

**भारतीयमानक**  
**Indian Standard**

**जलोदमृदामेंघोलअभिपूरणसामग्रीकाचुनाव - मार्गदर्शीसिद्धांत**

**CHOICE OF GROUTING MATERIALS FOR ALLUVIAL GROUTING – GUIDELINES**

[(*First Revision of IS 14343*)]

Foundation and Foundation Treatment Sectional Committee, WRD 08

**FOREWORD**

(*Formal Clause will be added later*)

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Foundation and Substructures Sectional Committee had been approved by the River Division.

Grouting in alluvial soils can be resorted to as a temporary measure in case of stabilising the foundation soil of any adjoining building during excavation for foundation; and as a permanent measure like stopping seepage through foundation of a dam. Before commencing any grouting project, it is essential that full consideration be given to all available grouting materials, in order to choose the most appropriate materials for a particular application. From a practical point of view grouts are usually divided into two broad groups namely particulate grouts (suspensions) and non-particulate grouts (solutions). This division is important in grouting, since the presence of solid particles in a grout immediately places an absolute limit on the type of ground which the grout can effectively permeate. In other words the pore size in alluvium must be sufficiently large for the solid particles to pass through.

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 : 2022 'Rules for rounding off numerical values (*first revision*)'. 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***

### **CHOICE OF GROUTING MATERIALS FOR ALLUVIAL GROUTING – GUIDELINES**

[(*First Revision of IS 14343*)]

#### **1 SCOPE**

**1.1** This standard lays down guidelines to cover primarily both suspension and solution grouts with particular reference to alluvial grouting. Under suspension grouts, grout materials like cement, clays, bentonite, flyash, etc, are covered, whereas under solution grouts, chemical grout materials are covered.

**1.2** This standard does not cover compaction grouting or grouting for reducing compressibility of soil which is excluded from the scope of this standard.

#### **2 REFERENCES**

The Indian Standards listed in Annex **A** 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 editions of the standards indicated in Annex **A**.

#### **3 GENERAL**

Grout materials can be broadly classified into two groups:

- a) Particulate grouts, and
- b) Non-particulate grouts.

The functional difference between particulate (*see5*) and chemical (*see6*) grouts is that the penetrability of the former is a function of particle size, while in the latter, it is a function of solution viscosities.

Suspension grouts actually require a small quantity of water for gellification/hydration. However, in order to increase their flowability, a high proportion of water is added initially. Most of this excess water is separated during passage of grout through voids. In solution grouts, on the other hand, the final water solid ratio is same as the initial.

#### **4 CHOICE OF A GROUT MATERIAL**

**4.1** Selection of grout materials involves a balance between various desirable characteristics of grout materials as well as requirement of grout slurries such as particle size, viscosity, jellification time, gel strength, stability and permanence coupled with economy. Grout solutions should be non-toxic, non-corrosive and non-exploding.

**4.2** Choice of grouting materials and mixtures for appropriate field conditions are given in IS 4999. Permeability is the soil property most closely related to groutability. The general relationship between these two factors is shown in Table 1.

## 5 PARTICULATE GROUTS

Particulate grouts are suspensions or multiphase systems capable of forming subsystems after being subjected to natural sieving processes, with chemical properties which must be carefully scrutinized so as to ensure that they do not militate against controlled properties of setting or strength.

**Table 1 General Relationship Between Permeability and Groutability**

(Clause 4.2)

PERMEABILITY	GORUTABILITY
$K = \text{less than } 10^{-6} \text{ cm/sec}$	UngROUTABLE
$K = 10^{-6} \text{ cm/sec to less than } 10^{-5} \text{ cm/sec}$	Groutable with difficulty by grouts having viscosity lower than 5 cP and UngROUTABLE at higher viscosities
$K = 10^{-5} \text{ cm/sec to less than } 10^{-3} \text{ cm/sec}$	Groutable with low viscosity grouts but with difficulty when viscosity is greater than 10 cP
$K = 10^{-3} \text{ cm/sec to less than } 10^{-1} \text{ cm/sec}$	Groutable with all commonly used chemical grouts
$K = 10^{-1} \text{ cm/sec or more}$	Groutable with suspended solids grout or chemical grout with filler

The groutability of a formation cannot be based upon a one-to-one ratio of void size to particle size, because two or more particles may clump together, and block the opening (called blinding). It is generally considered that opening size must be at least three times the particle size in order to permit grouting. Rules of thumb have emerged from experience, and these are shown in Table below:

**TABLE** Approximate Guidelines to Groutability of Granular Soils and Rock when Particulate Grouts Are Used

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$$\text{For Soils, } N = \frac{(D_{15})_{\text{Soil}}}{(D_{65})_{\text{Grout}}}$$

