ancillary treatment and all works necessary to ensure that stability of roadways, adjacent structures, services and underground constructions and for all remedial works needed to make good any damage to the satisfaction of the relevant Authority or owner of the property and the Engineer.

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