

SPECIFICATIONS FOR UNDERWATER CONCRETE

1035. 1. DESCRIPTION

The work will consist of the mixing of concrete in accordance with the "Specifications for Reinforced Concrete", and the depositing of such concrete under water by means of the tremie method, or the underwater injection of grout into already placed aggregate by means of the intruded grout method.

1035. 3. SUPPLY OF MATERIALS

Material supply shall be as per Sections 3.1 and 3.2 of the "Specifications for Reinforced Concrete" with the exception of the following:

- (a) The coarse aggregate for intruded grout concrete shall conform to the following gradation:

Maximum Size	-	100% shall pass a 75 mm sieve
Minimum Size	-	material passing a 19 mm sieve shall not exceed 5% by mass of the coarse aggregate.

A maximum of 0.5% by mass of fines passing a standard 75 um sieve can be tolerated in the coarse aggregate and the fines shall be tested in accordance with ASTM Designation C117 (latest edition). The coarse aggregate, within the limits of the sizes specified, shall be well graded in order to produce a void ratio as close as possible to 40%.

- (b) The sand for the intruded grout shall be well graded, preferably of round grains and shall conform to the following gradation:

Passing 1.18 mm sieve	95 - 100%
Passing 600 um sieve	60 - 85%
Passing 300 um sieve	20 - 45%
Passing 150 um sieve	15 - 30%
Passing 75 um sieve	0 - 10%

1035. 5. EQUIPMENT

5.1 Tremie Equipment

The tremie pipe shall consist of a tube, having a diameter of not less than 250 mm, constructed with sections having flange couplings fitted with gaskets. The discharge end shall have a proper seal so that water will not enter the tube at any time. Tremie concrete may also be deposited by means of a bottom dump tremie bucket equipped with a closing top. The tremie bucket shall be of a type approved by the Engineer.

The discharge ends on both the tremie pipe and the tremie bucket shall be fabricated to allow for the full opening of the discharge ends of the pipe or bucket, by slightly raising the pipe or bucket.

1035. 5. EQUIPMENT (Cont'd)

5.2 Intruded Grout Equipment

The Contractor shall be responsible to ensure that the plant and equipment are of adequate size and in good repair. The final approval of the Engineer will be required before the equipment can be used in this work.

1035. 7. CONSTRUCTION METHODS

7.1 Tremie Concrete

7.1.1 Strength

Tremie concrete shall attain a minimum strength of 28.0 MPa at 28 d, using a slump of 150 to 200 mm. Sufficient additional cement shall be added to the mix in order to compensate for the dilution due to the depositing of concrete in water.

7.1.2 Depositing Tremie Concrete

Underwater concrete shall be deposited in a manner meeting with the approval of the Engineer and the concrete depositing shall not be started until the Engineer's approval has been obtained.

To prevent segregation, concrete deposited under water shall be carefully deposited in a compact mass in its final position by means of a tremie pipe, or other approved method, and shall not be disturbed after being deposited. Still water shall be maintained at the point of deposit. The water level shall be regulated so that there shall be no fluctuation of water head that may be injurious to the concrete.

Concrete depositing under water shall be carried out continuously from start to finish. The surface of the concrete shall be kept as horizontal as is practicable at all times. To ensure thorough bonding, each succeeding layer of concrete shall be deposited before the preceding layer has taken its initial set.

In the event of long delays in the pour during which the already deposited tremie has started to set, the Contractor shall remove the laitance, drill holes and supply and grout dowels in the already deposited portion before resuming the tremie pour; or the Contractor may be required to remove the concrete already deposited and start again.

The minimum rate of depositing underwater concrete shall be 15 m³/h. Continuous soundings shall be taken during the concrete pour and all irregularities in the concrete profile shall be corrected. If a tremie pipe is used for depositing, it shall be supported so as to permit:

- (i) free movement of the discharge end over the entire top surface of the work, and
- (ii) rapid lowering when necessary to retard or stop the flow of concrete.

The discharge end shall be closed at the start of the work in order to prevent water from entering the tube and it shall be sealed at all times when not in the deposited concrete. The tremie tube shall be kept full up to the bottom of the hopper. When a batch is dumped into the hopper, the flow of concrete shall be induced by slightly raising the discharge end, always keeping it in the deposited concrete.

