भारतीय मानक

नदी घाटी परियोजनाओं में शैल नीवों का दाब अभिपूरण — सिफारिशें

(दूसरा पुनरीक्षण)

Indian Standard

PRESSURE GROUTING OF ROCK FOUNDATIONS IN RIVER VALLEY PROJECTS — RECOMMENDATIONS

(Second Revision)

UDC 627·81 : 624·159·4 : 666·972·033·14

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March 1994 Price Group 7

Foundation and Sub-structures Sectional Committee, RVD 8

FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Foundation and Sub-structures Sectional Committee had been approved by the River Valley Division Council.

The treatment of rock foundations by pressure grouting is an art of applying the knowledge of local geology and certain basic principles, covering grout penetration and travel, to the specific requirements of a job. The success of a grouting job depends on a coordinated handling of all the technical and organizational aspects of the work comprising exploration, establishing design requirements, initial trials, field control and final testing and evaluation. It would be futile to prepare a rigid set of rules or stipulate standard procedures which can be enforced without leaving any latitude for the exercise of discretion by the site engineer. The aim of these recommendations is to summarize well known and proved principles and to describe commonly used procedures, equipment and techniques in order to enable an engineer-in-charge of a grouting job to provide guidelines for a specific case. The need for following an experimental approach and learning through trial is emphasized while providing guidelines which would permit a site engineer to use his discretion without compromising the overall design requirements. This standard has been formulated to give guidance in this regard.

This standard was first published in 1971 and was revised in 1984. Based on experience gained in the use of this standard this further revision was taken up. The salient changes made in this revision are providing the guidelines for testing the efficacy of the grouting operation besides updating other provisions in light of latest Indian Standards.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

PRESSURE GROUTING OF ROCK FOUNDATIONS IN RIVER VALLEY PROJECTS — RECOMMENDATIONS

(Second Revision)

1 SCOPE

This standard lays down recommendations for pressure grouting of rock by cement with and without suitable admixtures and fillers, applicable to curtain and consolidation grouting generally used in River Valley Projects.

2 REFERENCES

The Indian Standards listed in Annex A are necessary adjuncts to this standard.

3 GENERAL

3.1 Pressure grouting of rock foundations is normally carried out to fill discontinuities, cavities or voids in rock mass by suitable materials. The grouting programme should aim at satisfying the design requirements economicallyand in conformity with the rest of the construction schedule. The design requirements for adopting a grouting programme are as under. The parameters will depend on the type of structure.

A) *Curtain grouting*

i) To safeguard the foundation against erodibility hazard, and/or

ii) To reduce quantity of seepage.

B) *Consolidation grouting*

iii) To reduce the deformability of jointed or shattered rock.

3.1.1 Even though the overall objective is to reduce the permeability of the rock foundation, the relative emphasis between control of the rate of seepage and control of uplift depends on the value of the water stored and the nature of foundation strata. In cavernous and highly jointed rocks the reduction of the rate of seepage may be an important safety consideration. On the other hand in massive relatively unweathered rocks, the quantity of seepage may not be of consequence, as long as the desired reduction in uplift pressure is achieved. In such cases, uplift control may be achieved primarily by drainage while the aim of grouting would be to ensure that local concentrations of seepage do not occur which are liable to impair the efficiency of the drainage system.

3.2 Before arriving at design requirements for any job the primary objectives should be defined, for example, reduction of rock deformability, etc. The depth, spacing and pattern of grout holes, the choice of method of grouting, materials injected and consumption limits as well as controls on pressure depend on the objectives as described in **3.1**. These controls and criteria would have to be established by trials and it is desirable to establish the programme of trials at the initial stages of the work.

3.3 The criterion given in **3.3.1** and **3.3.2** are suggested for deciding whether or not to grout any portion or zone of rock. Overall design requirement, importance of the structure and the value of water as well as geological conditions should also be taken into consideration.

3.3.1 *To Safeguard the Foundation Against Erodibility Hazards*

The limiting lugeon values given in Table 1 are recommended for deciding the necessity or otherwise of grouting. Lugeon values in excess of those given in the table would indicate that grouting is desirable.

Table 1 Suggested Limiting Lugeon Values from Erodibility Considerations

Item	Rock Below Cutoff Trench	Rock Below Masonry Dam
Group A Laminar flow	5 to 10	5 to 7
Group B Turbulent Flow	3 to 5	3 to 5
Group C Dilation	1 to 3	1 to 3
Group D Washout and Hydraulic fracturing	1 to 3	1 to 3
Group E Void fill	3 to 5	3 to 5

3.3.2 *To Reduce Quantity of Seepage*:

i) For dams exceeding 30 m height, curtain grouting should be carried out when the water absorption exceeds one lugeon.

ii) For dams under 30 m height, curtain grouting should be carried out where the water absorption exceeds 3 lugeon.

4 COORDINATION WITH OTHER CONSTRUCTION ACTIVITIES

4.1 Grouting operations are generally nter-dependent with other construction operations; for example, excavation and blasting in the vicinity of the area that is being grouted may cause leakage of grout and render the grouting operation ineffective or it may be necessary to complete the grouting operations to enable a start to be made of other operations, such as concreting or masonry work. Sometimes it may be necessary to carry out grouting before removal of the overburden to obtain the necessary load of surcharge over the zone required to be grouted. In other cases removal of the overburden may be necessary to facilitate sealing of the cracks prior to grouting. Draining holes should always be drilled only after grouting is completed within the expected distance of grout travel. Generally, it is preferable to complete blasting before taking up grouting operations. If blasting after grouting is unavoidable, thorough testing and regrouting is essential after blasting.

4.2 A drainage and grouting gallery is a commonly used device to facilitate grouting after placing the masonry or concrete in the foundation and ensuring that the necessary cover of concrete is obtained, to enable the desired grouting pressures to be developed. Sometimes holes are drilled in the foundation and GI pipes left in place, through the masonry or concrete, and the foundation grouted through these pipes later.

4.3 It is difficult to make general stipulations regarding the coordination of grouting with other construction activities, but it would be evident from the above that careful planning of all associated construction activities, such as excavation, concreting, fill placement, drilling of drainage holes and their coordination with grouting is essential for successful execution of the grouting programme.

5 RELATION OF GEOLOGY TO GROUTING, THE IMPORTANCE OF FOUNDATION EXPLORATION AND INITIAL EXPERIMENTATION

5.1 Reliable geological interpretation of the type, distribution, approximate size and direction of discontinuities, voids, cavities, etc, in the foundation rock is necessary prior to grouting.

5.1.1 The sub-surface conditions should be investigated by core drilling a number of holes in the foundation area. Percolation tests should be conducted in the holes within the open area of the foundation charted for use in planning the grout treatment. When investigation holes have served their purpose, they should be completely filled with grout (*see* IS 5313 : 1980).

5.1.2 The grouting programme should be conducted in such a manner that the initial experimentation generally covers all the typical geological situations.

5.1.3 The depth, spacing and orientation of grout holes should be related to the geological features; for example, inclined holes should be preferred when the rock permeability is primarily due to closely spaced vertical/sub-vertical system of joints. It is sometimes necessary to evolve a pattern of holes consisting of different sets of holes appropriate to each type of discontinuity, such as bedding planes, system of joints and lava contacts.

