IS 5878-7 (1972): Code of practice for construction of tunnels conveying water, Part 7: Grouting [WRD 14: Water Conductor Systems]

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CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS CONVEYING WATER

PART VII GROUTING

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Indian Standard

CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS CONVEYING WATER

PART VII GROUTING

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AMENDMENT NO. 2 JANUARY 2008
TO
IS 5878 (PART 7) : 1972 CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS CONVEYING WATER

PART 7 GROUTING

(*Page* 3, *clause* **0.4**) — Substitute 'IS 6066' *for* 'IS 6066 : 1971 Recommendation for pressure grouting of rock foundation in river valley projects'.

(*Page* 4, *clause* **0.6**) — Delete.

(*Page* 4, *clause* **0.7**) — Substitute '**0.6**' *for* '**0.7**'.

(*Page* 4, *clause* **1**) — Insert the following clause after **1** and renumber the subsequent clauses:

2 REFERENCES

2.1 The following standards contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent additions of the standards indicated in below:

IS No.	*Title*
269 : 1989	Specification for 33 Grade ordinary Portland cement (*fourth revision*)
455 : 1989	Specification for Portland slag cement (*fourth revision*)
1344 : 1981	Specification for calcined clay pozzolana (*second revision*)
1489 (Part 1) : 1991	Specification for Portland pozzolana cement: Part 1 Flyash based (*third revision*)
3812 : 1981	Specification for flyash for use as pozzolana and admixture (*first revision*)

IS No.	*Title*
5878 (Part 6) : 1975	Code of practice for construction of tunnels: Part 6 Steel lining
6066 : 1994	Recommendation for pressure grouting of rock foundation in river valley projects.
8112 : 1989	Specification for 43 grade ordinary Portland cement (*first revision*)
12269 : 1987	Specification for 53 grade ordinary Portland cement (*first revision*)

2.2 The reference to Indian Standards, wherever mentioned in this Code, shall be as per clause **2.1**.

(*Page* 12, *clause* **6.3.5**, *second sentence*) — Substitute '**7.3.2**' *for* '**7.3.1**'.

(*Page* 14, *clause* **7.3.1**) — Substitute the following for the existing:

'**7.3.1** Grouting should be done with cement conforming to IS 269 or IS 8112 or IS 12269 or IS 455 or IS 1489 (Part 1) as specified by the Engineer-in-Charge.'

(*Page* 14, *clause* **7.3.4**, *second sentence*) — Substitute the following for the existing:

'If intake is heavy, the grout may be thickened by incorporation of pozzolana such as flyash conforming to IS 3812 or calcined clay conforming to IS 1344 in the mix or by using inert material like fine sand, rock powder, clay or bentonite.'

(WRD 14)

Reprography Unit, BIS, New Delhi, India

Indian Standard

CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS CONVEYING WATER

PART VII GROUTING

0. FOREWORD

0.1 This Indian Standard (Part VII) was adopted by the Indian Standards Institution on 29 December 1972, after the draft finalized by the Water Conductor Systems Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The treatment of rock around the tunnel bore, and the treatment of the plane of contact between the rock and concrete lining and of the contact plane between concrete and steel lining in tunnels, by pressure grouting is a very important aspect of the construction of tunnels, as the design of lining is based on properly executed grouting of the rock and the contact zones. The success of the grouting depends upon a co-ordinated handling of the work of exploration, initial trials, field control and testing.

0.3 It has been appreciated that it would not be appropriate to stipulate rigid standards to meet the various uncertain and diverse conditions that are met with in underground works. The aim of these recommendations is to summarize the commonly used procedures, equipment and technique in order to enable the Engineer-in-Charge of the job to evolve a procedure suited to the particular job and to achieve the degree of stabilization required by the designs by a process of experimentation on the proper lines.

0.4 This standard covers special features for grouting used for tunnels only. However, for foundation grouting a reference may be made to IS : 6066-1971*.

