SECTION - 1

CHAPTER - 17

WHITE WASHING, COLOUR WASHING AND DISTEMPERING.

CHAPTER - 17

WHITEWASHING, COLOUR WASHING AND DISTEMPERING

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CHAPTER - 17

WHITEWASHING, COLOUR WASHING AND DISTEMPERING

17-1 REFERENCES

IS : 44 - 1969	Iron oxide pigments for paints (Amendment No.1) (first revision) (Reaffirmed 1983)
IS : 55 - 1970	Ultramarine blue for paints (first revision) (Amendment No.1) (Reaffirmed 1989)
IS : 253 - 1985	Edible commons salt (third revision)
IS : 261 - 1982	Copper Sulphate (second revision) (Amendment No.1) (Reaffirmed 1988)
IS : 427 - 1965	Distemper, dry colour as required (revised) (Amendment No.1 to 3) (Reaffirmed 1986)
IS : 428 - 1969	Distemper, oil emulsion, colour as required (first revision) (Amedment No. 1 & 2) (Reaffirmed 1986)
IS : 712 - 1984	Building limes (third revision)
IS : 797 - 1982	Common salt for chemical industries (third revision) (Amendment No.1) (Reaffirmed 1988)
IS : 852 - 1969	Animal glue for general wood-working purposes (first revision) (Amendment No.1)
IS : 1477 (Part II) - 1971	Painting of ferrous metals is buildings : Painting (first revision)
IS : 2395 (Part I) - 1966	Operations and workmanship for painting concrete, masonry and plaster surfaces
IS : 5410 - 1969	Cement paint, colour as required (Amendment No. 1 to 3) (Reaffirmed 1986)
IS : 6278 - 1971	Code of practice for whitewashing and colour washing (Reaffirmed 1987)

Specification - 1977 of "Central Public Works Department".

Standard Specification - 1977 of "National Building Organisation".

Khanna Hand Book for Civil Engineers (Edition - 1982).

17.2 MATERIALS

17.2.1 Cement Paint

It is a material consisting of portland cement and other ingredients like lime, pigments, hygroscopic alts, water repellants and fungicides. It shall conform to IS:5410 - 1969.

17.2.2 Clearcole

This shall be made from glue and boiling water by mixing one kilogram of glue to every 15 litres of water. The mixture shall be suitably added with whiting for use as priming/sealer coat before applying lime wash or distemper.

17.2.3 Lime

Lime used for whitewashing shall be freshly burnt class "C" lime (fat lime) and white in colour conforming to IS:712 - 1984.

17.2.4 Water

Water shall be clear, free from all organic and suspended impurities. Portable water is most suitable for the purpose.

17.2.5. Gum or Glue

Best quality gun conforming to IS:852-1969 shall be used.

17.2.6 Sodium Chloride

It shall conform to either IS:253 - 1985 or grade II of IS:797-1982.

17.2.7 Ultramarine Blue or Indigo

This shall conform to IS:55 - 1970.

17.2.8 Pigments

Mineral colours, not affected by lime shall be used in preparing colour wash.

17.2.8.1 Yellow and Red Ochre - The ochres shall conform to IS:44-1969. The solid lumps shall be crushed to powder.

17.2.8.2 Blue Vitriol - Fresh crystals of hydrous copper sulphate (blue vitriol) shall conform to IS:261 - 1982 and shall be grounded to the fine powder.

17.2.9 Distemper

17.2.9.1 Dry Distemper - Dry distemper conforming to IS : 427 - 1965 shall be used.

17.2.9.2 Oil Bund Distemper – It shall be of approved shade of colour conforming to IS : 428 - 1969

17.2.10 Water Proof Cement Paint

It shall be as specified in IS : 5410 – 1969

17.3 WHITEWASHING AND COLOURWASHING

17.3.1 Scaffolding

Wherever scaffolding is necessary, it shall be erected in such a way so that, as far as possible no part of scaffolding shall rest against the surface to be white or colour washed. A properly secured and well tied suspended platform (JHOOLA) may be used for whitewashing. Where ladders are used, pieces of old gunny bags shall be tied at top and bottom to prevent scratches to the wall and floors. For whitewashing of ceilings, proper stage scaffolding may be erected, where necessary.

17.3.2 Preparation of Surfaces

17.3.2.1 New Surface - The surface shall be thoroughly cleaned of all dirt, dust, mortar drops and other foreign matter, before white wash is to be applied.

17.3.2.2 Old Surface

17.3.2.2.1 Surfaces, Where the Same Whitewash is to be Repeated - Old surfaces already white washed shall be broomed down to remove all dust and dirt. All loose scales of lime wash and other foreign matter shall also be removed. Where heavy scaling has taken place the entire surface shall be scrapped clean. This will also apply, where a colour wash has to be given on an already white washed surface.

17.3.2.2.2 Surfaces, Where Different Colour Wash is to be Repeated - Old colour wash on surfaces shall be entirely removed before white wash or colour wash is applied. The surface shall be prepared by brushing or by scrapping or by other suitable means to produce clean surface and shall be broomed to remove dust, dirt, etc.

17.3.2.2.3 Old Surface Spoiled by Smoke Soot - The surface shall be scrapped with steel wire brushes or steel scrapers. The surface shall then be broomed to remove all dust and dirt and shall be washed with clean water.

17.3.2.2.4 Oil and Grease Spots - Oil and grease spots shall be removed by a suitable chemical as specified at para 6 of IS:1477 (Pt I)- 1971 and smooth surfaces shall be rubbed with wire brushes.

17.3.2.2.5 All unsound portions of the surface plaster shall be removed to full depth of plaster in rectangular patches and plastered again after raking the masonry joints properly. Such portions shall be wetted and allowed to dry. They shall then be given one coat of white wash. All unnecessary nails shall be removed; the holes and cracks filled with lime putty or plaster of Paris to make the surface smooth.

17.3.2.2.6 When whitewashing old surfaces, if the surface was found to be infected with any growth of moulds, moss then such growth shall be removed by scraping with steel scraper and ammoniacal copper solution consisting of 15g of copper carbonate dissolved in 60ml of liquor ammonia in 500ml water shall be applied to the surface and allowed to dry thoroughly before applying whitewash or colourwash. An alternative to ammoniacal copper solution treatment may consist of 2 percent sodium pentachlorophenate solution in water.

17.3.2.2.7 Local areas affected by efflorescence, shall be initially treated in accordance with the method described below and then applied with whitewash or colourwash.