1035. 7. CONSTRUCTION METHODS (Cont'd)

7.1 Tremie Concrete (Cont'd)

7.1.2 Depositing Tremie Concrete (Cont'd)

If a bottom dump tremie bucket is used for depositing the concrete, the rate of lowering and raising shall be such that the bucket shall not create undue turbulence inside the cofferdam. The bucket shall always be in the deposited concrete before the bottom is opened.

The Contractor shall deposit tremie concrete to such elevations that after all unsound concrete has been removed from the surface, the finished elevations shall be those which are shown on the plans.

7.1.3 Testing

In addition to the testing as outlined in Section 7.15 of the "Specifications for Reinforced Concrete", the Contractor shall obtain two (2) continuous test cores from separate locations in each pier as designated by the Engineer, 7 d after the completion of the pour. The cores shall be taken vertically through the full depth of the tremie concrete and complete recovery of the cores will be required. The minimum diameter of the cores shall be 50 mm.

In the event that the concrete tested in accordance with the requirements as outlined above proves to be unsound, the Engineer may require that further test cores be taken to establish the condition of the entire tremie pour.

The Contractor shall then correct the unsound condition by either pressure grouting the entire mass, removing the concrete or by other methods that meet with the approval of the Engineer. All work involved in testing and correcting the unsound condition in the underwater concrete shall be done at the Contractor's expense.

All holes left after coring shall be regouted at the Contractor's expense.

7.1.4 Dewatering

Dewatering shall begin when the underwater concrete is sufficiently hard and strong as determined by the Engineer. All laitance or other unsatisfactory material shall be removed from the exposed surface by scraping, chipping, or by other means which will not injure the concrete mass.

7.1.5 Cold Weather Precautions

During freezing weather, the Contractor shall make provisions for heating the aggregates and the water to be used in the concrete, as well as the water inside the cofferdam. The deposited concrete shall be protected against freezing for a period of at least 7 d starting from the time of completion of the depositing of concrete. Concrete materials and deposited concrete shall be heated only on the written order of the Engineer and the Contractor will be paid for the actual quantity of concrete agreed to be heated on such a written order.

Aggregates shall be heated to a temperature of not less than 20⁰ C and not more than 65⁰ C. The water for the concrete shall be heated to a temperature of between 55⁰ C and 65⁰ C. The temperature of the mixed concrete shall not be less than 15⁰ C and not more than 25⁰ C at the time of placing in the cofferdam.

1035. 7. CONSTRUCTION METHODS (Cont'd)

7.1 Tremie Concrete (Cont'd)

7.1.5 Cold Weather Precautions (Cont'd)

The Contractor shall heat the water inside the cofferdam to a minimum temperature of 5⁰ C before placing any concrete. After placing the underwater concrete, and before dewatering, the Contractor shall maintain the temperature of the water above the concrete in the cofferdam at 5⁰ C.

The Contractor shall furnish sufficient canvas and framework or other types of housing to enclose and protect the cured concrete in such a way that, after dewatering, the air surrounding the concrete can be kept at a temperature of not less than 10⁰ C until such time as the adjoining concrete is placed.

The Contractor shall supply the heating apparatus and the necessary fuel. When dry heat is used, a means of maintaining atmospheric moisture shall be provided.

Sufficient stand-by heating equipment shall be available to allow for any sudden drop in outside temperatures and any breakdowns which may occur in the equipment.

The heating apparatus and the housing for the aggregates shall be adequate to heat the aggregates uniformly, precluding the possibility of the occurrence of hot spots which may burn the materials.

Heating apparatus used to heat the housing, shall be of type approved by the Department of Labour and Manpower. Every heater and other heating apparatus used in a housing which discharges or releases smoke or gas fumes, shall be adequately ventilated in such a manner as to carry away all such smoke or gas fumes from the housing.

The methods of heating concrete materials and of maintaining the temperature of the deposited underwater concrete shall meet with the approval of the Engineer in all particulars.

7.2 Intruded Grout Concrete

7.2.1 Strength

Intruded grout concrete shall be composed of coarse aggregate, the voids of which shall be filled completely by the injection of an approved grout after the placement of the aggregate. The concrete shall have a 28 d strength of 28.0 MPa.

7.2.2 Grout

(a) The grout mix to be used shall be submitted for approval to the Engineer by the Contractor and it shall be shown that the mix has been used successfully in work of a similar nature.

(b) Strength Requirement of Grout

The grout mix shall be designed for a minimum 28 d cube compressive strength of 35.0 MPa with the cubes being cured under laboratory conditions.