6 GROUTING METHODS

6.0 Rock grouting consists essentially of drilling a series of grout holes in rock and injecting grout under pressure, which eventually sets in the openings and voids in the rock. The drilling and grouting operations can be carried out either to the full depth in one operation or in successive depths either by stage grouting or by packer grouting.

Grouting in the valley should proceed from river bed towards abutments.

6.1 Full Depth Grouting

In the full depth method each hole is drilled to the full desired depth, washed, pressure tested and grouted in one operation. This method is usually limited to short holes, 5 m or less in depth, or holes up to 10 m that have only small cracks and joints with no risk of surface leakage. In deep bore holes high grouting pressures have to be used to achieve proper penetration of the grout at an economic spacing of holes. As full depth grouting involves the risk of disturbance in the upper elevations, it is not generally considered suitable for grouting deep holes. For grouting in heterogeneous strata, where the nature of rock discontinuities is subject to large variations in relation to the depth, full depth grouting is not recommended and stage grouting is preferred to packer grouting in such cases.

6.2 Stage Grouting

6.2.1 Stage grouting is conducted to permit treatment of various zones individually, by grouting successively increasing depths, after sealing the upper zones. Stage grouting, in descending stages, can be carried out by adopting the procedure given below.

6.2.2 Grouting is done by drilling the holes to a predetermined depth and grouting this initial depth at an appropriate pressure. Grout is then washed from the hole prior to its final set (within 2-4 hours) and the hole deepened for the next stage. Alternatively the grout is allowed to harden and redrilling is carried out through the hardened grout and the hole extended to the next stage. In another procedure called the one stage redrilled method, which is sometimes used, grout is washed out within a small depth of the top of the stage being grouted and only one stage is redrilled for proceeding to the next stage. In each of the above procedures the cycle of drilling-grouting-washing or redrilling is repeated until the required depth of the hole is reached.

6.2.3 For stage grouting, the connection at the top of the hole can be made directly to the header or by seating a packer at the top of the hole in the casing pipe. Alternatively, it is sometimes advantageous to install a packer immediately above the stage that is being grouted in order to isolate the upper portion of the hole. Higher pressures can then be permitted for grouting of the lower stage without causing upheaval in the higher stages.

6.2.4 An alternative procedure would be to withdraw the grout pipe, after completing the grouting operation, by a distance equal to the depth of the stage grouted. After the initial set occurs, that is, about half an hour, the portion of the hole above the stage grouted may be washed. In this method the grout sets in the length of one stage and it is necessary to redrill one stage before proceeding with further grouting. It is more convenient to install the packer at the top of the hole when one-stage redrilling procedure is adopted.

6.2.5 Grouting with double packer is suitable where a few well defined seams or zones exist and the packers can be seated above and below such zones. Rotary drilling method is preferred when double packers are used.

6.2.6 When packers can be seated and there is no risk of upheaval, grouting can be carried out with single packer in ascending stages.

6.2.7 However, in many cases packers may function yet grout may overtravel and cause upheaval in the zones above the section being grouted. The method of stage grouting in descending order is therefore a more dependable method for badly jointed and fissured strata vulnerable to upheaval.

6.2.8 In relatively compact rocks it may be more convenient to seat the packer at the top of the stage being grouted. The hole may then be washed, as soon as the period of initial set of cement is over, to the entire depth of the hole up to the bottom of the stage in progress.

6.2.9 On the other hand in strata vulnerable to upheaval, it may be necessary to allow the grout to set and form a sheath around the hole in order to enable high pressures to be used in the lower portions of the hole. In such cases, the washing and single stage redrilling procedure would have to be adopted.

7 PATTERN AND DEPTH OF HOLES AND SEQUENCE OF GROUTING

7.0 The pattern and depth of holes is governed primarily by the design requirements and the nature of the rock. When the purpose is consolidation, the holes are arranged in a regular pattern over the entire surface area required to be strengthened and the depth is determined by the extent of broken rock as well as the structural requirements regarding the deformability and strength of the foundation. When the purpose is impermeabilization, the grout holes are arranged in a series of lines to form a curtain approximately perpendicular to the direction of seepage. The depth of holes is dependent on design considerations as also on the depth of pervious rock and the configuration of zones of relatively impervious strata.

7.0.1 The size of grout holes is generally less important than the cost of drilling holes and the control of inclination. For grouting with cement, 38 mm holes are used. The advantage gained by drilling large holes does not often justify the increase in drilling costs. In long holes the diameter at the top of the holes may have to be larger than the final diameter at the bottom of the hole to facilitate telescoping or to allow for the wear of the bit.

7.1 Patterns of Holes for Curtain Grouting

7.1.1 *Single Line Grout Curtains*

Single line grout curtains are effective only in rocks having a fairly regular network of discontinuities with reasonably uniform size of openings. In such cases a curtain of adequate width can be achieved by grouting a single line of holes. In massive rocks with fine fissures, uplift control is primarily achieved by drainage and the grout curtain is used only as a supplementary measure to avoid concentrations of seepage which may exceed the capacity of the drainage system. Single line curtain may serve this limited objective in comparatively tight rock formations.

7.1.1.1 In single line curtains it is customary to drill a widely spaced system of primary holes, subsequently followed by secondary and tertiary holes at a progressively smaller spacing. The usual practice is to split the spacing from primary to the secondary and secondary to tertiary phase. One of the criteria for deciding on the primary spacing is the length of expected intercommunication of grout between holes. The initial spacing usually varies between 6 m to 12 m but the choice of spacing should be based on the geological conditions and on experience. At every phase of the grouting operation, the results of percolation tests and grout absorption data should be compared with the previous set of holes in order to decide whether a further splitting of the spacing of holes is worthwhile. When no significant improvement is noticed either in terms of decrease of the grout absorption or water percolation, careful review should be made of the rock features, the nature of the rock and its relations to the patterns of holes. Sometimes it may be more advantageous to drill another line of holes at a different angle and orientation than to split the spacing further. Spacings below one metre are rarely necessary and the requirement of a spacing closer than one metre may often indicate an unsuitable orientation and inclination of holes. Possibly multiple line curtains may be necessary. If the area is too limited, the setting time of the grout becomes important since it is not desirable to drill too close to a freshly grouted hole. Before pressure grouting is started, drilling of all the holes should be completed within a distance of 20 m of the hole to be grouted.

7.1.1.2 Depending upon initial investigation and strata conditions the spacing of primary hole treatment should be decided. If the primary holes were spaced more than 6 m apart secondary holes should be drilled and grouted. On completion of primary holes spaced closer than 6 m or secondary holes (when the primary holes are spaced more than 6 m), should the percolation tests carried out in a few test holes indicate that further grouting of the area is necessary, secondary or tertiary treatment, as the case may be, should be carried out systematically thereafter in the whole area or in the particular section where the rock conditions are bad. Similarly tertiary holes should be taken over the whole area or the full length of the section which requires the treatment.