Sealing coats my not effectively hold back strong efflorescence. Dry brushing of the growth as it appears is the only remedy. Efflorescent salts shall not be removed by washing with water as it may carry some of the slats back into the pores. On redrying, efflorescence may be even worse than before if the salts were still present in the structure. Efflorescences will continue as long as there is sufficient water in the structure or plaster backings to carry the soluble salts forward and it is useless to attempt to seal the moisture by the paint film on the surface. The treatment of an old wall with hydrofuge silicone will frequently stop the efflorescence as the liquid blocks the passage for movement of moisture. In the case of efflorescence due to the rising of salt solutions through capillary action from sub-soil the only remedy is to provide bitumen or metallic seals in the walls above the ground level so that an effective barrier to the capillary action is created.

17.3.3 Preparation of whitewash and Colourwash

17.3.3.1 Preparation of Whitewash - White wash, shall be prepared from fat lime conforming to IS:712-1984. The lime shall be slaked at site and shall be mixed and stirred with about five litres of water for one kilogram of unslaked lime to make a thin cream. This shall be allowed to stand for a period of 24 hours and this shall be screened through a clean coarse cloth. Add one kilogram of gum dissolved in hot water shall be added to each cubic metre of lime cream. About 1.3 kg of sodium chloride dissolved in hot water may be added for every 10 kg of lime. Shall quantity of ultramarine blue (upto 3g per Kg of lime) shall also be added to the last two coats of white wash solution and the whole solution shall be stirred thoroughly before use.

NOTE -1 Whitewash may also be prepared by dissolving whiting (ground white chalk) in sufficient quantity of warm water and thorough stiring to form a thin slurry which shall then be screened thorough a clean coarse cloth. 2kg of gum, 0.4kg of copper sulphate dissolved separately in hot water shall be added for every cubic metre of the slurry which shall then be diluted with water to the consistency of milk so as to make a wash ready for use.

NOTE -2 The addition of sodium chloride (common salt) to lime wash helps in making the coating hard and rub resistant.

17.3.3.2. Preparation of Colourwash - Sufficient quantity of colour wash enough for the complete job shall be prepared in one operation to avoid any difference in shade. The basic white wash solution shall be prepared in accordance with para 17.3.3.1. Mineral colours not affected by lime shall be added to the white wash solution as prepared in para 17.3.3.1.

17.3.3.2.1 *Preparation of Colourwash with Pigments* - It shall be prepared as under :

(a) **WITH YELLOW AND RED OCHRE -** Solid lump, if any, in the powder, shall be crushed to powder and solution in water prepared and then added to white wash sieving it through a coarse cloth, mixed evenly and thoroughly to white wash in small quantities, till the required shade is obtained.

(b) **WITH BLUE VITRIOL -** Fresh crystals of hydrous copper sulphate i.e. Blue Vitriol shall be ground to fine powder and dissolved in small quantity of water. Sufficient quantity of solution enough to produce the colour wash of required shade shall be strained through a clean coarse cloth. The filtrate being mixed evenly and thoroughly to the white wash.

(c) Clour wash from other colouring pigments shall be prepared in accordance with the instructions of the manufacturer.

17.3.3.3 For exterior work the whitewash or colourwash that will adhere well to stone and masonry surfaces may also be prepared by scattering one part by weight of tallow in small lumps over 12 parts of quick lime, slaking it with only just sufficient water to form a thick paste, stirring occasionally to assist in dispersing the tallow, and allowing it to stand until cool. The resultant paste shall then be let down to thin wash, which is strained through a coarse cloth. If tallow is not obtainable, then linseed oil or caster-oil about 10% by weight of dry lime may be used. If the oil does not sponify and incorporate with lime, it should be heated up until the oil disappears. The oil forms with lime an insoluble soap, which then once dry, will not wash off with heavy rain. In case of colourwash, mineral colours, such as oxide of iron red and yellow colours, based on chromium oxide and carbon black not affected by lime may be added. Use of linseed oil is likely to give slight yellow tinge to whitewash.

17.3.4 Application of Whitewash and Colourwash

17.3.4.1 Application of Whitewash - White shall be applied with 'MOONJ' brush to the specified number of coats. The operation for each coat shall consist of a stroke of the brush given from the top downwards, another from the bottom upwards over the first stroke, and similarly one stroke horizontally from the right and another from the left before it dries. Each coat shall be allowed to dry before the next coat is applied. No portion of the surface shall be left out initially to be patched up later on. The brush shall be dipped in white wash, pressed lightly against the wall of the container, and then applied lightly pressing against the surface with full swing of hand.

17.3.4.1.1 The whitewashing on ceiling should be done prior to that on walls.

17.3.4.1.2 For new work, minimum two coats shall be applied so that the surface present a smooth and uniform finish through which the plaster does not show. The finished dry surface shall not show any signs of cracking and peeling and the white wash shall not come off readily on the hand, when rubbed.

17.3.4.1.3 For old work, after the surface has been prepared as described in para 17.3.2.2, a coat of white wash shall be applied over the patches and repairs. Then one, or two or more coats of white wash shall be applied over the entire surface. The white washed surface shall present a uniform finish through which the plaster patches do not show.

17.3.4.2 Application of Colourwash - The colour wash shall be applied in accordance with the procedure given in para 17.3.4.1 For colour washing on new works, after the surface has been prepared as in 17.3.2.1, the first primary coat shall be of white wash and the subsequent coats (minimum two) shall be of colourwash, and the entire surface shall present a smooth and uniform finish. To start with, 0.1 sqm of the prepared surface shall be colour washed with the first coat of white wash and subsequent coats of colour wash solution in full number of coats and the shade so obtained shall be examined before the entire work of colourwashing is taken up in hand. It shall be noted that small areas of colourwash will appear lighter in shade than when the same shades are applied to large surfaces.

17.3.4.2.1 For colourwashing on old work, after the surface has been prepared as in 17.3.2.2, a coat of colour wash shall be applied for the patches and repairs. Then the specified number of coats of colour wash shall be applied over the entire surface. The colour washed surface shall present a uniform colour shade. No primary coat is needed for old surface bearing colour of the same shade.

17.3.4.2.2 One surfaces requiring a change of colour, after the surface has been prepared as in para 17.3.2.2.2, two coats of white wash shall be applied before application of specified number (minimum two) of coats of colour wash of the new shade.