0.5 The other parts of this standard are as follows:

Part I	Precision survey and setting out
Part II	Underground excavation in rock
Part III	Underground excavation in soft strata
Part IV	Tunnel supports
Part V	Concrete lining
Part VI	Steel lining

*Recommendations for pressure grouting of rock foundations in river valley projects.

0.6 This standard is one of a series of Indian Standards on tunnels. Other standards published so far in the series are the following:

IS : 4081-1967 Safety code for blasting and related drilling operations

IS : 4137-1967 Safety code for working on compressed air

IS : 4756-1968 Safety code for tunnelling work

IS : 4880 (Part II)-1968 Code of practice for design of tunnels conveying water: Part II Geometric design

IS : 4880 (Part III)-1968 Code of practice for design of tunnels conveying water: Part III Hydraulic design

IS : 4880 (Part IV)-1971 Code of practice for design of tunnels conveying water: Part IV Structural designs of concrete lining in rock

IS : 4880 (Part VI)-1971 Code of practice for design of tunnels conveying water: Part VI Tunnel supports

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the results of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This code gives recommendations regarding pressure grouting for tunnels primarily using cement with or without suitable admixtures. Chemical grouting is not dealt with in detail as the properties of chemical grouts as well as the techniques adopted vary from place to place to meet the special localized conditions of the job.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following terminology shall apply.

2.1 **Backfill Grouting** — Due to the irregular excavated section of the rock, empty pockets are left behind the concrete in the lining in the arch portion of a tunnel or a cavity. Backfill grouting is the process of filling these spaces by sand-cement grout.

*Rules for rounding off numerical values (*revised*).

2.2 **Circulating System** — The piping arrangement by which grout is conveyed from the grout pump to the grout hole and through a return line from the hole to the grout tank.

2.3 **Consolidation Grouting** — The process of pressure grouting to fill up voids in rock or to consolidate the rock mass around the periphery of the bore, generally to a uniform distance from the finished surface of the concrete lining. This is done under relatively high pressures.

2.4 **Contact Grouting or Pack Grouting** — The process of grouting behind the concrete lining or steel liner, to fill up the shrinkage gap and voids, if any, between the concrete lining and the rock surface and/or between the steel liner and the concrete behind it.

2.5 **Manifold or Header** — The piping arrangement at the mouth of the hole for connecting the supply/return lines to the hole being grouted.

2.6 **Packer** — A devise used in a hole to segregate a part of the hole to be grouted from the remaining length of the hole.

2.7 **Grouting Pattern** — An arrangement of holes for grouting.

2.8 **Pressure Testing** — The process of pumping water into a hole through a direct connection or a packer to measure the rate of acceptance of water under pressure (sometimes also referred to as water testing).

2.9 **Single Line System** — The piping arrangement by which grout is conveyed from a grout pump to the grout hole through a single line, there being no provision for a return line as in the circulating system.

2.10 **Single Stage Grouting** — The process of grouting the entire depth of the hole, drilled to the final designed depth, in one operation.

2.11 **Stage** — A complete operational cycle of drilling cleaning/washing, pressure testing (as may be required) and pressure grouting.

2.12 **Stage Grouting** — A grouting operation in which the hole is drilled and grouted in stages, redrilling through set grout if unavoidable, instead of being drilled to the entire depth and then grouted either in one operation as in single stage grouting, or in different operations using packers.

2.13 **Umbrella Grouting** — This is grouting from the face of the excavation in a pattern resembling a half opened umbrella, to consolidate the rock prior to excavation.

3. GENERAL

3.1 Grouting is carried out to fill discontinuities in the rock by a suitable material so as to improve the stability of the tunnel roof or to reduce its

permeability or to improve the properties of the rock. Grouting is also necessary to ensure proper contact of rock face of the roof with the lining. In such cases the grouting may be done directly between the two surfaces or the process of grouting may be used to fill the voids in the rubble packing where used. All the three types of grouting may not be required in all cases. The grouting procedures should aim at satisfying the design requirements economically and in conformity with the construction schedules. The basic design requirement generally involve the following:

a) Filling up the voids, cavities, between the concrete lining and rock and/or between the concrete and steel liner;

b) Strengthening the rocks around the bore by filling up the joints in the rock system;

c) Strengthening the rock shattered around the bore;

d) Strengthening the rock, prior to excavation by filling of the joints with cementing material and thus improving its stability; and

e) Closing up water bearing passages to prevent the flow of water into the tunnel and/or to concentrate the area of seepage into a channel from where it can be easily drained out.