7.1.1.3 In addition to the systematic grouting of primary, secondary or tertiary and subsequent holes it may be necessary to drill and grout additional holes for treatment of peculiar geological features, such as faults, shear zones and weathered rock seams.

7.1.2 *Multiple Line Grout Curtains*

In rocks with a wide range of sizes or openings, cavities and discontinuities which are irregularly distributed, a single line curtain may not be effective. The larger openings may absorb excessive volumes of grout, if high pressures and thin grouts are used. On the other hand thicker grouts (1 : 1 or thicker, or grouts with fillers) used for sealing the larger openings may block the sides of holes and prevent penetration into finer cracks. In such cases it may be advantageous to use a multiple line curtain consisting of outer lines which are drilled and grouted initially with thicker grouts. It may sometimes be difficult to treat the outer rows of holes to refusal and grouting may have to be stopped after injecting a limiting volume of grout which may be arrived at on the basis of experience and/or initial trials. After completing the grouting of outer holes, intermediate line, or lines, of holes may be drilled and grouted at comparatively higher pressure with thinner grouts. Grouting of the outer rows which is carried out initially facilitates confinement of grout and thus ensures effective subsequent treatment of inner cracks at higher pressure through the central row or rows of holes. The final spacing of inner and outer rows may be different in a multiple line pattern, the spacing in each row being governed by the nature of rock discontinuity, intended to be treated by the particular row. In any case in the central row the split spacing method should be followed until the desired degree of impermeabilization is achieved.

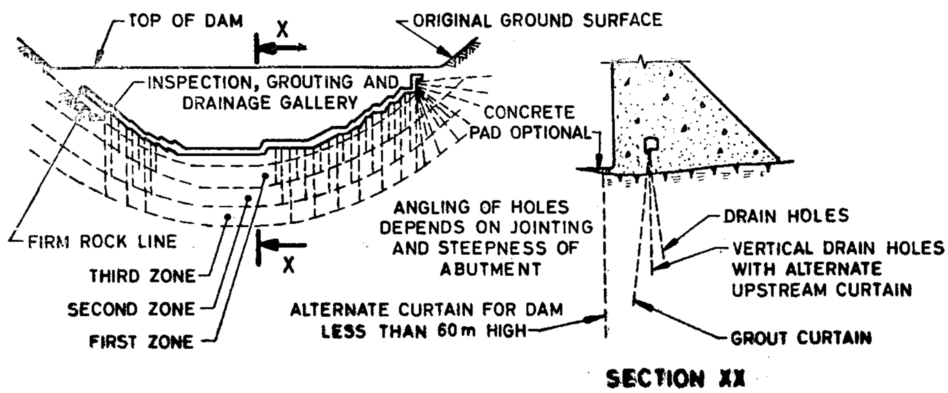
7.2 Pattern of Holes for Consolidation Grouting

7.2.1 The choice of pattern of holes, for consolidation grouting depends on whether it is necessary to wash and jet the hole systematically (*see* **10.4**). When washing has to be carried out a hexagonal pattern (*see* Fig. 1) would be preferred as this admits for flow reversal. When systematic washing and jetting is carried out to remove all soft material in seams it is generally not necessary to use a primary and secondary system of holes.

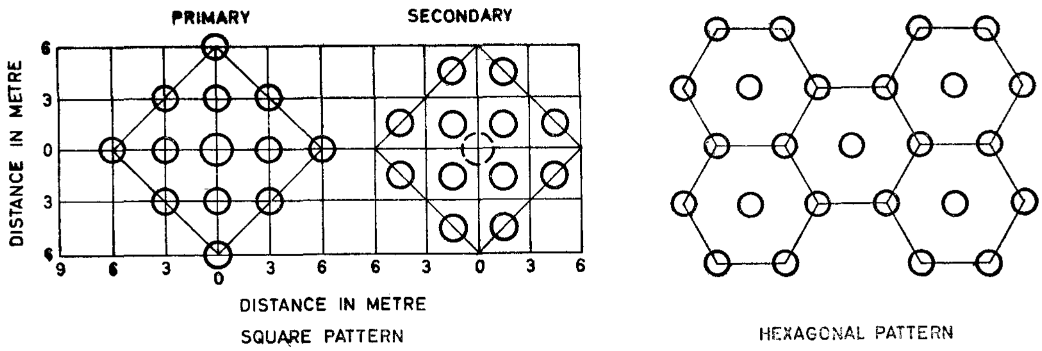
7.2.2 When it is desirable to test the efficacy of consolidation grouting by comparing the grout absorption in primary and secondary holes a rectangular or square pattern (*see* Fig. 1) of holes would be preferred. This is generally the case when the joints are irregular and relatively free from in-filling or it is not necessary to remove the material filling the joints.

7.3 Sequence of Grouting

7.3.1 While carrying out grouting operations it is necessary to ensure that no hole is drilled so



1A Typical Profile of Curtain Grout Holes



1B Consolidation Grouting

FIG. 1 PATTERNS OF GROUT HOLES

close to a hole being grouted that inter connections develop. Spacing between primary holes is generally so selected that the drilling could be carried out without interference from grouting due to inter-connections from adjoining holes. Sometimes a situation arises when drilling of upper stages of secondary holes may be in progress concurrently with the grouting of the deeper stages of primary holes. In such cases, inter-connections would not be prevented if a sufficient cover of rock is not available between the portion which is being grouted and the zone in which the drilling of secondary holes may be in progress. As a rule the drilling of secondary holes in any zone of the foundation shall not be taken up until sufficient cushion of already grouted stages of primary holes in the same area is not available.

7.3.2 In multiple line curtains relative sequence of outer and inner rows shall also be strictly followed as described in **7.1.2**.

7.3.3 When grouting in rock overlain by pervious soil it is necessary to complete grouting of the contact zones of the rock and soil before commencing the grouting of the rock otherwise the grout would escape into the soil and it may not be possible to control or detect excessive leakage.

8 GROUT MIXTURE

8.1 Rock grouting is usually performed with a mixture of cement and water with or without additives.

8.2 The cement generally used is any of the following:

i)	Ordinary Portland	— IS 269 : 1989 or IS 8112 : 1989 or IS 12269 : 1987
ii)	Portland Pozzolana	— IS 1489 (Part 1) : 1991, (Part 2) : 1991
iii)	Portland Slag	— IS 455 : 1989
iv)	Supersulplated Cement	— IS 6909 : 1990
v)	Sulphate Resisting Portland	— IS 12330 : 1988

8.3 Other solid materials may be used as additives to the grout mixture among which are the following:

a) Pozzolanas, such as fly ash (*see* IS 3812 : 1981) and calcined shale (*see* IS 1344 : 1981). As early strength is important on most grouting jobs, the pozzolanas may behave only as inert non-cementing fillers.

b) Fine sands (*see* IS 383 : 1970) are an economical material widely used in grouting. The use of coarse sanded grout mixtures is particularly advisable when large voids or cavities are to be grouted.

c) Other fine non-cementitious materials like bentonite (*see* IS 12584 : 1989) clay and silt may also be used. These materials add to the bulk of the grout mixture and reduce the cost but also reduce the strength and may reduce the watertightness of the hardened grout. However, bentonite when used in small quantities offers certain advantages in reducing bleeding and segregation.