17.3.5 Protective Measures

Surfaces of doors, windows, floors, articles of furniture, etc. and such other parts of the building not to be white washed or colour washed shall be protected from being splashed upon. Such surfaces shall be cleaned of whitewash or colourwash splashes, if any.

17.4 DISTEMPERING

17.4.1 Dry Distempering

17.4.1.1 Scaffolding - Specifications as per para 17.3.1 shall be followed.

17.4.1.2 Preparation of Surfaces - Specifications as described under para 17.3.2 shall be followed. For removal of loose pieces and scales from old surfaces sand papering shall be done in place of brooming and new surface shall be sand papered smooth after cleaning. New plaster surfaces shall be allowed to dry for at least two months before applying distemper.

17.4.1.3 Primary Coat

17.4.1.3.1 New Surfaces - A primary coat of chalk whiting prepared as per Note 1 of para 17.3.3.1 shall be applied over the prepared surface in case of new work. Whitewashing with lime shall not be used as a primary coat for distemper. The treated surface shall be allowed to dry before distemper coat is given.

17.4.1.3.2 Old Surfaces - On surfaces requiring a change in shade of dry distemper after the surface has been prepared as in 17.4.1.2, two coats of chalk whiting shall be applied before application of specified number (minimum two) of coats of the new shade dry distemper.

17.4.1.4 Preparation of Distemper - Dry distemper of required colour and specification specified in IS:427 - 1965 of approved brand and manufacture shall be used. The shade shall be got approved from the Engineer-in-Charge before application of the distemper. The dry distemper shall be stirred slowly in clean warm water using 6 decilitres (0.6 litres) of water per kilogram of distemper or in the proportion as specified by the manufacturer. It shall be allowed to stand for at least 30 minutes (or if practicable over night) before applying. The mixture shall be well stirred before and during use to maintain an even consistency. The distemper shall not be mixed in larger quantity than is actually required for the day's work. Sufficient quantity of distemper shall be mixed to finish one room at a time.

17.4.1.5 Application of Distemper

17.4.1.5.1 For the new surfaces, after the primary coat has dried, the surface shall be lightly sand papered taking care not to rub out the primary coat, and then dusted off with clean cloth. Prepared distemper shall then be applied in minimum two coats with proper 15cm double bristled distemper brushes in horizontal strokes immediately followed by vertical ones which together shall constitute one coat. The subsequent coats over the preceding one shall be applied only after the previous coat has dried. For old surfaces, the distemper shall be applied in one coat or more over the prepared surface in the same manner as for new surfaces. Distempering shall be done in dry climates as they give poor results in wet localities.

17.4.1.5.2 The finished surface shall be given uniform surface without patches, brush marks, distemper drops etc.

17.4.1.5.3 The application of a coat in each room shall be finished in one operation and no work shall be started in any room, which cannot be completed the same day.

17.4.1.5.4 After each day's work, brushes shall be throughly washed in hot water and hung down to dry. Old brushes which are dirty or caked with distemper shall not be used.

17.4.1.6 Protective Measures - Specifications as per para 17.3.5 shall be followed.

17.4.2 Oil - Bound Distempering

17.4.2.2 Scaffolding - Specifications as per para 17.3.1 shall be followed.

17.4.2.2 Preparation of surfaces - Specification of para 17.4.1.2 shall be followed except that any unevenness on new surfaces shall be made good by applying putty, (made of plaster of Paris mixed with water) on the entire surface including filling up undulation and then sand papering the same after it is dry. In case of old surfaces already dry distempered and required for applying oild bound distempers, the distempers, the distemper whether in good or bad conditions shall be removed completely by washing even to the last trace and allowed to dry completely and then sand papered smooth.

17.4.2.3 Primary Coat

17.4.2.3.1 New Surface - The primary coat on new surface shall be alkali resistance cement primer or distemper primer as specified in the item. These shall be of the same manufacture as oil bound distemper. If the wall surface plaster has not dried completely alkali resistance cement primer shall be applied before distempering the walls. But if the distempering is required , after the wall surface is dried completely distemper primer shall be applied. The application of the cement primer shall be done in the manner as described below :

The cement primer shall be applied with a brush on the clean dry and smooth surface. Horizontal strokes shall be given first and vertical strokes shall be applied immediately afterwards. This entire operation will constitute one coat. The surface shall be finished as uniformly as possible leaving no brush marks. It shall be allowed to dry for at least 48 hours, before oil bound distemper is applied. However, oil bound distemper is not

recommended to be applied within six months of the completion of wall plaster.

17.4.2.3.2 Old Surface - For old surfaces, no primary coat is necessary, On surfaces requiring a change in shade of oil bound distemper, after the surface has been prepared as per para 17.4.2.2, two coats of distemper primer as per manufacturer's instruction shall be applied before applications of specified number (minimum two) of coats of new shade oil-bound distemper.

17.4.2.4 Preparation of Oil Bound Distemper - Oil bound distemper as specified in IS : 428 - 1969 of, approved brand and manufacture shall be used. The distemper shall be diluted with water or with any other prescribed thinner in a manner recommended by the manufacturer. Only sufficient quantity of distemper required for day's work or at least to finish one room at a time shall be prepared.

17.4.2.5 Application of Distemper Coat - Specification given at para 17.4.1.5 shall be followed, except that the distemper coat on new surfaces shall be applied after the primary coat has dried for at least 48 bours.

17.4.2.6 Protective Measures - Specification as per para 17.3.5 shall be followed.

17.5 WATER PROOF CEMENT PAINTING

17.5.1 General

Portland cement paints are suitable for use on exterior and interior cement concrete and stucco surfaces not subjected to mechanical abrasion. They are recommended where it is desired to decorate or reduce the water permeability of exterior walls built of porous, open textured concrete such as concrete block masonry. They may also be used where the concrete or stucco is damp at the time of painting or may become damp subsequently. They are not well suited for interior surfaces requiring frequent and thorough cleaning, as coatings of these paints are not easily washed and tend to erode with vigorous scrubbing. Cement painting shall be deferred until the cement concrete stucco has aged at least three weeks. The application of tinted paints to cast in place concrete will be drier and a less likely source of efflorescence.

17.5.2 Scaffolding

Specifications as per para 17.3.1 shall be followed.