$N > 24$ , grouting is feasible  
 $N < 11$ , grouting is not feasible

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$$\text{For Soils, } N_C = \frac{(D_{10})_{\text{Soil}}}{(D_{95})_{\text{Grout}}}$$

$N_C > 11$ , grouting is feasible  
 $N_C < 6$ , grouting is not feasible

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$$\text{For Rock, } N_R = \frac{\text{Width of Fissure}}{(D_{95})_{\text{Grout}}}$$

$N_R > 5$ , grouting is feasible  
 $N_R < 2$ , grouting is not feasible

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## 5.1 Characteristics of Grout Materials

### 5.1.1 Cement

The main ingredient for the preparation of grout suspension is Portland cement, generally available in various types known as Portland, High Furnace, Pozzolanic, Sulfate Resistance cement, which are also ranged by the strength they achieve and heat developed during setting.

Ordinary portland cement suitable for cement concrete is generally used for grouting, especially for consolidation grouting. For curtain grouting, however, portland pozzolana cement can also be used. Cement for grouting should conform to IS 269 or 1489 (Part 1) 1489 (Part 2).

Ultrafine cement is a portland cement or slag with an average particle size of 4 microns or less. These finely ground materials are also called microfine and superfine cements. All of these terms should be considered synonymous, since at present there is no industry standard. The use of grout made with ultrafine cement for underground grouting of rock is usually limited to consolidation grouting of tightly jointed rock and grout curtains installed in association with hydraulic structures where superior permeation and penetration of the surrounding rock by the grout are

required. Grouts made with ultrafine cement are also used for embedment grouting to fill very small voids, usually caused by shrinkage, between steel shaft and tunnel liners and the backfill concrete or grout. Additionally, ultrafine cement grouts are used in grouting fine-grained soils. It possess Blaine fineness of the order of 9000 cm<sup>2</sup>/g to more than 12000 cm<sup>2</sup>/g.

### 5.1.2 Clays

Clays have a special value as a grout constituent. Clay is added as a fine grain filler to reduce the cement consumption, but it also improves the stability and the viscosity of the suspension. They are complex comprising of minute mineral particles mostly smaller than 2 micron and chemical analysis has demonstrated the presence of the following essential constituents silicon dioxide, aluminium oxide, ferric oxide and water with calcium oxide, magnesium oxide, potassium oxide, sodium oxide and phosphorus oxide. The commonest minerals present are kaolinite and montmorillonite with silica/alumina ratios of 3 : 6 and 3 : 5 respectively. Not all clay minerals are useful in grouting, but sodium and calcium montmorillonites are useful because they have suitable water absorption properties and can produce gels at low concentrations. Clays have special value as a grout constituent because of their ability to form gels and also their small particle size. As a first guide in selection of clay, particle size distribution and liquid limit provide useful means of eliminating the poorer samples. Normally a clay having 50 to 60 percent particles smaller than 0.002 mm is preferred. The sand size particles, if present, in the clay are generally removed through processing in hydrocyclones. Details of a typical hydrocyclone are shown in Fig. 1. Normally a clay with liquid limit less than 60 percent is not considered suitable for grouting.

The kaolinite minerals consist of basic sheets bound together by Van der Waals forces and hydrogen bonds which are strong enough to prevent much swelling in presence of water. The specific surface is in the range of 10 – 20 m<sup>2</sup>/g, and the unit mass around 2.60 – 2.68 g/cc. the ion exchange capacity is 3 – 15 meq/100g. It is widely used as a filler in cement / clay suspension.

Montmorillonite consists of three blocks in the arrangement: Si:G:Si with common oxygen atoms and hydroxide groups on both adjacent Al planes and top of the Si tetrahedrons and build large planes. The bonds on these planes result from Van der Waals forces and cations which may be present to equilibrate missing ions in the structure. These are weak bonds and they are easily broken by splitting or by absorption of water molecules, which produces a high swelling potential on wetting. This property is very important for grouting.

The Specific surface is 50 – 120 m<sup>2</sup>/g when dry and 700 – 840 m<sup>2</sup>/g after swelling and dispersing in water. Montmorillonite is used for the preparation of stable cement suspensions, thixotropic suspension, for plasticizing thick mortar used for grouting large fissures and cavities.

In soils of low permeability, clay-cement grouts cannot be used because the cement particles would be preferentially filtered out during the injection process. Clay-cement grouts are used primarily for the treatment of rather coarse alluvial soils and fractured rock strata so fluidity is not too significant, because the openings available in the ground are large enough to accept cement particles without any risk that filtration may occur. The permeability of such ground will exceed  $10^{-1}$  cm/s.