3.2 Before drawing up the specifications for grouting the design requirements shall be established. In general for all underground structures, grouting is an universal requirement for all concrete lined tunnels. Design requirements are only to establish the maximum allowable pressure at which this grouting is to be carried out and the zone in the cross-section and the spacing of grout holes, both in the direction of the tunnel. For consolidation grouting the design requirement to be established is the thickness of the rock stratum around the bore that is to be strengthened and made impermeable, the pressure and the spacing pattern of holes. This will determine the depth to be grouted.

3.3 For tunnels, the commonly used procedures are to continue grouting to refusal at the design pressure in each hole or to interrupt the grouting if there is heavy intake with little or no pressure build up, indicating a very open structure and escape of grout to a long distance.

4. PATTERN, DEPTH AND ARRANGEMENT OF HOLES

4.1 Backfill Grouting

4.1.1 The purpose of backfill grouting is to fill the spaces left unfilled with concrete between the concrete lining and the rock surface in the arch portion of any tunnel or cavity.

4.1.2 Backfill grouting should be done after the concrete in lining has gained strength. This period of waiting may be from 21 to 28 days. In

case of precast lining segments this restriction of waiting will not apply and the grouting may be done immediately after the segments are erected.

4.1.3 Backfill grouting is limited to the arch portion of a tunnel or cavity and is not required in case of shafts if the concrete is poured vertically.

4.1.4 The grout holes at the crown should be placed 5 to 10 degrees from the crown, alternately in the left and right of the crown. In addition to the crown hole there shall be two more holes, one on either side of the crown. These holes will be 90° apart and will be located such that one of these two holes is at 22½° from the crown being alternately on the right and left of the crown. Such sections shall be normally 3 m apart. The exact location of the holes may be varied or additional holes provided depending upon the actual excavation profile at any section. The exact spacing of sections may also be varied on similar considerations. It should, however, be also adjusted to suit the length of the arch shutter used in such a way that there is no hole at the joint and the normal pattern of holes is more or less uniform in the shutter length.

4.1.4.1 In the case of circular or horse-shoe tunnels, in addition to these holes, two holes (one on either side), located roughly at 45 degrees on either side of the invert should be used. The location should be such that the holes are about 45 to 60 cm, above the junction of the invert and arch.

4.1.5 The mortar used for backfill grout shall normally consist of cement, sand and water mixed in the proportion of 1 : 1 : 1 by weight. It may, however, be suitably modified if site conditions so warrant. The size and grading of sand should be determined for each job by actual experimentation as it would depend on the type of sand and equipment available.

4.1.6 Backfill grouting should normally be done at a pressure of 2 kg/cm².

4.2 Contact Grouting

4.2.1 The aim of contact grouting is to fully pack up the space between the concrete lining and the rock surface or the space between the steel liner and concrete lining caused by shrinkage or left unfilled even after backfill grouting. This is required for fulfilling the design assumption of the rock/concrete taking part of the load along with the lining and to prevent local accumulation of water, if any, and building up local pressures.

4.2.2 Contact grouting should be done after the concrete lining has gained strength to withstand the pressure and shrinkage, if any, has taken place. The usual minimum period of 25 to 28 days of waiting should be allowed.

4.2.3 The contact grouting should be limited to only the top arch (90° on either side of the crown) of tunnels. In case of vertical shafts and steel liner, contact grouting should be done along the full periphery. In case of steel liners, the grouting should be done usually at specific points as is recommended in the ' Indian Standard code of practice for construction of tunnels: Part VI Steel lining ' (*under preparation*)*.

NOTE — Until the standard under preparation is published the details of grouting in case of steel liners are left to the discretion of the Engineer-in-Charge.