17.5.3 Preparation of Surfaces

Specification as per para 17.3.2 shall be applicable, except that word "whitewash" / "colourwash" shall be substituted with "water proof cement paint". The surface to which the paint is applied shall be free from chalking or other extraneous matters which interfere with the adhesion of the paint to the surface. Before applying a cement paint the concrete shall be thoroughly wetted to control surface suction and to provide a reserve of moisture to aid in the proper curing of the paint. A garden hose adjusted to give a fine spray may be used for this purpose. For concrete masonry walls that readily absorb moisture, the surface shall be wetted in one operation not more than one hour before painting. The surface shall be moist but not dripping wet when the paint is applied. Dense concrete absorbs moisture so slowly that it shall be wetted in a least two operations not less than 30 minutes apart. It will be more effective to dampen larger areas in advance of painting so that ample time is allowed for the moisture to soak in to the concrete.

17.5.4 Preparation of Paint

17.5.4.1 Portland cement paints as specified in IS : 5410 - 1969 shall be made readily be adding paint powder to water and stirring to obtain thick paste which shall then be diluted to a brush able consistency. Generally equal volumes of paint powder and water make a satisfactory paint. In all cases the manufacturer's instructions shall be followed. The paint shall be mixed in such quantities as can be used up within and hour or mixing as otherwise the mixture will set and thicken, affecting flow and finish. However, in absence of any specific instruction from manufacturer following procedure may be followed:

Cement paint shall be mixed with water in two stages. The first stage shall comprise of two parts of cement paint and one part of water stirred thoroughly and allowed to stand for 5 minutes. Care shall be taken to add the cement paint gradually to the water and not vice versa. The second stage shall comprise of adding further one part of water to the mix and stirring thoroughly to obtain a liquid of workable and uniform consistency. The covering capacity of cement paint for two coat brush work on plastered surfaces shall be 3 to 4 Sqm per K.g.

17.5.4.2 The lids of cement paint drums shall be kept tightly closed when not in use, as by exposure to atmosphere the cement paint rapidly becomes air set due to its. hygroscopic qualities.

17.5.5 Application of Paint

17.5.5.1 No painting shall be done when the paint is likely to be exposed to a temperature of below 7^{o} C within 48 hours after application.

17.5.5.2 When weather conditions are such as to cause the paint to dry rapidly, work shall be carried out in the shadow as far as possible. This

helps the proper hardening o the paint film by keeping the surface moist for a longer period.

17.5.5.3 To maintain a uniform mixture and to prevent segregation, the paint shall be stirred frequently in the bucket.

17.5.5.4 For new surfaces, the surface shall be treated with minimum two coats of water - proof cement paint. Not less than 24 hours shall be allowed between two coats. The second or subsequent coat shall not be started until the preceding coat has become sufficiently hard to slightly moistened before applying the subsequent coat. For old surfaces, the treatment will be with one or more coats and shall be done in the same manner as for new surfaces.

17.5.5.5. The finished surface shall be even and uniform in shade without patches, brush marks, paints drops, etc.

17.5.5.6 Cement paints shall be applied with a brush with relatively short stiff hog or fiber bristles. The paint shall be brushed in uniform thickness and shall be free from excessively heavy brush marks. The laps shall be well brushed out. The paint shall be applied, first using vertical strokes until the surfaces are covered, and then brushes cross wise for complete coverage with light strokes, as to smooth out lapse and brush marks and finally laid of vertical strokes.

17.5.5.7 When painting concrete masonry for the dual purpose of moisture proofing and decoration both the coats shall be vigorously scrubbed on in such a manner as to work the paint into the voids and provide a continuous paint film free from pinholes through which water may penetrate.

17.5.5.8 Spray application may only be adopted for dense concrete or interior surfaces where the paint is not required for water proofing purposes.

17.5.5.9 Cement paints shall not be applied on surfaces already treated with whitewash, colourwash, distemper dry or oil - bound, varnishes, paints etc. It shall not be applied on gypsum, wood and metal surfaces.

17.5.6 Curing

Hardening of paint films depend upon the availability of moisture for chemical reaction with the Portland cement. Painted surfaces shall be sprinkled with water using a fog spray two or three times a day. It is recommended that this shall be done between coats and for least two days following the final coat. The curing shall be started as soon as the paint has hardened so as not to be damaged by the spray, about 12 hours after the application.

17.5.7 Protective Measures

Specifications as per Para 17.3.5 shall be followed.

17.6 CEMENT SLURRY WASH

17.6.1 Scaffolding

The specification for scaffolding shall be the same as described under para 17.3.1.

17.6.2 Preparation of Surface

The surfaces must be clean and free from oil, grease, dust or loose material. The area to be coated by cement slurry shall be thoroughly wet.

17.6.3 Preparation of Cement Slurry Wash.

Cement shall be mixed with water to form slurry to the consistency of good ready mixed paint. About 14 kg of cement per 100 sqm of surface shall be used.

17.6.4 Application of Cement Slurry Wash

The cement slurry wash shall be applied with a white wash flat brush, over the well wetted surface in two coats or in one coat.

17.6.5 Protective Measures.

Curing is essential to ensure complete hydration of cement base. The finished surface should be sprinkled with water two or three times a day for 3 days, for if the wash dries before it has attained its set, it may dust off.

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18.1 REFERENCES

IS:16(PT.I) 1973	Hand made shellac(second revision) (amendment 1to3(Reaffirmed 1987)
IS:16 (Pt.II) 1973	Machine made shellac (second revision)(amendment No.1 to3) (Reaffirmed 1986)
IS:75-1973	Linseed oil, raw and refined (second revision) (with amendment No1)(Reaffirmed 1984)
IS:104-1979	Ready mixed paint] brushing grey filler, for enamels, for use over primers (second revision)
IS:110 -1983	Ready mixed paint, brushing grey filler, for enamels, for, use over primers (Second revision)
IS:158-1981	Ready mixed paint, brushing bituminous black, lead free, acid, alkali, and heat resisting (third revision) (amendment No.1)
IS:218-1983	Creosote oil for use as wood preservatives (Second revision)
IS:290-1961	Coal tar black paint (Revised) Reaffirmed 1986)
IS:324-1959	Ordinary denatured spirit (Revised) (with amendment No.1) (Reaffirmed 1984)
IS:337-1975	Varnish, finishing interior (First revision)(Reaffirmed No.1)
IS:341-1973	Black Japan, Types A,B and C (Firs revision)Reaffirmed 1986)
IS:345-1952	Wood filler, transparent, liquid (with amendment No.1and 2) (Reaffirmed 1986)
IS:347-1975	Varnish, shellac for general purposes (first revision)Reaffirmed 1986)
IS:348-1968	French polish (First revision) (with amendment No.1) (Reaffirmed 1986)
IS:384-1979	Brushes, paints and varnishes, flat (Fourth revision) Reaffirmed 1985)
IS:423-1961	Plastic wood for joiners filler (Revised)(with amendment No.1) (Reaffirmed 1986)
IS:486-1983	Brushes sash tool, paints and varnished (third revision) (Reaffirmed 1989)
IS 487 - 1985	Brush paint and varnish (i) oval, ferrule bound, and (ii) round, ferrule bound (third revision).
IS:524-1983	Varnish, finishing exterior exterior synthetic, air-drying (Second revision).
IS:1303-1983	Glossary of terms relating to paints (Second revision).
IS: 1407-1980	Round paint tins (Second revision)(Reaffirmed1987)
IS: 1477-(part I 1971	Code of practice for painting of ferrous metals in buildings: Pre - treatment (First revision)-(Reaffimed1979).