### **5.1.3 Bentonites**

Bentonite is a volcanic clay, rich in colloids. It tends to hold the cement particles in suspension and acts as a lubricating material. When mixed with cement, sodium bentonite (a type of clay) changes to calcium bentonite, which then flocculates. The flocs are gelatinous and large and prevent sedimentation of cement particles. Thus it is a common additive for reducing bleeding. Bentonite delays setting of cement and increases penetrability and workability of grout. For detailed requirements of bentonite see IS 12584.

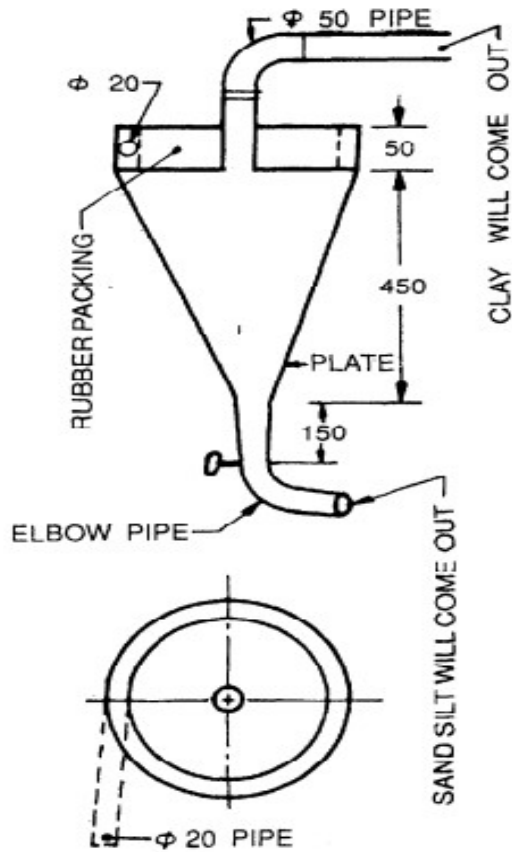
### **5.1.4 Pozzolana**

Pozzolanas as silicates and alumina silicates are not cementitious but react with free lime in cement, in presence of water, to form cementitious compounds. Pozzolanas naturally available include finely ground shale, pumicite and diatomite. Flyash, a byproduct of pulverised coal and blast furnace slag are examples of artificial pozzolana. Since fly ash and slag are waste products they are normally used as cheap bulk fillers in low strength grouts for cavity filling. Fly ash shall conform to IS 3812 and calcined clay pozzolana shall conform to IS 1344.

### **5.1.5 Admixtures**

It is well known that lean cement grouts show high bleeding percentages, prolonged gel times and low strengths. Proper use of admixtures can improve these unfavourable properties to some extent. For example a good accelerator like sodium silicate or calcium chloride can reduce the gel time, an expander like aluminium powder can reduce the bleeding percentage and a fluidifier like calcium lignosulfonate can help in increasing the unconfined compressive strength of grout. Some admixtures and their dosages as well as effects are given in Table 2.

There are, however, certain drawbacks in using admixtures. Addition of a third or even fourth ingredient complicates the mixing procedure, for example an admixture may not behave exactly the same way with all cements and its effect could be temperature dependent.



All dimensions in millimetres.

FIG. 1 ILLUSTRATION OF A TYPICAL HYDROCLONE

**Table 2 Admixtures for Grouting**

(Clause 5.1.5)

Admixture	Chemical	Optimum Dosage (percentage by weight)	Remarks
Accelerator	Calcium Chloride	1 - 2	Accelerates set and hardening
	Sodium silicate Sodium aluminate)	0.5 - 3	Accelerates set
Retarder	Calcium Lingnosulphonate	0.2 - 0.3	Also increases fluidity

	Tartaric acid Sugar	0.1 - 0.5	
Fluidifier	Calcium Lingnosulphonate	0.2 - 0.3	
	Detergent	0.05	
Expander	Aluminium powder	0.005 - 0.02	Up to 15 percent pre-set expansion Up to 1 percent post-set expansion
	Saturated brine	30 - 60	

#### **5.1.6 Filler Material**

Sand (4.75 mm to 75 micron) can be added to lean cement/water suspensions to form an economical grout where penetrability criteria is satisfied. Sand shall conform to IS 383.

Sand is added to stable grout suspensions when a system of large fissures has to be injected. The grain size distribution and the maximum grain size are chosen to match the size of the fissures and to suit the available grouting pumps, the lines and the fittings.

#### **5.1.7 Water**

Water used for grouting shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious. Potable water is generally considered satisfactory.

### **5.2 Characteristics of Grout Slurries**

The composition and the properties of grout suspensions should be defined and specified in the design stage of project to meet the requirements of the job. The properties and characteristics of the suspensions and of the injected mass are tested in the laboratory. Grout slurry should have good penetrability (which is based on particle size of grout materials), high fluidity, stability, controllable gellification time and high set strength.