4.2.4 The holes at the crown shall be placed 5 to 10 degrees from the crown, being alternately to the left and right of the crown. In addition to the crown hole, there shall be two more holes one on either side of the crown in each section. These holes will be 90° apart and will be located such that one of the two holes is at 22½° from the crown, being alternately on the right and left of the crown. Such holes shall normally be 3 m apart.

4.2.4.1 In the case of circular or horse-shoe tunnels, in addition to these holes, two holes (one on either side), located roughly at 45 degrees on either side of the invert should be used. The location should be such that the holes are about 45 to 60 cm above the junction of the invert and arch.

4.2.5 The depth of holes for contact grouting shall be such that at each location, the holes extend 30 cm beyond the concrete lining into rock.

4.3 Consolidation Grouting

4.3.1 The aim of consolidation grouting is to fill up the joints and discontinuities in the rock up to the desired depth.

4.3.2 Consolidation grouting shall always be done after the backfill grouting is completed in a length of at least 60 m ahead of the point of grouting.

4.3.3 Consolidation grouting should be usually done all round the bore, and for a uniform radial distance from the finished concrete face. The depth of the holes to be drilled which determine the depth of the rock to be grouted should be determined by the designer based on the design of the concrete lining and the extent to which cracks are assumed to extend in rock when the lining is stressed by internal pressure. Usually the depth should be between 0·75 D and D where D is the finished diameter of the tunnel, except in special reaches where it could be more.

NOTE — The maximum depth so far used in the country is about 15 m.

4.3.4 The pattern of grout holes for consolidation may be a set of holes in one vertical plane, such a plane being called the grout plane. The spacing of the grout planes will depend upon the structural formation of rock and the travel of grout at the specified pressure. The exact spacing

*Since printed as IS : 5878 (Part VI) - 1975

as in the case of contact grouting should also be adjusted in the field to suit the length of the shutter used for concreting. In this plane the number of holes may normally be 4 for small size tunnels, and 6 for large size tunnels. The arrangement should be staggered in alternate grout planes, by about half the spacing between the holes along the periphery in the plane. In special locations the number of holes may be increased. The top three holes in grout pattern may be used for both backfill, contact and consolidation grouting.

4.3.5 Around shafts and large opening like powerhouse, the grout pattern will be similar, but the number of holes in the plane may be increased depending on the size, but the spacing should not generally exceed the depth of the hole.

4.3.6 Contact grouting would not generally be necessary where consolidation grouting had been done. However, it should be decided by actual contact grouting in jump holes after consolidation grouting.

4.3.7 Depending upon the rock formations and the grout intake, the consolidation grouting should be done in one or more stages with increasing pressures.

4.3.8 Maximum grout pressure should not normally exceed twice the design load on lining or supporting system as the case may be.

5. PRESSURE TO BE USED FOR GROUTING

5.1 The pressures to be used for grouting will depend on the rock characteristics, the design requirements and the rock cover. With adequate rock cover, (more than 3 times the diameter of the tunnel), the other two will govern. For backfill grouting the maximum pressure recommended is 5 kg/cm^2. For consolidation grouting a maximum pressure of 7·0 kg/cm^2 is normally recommended but this may be increased up to 20·0 kg/cm^2 in special cases provided that there is adequate cover and the joints in the rock are not likely to open up by this pressure.

5.2 The pressure gauge should be watched constantly so that the pressure on the grout is regulated as long as grouting is in progress. Any desired increase or decrease in the grouting pressure is obtained by changing the speed of the grout pump. When the grout in the supply line becomes sluggish, the grout-hole valve should be closed and the blow off valve is opened so that the supply line may be flushed or washed.

6. OPERATIONS

6.1 General — The process of grouting consists of the following operations:

a) Drilling holes,

b) Cleaning and washing holes,

c) Testing holes — pressure testing or water testing,

d) Grouting holes, and

e) Testing the grouted zone for efficacy of grouting.