IS: 1477-(part II) 1971	Code of practice for painting of ferrous metals in buildings: Painting (First revision)-(Reaffimed1979).
IS: 2074-1979	Ready mixed paint, air drying red oxide-zinc chrome priming (First revision)(with amendment Nos. 1 to 4) (Reaffirmed 1986)
IS:2338(part I) 1967	Code of practice for finishing of wood and wood based materials: Operations and - Workmanship.
IS:2338(part II) 1967	Code of practice for finishing of wood and wood based materials: Schedules.
IS: 2339-1963	Aluminium paint, for general purposes, in dual container (with amendment Nos. 1 and 2 (Reaffirmed 1986)
IS:2395(Part I) 1966	Code of practice for painting concrete, masonry and plaster surfaces : Operations and -Workmanship.
IS:2395(Part II) 1967	Code of practice for painting concrete, masonry and plaster surfaces: Schedules
IS:2524(part I) 1968	Code of practice for painting of non-ferrous metals in buildings: Pre-treatment.
IS:2524(part II) 1968	Code of practice for painting of non-ferrous metals in buildings: Pre-treatment.
IS:2525-1979	Steel drums (Second revision)
IS:2631-1976	Isopropyl alcohol (First revision)(Reaffirmed 1984).
IS:2932-1974	Enamel, synthetic , exterior (a) under coating , (b) finishing (First revision) (with amendment Nos. 1 and 2) (Reaffirmed 1981).
IS:3140-1975	Code of practice for painting asbestos cement building products.
IS:3536-1966	Ready mixed paints, brushing , wood primer , pink (with amendment No.1) -(Reaffirmed 1979).
IS:3585-1966	Ready mixed paint, aluminum, brushing, priming, water resistant, for work (with amendment No.1) (Reaffirmed 1986).
IS:5411-(part I) 1974	Plastic emulsion paint for interior use (First revision)(with amendment) (Reaffirmed 1987).
SP 1650-1973	Standard colours for building and decorative finishes (with supplement) (Reaffirmed 1979)
	Standard Specifcation-1977 of " National Building Organisation" Specification -1977 of "Central Public Works Department Volume one.

18.1.1 The Indian Standard Colour Numbers are given below:

101	Sky blue	102	Turquoise blue
103	Peacock blue	104	Azure blue
105	Oxford blue	106	Royal blue
169	Traffic blue	174	Oriental blue

216	Eau-de-nil	217	Sea green
218	Grass green	219	Sage green
220	Olive green	221	Brilliant green
222	Light bronze green	223	Middle bronze green
224	Deep bronze green	225	Light Brunswick green
267	Traffic green	275	Opaline green
278	Light olive green	279	Steel furniture grey
280	Verdigris green	281	Apple green
283	Aircraft grey green	309	Canary yellow
352	Pale cream	353	Deep cream
354	Prime rose	355	Lemon
356	Golden yellow	358	Light buff
359	Middle Bugg	360	Deep buff
363	Dark stone	364	Portland stone
365	Vellum	368	Traffic yellow
384	Light straw	385	Light biscuit
386	Beige	397	Jasmine yellow
410	Light brown	411	Middle brown
412	Dark brown	413	Nut brown
414	Golden brown	442	Light salmon pink
443	Salmon pink	444	Terra cotta
445	Venetian red	446	Red oxide
448	Deep Indian red	449	Light purple brown
451	Chocolate	473	Gulf red
536	Fire red	537	Signal red
538	Post office red	540	Crimson
541	Maroon	557	Light orange
570	Traffic red	574	Indian grey
628	Silver grey	629	Quaker grey
630	French grey	631	Light grey
632	Dark admiral grey	633	R A F blue grey
634	Slate	635	Lead
692	Smoke grey	693	Air-craft grey
694	Dove grey	697	Light admiral grey

18.2 TERMINOLOGY

Abrasion Resistance - Resistance of a coating frictional rubbing**. Abrasion test** may be made by means of the finger alone, or with cloth or a pad with or without

a mildly abrasive powder. The pressure, speed and time of rubbing as well as the character of the rubbing agent, should be controlled when making comparisons of abrasion resistances of different surfaces.

Accelerated Weathering (Artificial Weathering) - Laboratory tests designed to simulate, intensify and accelerate the destructive action of natural outdoor weathering agents, such as light, heat, cold water, water vapour, rain etc. on paint films. There is no universally accepted test and different procedures may have to be used to suit different conditions.

Accelerator-Any substance which increases the speed of a chemical reaction and thus hastens the curing or cross linking of a system

Acid Resistance- Resistance of paint, enamel or varnish film to acids. The term of little value, unless it is referred to a standard performance under specified conditions.

Acoustic Material - A soft or aerated material lightly bound or bonded to form a soft, absorbent coating or fabricated stab for the purpose of eliminating echoes. Special care should be taken while decorating to avoid modification of acoustic properties.

Adhesion - The degree of attachment between a paint or varnish film and the underlying material which may be another film or paint or any other material, such as wood, metal, plaster etc.

After Tack - A film defect, in which the painted surface having once reached a tack-free stage, subsequently develops a sticky condition.

Alkali Resistance - Resistance of paint, enamel or varnish film to alkalis. The term is of little value unless it is referred to some standard of performance under specified conditions.

Anti - Condensation Paint - A paint designed to minimize the effects of condensation of moisture under intermittently dry and humid conditions. Such a material normally has a matt textured finish and frequently contains cork or some other heat insulating materials as a filler.