**5.2.1 Penetrability** is the property of the grout which mostly controls the selection of a particular grout for treatment of soil. Penetrability of a grout depends mainly on the average particle size of the grout material and the average size of openings in the soil. While average particle size of a grout material can easily be ascertained and controlled, it is difficult to ascertain the size of average openings in the alluvium to be treated. Some estimation of the average opening in the soil can be had from the average permeability test and grain size curve of soil. From these  $D_{15}$  of the soil can be judged. As an initial guide  $D_{15}$  (soil)  $D_{85}$  (grout) should be kept more than 25. This will ensure 'reasonable penetration of grout into the soil to be treated. **Table 1** should be referred to for selection of grout on the basis of permeability.

### **5.2.2 Viscosity**

Once the grout materials are selected for a particular grouting project based on particle size requirement, the next stage is to decide the proportion of these materials in the grout mix, such that the resulting grout slurry has sufficiently low viscosity to be easily pumped, but not so low as to travel undesirably long distances without appreciable pressure drop. Viscosity of a grout can be measured in laboratory by rotational viscometer. However, this type of instrument is not commonly used. Therefore some form of funnel viscosity is usually preferred for giving information about fluidity of the grout slurry. A description of measurement of fluidity by Marsh Funnel Test is given in Annex B. The Marsh Funnel Test is a good indicator of true viscosity of the grout slurry, it is also an important index property for quality control of field mixes.

### **5.2.3 Stability**

Carefully composed grout suspensions in which particles do not settle at all within more than 24 hours are called stable grout. Some small amount of clear water may appear at the surface, which is not due to particle sedimentation but it is the consequence of syneretic volume shrinkage caused by the action of electrochemical forces and gravity on the whole volume of the suspension.

A stable mix will generally maintain its characteristics during pumping, penetration and final jellification. Stability of a grout suspension is commonly determined by a bleeding (or sedimentation) test. A stable mix is taken as one having less than 5 percent bleeding.

The stability criteria is not applicable to cement and other cement grouts which would have a water/solid ratio considerably smaller than the initial value after deposition and setting.

#### **5.2.4 Gellification Time**

A fundamental requirement of a grout is that it shall develop adequate gel strength after a control-lable interval of time. This should be determined by relevant test procedures. This requirement is not applicable to cement grout.

#### **5.2.5 Set Strength**

The set strength of a grout is generally determined in terms of unconfined compressive strength and laboratory vane shear strength. It is also desirable in certain situations to determine strength of grouted soil either in the field or in the laboratory. The strength requirement of a set grout/grouted mass should correspond to the purpose of grouting. **The strength of the grouted mass can be evaluated by penetration / washout gradient test.**

#### **5.2.6 The resistance of grouts to chemical deterioration**

**When the ground water or the impounded water at the site are chemically aggressive to Portland cement, injected grouts must be selected, which are resistant to chemical dissolution, alteration or their long-term effects, which would deteriorate the strength of the grouts and their erodibility, or partially dissolve some of their ingredients. Although the permeability of most injected grout is low, allowing only seepage of water at very slow speed, after a long period of time substantial deterioration of the grout may occur, thus reducing the efficiency of the grouted curtain. Even worse, water penetrating through not completely filled fissures / voids may more intensively deteriorate the grout and cause deterioration of the grouted works in a much shorter time. In such cases it is necessary to make chemically resistive grouts. When the chemical composition of the ground water and the water which shall fill the lake is suspect, its aggressivity to the components of the grout should be investigated. Aggressive ingredients may consist of:**

- **Sulfates which deteriorate calcium compounds of the cement;**
- **Carbon dioxide which dissolves free lime of the cement, calcite minerals contained in some sands;**
- **Very soft water which dissolves calcite salts ;**
- **Humous acids.**

### **6 NON-PARTICULATE GROUTS**

Non-particulate grouts are solutions or intimate one phase systems, retaining an originally designed chemical balance until completion of the relevant reactions. Solutions in which the solute is present in the colloidal state are known as colloidal solutions. Chemical grouts fall under this category.

## 6.1 Chemical Grouts

Some of the widely used chemical grouts are given in 6.3 to 6.5.

## 6.2 Salient Features of Chemical Grouts

6.2.1 Chemical grouts should have the following properties to be an ideal grout material:

- a) A powder readily soluble in water (this eliminates the expense of transporting a solvent, water being the least expensive solvent).
- b) Inexpensive and derived from chemicals in abundant supply
- c) Stable at all anticipated storage conditions.
- d) Nontoxic, noncorrosive and nonexplosive.