6.2 Drilling — The size of holes to be drilled is generally decided by the depth of the hole to be drilled and the inclination of the holes. In all underground work, it is recommended that drilling through the lining should be avoided to the maximum extent possible. This is generally feasible since the general pattern is fixed before hand and black iron or galvanized pipes are placed in position while concreting. This ensures that the holes are located to the particular pattern and avoids unnecessary damage to concrete lining. It is very important that pipes are put in location of holes in the case of reinforced lining or where heavy steel supports are provided as this will avoid the expense of unnecessary trial holes that would have to drill to avoid drilling through reinforcement. A recommended method for guarding against the pipes getting filled up with concrete or mortar when concreting is to fill them solidly with moist earth just before these are fixed in position on the shutter. The usual nominal size of holes in underground works is 35 to 40 mm. The usual size of pipes embedded in concrete lining for drilling holes is 50 mm internal dia.

6.2.1 *Method of Drilling* — For pack grouting where the holes are drilled only to 15 cm in the rock, percussion drilling using an ordinary jack hammer is recommended. For consolidation grouting either percussion drilling or rotary drilling may be used. Rotary drilling is recommended where cores are required, and where the grouting has to be done using packers.

NOTE — With rotary drilling the EX size holes are usually adequate. Percussion drilling being faster and cheaper, is usually preferred. Percussion drilling cannot be done through clay, especially if the clay is moist and rotary drilling has to be used in such cases.

6.2.2 *Drilling Equipment* — The drilling equipment shall be capable of drilling holes of the required diameters and depths. It shall be operated by compressed air and should be equipped to provide for a continuous water or air flushing.

6.2.3 *Drilling Sequence* — It is preferable to drill a hole and grout it before drilling the adjoining hole in the same plane or in another plane since this will avoid the blocking of holes by the flow of grout if the adjoining holes are interconnected. However, if the construction schedule so requires and drilling is a time consuming part of the operation, the holes may be drilled in advance and a sequence evolved to avoid blocking of previously drilled holes to the maximum extent possible without too much movement of drilling rig. In case of pack grouting the side holes should be drilled and grouted first, before drilling and grouting the crown holes.

Depending on construction difficulties, for consolidation grouting, the drilling and grouting are recommended to be done from invert upwards doing the crown holes last. However, where the invert hole is exactly at the bottom and it cannot be drilled and grouted without interfering with other operations in the tunnels this should be done last.

6.3 Injection — Holes should be injected by direct connection to the grout pump. Each bore hole should be provided with a short standpipe threaded at the outer end to accept a manifold which should be provided with a pressure gauge, a relief valve and a valve enabling the delivery from the pump to be cut-off from the hole. A return grout line, equipped with a pressure relief valve can be set to open at any required pressure, may be connected to the manifold as a precaution against the application of excessive pressures. The return line should be led back to the mixing tanks in order to avoid unexpected discharge of grout into the working area. The valve for the return line may also be operated manually. When the pump discharge and pressure can be regulated at will in any desired combinations with compressed air operated pumps or pumps driven by a fluid under pressure, the use of return lines is not obligatory.

6.3.1 Once the grouting of a hole has been commenced it should be continued without interruption until completion. In general, grouting should be considered complete when the intake of grout at the desired limiting pressure is less than 2 l/min, averaged over a period of 10 min, for pressures more than 3·5 kg/cm^2 or 1 l/min for pressures lower than 3·5 kg/cm^2.

6.3.2 As far as practical, a continuous flow of grout should be maintained at the desired pressure and the grouting equipment shall be operated to ensure continuous and efficient performance throughout the grouting operation. If any hole continues to absorb large quantities of the thickest pumpable grout at low pressure, the injection may be suspended overnight and then resumed next day.

6.3.3 Should any hole connect to another during injection, the grout should be allowed to escape from the coupled hole till it is of the same consistency as that being injected; the coupled hole should then be capped and the combined holes brought up to pressure and grouting continued. It is not always necessary to grout again through such connected hole. Where leakages of grout occur on the surface, they should be stopped by caulking with wooden wedges, cement, etc.