Anti - Corrosive - A general term used to describe material used for preventing corrosion.

Barrier Coat - A coating used to isolate a paint system from the surface to which it is applied in order to prevent chemical or physical interaction between them, to prevent the paint solvent attacking the underlying paint or to prevent bleeding from underlying paint or material.

Binder - The non-volatile portion of the 'Vehicle' of a paint. It binds or cements the pigment particles together and the paint film as a whole to the material to which it is applied.

Bituminous Paints - Paints based essentially on bituminous ingredients.

Bituminous Solution - Bitumen or asphalt dissolved in organic solvent.

Bituminous Varnish - Varnish essentially based on bituminous/asphalt ingredients.

Black Japan - A black material, similar to a normal oil varnish, containing a drying oil and gilsonite or other asphaltic material. It dries, by oxidation, to a hard glossy film in which the gilsonite may be regarded as replacing the copal resin in a normal varnish: A good black japan can be varnished over without bleeding of the gilsonite.

Blast Cleaning - The cleaning and roughening of a surface, by the use of natural or artificial grit or fine metal shot (usually steel), which is projected on to a surface by compressed air or mechanical means.

Bleeding - The process of diffusion of a soluble coloured substance from a substratum, into and through a paint or varnish coating from beneath, thus producing an undesirable staining or discoloration.

Blistering - The formation of dome-shaped projections or blisters in paint or varnish films by local loss of adhesion and lifting of the film from the underlying surface. Such blisters may contain liquid, vapour, gas or crystals.

Boiled Linseed Oil - Raw linseed oil that has been heated in the presence of metallic compounds known as 'driers'.

Bridging - The covering over of an unfilled gap, such as a crack or comer, with a film of paint. This introduces a weakness in the coating which may lead to an eventual cracking of the dried paint.

Bring Forward - A term used in repainting, to repair local defective areas with the appropriate paints so as to bring them in conformity with the surrounding areas before applying the finishing coat.

Brittleness - Change characterized by an appreciable reduction in the initial flexibility, cohesion and adhesion of the film.

Bronzing - A characteristic metallic lustre shown by certain highly coloured pigments in full strength, for example, certain prussian and pthalocyanine blues.

Brush Mark - Ridge in a dried paint film and varnish, left by the brush.

Bubbling - A film defect, temporary or permanent, in which bubbles of air or solvent vapour, or both, are present in the applied film.

Burning Off - The removal of paint by a process in which the paint is softened by heat, for example, on a flame, and then scraped off while still soft.

Caking - The setting of pigment particles of paint into a hard compact mass,

which is not easily redispersed by stirring.

Cement Paint - A paint. based on portland cement, supplied as a dry powder, for mixing with water immediately by stirring.

Chalking - A phenomenon manifested in paint film by the presence of loose removable powder, evolved from the film itself at or just beneath the surface. Chalking may be detected by rubbing the film with the finger tip or other means.

Coat - The paint, varnish or lacquer applied to a surface in a single application to form a properly distributed film when dry. A paint system usually consists of a number of coats separately applied in a predetermined order at suitable intervals to allow for drying. It is possible with certain types of material, to build up paint systems of adequate thickness and opacity by a more or less continuous process of application, namely wet on wet spraying. In this case no part of the system can be defined as a separate coat in the above sense. Full coat is defined as thick a coat of paint, varnish or lacquer as can be applied in one operation (brush or spray) consistent with the production of a film of uniform appearance, satisfactory hardness, etc., when dry.

Coating - A liquid liquifiable for mastic composition, that is converted to a solid- protective, decorative or functional adherent film after application as a thin layer.

Cohesion - The forces which bind the particles of paint or varnish film together into a coherent whole.

Colour -The aspect of the appearance of objects which depends upon the spectral composition of light reaching the retina of the eye and upon its temporal and spatial distribution. Mixtures of blends of these are also colours. The colours of objects have three attributes, hue, lightness and saturation.

(a) *Hue* - Colours are first divided into groups having the same hue that is, into reds, yellows, greens, blues, purples, etc. Almost all systems of colour terminology use the term hue in this sense, but in ordinary speech this quality is often called colour.

(b) *Lightness* - The lightness of a colour is determined by the proportion of light which it reflects, irrespective of hue and saturation. Corresponding terms. used are 'Value' and 'Reflectance Value'.

***(c) Saturation* -** Colours of similar hue and lightness may .differ in colourfulness of intensity of colour. This quality is termed saturation and may be defined as the intensity of any particular hue when compared with a neutral grey off similar lightness, spectrum colours being the most intense or of highest saturation. The terms 'Chroma' and 'intensity' are also used in similar sense.

Consistency - It is the apparent viscosity of a paint or varnish when shearing forces of varying degree are applied to it in various ways, for instance, when it is

stirred in the can or poured from one vessel to another or brushed (or otherwise spread out) over a surface.

Copal- Natural resin formed from the exudation of various tropical trees. The hard fossil types are the basis of copal varnishes, the softer types frequently obtained by the tapping of live trees being mostly used for spirit varnishes. Congo copal is the main surviving member of the fossil class and manila copal that of the spirit soluble class.

Curing - The Process of condensation or polymerisation of a material by heat or chemical means, resulting in full development of desirable properties.

Curing Agent - An additive which promotes the curing of film.

Distemper - Although there is tendency to apply this term to all water paints used for house decoration, it should preferably be used solely to describe the earlier types of such products, namely, those in which the binding medium consists essentially of either glue or casein, or similar sizing material.

Driers - Substance which, when incorporated in relatively small proportion in drying oils, or in paints and varnishes based on drying oils, bring about an appreciable reduction in their drying time at ordinary temperature. These substances are usually compounds of lead, manganese, cobalt, etc. They are of the following types:

(a) *Soluble Driers* - Driers which are more or less readily soluble at ordinary temperature in drying oils, hydrocarbon solvents and the like. Usually they consist essentially of metallic salts of the organic acids, such as the resinates, linoleates or naphthenates or octoates of lead, manganese or cobalt.

(b) *Liquid Driers* - Solutions of 'Soluble driers' in volatile organic solvents, usually hydrocarbons.

(c) *Paste Driers* - Driers made by grinding suitable compounds of lead of manganese with a small amount of water, linseed oil and Paris white, with or without other material extenders, to form a stiff paste. They are still sometimes used by soluble and liquid driers. They are also known as patent driers.