8.3.1 While using additives, constant field checks and review should be undertaken to achieve the desired results in respect to permeability and strength.

8.4 Admixtures

Admixtures when added in small quantities to the grout mixture impart certain desirable characteristics like delaying or hastening the setting time and increasing the workability (*see* IS 9103 : 1979).

8.5 Water

The water for grout mixtures should be clean and generally free from organic material that would affect hardening or durability. A sample should be tested to determine if the water contains any deleterious materials.

8.5.1 Where the grouting is being done below the ground water table, the ground water should be analyzed for its salt contents and *p*H value, which may affect the rigidity and thixotropy of the grout.

8.6 The grout should fulfil the following requirements whatever be the constituents used and their proportions:

a) The set product should have desired strength to resist extrusion under the hydrostatic pressure to which the curtain will be subjected;

b) When grouting for consolidation, the set product should have desired strength;

c) The set product should have a sufficient degree of permanence to satisfy the requirements of the site. On important jobs products of proven long-term performance should be used; and

d) Particles in the liquids should be small enough to penetrate the pore spaces of encountered fissures.

9 DRILLING AND GROUTING EQUIPMENT

9.1 Drilling Equipment

9.1.1 The equipment should be capable of drilling holes of sizes described in 7 and to the required depths. The equipment should be capable of providing a continuous water or air flush of adequate capacity.

9.1.2 The various types of drilling equipment can be grouped as under:

a) *Percussive drilling equipment*:

i) Standard drifter or wagon drill;

ii) Down the hole drilling equipment; and

iii) Overburden drilling equipment.

b) Rotary drilling equipment with suitable drive, that is, hydraulic, electric, diesel or compressed air.

9.1.2.1 Percussive drilling methods are generally more economical in all types of rocks. For deep holes it may be advantageous to use overburden drilling equipment. By virtue of the separate rotation drive, greater speed and economy can be achieved, also by virtue of the greater rigidity of casing tube combined with the drill rods, better control on inclination of holes can generally be achieved in the overburden drilling equipment. Down the hole hammer is also capable of maintaining a better control on the inclination. However, the hammer may get clogged when the drill cuttings form slush in soft saturated strata and cannot be removed by air flushing.

9.1.3 During percussive drilling in stratified rocks where the resistance of the rocks is prone to variation the holes may get curved and control on inclination may be lost. In such cases guide tubes may be used for ensuring verticality of the holes or alternatively rotary drilling may be used.

9.1.4 Irrespective of whether air or water is used for flushing the hole during drilling, thorough cleaning by water flushing is essential before starting grouting operations.

9.2 Grouting Equipment

The grouting equipment should meet the following requirements:

a) Be of sufficient size to meet the maximum demand for grout;

b) Be capable of prolonged operation at anticipated maximum pressure;

c) Be of sufficiently rugged construction to minimize delays from failure of essential parts;

d) Permit quick cleaning by washing; and

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

Continuity of operations is necessary not only for efficiency, but also for effectiveness of grouting.

9.2.1 *Grout Mixers*

The mixers should have two tanks namely mixing tank and agitating tank. Mixers are generally cylindrical in shape, with the axis either horizontal or vertical and equipped with a system of power-driven paddles for mixing. Grout should be mixed in a mixer operating at 1 500 r.p.m. or more. The high speed of mixing serves the purpose of violently separating each cement grain from its neighbour thus permitting thorough wetting of every grain. This proves to be advantageous by chemically activating each grain to thorough hydration before reaching its final resting place. Further individuul grains penetrate finer cracks more readily then flocs. 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 speed centrifugal pump. They are sometimes referred to as colloidal type mixers, but they do not achieve a true colloidal grout mix. However, they possess considerable merit and produce grout of excellent texture. When mixing sand-cement grouts, their action tends to guard against segregation.

9.2.2 *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 ports. Grout pumps are of three types namely, piston, screw and centrifugal.

9.3 Grouting System Arrangements

9.3.1 *Manifold or Header*

A grout manifold is a '*T*' arrangement of pipe and various fittings, such as couplings, nipples, unions, tees, valves and a pressure gauge, all attached to the collar of the grout hole.

The functions of the manifold are given below:

a) Permit regulation of the flow of grout into the hole;

b) Maintain the desired allowable grout pressure;

c) Allow any excess grout to be drained from the system or returned to the agitator tank for recirculation; and

d) Close off the hole when washing the supply lines.

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

9.3.2 *Single Line System*

The single line system consists of one grout supply line from the pump to the grouting manifold at the hole.

9.3.3 The pressure gauge should be constantly monitored 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 opened so that the supply line can be flushed or washed. The grout hole valve should also be checked to ensure against a false refusal. Joints in hoses and pipes should be tight.

9.3.4 *Circulation System*

The circulation 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 agitator/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, so that complete control of pressure is maintained at the hole. There should be a pressure gauge at the delivery end of the pump. 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 necessary. Long supply lines should be avoided to reduce the chances of change in consistency of the grout and clogging. Field telephones are useful for communication between the pump operator and the grout man at the collar.

10 WASHING AND TESTING OF HOLES, SURFACE PREPARATION

10.1 The purpose of washing is two-fold. First to clean the holes to remove material deposited on the surface during the drilling operation and second to provoke deliberate inter-connections between adjoining grout holes to remove known seams and layers of erodable material. It should be borne in mind that inter-connections between holes are effective only if the washing operations are carried out systematically to remove all the soft material. Isolated inter-connections do not serve much useful purpose as soft materials may still remain in position in an unknown and irregular pattern. A distinction is therefore made between washing of holes at the end of the drilling operation (*see* **10.2**) and systematic washing of groups of holes in order to remove the erodable material in the intervening area for which the term jetting is used (*see* **10.4**).

10.2 Washing of Holes

10.2.1 On completion of the drilling of a stage and before injection, the holes should be washed by allowing the drilling water to run until the return from the hole is reasonably clean. The quantity of water flowing into the hole during the period should be adequate and generally not less than 15 l/min.

10.2.2 When no return of drilling or washing water occurs, the holes should be washed for a reasonable period based on site experience. This is generally for 20 minutes. If an abrupt loss of drill water occurs during drilling and similarly when a strong flow of artesian water is encountered, the drilling should be stopped and the hole grouted even if it has not reached its final depth.

10.2.3 Should inadvertent connections to adjacent holes take place, the washing out should be continued until the flow of water from the hole to which the connection was made is clear.

10.2.4 Where deliberate attempts to obtain connections between adjacent holes is required in order to remove known deposits of erodable materials, the jetting procedures described in **10.4** should be used instead of the washing procedures described in **10.2**.

10.3 Percolation Tests

10.3.1 For routine grouting operations, and simple water test conducted before and after grouting, the test pressure should be limited so as to avoid hydraulic fracture. The value of limiting pressure for various strata and depths should be established by preliminary investigations where cyclic tests should be conducted to evaluate pressure at which fracturing occurs. Additional tests may be carried out in trial grouting plots or in selected primary grouting holes to verify the pressure limits established during preliminary investigations.