6.2.2 The grout solution should be:

- a) A low-viscosity solution, preferably that of water.
- b) Stable under all normal temperatures.
- c) Catalyzed with common, inexpensive chemicals stable under all normal temperatures.
- d) Of stable pH on the positive side (so that it may be used in conjunction with cement).
- e) The end-product should be:
  - i) permanent gel,
  - ii) unaffected by chemicals normally found in groundwater, and
  - iii) of high strength.

Ideally, no such chemical exists. However, every criterion listed can be found in one or more commercially available materials. It is important, therefore, to determine which grout properties are critical to a specific project in order to have a sound basis for selecting a grout.

### 6.3 Silicate Grouts

Alkaline and non-alkaline type of chemical grouts include all alkali silicates with inorganic and organic compounds which may be broadly called sodium silicate formulation. A newly made silica gel will, upon standing exude water and shrink.

Sodium silicate ( $n\text{-SiO}_2 \cdot \text{Na}_2\text{O}$ ) is commercially available as an aqueous solution. The silica/alkali ratio 'n', if between 3 to 4 is more suitable for grouting. When sodium silicate solution and a concentrated solution of appropriate organic and inorganic salts is mixed, the reaction forming a gel is virtually instantaneous. The commonly used inorganic salts are sodium bicarbonate and sodium bisulphite and sodium and potassium chlorides. Generally used organic salts are acetates and ketones.

In all silicate based grouts, strength and viscosity are the functions of sodium silicate content and are directly related to each other. However, a peculiar characteristic of silicate grout is a reversal in temperature-gel time relationship at low temperatures. When temperature of the grout solution drops below  $15^\circ\text{C}$ , gel-times start getting shorter. In field work, this could cause unanticipated flash sets when working at temperatures near freezing.

Portland cement can be used as catalyst. However, the use of normal cement reduces the penetrability of grout suspension. Sodium silicate solution is generally considered totally non-toxic and free of health hazards and environmental effects. Sodium salts may sometime cause environmental hazards in special circumstances. Some of the organics used for reactions may have toxic, corrosive and/or environmental effect.

Although most of the silicate formulations are considered permanent materials the end product is sometimes subjected to a phenomenon called syneresis which often tends to cause doubt about permanence. A newly made silica gel will, upon standing, exude water and shrink and this process is called syneresis. The total water loss is related to gel properties, generally decreasing with increasing silicate content and shorter setting times. Syneresis also takes place in the voids of a stabilized soil mass. In a soil where voids are completely filled with new gel, the shrinkage accompanying syneresis results in an increase in residual permeability after several weeks.

As soils become progressively finer, the practical effect of syneresis becomes smaller. For medium and fine sands, effects are generally considered negligible.

### 6.4 High Polymer Type Chemical Grout

The groups of compounds classified as high polymer type grouts are given at **6.4.1** to **6.4.4**.

#### **6.4.1 Acrylamide Grouts**

Acrylamide grouts consist of a mixture of two organic monomers, acrylamide (or methanol acrylamide, methacrylamide) and methylene bis-acrylamide, a cross linking agent. The other activators used are TEA (Triethanolamine) and DMAPN (Dimethyl amino propionate). The acrylamide grouts are considered to be an ideal grout. They can penetrate more readily, maintain constant viscosity during the induction period and have better gel time control and adequate strength for most applications. Acrylamide grouts are more costly than silicate grouts and are neurotoxic. The stiffness of the grouts can be changed by changing the acrylamide to methylene ratio. The values of unconfined compression (UC) and Young's Modulus increase with the increase in percentage of methylene bis-acrylamide from 3 to 10. Grout solution with up to 20 percent solids have viscosities well under 2 cP. The gels are considered permanent. The minimum concentration of grout from which a gel will form is temperature dependent.

#### **6.4.2 Lignosulfonate Grouts**

Lignosulfonates are the waste liquor by-products of the wood processing industries. Lignosulfonate grouts consist of lignosulfonate and a hexavalent chromium compound. Generally calcium lignosulfonate is used with sodium dichromate. Initial viscosity varies from 3 to 8 cP. The strength of the soils grouted with lignosulfonates is of the same order of magnitude, but somewhat less, than that of acrylamide grouts. Since lignosulfonates are byproducts of other processes, they are relatively cheaper and can compete on cost basis with any other chemical grout. Lignosulfonates are considered to be permanent materials. However, they are toxic and should be handled with care.

#### **6.4.3 Phenoplasts**

Phenoplasts are polycondensates resulting from the reaction of a phenol or aldehyde. Mostly resorcinol and formaldehyde are used and sodium hydroxide is used as a catalyst. The only control of setting time is the dilution of grout components. Setting time varies greatly with solution pH, being shortest for any given grout concentration at a pH slightly above 9. Initial viscosities of resorcinol-formaldehyde grouts range from 1.5 to 3 cP for concentrations normally used for field work. The viscosity remains constant at those low levels until gellation starts. The strength of soil grouted by this grout is comparable to high concentration silicates. The strength of soils stabilised by resorcinol formaldehyde grout is directly proportional to the resin content. Resistance to wet-dry cycles is poor and can lead to complete disintegration. Phenoplasts always contain a phenol, formaldehyde and an alkaline base. All three components are health hazards and potential environmental pollutants. Gels formed are generally inert (nontoxic and non-caustic).