Drying - The process of change of a coat of paint or varnish from the liquid to the solid state, due to the evaporation of solvent, physicochemical reactions of the binding medium, or a combination of these causes. When the drying process takes place during exposure to air at normal temperature it is called 'air drying' ; if it accelerated by the application of a moderate degree of heat (normally not exceeding 80°C) it is termed 'forced drying'; as distinct from 'stoving'.

Durability - The degree to which paints and paint materials withstand the destructive effect of the conditions to which they are subjected.

Efflorescence - The development of a crystalline deposit on the surface of brick, cement, etc., due to water, containing soluble salts coming to surface and evaporating, so that the salts are deposited. In some cases, the deposit may be formed on the top of any paint film present, but usually the paint film is pushed up and broken by the efflorescence under the coat.

Emulsion - In scientific terminology this is an apparently homogeneous material formed by the incorporation of two liquids, which are normally immiscible. One liquid is dispersed in the other in the form of minute drops. If the droplets remain permanently dispersed, the emulsion is said to be stable and certain compounds are added as stabilizers because of their power to keep the droplets dispersed.

In paint industry, the term is frequently, if erroneously, applied to stable emulsion like dispersion of an organic binder in water, for example, polyvinyl acetate emulsions, used for making emulsion paint.

Emulsion Paint - Generally, a paint in which the medium is an 'emulsion' or an emulsion-like dispersion of an organic binder in water. Industrially the name is mainly restricted to those paints in which the medium is an 'emulsion' of a synthetic resin. The medium may also be called a latex by analogy with a natural rubber latex; polyvinyl acetate emulsion paint is a typical example.

Enamel or Enamel Paint - One of the class of finishes obtained by melting siliceous materials. The term is also used in the paint industry to describe pigmented varnishes which simulate in appearance, the flow, smoothness and gloss of 'Vitreous Enamels'. The same broad definition applies to 'Enamel Paint' and 'Hard Gloss Paint', although all these three may differ in degree in respect of one or more properties, such as flow, smoothness, gloss, opacity and in the retention of these properties on ageing.

Erosion - The wearing away of the top coat of a printed surface, for example, by chalking, or by abrasive action of wind borne particles of grit, which may result in exposure of the under lying surface.

Etch - Roughening of a surface by a chemical agent prior to painting in order to increase adhesion.

Etching Primer - A priming paint is usually supplied as two separate components which require to be mixed immediately prior to use, and therefore is suitable for a limited period only. The mixed paint contains carefully balanced proportions of an inhibiting chromate pigment, phosphoric acid, and a synthetic resin binder in a mixed alcohol solvent solution. On clean light alloy or ferrous or non-ferrous surfaces such paint gives excellent adhesion, partly due to chemical reaction with the substrate (hence the term 'etching primer') and gives a corrosion inhibiting film, which is a very good base for the application of subsequent coats of paint. Although these materials are referred to as primers, the film which they give are so thin that is better to consider them as etching solutions and to allow them with an ordinary primer if maximum protection is required.

These materials are also known as 'Pre-treatment Primers', 'Wash Primers', and 'Self-Etch Primers'.

Glazing - The enrichment or modification of a surface by the application of a thin, translucent, coloured coating.

Gloss - The degree to which a painted surface possesses the property of reflecting light in a mirror like manner (specular reflection).

Key - Any special quality of the surface or of a previous coat of paint, which assists adhesion of subsequent coat. One example is that of rough or abraded surface which provides a mechanical key for the applied film.

Knotting - A quick drying composition used in the prevention of joinery for painting, to form a local impervious covering for knots and other resinous areas liable to stain or soften a super imposed coat of paint.

Lead Paint - The term applied to any. paint, paste, stopping, filling or other material used in painting, which contains more than 5 percent lead as lead oxide (Pb O), in its pigment when determined by a certain defined method.

Linseed Oil - A drying oil extracted from the seeds of the flax plant (Linium usitatissimum). The oil is refined by treatments which remove water and mucilaginous material and is then described as acid or alkali refined oil according to the method of treatment. Further processing gives boiled oil blown oil or stand oil

Oil Bound - The description of water paint, the medium of which contains a proportion of drying oil in the binder.

Paint - A pigmented material, which when applied in a liquid form to a surface, forms after a time a dry adherent film. The following main types are recognized:

(a) *Oil Paint* - A paint that contains drying oil or oil varnish as the basic vehicle ingredient.

(b) *Water Paint (Emulsion Paint)* - A paint that contains a water emulsion or dispersion as the vehicle.

(c) *Paste Paint* - A paint in which the pigment is sufficiently concentrated to permit a substantial reduction with vehicle before use.

Pigment - Material, usually a fine powder, which is insoluble in paint media and which is used because of its optical, protective and decorative properties. In modern uses the term is often used to include extenders, as well as the white or coloured pigments.

Pink Primer - Traditionally a wood primer, pink in colour.

Pitting - The formation of holes or pits in a metal surface, by localized corrosion.

Plaster Primer - Primers, with a degree of resistance to alkali, which are used for priming plasters and cements of varying degrees of alkalinity. The primer shall not only resist saponification, but insulate succeeding coats of paint from attack.

Primer - The first complete coat of paint of painting system applied to a surface. The type of primer varies with the surface, its conditions and painting system to be used.

Putty - A highly pigmented stiff plastic material which is applied by a knife and which normally hardens on air-drying chemical curing or stoving.

Saponification - In general, the formation of soap by the reaction between a fatty acid/ester and an alkali In painting practice saponification refers to the decomposition of the medium of the paint or varnish film by alkali and moisture in a substrate, for example, concrete or rendering based on cement, sand and lime. Saponified paint or varnish films may become sticky and discolored. In very severe cases the film may be completely liquefied by specification.

Scumbling - A technique of painting, in which portions of the last colour coat are removed or textured whilst still wet, in order to expose part of colour underneath, used to achieve a variety of broken colour effects.

Size - This term originally referred to an aqueous solution of animal glue, but has subsequently been extended to cover water soluble cellulose derivatives and starches.

Sizing - It is the process of:

(a) applying size to various building and decorating materials to regulate porosity or to provide a buffer coat, for example, to prevent oil in varnish striking into a sanitary wallpaper.

(b) applying a mordant in gilding processes, for example, gold size or isinglass.

(c) applying a thin coat of varnish to tin plate or aluminum sheet before enamelling, in the tin printing industry.