6.3.4 Grouting shall be stopped whenever pressure gauges register a sudden drop of pressure or the rate of grout absorption increases abruptly or there is any indication of upheaval, disturbance or leakage. In such cases grouting may be resumed at a lower pressure but the efficacy of the grouting operation may be compromised by the temporary interruption.

6.3.5 The control of grout mixtures is not amenable to rules which can be fixed in advance and sufficient discretion should be left to the field personnel. In 7.3.1 the guiding principles for selecting grout mix proportions are discussed. As a general principle grout mixtures should not be thickened, if pressure starts to rise after continuous injection over a period of 10 minutes.

6.3.6 After grouting is completed the grout holes should be closed by means of a valve to maintain the grout pressure for a sufficient period to prevent escape of the grout due to back pressure and flow reversal. For this purpose a period of one hour is generally sufficient, however, this should be verified by trial.

6.4 Testing for Efficacy of Grouting — This testing may be done by drilling the holes in between the grout planes and by testing water intake in these test holes. If this is compared with the water test made before the grouting, this water test will give an indication of the efficacy of grouting. Further grouting of this test hole and intake in this hole will give further indications. It is only after these tests that the engineer-in-charge may decide on increasing the number of grout planes if required.

7. GROUTING EQUIPMENT

7.1 Grouting System Arrangements

7.1.1 *Manifold or Header* — A grout manifold is a 'T' arrangement of pipe and various fittings, such as couplings, nipples, unions, tee valves and pressure gauge all attached to the grout hole. The functions of the manifold are the following:

a) To permit regulation of the flow of grout into the hole,

b) To maintain the desired allowable grout pressure,

c) To allow any excess grout to be drained from the system or returned to the agitator tank for recirculation, and

d) To close off the hole when washing the supply lines.

7.1.1.1 Manifold designs vary and depend on the type of grouting system.

7.1.2 *Single Line System* — The single line system, as the name implies, consists of one grout supply line from the pump to the grouting manifold at the hole.

7.1.3 *Circulating System* — The circulating system requires two pipe lines, a supply line from the grout pump to the grout hole and a return line from the grout hole to the agitating pump. By opening the supply and grout-hole valves, grout is forced into the hole as required. Pressure is maintained by adjusting either the supply valve or the return valve or

both. Complete control of the pressure is maintained at the hole. No grout is wasted when washing out the grout lines and close control of the grouting operations is maintained. When direct electric or diesel drive pumps are employed, use of a return line is obligatory.

7.2 General Requirements of Grouting Equipment

7.2.1 The grouting equipment should meet the following requirements:

a) Of sufficient size of supply to the maximum demand for grout,

b) Capable of prolonged operation at anticipated maximum pressures,

c) Of sufficiently rugged construction to minimize delays from failure of some essential part,

d) Permit quick cleaning by washing, and

e) Provide quick access to key parts in case of mechanical failure.

7.2.1.1 Continuity of operations is mandatory not only for efficiency but also for effectiveness of the grouting.

7.2.2 *Grout Mixers* — Mixers are generally cylindrical in shape, with the axis either horizontal or vertical and equipped with a system of power-driven paddles for mixing. Some mixers use a high-speed centrifugal pump for mixing. Vertical, barrel-type mixers have proved satisfactory when small mixers are required for use in confined or limited working spaces. This type of mixer consists essentially of a vertical barrel having a shaft with blades for mixing, driven by a motor mounted on top of the mixer above the barrel. Centrifugal pump mixers mix the grout by recirculating it through a high revolution per minute centrifugal pump.

7.2.3 *Grout Pumps* — A pump suitable for grouting should permit close control of pressures, allow a flexible rate of injection and be designed to minimize clogging of valves and port. Grout pumps are of three types, piston, screw and centrifugal. Piston type pumps may be powered by compressed air, or electric motors. One of the most common types is the air-driven duplex, double acting pump with special fittings for cement-grout service. Screw type pumps are simple to operate, easy to clean and can be readily transported because of their light weight. They are particularly advantageous in grouting 'slow take' holes and in pumping sand-cement grouts. Centrifugal pumps in a number of models have been used for pressure grouting. Where large volumes of grout are to be pumped rapidly at low pressure centrifugal pumps are satisfactory. Their weak points are the bearings that may be cut out by the abrasive action of the grout, and the difficulty in cleaning. They are not satisfactory for slow pumping over prolonged periods.