#### **6.4.4 Polyurethane Grouts**

Polyurethanes are plastics that are used in a wide range of fields as hard or elastic, and unfoamed or foamed materials. Polyurethanes are formed by the reaction of two components namely polyisocyanates and polyalcohols or with other chemicals such as polyethers, polyesters and glycols, which have hydroxyl groups.

The catalysts used are tertiaryamines and tin salts may be used to control the reaction rate. Surface active agents are used to control bubble size. The foam structure itself is produced by a blowing agent reacting chemically to produce carbon dioxide.

#### **6.4.5 Aminoplasts or Urea Resins**

The major ingredients of this type of grout are urea and formaldehyde. In addition to urea, melamine, ethylene and propylene urea, aniline and other chemically related materials can be used. These grouts will set only in acidic conditions, therefore, they should be used only when it is known that ground and groundwater pH is below 7. Urea formaldehyde grouts have viscosities between 10 and 20 cP. Soils stabilised by these grouts have strengths comparable to the phenoplasts. The grout is toxic and corrosive. However, **properly designed** gel is inert.

### **6.5 Other Chemical Grouts**

It is possible, to a certain extent, to combine two available grouts so as to simultaneously obtain the optimum properties of each. To do so the materials must be chemically compatible. The silicates and the acrylamides can be used together. Polyesters and epoxies have been used to anchor rock reinforcement in drilled holes.

### **6.6 Grout properties**

Grout properties which are of importance may be broadly classified as given in **6.6.1** to **6.6.3**.

#### **6.6.1 Mechanical Properties**

##### **6.6.1.1 Permanence**

All grouts which contain water not chemically bound to the grout particles, are prone to mechanical deterioration if subjected to alternate freeze-thaw and/or wet-dry cycles. The rate of such deterioration varies with the amount of free water available in the grout as well as with the degree of drying or freezing. Chemical deterioration of grouts can occur if the grouts react with the soil or groundwater, or if the grout itself is soluble in groundwater or if the reaction products, which form the grout, are inherently unstable.

### 6.6.1.2 Penetration ability

The comparative ability of grouts to penetrate a formation is mainly a function of their relative viscosities. Thus viscosity is used as an indicator of penetrability. A rough estimate of penetrability of various chemical grouts in relation to soil grain size can be had from Fig. 2. Alternatively, penetrability can also be related with permeability higher than  $10^{-3}$  cm/s.

The usable viscosities of various materials depend on the minimum desirable field concentration of solids. The penetrability of various chemical grouts depends on the soil grain size. In terms of permeability a conservative criterion is that grouts with viscosities less than 2 cP, such as acrylamide based materials, can usually be pumped without trouble into soils with permeability as low as  $10^{-4}$  cm/s. At 5 cP, grouts such as the chrome lignin and phenoplasts, may be limited to soils with permeabilities up to  $10^{-3}$  cm/s, while silicate based grouts with viscosities of 10 cP may not penetrate soils with permeability below  $10^{-2}$  cm/s.

### 6.6.1.3 Strength

Chemical grouts have little strength compared to cement. However, what is important is the strength of the soil formation grouted with chemical grout. In most of the uses strength of grouted soil remaining immersed in a saturated formation is more important. This is termed as wet strength as compared to dry strength generally worked out in laboratory after air/oven drying. Unconfined compression tests are generally performed to evaluate strength of grouted mass, however, the triaxial test is a better choice.