10.3.2 Water percolation tests [*see* IS 5529 (Part 2) : 1985] may be used to measure the effectiveness of the grouting treatment. The tests may be simple or cyclic. Cyclic testing is recommended for the investigation stage while before and during grouting operations simple tests should be carried out.

10.3.3 Water tests should be carried out in primary stages before injection to amplify information available from the site investigation. Test should be carried out in secondary stages before injection to indicate the results of primary injections. Tests may be carried out in individual test holes at any time to indicate the results of all treatment carried out before that time. Test holes drilled for this purpose should be sited midway between completed injection holes.

10.3.4 Percolation tests carried out in any stage before injection also serve to indicate whether injection of that stage can be omitted. They also give some guidance as to the initial grout mix. The actual criteria to be used should be determined in the light of site cxperience.

10.3.5 Observations during grouting of thin mixes are not substitutes for water testing and should not be accepted in lieu of water testing.

10.4 Jetting

10.4.1 Jetting operations are carried out in order to deliberately provoke connections between boreholes and to remove known deposits of arodable materials.

10.4.2 Jetting should be carried out on groups of holes arranged in a square, triangular or hexagonal pattern known as cells.

10.4.3 Experience has indicated that the hole spacing within each cell should not exceed about 1·5 m for successful jetting. The optimum spacing at any site can be arrived at by washing holes in a pattern of primary and secondary cells.

10.4.4 All holes in a cell should be fitted with stand-pipes, and then drilled to the level of the first seam to be treated. Where a network of seams exists, all holes should be drilled to the short first stage depth of 3 m to 6 m. The stand-pipes should then be capped with three-way plugcocks and the cell is then ready for jetting.

10.4.5 A manifold should be fitted to the first hole, so arranged that compressed air and water at high pressure can be fed to the hole in rapid alternation. Air and water pressures used in jetting any stage should not exceed the grouting pressures specified for that stage. Uplift meters with anchor rods set well below the zone being treated may be installed for observing any upheaval.

10.4.6 All other cocks in the cell should then be opened and water followed by air applied alternately until a connection is made. Jetting should continue on this connection until no further erodable matter can be removed. Should any other hole connect to the manifolded hole during the operation, its cock should be closed.

10.4.7 When the first connection has been cleaned out, the cock on the connected hole should be closed and the process repeated until connections have been established, if possible, to all holes in the cell from the original hole.

10.4.8 The following alternative procedure may also be used for washing the 'cells'.

In washing a cell water is connected to one hole and air to the adjacent hole, on each side. The water and air connections are changed at frequent intervals to cause the water to flow in every possible direction through the seam. Application of air and water pressure is continued until all possible inter-connections between adjacent holes are established.

10.4.9 As many combinations of holes as necessary, are used to ensure the cleaning of all seams. The washing of any set of holes is continued until all loose materials are removed from the seams and crevices. It is neither desirable nor practicable to continue washing until the discoloration in the effluent disappears completely, but it is continued till reasonably clear water emerges from the holes. Washing is done generally for a minimum period of 20 minutes for each hole. In some zones, washing operations may have to be extended for several hours.

10.5 Surface Treatment

10.5.1 For effective treatment of the surface zones, sufficient pressure should be developed to achieve the spread required with a convenient spacing of holes. Adequate cover should be maintained during grouting to ensure that adequate pressure is applied without causing upheaval or excessive surface leakage. The following alternative methods may be used:

a) When the top material is a weak rock which can be removed without blasting, one stage of 3 m may be grouted at low pressure using top packer in the casing. The casing should be sealed by cement mortar. The grouting of the top stage is considered only as a capping operation and the rock in this zone should be removed after completion of the grouting operations.

b) Alternatively, a cap of concrete about 1 m deep should be placed and grout holes should commence through the cap. Explosives should not be used for excavation of 1 m rock zone for forming the cap. It should be noted that rock bolting is not an effective replacement for the cap.

c) When the rock is heavily jointed with close spacing of joints, the excavation should be carried out up to the stipulated grade. Thereafter the surface should be covered by slush grout/gunite consisting of a thick cement sand mixture. After the slush, grouting backfill of earth or concrete should be placed. A cover of 4 m to 6 m of earthfill may be required to provide sufficient weight to counteract grouting pressures. For concrete/masonry dams, it may be necessary to grout through a gallery to ensure adequate depth of concrete cover.

10.5.2 It may be difficult to excavate without blasting in order to enable methods (a) or (b) to be used. It may generally be more convenient in concrete dams to conduct shallow low pressure blanket grouting of the surfacial zones, which may be somewhat disturbed by blasting, after covering the surface with slush grouting. It would then be obligatory to use the gallery for effective treatment of the main grout curtain.

11 INJECTION

11.1 Holes should be injected by direct connection to the pump. Each hole should be provided with a packer at the surface or with a short stand pipe threaded at its outer end to accept stand or control fittings, which should be provided with a pressure gauge, bleeder valve and a valve enabling the delivery from pump to be cut-off from the hole. Either single line or circulating system as described under **9.3.2**, **9.3.3** and **9.3.4** may be used, usually the circulating system is preferred, however, when adequate controls are possible to regulate the pump discharge and pressure by using pumps of suitable design, single line grouting system can be used.

11.2 Once the grouting of a stage or group of holes has been commenced, it should be continued without interruption up to completion. In general a stage may be considered complete when the absorption of grout at the desired limiting pressure is less than 2 l/min averaged over a period of 10 minutes.

11.3 As far as practical, a continuous flow of grout should be maintained at the desired pressure and the grouting equipment should be operated to ensure continuous and efficient performance throughout the grouting operation. The personnel-in-charge of grouting as well as the grouting equipment in use, should respond quickly and effectively to manipulate the desired changes in the grout mix consistency, rate and pressure of injections, etc, as directed by the engineer-in-charge during the grouting operation.

11.4 Should it be necessary to interrupt injection before it is completed, for instance if there is a plant breakdown, about 500 l to 1000 l of clean water should be run into the hole and allowed to stand.

If any stage continues to absorb large quantities of the thickest pumpable grout at nil pressure, grouting may be stopped when a predetermined limit of consumption is reached. Alternatively, sometimes it is possible to suspend injection overnight and resume the work next day. Even then the limit of consumption should apply. When any of the procedures recommended is adopted, the grouting operation should be controlled as given in **12**.

11.5 Should any hole connect to another during injection, the grout should be allowed to escape from the coupled hole until 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. After the first hole has been grouted, all the other holes are successively connected to the grouting header to subject them to full pressure.

Where leakages of grout occur on the ground surface, they should be restricted by caulking with wooden wedges, lead wool, etc, or by thickening the grout followed by retreatment with thinner grouts and through fresh holes, if necessary.

11.6 Grouting should 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. Additional holes may have to be drilled and grouted in the vicinity for sealing fine cracks which may not be effectively treated due to premature blocking of holes by interruption of grouting operations.