1035. 7. CONSTRUCTION METHODS (Cont'd)

7.2 Intruded Grout Concrete (Cont'd)

7.2.2 Grout (Cont'd)

(c) Grout Properties

The grout shall have a median flow resistance, high plasticity, high mobility retention, and exhibit little bleeding.

(d) Consistency

The quantity of water used in the grout shall be the minimum required to produce the proper consistency for placing. This consistency shall be such that the "Flow Factor" at the mixer and at the point of injection into the coarse aggregate shall be 20 ± 2 s when measured with the 1 725 ml flow cone.

(e) Temperature of Grout

The temperature of the grout at the point of intrusion shall not be less than 24° C.

7.2.3 Placing of Coarse Aggregate

The coarse aggregate shall be handled and deposited in the forms in a manner that will avoid segregation.

The coarse aggregate shall not be dropped more than 1.5 m in air or water or a combination of both. Drop bottom buckets, through pipes or similar devices, shall be used to deliver the aggregate to within 50 mm of its final position.

The aggregate shall be deposited uniformly and not transported in the forms or cofferdam by shovelling, raking or blowing.

Aggregate containing ice or frozen lumps shall not be placed in the forms or cofferdam. Care shall be taken that any reinforcing steel and embedded items are not displaced from the locations indicated on the plans. The cofferdams or forms shall be maintained ice free after the aggregate is placed and until such time as the grouting and curing of the concrete have been completed. Should ice form in the cofferdams or in the forms at any time prior to the placing of the aggregate, adequate precautions shall be taken to avoid damage from ice pressures.

7.2.4 Mixing and Placing of Grout

(a) Mixing

Mixing shall be done with approved mixing and pumping equipment. All oil, rust inhibitors, dirt and other deleterious material shall be removed from those portions of the equipment that will be in contact with the grout. The grout shall be mixed at high speed and for a sufficient length of time to produce a uniformly homogeneous material. The grout shall pass a 3 mm sieve prior to injection into the coarse aggregate.

1035. 7. CONSTRUCTION METHODS (Cont'd)

7.2 Intruded Grout Concrete (Cont'd)

7.2.4 Mixing and Placing of Grout (Cont'd)

(b) Pressure

The pressure at the point of injection will vary, depending on the conditions. The pressure to be employed shall be that pressure which will force grout into the coarse aggregate at such a rate to fill all voids in the aggregate without causing damage to the cofferdam.

(c) Placing

The grout shall be injected into the aggregate commencing from the lowest point. As the pumping of the grout under low pressure progresses, the injection point shall be raised, but the actual point of injection shall always be kept below the level of the grout in order to prevent the formation of air pockets and voids. All pumping shall be done slowly to permit the grout to fill all voids and pumping shall be continuous until the pour is complete. Continuous pumping may require stand-by pumps or other additional equipment. Injection points or inserts may be placed during the placing of the coarse aggregate.

Sufficient injection points shall be used to ensure that the entire volume will be filled. The level of the grout shall be kept as nearly horizontal as is practicable at all times.

(d) Observation Wells

A series of observation wells made of 50 mm diameter pipe shall be installed to provide accurate readings of the level of the grout.

(e) Laitance

A minimum of 150 mm and sufficient extra depth from the top of the intruded grout concrete shall be removed to reveal sound concrete as soon as possible after the dewatering of the cofferdam. This finished level shall correspond to the final elevation for the top of the footing as shown on the plans.

7.2.5 Testing

The Contractor shall take one 150 mm diameter continuous test core and two 75 mm diameter continuous test cores for each pier 7 d after the grouting is completed. The location of the cores in each pier shall be determined by the Engineer. All cores shall be taken vertically for the full depth of the concrete and complete recovery of the cores will be required. If crevices are detected or if, in the estimation of the Engineer, there is an inadequate bond between the grout and the aggregate, the pier shall be regouted and further cores obtained. All work involved in testing and correcting an unsound condition in the underwater concrete shall be done at the Contractor's expense. All holes left after coring shall be regouted at the Contractor's expense.

7.2.6 Dewatering

Dewatering shall begin when the intruded grout concrete is sufficiently hard and strong.