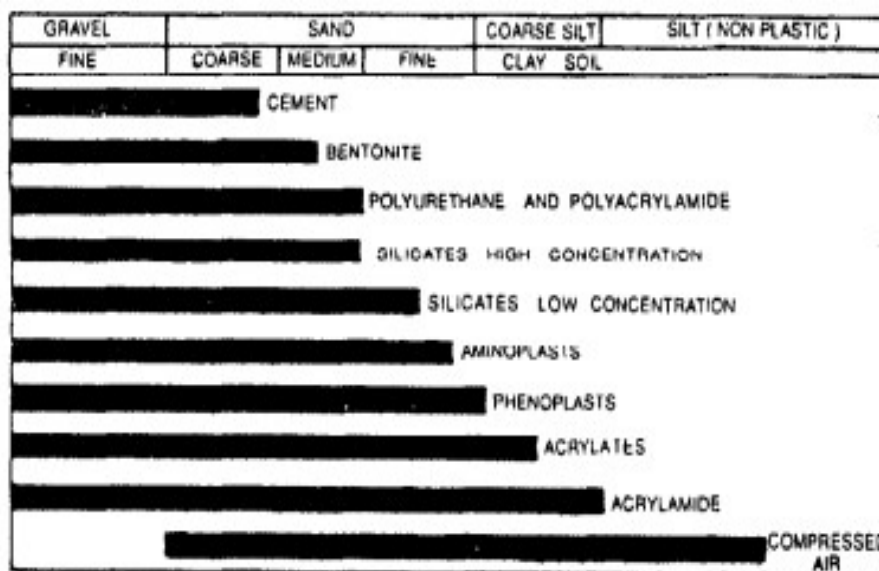


FIG. 2A PENETRABILITY OF VARIOUS GROUTS

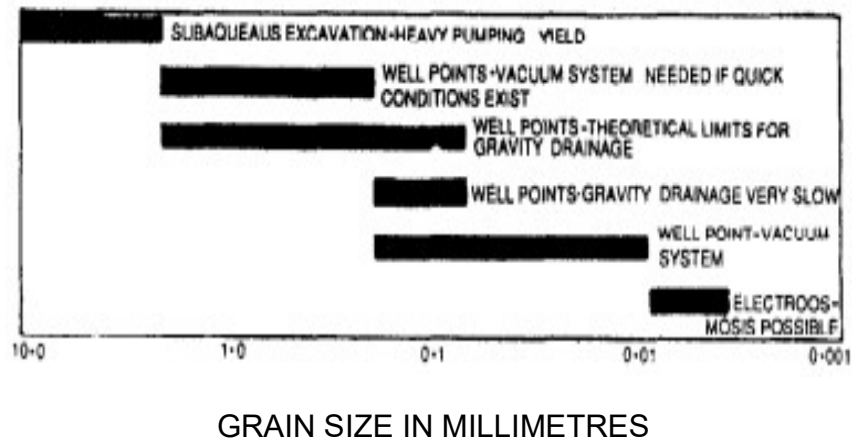


FIG. 2B EFFECTIVE RANGE OF GROUND WATER CONTROL MEASURES

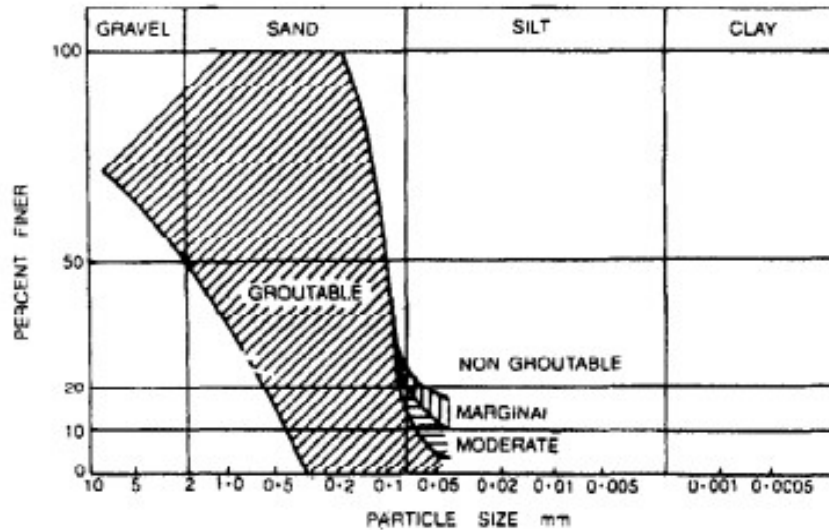


FIG. 2E GROUTABILITY OF SOIL BY VARIOUS SOLUTION GROUTS

## 6.6.2 Chemical Properties

### 6.6.2.1 Gel time control

The time lag from the mixing of the chemical components to the formation of a gel is referred to as gel time. With most grouts, the gel time can be changed by varying the concentration of either the activator, the inhibitor or the catalyst. If a wide range of gel time can be obtained and accurately repeated, gel time control is called good or excellent and if there is only a narrow range of gel time control, then it is termed fair or poor.



### **6.6.2.2***Sensitivity*

The degree to which a chemical grout is sensitive to the pH of ground water, temperature conditions and chemical activity of dissolved salts in ground water is termed as its sensitivity. Materials which are highly sensitive cause difficulty in handling. Materials which are highly sensitive, cause difficulty in handling. Prior knowledge of sensitivity of chemical grout to particular pH is useful. If not trial experiments should be conducted, for Materials which are highly sensitive cause difficulty in handling.

### **6.6.2.3***Toxicity*

Some of the chemical grouts used in the past and/or still in use, are classified as neurotoxic, cancer causing, toxic, corrosive, highly irritating, etc. There have been a number of incidents of people adversely affected by exposure to grouts.