7.2.3.1 For underground work the air-driven duplex double acting pumps are recommended to be used as it is possible to vary the pressure and intake in a wide range easily with such pumps.

7.2.3.2 Pneumatic grouting machines are not recommended for consolidation grouting because they do not readily admit of control on grouting pressure, at will during the grouting operations. With pneumatic machines it will not be possible to start with low pressure and build up the pressures gradually. However, for contact grouting where grouting is done at low pressure, and where the control of pressure is not very important and especially where the contact grouting is done with mix of cement sand mortar, these grouters are recommended to be used.

7.2.3.3 Although the use of the duplex type pump is better for contact grouting, the pumping of cement mortar grout through such machine is slow and costlier than injecting grout with pneumatic grouters.

7.3 Grouting Materials

7.3.1 Grouting should be done with cement conforming to IS : 269-1967* or IS : 455-1967†.

7.3.2 *Grout Mix* — Grout mixes may vary from a very thin mixture of 20 : 1 to thick mixture of 0·5 : 1 (ratios of weight of water and cement). The normal range mixtures falls between 5 : 1 to 0·8 : 1. The choice of the grout mixtures at the start of the grouting operations may be based on the results of water tests prior to grouting or intake of holes already grouted.

7.3.3 If the grout is too thick, passage of grout travel may get obstructed at a short distance and the fine seams may not be filled up. On the other hand if thin grout is continued for too long a time the grouting operation may get unduly prolonged and may be rendered unduly expensive. No general rules may be stipulated regarding the manner in which the thickening of the grout is to be carried out. The appropriate sequence for every site may be decided after a review of the results of initial grouting. As a guide the mix should be thickened if there is no increase in the pressure after a continuous grouting of about 10 min or after two batches of four bags of cement each have been pumped. In the case of contact grouting the mix generally used may be the thickest mix namely 0·5 to 1.

7.3.4 *Additives in Grouting* — It is generally advisable to carry out both pack grouting and consolidation grouting with mixture of cement and water only. If intake is heavy and it is desired to keep down the cost of grouting, the grout may be thickened by using inert material like pozzolanas, fine sand, rock powder, clay or bentonite.

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*Specification for ordinary, rapid-hardening and low heat Portland cement (*second revision*).

†Specification for Portland blastfurnace slag cement.

7.3.5 Where it is necessary to inject porous or finely fissured rocks which will not accept cement or where it is necessary to block flowing water, chemical grouts with or without cement may be tried. In such cases additives to accelerate the setting time of cement may also be used. Where such additives are used along with cement it is recommended that the additives should be added at the manifold and not in the grout mixture or in the grout pump to avoid the danger of clogging of the grout lines in case of any interruptions.

8. RECORDS

8.1 It is necessary that accurate records of grouting should be maintained regularly so that it is possible for the engineer-in-charge to make any changes that may be required in grouting patterns or sequences. The records to be maintained shall indicate the following data:

a) Co-ordinate of the hole;

b) Depth of the hole;

c) Features of grouting — pack grouting or consolidation grouting;

d) Results of pressure test, if carried out;

e) Time and date of starting the grouting of the hole;

f) Consumption of grout separately for each type of mix used and the time required to inject the particular mix along with the pressure developed during the grouting of each mix;

g) Time of completion of hole;

h) Total quantity of cement and other materials used for each hole;

j) Cement wasted;

k) Stoppages, if any, and reasons for stoppage; and

m) From this data the rate of injection of each type of mix for the pressure range should be calculated and recorded.

8.2 Remarks — Remarks should indicate if any holes are abandoned, reasons for abandoning the holes and also the connections to any other holes, leakage, if any, and any other information.

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