11.7 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. Grouting normally starts with a thin mixture which is gradually thickened until about 75 percent of the final desired pressure has been obtained with the pumps operating at normal speed. As the hole approaches refusal, the thick grout is replaced with thinner grout which is used until the hole refuses. In **12**, the guiding principles for controlling pressures and selecting grout mix proportions are discussed. As a general principle grout mixture should not be thickened if pressure starts to rise after continuous injection over a period of 10 minutes. Hasty changes in mix proportions are not desirable and the response of the hole to the selected mix proportions or pressure should be judged only after observing for a sufficient period. The choice of the initial mix proportions should be based on the water intake tests. There are no general rules on the basis of which the initial mix proportions can be decided directly in terms of the percolation test results. Experimentation, at the start of the work, should be used to establish the guidelines for choice of mix proportions. Use of excessively thin mixes in the initial stages is generally wasteful and may sometimes cause softening of rocks, like shale. Therefore, a starting mix of 5 : 1 is recommended and in exceptional cases 10 : 1 may be adopted.

11.7.1 The ratio of water to solids, of the grout deposited finally *in-situ*, is generally quite different from the water content of the mixed grout during injection. The excess water from the grout is removed during the grouting process by filtration except in exceptional circumstances, as well as when the grout contains admixtures (such as clay) resulting in formation of stable suspensions, the grout properties should be tested at the water-solid ratios used for the mixed grout, in order to verify the suitability of the grout *vis-a-vis* the criteria mentioned in **8.6**. For neat cement grouts, with non-cohesive admixtures, it is generally found that the set grouts are very much denser than grout specimens prepared in the laboratory from the mixed grout; hence due allowance should be made for the removal of water *in-situ* while interpreting the laboratory test data.

11.8 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, due to causes like artesian conditions. For this purpose a period of one to two hours is generally sufficient, however, this should be verified by trial.

12 CONTROL OF GROUTING OPERATION

12.1 Pressure

The pressure should be adequate to achieve the desired grout and the pressure should be limited so as to avoid disturbance and upheaval of the ground and should take into account reservoir pressure.

12.1.1 For structures on rock foundations, it is a basic requirement that no disturbance should be caused to the surface zones of the foundation by the grouting operation. When grouting is undertaken below an existing structure no upheaval of the foundation can be allowed as it would have very harmful consequences on the structure and/or equipment.

12.1.2 In general, the disturbance caused by grouting is dependent more on the manner in which the pressure is developed and the nature of the rock than on the absolute magnitude of pressure. Relatively higher pressures can be sustained without damage to the foundations, when pressure is built up gradually, as resistance to flow is developed by deposition of grout. On the other hand, when pressures are raised hastily, damage could occur even at relatively low pressures. In general, horizontal stratified or low dipping rocks are more vulnerable to disturbance by grouting pressure than fractured igneous or metamorphic rocks or steeply dipped sedimentary rocks. Rocks previously subjected to folding and fracturing or rocks in the process of adjustment after removal of overburden load are also more vulnerable to disturbance.

12.1.3 It is always advisable to begin with a low initial pressure say 0·10 to 0·25 kg/cm²/m of overburden, and build-up the pressure gradually. Initially the rate of intake may be 20 l/min to 30 l/min. In order to avoid the premature build-up of high pressure a general guideline should be followed that the pressure should be raised only when the intake rate falls below 5 l/min. When surface leaks develop, pressure should be immediately reduced. Sub-surface cracking may sometimes be indicated by an abrupt rise in the rate of intake after grouting at a constant value of pressure for a considerable period.

12.1.3.1 The most common difficulty experienced in consolidation grouting is surface leakage. It is therefore customary to pipe through the required height of concrete or masonry and carry out the grouting after the rock has been completely covered. This not only eliminates surface leakage but permits use of higher pressures so that even the smaller seams can be grouted effectively.

12.1.3.2 The true pressure at any depth should take into account the pressure head caused by the weight of the grout in the hole. This correction in kg/cm² may be computed by multiplying the depth of the hole in metres by factors relative to the water-cement ratio given in Table 2 and added to the pressure gauge reading at the top of the grout hole.

Table 2 Multiplying Factors

Water-Cement Ratio	Factor	Water-Cement Ratio	Factor
0·75	0·151	2·50	0·118
1·00	0·140	2·75	0·117
1·25	0·131	3·00	0·112
1·50	0·127	4·00	0·110
1·75	0·123	5·00	0·107
2·00	0·121	10·00	0·102
2·25	0·119		

12.1.4 Control of pressure should be exercised according to the following guidelines:

a) The limiting value of pressure for each zone and depth may be established initially from the results of trial grouting, along with observations of upheaval by uplift gauge. Figure 2 may be used as a guide, subject to verification by trial grouting;

b) Pressure limits may be decided by analysis of the results of cyclic percolation test; and

c) Limiting pressures may be decided by continuous review of the trends of pressure and rate of intake during grouting operations.

12.1.4.1 Limiting values of pressure for each zone may be established initially on the basis of the categorization of rock as suggested in Fig. 2 should be taken as initial values to be confirmed by trial and observations. The choice of pressure may also be established by examining water test data.

12.1.4.2 The pressure limits initially established as per **12.1.4.1** should be further reviewed by examining trends of grout intake and pressures during initial stages of actual grouting operations. The method of interpretation of trends of grouting pressure is described in Annex B. It should be recognized that the resistance to flow of grout pressures is built up gradually. Consequently higher pressures may be used in water tests without causing hydraulic fracturing. Normally, the aim should be to obtain 'A' type trends. This trend signifies increase of resistance of flow as the joints/cracks/cleavages are filled by the grout. 'B' type trends can be permitted since they imply a fluctuating response. Grouting with 'B' type trend may be continued till the limit of consumption is attained or refusal may be attained eventually by restricting the pressures or by thickening the grout when 'B' trends develop. 'B' trends thus constitute a permissible deviation from the ideal which should be minimized by careful control. When pressure limits are properly chosen 'A' type trends would predominate. Under no circumstances 'C' type trends should be permitted since they imply hydraulic fracturing. The pressure control criteria initially chosen as per **12.1.4** should be modified on the basis of the analysis of the trends of grouting pressures and intake. The chosen pressure limits ensure that 'A' trends are generally achieved and 'C' trends are eliminated.

12.1.5 Situations arise in practice when hydraulic fracturing may occur before uplift is observed or surface leakage is noticed. This is attributable to developments of localized high strains in rock associated with hydraulic fracturing. Upheaval may be noticed only when sufficient volume of grout is injected into the fractured zones to cause displacements in the surfacial zones.