1035. 7. CONSTRUCTION METHODS (Cont'd)

7.2 Intruded Grout Concrete (Cont'd)

7.2.7 Cold Weather Precautions

During freezing weather the Contractor shall make provisions for heating the water and aggregate inside the cofferdam, as well as the grout. The intruded grout concrete shall be protected against freezing for a period of at least 7 d, starting from the time of completion of the grouting of the aggregate. Concrete materials and intruded grout concrete shall be heated only on the written order of the Engineer and the Contractor shall be paid for the quantity of concrete agreed to be heated on such a written order.

The Contractor shall heat the entire aggregate mass and the water inside the cofferdam, to a minimum temperature of 5⁰ C before any grout is injected. After the grouting is completed and before dewatering commences, the Contractor shall maintain the temperature of the water above the concrete in the cofferdam at 5⁰ C.

The water for the grout shall be heated to a maximum temperature of 32⁰ C and the temperature of the grout shall not be less than 24⁰ C at the point of injection. If necessary, the Contractor shall enclose his grouting equipment in order to obtain the specified temperatures.

The Contractor shall furnish sufficient canvas and framework or other types of housing in order to enclose and protect the structure in such a way that, after dewatering, the air surrounding the concrete shall be kept at a temperature of not less than 10⁰ C until such time as the adjoining concrete is placed.

The Contractor shall supply heating apparatus and the necessary fuel. When dry heat is used, a means of maintaining atmospheric moisture shall be provided.

Sufficient stand-by heating equipment shall be available to allow for any sudden drop in outside temperatures and any breakdowns which may occur in the equipment.

The heating apparatus for the housing shall heat the air inside the housing uniformly, precluding the possibility of the occurrence of hot spots which may burn the materials.

Heating apparatus used to heat the housing, shall be of a type approved by the Department of Labour and Manpower. Every heater and any other heating apparatus used in a housing which discharges or releases smoke or gas fumes, shall be adequately ventilated to carry away all such smoke or gas fumes from the housing.

The method of heating the aggregate and grout and maintaining the temperature of the intruded grout concrete under water shall meet with the approval of the Engineer.

1035. 9. METHOD OF MEASUREMENT

- (a) Underwater concrete will be measured on a volume basis. The volume to be paid for will be the total number of cubic metres as computed from the neat dimensions as shown on the plans or as ordered in writing by the Engineer. No deductions will be made for pile heads, reinforcing steel, structural steel, bolts or observation wells.

The supplying and placing of miscellaneous materials will be considered incidental to the Contract Unit Price for "Mixing and Placing Underwater Concrete" and no separate measurement or payment will be made for these items.

1035. 9. METHOD OF MEASUREMENT (Cont'd)

The work of taking test and inspection cores and of assisting the Engineer in making cylinders will be considered incidental to the Contract Unit Price for "Mixing and Placing Underwater Concrete" and no separate measurement or payment will be made for this work.

- (b) Measurements for reinforcing steel will be as specified in the "Specifications for Reinforced Concrete".
- (c) Measurements for heating concrete shall be as specified in the "Specifications for Reinforced Concrete".

1035. 11. BASIS OF PAYMENT

- (a) Mixing and placing of underwater concrete will be paid for at the Contract Unit Price per cubic metre for "Mixing and Placing Underwater Concrete", measured as specified which price will be payment in full for performing all operations described for underwater concrete and all other items incidental to the work included in this Specification.
- (b) Basis of payment for reinforcing steel will be as specified in the "Specifications for Reinforced Concrete".
- (c) Heating the inside of cofferdams, concrete materials and maintaining the temperature of tremie or intruded grout concrete will be paid for at the Contract Unit Price per cubic metre for "Heating Concrete", measured as specified which price will be payment in full for performing all operations described for heating underwater concrete and all other items incidental to the work included in this Specification.

If the prevailing temperature at the time of mixing and placing tremie concrete or grouting the aggregate is such that all heating operations are not considered necessary by the Engineer, the Contractor will be instructed in writing to carry out heating in part only. Partial heating will be paid as a percentage of the Contract Unit Price per cubic metre for "Heating Concrete", measured as specified.

These percentages will be as follows:

A. FOR TREMIE CONCRETE

- (i) Heating water 10%
- (ii) Heating aggregates 30%
- (iii) Heating the water inside the cofferdam and housing and heating the deposited concrete 60%

B. FOR INTRUDED GROUT CONCRETE

- (i) Heating grout 10%
- (ii) Heating water and aggregate inside the cofferdam and housing and heating the intruded grout concrete 90%