All chemical grouts should therefore be handled with care in the field, with safety and cleanliness equal to or better than the manufacturer's recommendations.

### **6.6.3***Economic Factors*

Cost is a very important factor in selecting the construction method best suited to solving a specific field problem. When grouting is compared with other methods such as well pointing or slurry trenching, chances are that the cost comparison will be realistic. When comparing two different grouts, however, the mistake is often made of comparing raw material costs rather than in-place costs. Selecting the most suitable material for a specific job will generally overcome the possible lower material cost of other products.

## ANNEX A

(Clause2)

### LIST OF REFERRED INDIAN STANDARDS

<i>IS No.</i>	<i>Title</i>
269 : 2015 (Reviewed In : 2020)	Ordinary portland cement - Specification ( <i>Sixth Revision</i> )
383 : 2016 (Reviewed In : 2021)	Coarse and Fine Aggregate for Concrete - Specification (Third Revision)
1344 : 1981 (Reviewed In : 2018)	Specification for Calcined Clay Pozzolana
1489 (Part 1) : 2015 (Reviewed In : 2020)	Portland pozzolana cement – Specification: Part 1 fly Ash Based
1489 (Part 2) : 2015 (Reviewed In : 2020)	Portland - Pozzolana cement - Specification: Part 2 calcined clay based
1892 : 2021	Subsurface investigation for foundations — Code of practice (second revision)
<b>3812 : 1981</b>	<b>Fly Ash For Use As Pozzolana And Admixture (Withdrawn)</b>
4999 : 1991 (Reviewed In : 2018)	Recommendations for grouting of pervious soils (First Revision)
5529 (Part 1) : 2013 (Reviewed In : 2019)	In-situ permeability test Part 1 Test in overburden - Code of practice
<b>11293 (Part 1) : 1985</b> (Reviewed In : 2019)	<b>Guidelines for the design of grout curtains: Part 1 earth and rockfill dams (Withdrawn)</b>
12584 : 1989 (Reviewed In : 2018)	Bentonite for grouting in civil engineering works – Specification

## **ANNEX B**

*(Clause 5.2.2)*

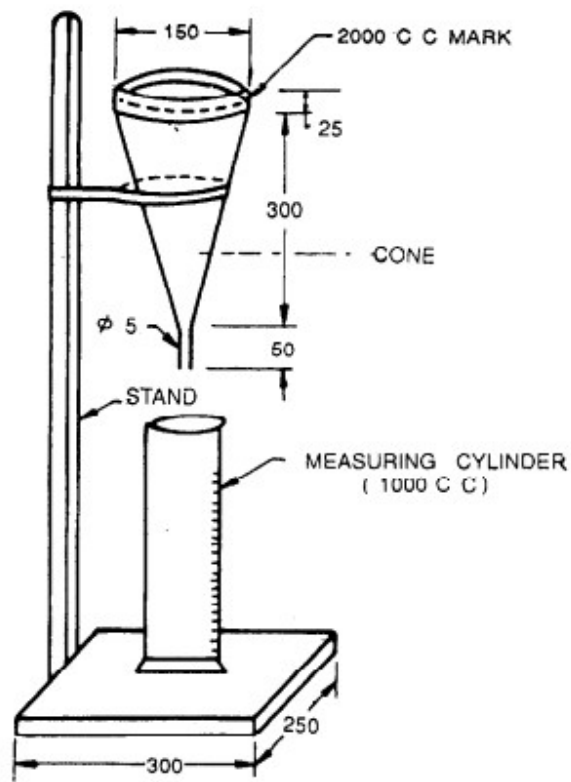
### **DESCRIPTION OF MARSH FUNNEL AND METHOD FOR DETERMINATION GROUT SLURRY**

#### **A-1 DESCRIPTION OF MARSII FUNNEL**

A Marsh Funnel as shown in Fig. 3 has a diameter of 150 mm at the top and a height of 300 mm, the bottom orifice outlet has an inside diameter of about 5 mm. The top of the cone has a screen with 1.5 mm openings, for screening out lumps of poorly mixed slurry

#### **A-2 METHOD**

Pour 2 000 cc of slurry into the funnel. Record the time taken for 1000 cc of the slurry to pass through the funnel into the measuring cylinder. The result to the nearest second is the Marsh funnel viscosity. For clear water at 21°C the Marsh funnel viscosity is 27 seconds. For grout slurries, the Marsh funnel viscosity has a good relationship with viscosity in centipoise determined by a rotational viscometer. The relationship is nearly straight line in the range of 30-40 seconds. This can be developed for each individual grout mix.



All dimensions in millimetres

FIG. 3 ILLUSTRATION OF A TYPICAL MARSH CONE