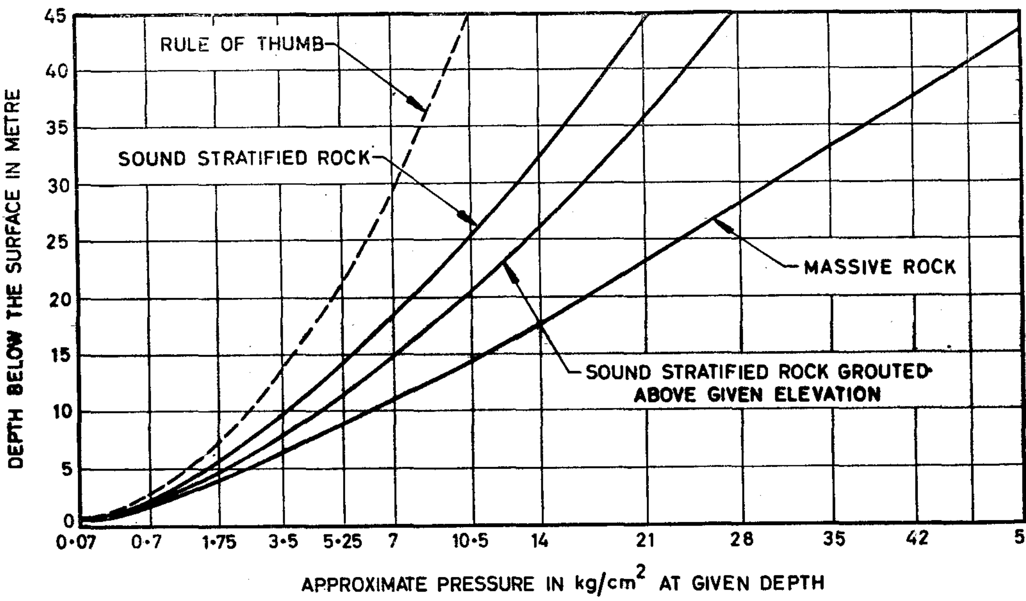


FIG. 2 GUIDE FOR GROUTING PRESSURES

Observations of pressure trends provide a more definite indication of hydraulic fracturing and therefore greater reliance should be placed on interpretations of trends of pressures and grout intakes, rather than upheaval measurements.

12.2 Grout mixture (ratios by weight of water and cement) ranging from 5 : 1 to 0·8 : 1 are recommended. It is only in exceptional circumstances that mixtures leaner than 10 : 1 need be used. The choice of grout mixtures may be based on results of percolation tests conducted prior to grouting (*see* **12.1.4**). The ideal would be to conduct a percolation test in each hole, for each stage. However, the number of percolation tests may be reduced if extent of zones of different types of rock and rock characteristics can be established on the basis of geological evidence and results of initial experimental grouting operations. It is inadvisable to relax the requirements of percolation testing in the initial stages of grouting and grout absorptions at low water-cement ratios are a poor substitute for water percolation tests.

12.2.1 If grout is too thick, passages of grout travel may get obstructed at a short distance and fine seams may not be filled up. On the other hand if injection with thin grout is continued for too long a time, the grouting operation may get unduly prolonged and may be rendered unduly expensive. If openings are large and grout is thin, grout consumption will be excessive even with low pressure. In the case of fine cracks additions of bentonite, say 2 to 3 percent in a grout mix, will have lubricating action. No general rules can 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. A judgement about the efficacy of a particular sequence may be had by comparing the grout consumptions of the primary and secondary or secondary and tertiary holes. As a guide, the mix should be thickened if there is no increase in the pressure after continuous grouting of about 10 min.

12.2.2 When multiple line grout curtains are used, the control of grouting operation would differ from single line curtains. In the outer lines thick grouts may be used to prevent overtravel and to block the more pervious zones. In the inner or central lines, grouts may be thickened very gradually and comparatively thinner grout may be used at the start. Similarly the thickening of grouts may be carried out more gradually in tertiary holes as compared to primary and secondary holes. In order to prevent overtravel of grout in the case of wide joints, sodium silicate or sodium hexa meta phosphate is sometimes added, while for increasing the flowability in the case of thin joints, 2 percent to 3 percent bentonite is added.

12.2.3 The thinning of the grout may be helpful in preventing abrupt rise in pressure and/or clogging of the equipment at the end of the grouting operation. Thinning of the grout is not permissible when stable grout suspensions are used that do not allow exclusion of the excess water by filtration. If such grouts are diluted, the strength and imperviousness may be compromised. Alternatively it is recommended to keep more than one grout design ready with the use of clay-cement, bentonite-cement, bentonite-chemical, etc, so that these mixes can be used without change of mix design.

12.2.3.1 A recommended method is also to arrange for grout refusal to occur while a thin mix is being pumped, even though 3 : 1 to 1 : 1 mixes were used temporarily.

12.2.3.2 With packer grouting and thin beginning mixes, the section of hole just completed is automatically exposed to the new beginning mix. This of course does not apply to the last or top section of the hole. In special cases, such as a large opening into which a lot of grout has been pumped or in a zone in which refusal was specially difficult to obtain or again in the case of a deep interconnection this process might not be performed and thin mixes may be omitted for 6 m or so, overlying the troublesome zone, or the section might be allowed to rest for a few hours before higher sections are treated.

12.3 Control of Grout Consumption

When pressure does not build up even after grouting a thick grout, that is, grout with water cement ratio lesser than 0·6 : 1 by weight or richer, or by grouts with fillers, such as clay, sand and bentonite, it is desirable to stop grouting after the predetermined limit of consumption is reached. The choice of the limit of consumption will depend on the length of a stage and the size of the cavities, open joints and fissures. After grouting a hole, in which grouting has to be stopped because the consumption limit was reached, it is necessary to drill additional holes in the vicinity and grout them with more fluid grouts in order to penetrate the finer cracks and joints which may not have been grouted in the initial operation. In such situations a multiple line curtain may be used with advantage and the sequence of grouting should be as given in **12.2.2**. Guidance regarding method of recording the details of grouting operation and determining the quality of grout consumed are described in Annex C.

12.4 Back Filling of Grout Holes

Grout holes are backfilled with grout having a water-cement ratio of 0·7 : 1 with 3 percent of bentonite. A delivery pipe of minimum 25 mm diameter is lowered to the bottom of the hole. Grout is pumped in the delivery pipe until it flows from the hole, then the delivery line is slowly withdrawn while pumping continues. If settlement of grout occurs after initial set, the holes are again back filled with grout.

13 TESTING THE EFFICACY OF GROUTING OPERATION

13.1 The efficacy of the grouting operation may be estimated using one of the following methods:

a) Pre and post grouting permeability values using percolation tests.

b) Pre and post grouting P-wave velocities using seismic refraction/cross hole geophysical techniques and changes in mass using gravity methods.

c) Pre and post grouting deformation module using static methods.

d) Pre and post measurement of pore water pressure.

14 RECORDS

14.1 The information to be recorded daily is as follows:

1) Result of the pressure test;
2) Grouting feature, for example, curtain and consolidation;
3) Date;
4) Shift;
5) Name of foreman;
6) Grouting method, packer grouting or full-depth grouting and stage whether first, second or third;
7) Hole station number or co-ordinates;
8) Time grouting begun;
9) Time of each change in mix, pressure, or pumping rate;
10) Name of inspector;
11) Time of hole completion;
12) Total quantity of cement used for each pressure or mix change;
13) Water-cement ratio at the start and each change thereafter;
14) Air pressure;
15) Grout consumption and time required for consumption of each batch;
16) Pressure recorded at 3 min to 15 min intervals and on completion;
17) Rate of injection;
18) Cement washed;
19) Total quantity of cement injected into the hole;

20) Reason for abandoned holes;

21) Number and depth of holes left for redrilling; and

22) In addition, the inspector should record under 'Remarks' any change or incident affecting the grouting operation; such as 'tight hole', 'no leakage', 'had leakage', 'leaks caulked', 'grout pump down', 'hole completed', and so forth.

14.2 Reports

In order to facilitate control and planning of grouting operations, reports should be prepared at regular intervals to summarize important observations and data. It serves no useful purpose to maintain elaborate records unless they can be compiled in such a form that significant trends can be determined regarding the efficacy or otherwise of the grouting operations. In the absence of such reports timely action would not be possible and procedures which may be ineffective or unsuitable may be continued indefinitely. These reports may consist of:

a) a hole-wise register of drilling, water tests, grouting and interconnections.

b) for consolidation grouting — a plan showing grout hole stages and grout intake.

c) for curtain grouting — a 'L' section showing drilling stages and grout intake.

ANNEX A

(*Clause* 2)

LIST OF INDIAN STANDARDS

IS No.	*Title*
269 : 1989	Specification for 33 grade ordinary Portland cement (*fourth revision*)
383 : 1970	Specification for coarse and fine aggregates from natural sources for concrete (*second 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 Fly ash based (*third revision*)
1489 (Part 2) : 1991	Specification for Portland pozzolana cement : Part 2 Calcined clay based (*third revision*)
3812 : 1981	Specification for fly ash for use as pozzolana and admixture (*first revision*)
5313 : 1980	Guide for core drilling observations (*first revision*)
5529 (Part 2) : 1985	Code of practice for *in-situ* permeability test : Part 2 Test in bedrock (*first revision*)
6909 : 1990	Specification for supersulphated cement
8112 : 1989	Specification for 43 grade ordinary Portland cement (*first revision*)
9103 : 1979	Specification for admixtures for concrete
12269 : 1987	Spcification for 53 grade ordinary Portland cement
12330 : 1988	Specification for sulphate resisting Portland cement
12584 : 1989	Specification for bentonite for grouting in civil engineering works

ANNEX B

(*Clause* 12.1.4.2)

METHOD OF INTERPRETATION OF TRENDS OF GROUTING

B-1 The categorization should be done as follows by computing the ratio of rate of grout intake and grouting pressure and examining the trend of variation as the grouting operation continues:

a) Ratio of $\frac{\text{Rate of grout intake}}{\text{Grouting pressure}}$ Decreasing : 'A' trend

b) Ratio of $\frac{\text{Rate of grout intake}}{\text{Grouting pressure}}$ Constant : 'B' trend

c) Ratio of $\frac{\text{Rate of grout intake}}{\text{Grouting pressure}}$ Increasing : 'C' trend

ANNEX C

(*Clause* 12.3)

C-1 For measurement of the quantity of grout injected in each hole, a grout history sheet on proforma given on next page should be recorded giving grout in-take per minute, viscosity of grout mix in form of solids and water ratio, pressure of injection, time of pumping in water for lubrication event of blowing grout to keep the grouting system alive. In addition, various other points of importance observed during the operation of grouting are recorded for every 5 min to 10 min intervals and thus the grout history sheet when plotted as shown in Fig. 3 should depict the exact amount of grout injected. Actually this graph from the grout history sheet should be plotted to depict the factual amount of grout injected. The area under the curve would represent the quantity of grout actually injected. A register should be maintained of 100 such sheets. Each sheet should be machine numbered on both sides.

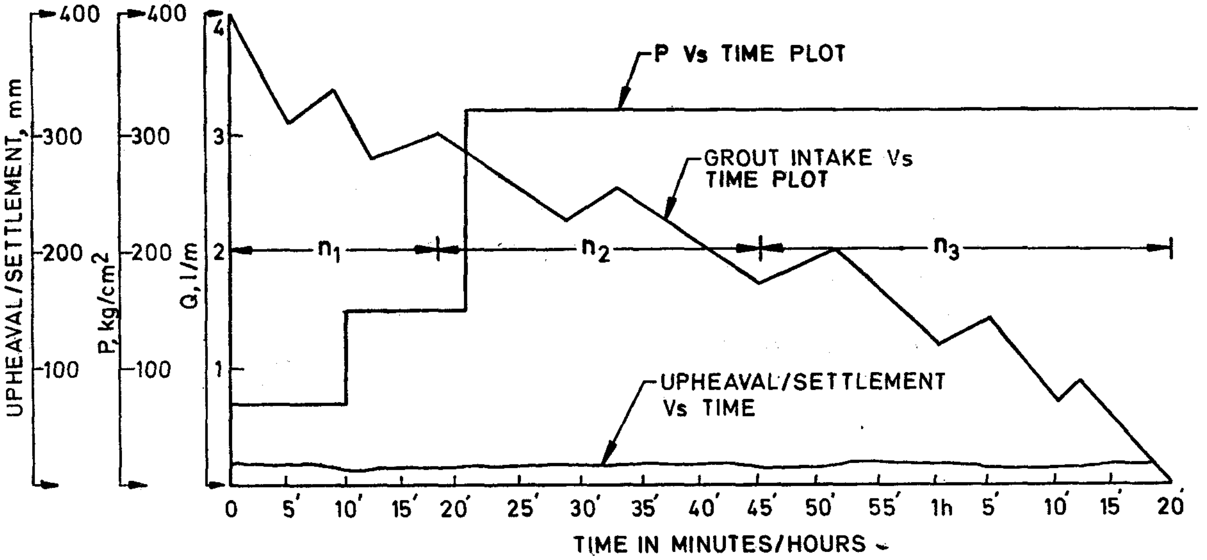
C-2 Recording of the surface leakage, if any, should be made in the remarks column of the grout history sheet showing the location. The leakage should be immediately stopped by reducing the pressure and caulking suitably. The grout should not be allowed to leak more than 5 percent by visual judgement.

C-3 Measurement of cement, blown off and circulated in the grout lines, should be separately recorded in mass of the cement used for purposes of accounting the cement actually used for the work.

C-4 In case of stage grouting of the hole, cement grouted in each stage should be summed up.

C-5 Many of the holes often require regrouting and this should be recorded in linear metre separately.

C-6 For work of grouting for anchors (plain or cylindrical) stubbed with under-reaming, the quantity of grout should be in mass of cement. Aluminium powder should be according to quantity actually used. The length of holes and anchor bars should be referred in linear metres. For under-reaming for stubbed anchor, the unit for bulbs should be in numbers for record of the under-reaming done with section of bulb provided.



NOTE — Area under the curve 'grout intake Vs Time' also includes the amount of grout blown off in case grout intake Vs Time plot accounts for blowing off.

n_1, n_2, n_3 = Water : Solid ratio

P = Pressure

Q = Grout intake

FIG. 3 GRAPH FROM GROUT HISTORY SHEET

Typical Proforma of Grout History Sheet

(*Clause* C-1)

Feature and RD of Hole	*Hole No.*	*Depth Drilled*	*Method*	*Pressure*		*Grout Consistency*	*Time*	*Rate of Consumption*	*Remarks About Type of Leakage*
				Specified	Used				

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This Indian Standard has been developed from Doc : No. RVD 8 (98).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at New India Printing Press, Khurja, India