Solids - The non-volatile matter in a coating composition which after drying, are left behind and constitute the dry film.

Solvent - Liquids, usually volatile, which are used in the manufacture of paint, to dissolve or disperse the film-forming consistents, and which evaporate during drying, and therefore do not become a part of the dried film. They are used to control

the consistency and character of the finish and to regulate application properties. .

Spinning - A method of coating, which distributes the paint over a flat surface by centrifugal action.

Spirit Varnish - A lacquer based on a solution of resin or resins in industrial methylated spirit. The more correct term would be 'spirit laquer'.

Stain - A solution or suspension of colouring matter in a vehicle designed to colour a surface by penetration without hiding it. True stains are classified as 'Water Stains', 'Oil Stains' and 'Spirit Stains' according to the nature of the vehicle. The so called varnish stains are varnishes coloured with transparent material. These have not the same power of penetration as the true stains, and leave a colour coating on the surface.

Thinner - Volatile liquids added to paints and varnishes to facilitate application and to aid penetration by lowering the viscosity. They should be miscible with the paint or varnish at ordinary temperatures and should not cause precipitation of the non-volatile portion either in the container or in the film during drying. For some purposes, thinner containing a small proportion of non-volatile material may be used.

Tints - The colour of a large proportion of white paint mixed with a small proportion of coloured paint or stainer.

Turpentine - A colourless volatile liquid, distilled from the products of certain pine trees and consists of complex mixture of terpene hydro-carbons.

Undercoat - The coat or coats applied to a surface after priming, filling, etc., or after the preparation of previously painted surface, and before the application of finishing coat.

18.3 MATERIALS

18.3.1 Ready Mixed Paint, Brushing, Wood Primer, Pink

The material is intended for use as a primer for new wood work (hard and soft wood). This shall conform to the requirement as per IS:3536-1966.

18.3.2 Ready Mixed Paint, Aluminium, Brushing, Priming, Water Resistant

The material is used as primer in the painting system normally followed for paints on wooden surfaces. It is used for protection of wood work both under marine and inland outdoor condition. It may also be used for application to metal surfaces. This shall conform to the requirements as per IS:3585-1966.

18.3.3. Ready Mixed Paint, Brushing, Zinc Chrome, Priming

The material is used for protection of aluminium and light alloys and may also be used for steel work. This shall conform to the requirements as per IS: 104-1979.

18.3.4 Red Oxide Zinc. Chrome Primer

The material is intended to be used as primer coat on new G. S. sheets, on gates of dams and canals. This shall conform to the requirements as per IS:2074-1979.

18.3.5 Ready Mixed Paint

Ready mixed paint of approved brand and manufacture and of required shade confirming, in all respect to the relevant Indian Standard specifications shall be used.

18.3.6 *Enamel Paint*

Commercially known as enamel, exterior- (a) under coat, (b) finishing coat, conforming to IS:2933-1975 of approved brand, manufacture and of the required colour shall be used. For the under coat,. the paint of same quality but of shade to suit that of the finished coat, shall be used. The material shall be supplied in brushing consistency but shall be suitable for application by brushing and spraying after thinning with a suitable thinner. The paint is used in painting for protection and decoration purpose and the specifications for the preparation of surface and its application shall be as per para 18.4

The paint shall be packed in metal containers conforming to IS: 1407-1968 and IS 2552-1970. Each container shall be marked with the -

(a) name and class of the material,
(b) name of the manufacturer and his recognised trade mark, if any,
(c) volume of the material,
(d) month and year of the manufacture, and
(e) batch number or lot number.

18.3.7 Synthetic Enamel Paint

Synthetic enamel paint, conforming to IS:2932-1974 of approved brand, manufacture and of the required colour for exterior on the finished coat and as an under coat of suitable shade to match the finished coat, shall be used.

18.3.8 Plastic Emulsion Paint

Plastic emulsion paint as per IS:5411(Pt. 1) - 1974 of approved brand, manufacture and of the required shade shall be used. The consistency of paint shall be smooth, uniform and suitable for application by appropriate method.

18.3.9 Aluminium Paint

Aluminium paint shall be conforming to IS:2339-1963 of approved brand and manufacture. The paint is available in compact dual containers with the paste and the medium separately. The paste and the medium shall be mixed together to proper consistency before use.

18.3.10 Anti-Corrosive Bituminous Ready Mixed Paint

It shall be of approved brand and manufacture, conforming to IS:158-1981. It shall be bituminous black, lead free, acid-alkali-heat resistant. The consistency of the paint shall be smooth and uniform and suitable for application by brushing without appreciable drag on the brush. The finish of the paint shall be smooth and egg-shell to semi glossy. It shall not show sign of corrosion when protected against corrosion under conditions of condensation. The packed containers with material shall be marked with the particulars specified under second sub para of para 18.3.6 above.

18.3.11 Coal Tar Black Paint

It shall be of approved brand and manufacture conforming to IS:290-1961. The coal tar black paint shall be of two types namely :

(a) Type - A Quick drying, and
(b) Type - B 8ww drying.

The maximum drying time shall be 4 hours for Type - A and 24 hours for Type - B. Depending upon the requirements suitable type can be selected. The specifications for packing shall be as specified in second sub para of para 18.3.6 above. The container shall also be marked "Inflammable liquid" in red letters and with the flash point of the material

18.3.12 Black Japan Paint

It shall be approved brand and manufacture conforming to IS:341-1973. The maximum drying time for surface is specified as 4 hours. The finish of the paint shall be smooth, uniform and glossy. It is used for the protection and decoration of metal and wood surfaces which are likely to be marked with white paint or finished with varnishes. The specifications for the preparation of surface, application and precautions to be taken shall be as per para 18.8.2, 18.8.3 and 18.8.4 respectively.

18.3.13 Wood Preservative (creosote oil)

It shall be of specified quality and approved make and conforming to IS:218-1983. Generally, it shall be creosote oil Type-1 or anthracene oil. The creosote oil shall be homogeneous liquid and consists essentially distillate of coal tar.

18.3.14 Synthetic Varnish For Exterior Finishing

It shall conform to 1S:524-1983, it shall be capable of being thinned with petroleum hydrocarbon solvent, 145/205 low aromatic grade. It can be used either

directly or in conjunction with enamel paint.

18.3.15 Copal Varnish

It shall conform to IS:337-1975. It shall be clear, transparent and free from foreign matter, sediment and undissolved water. Its finish shall be smooth and glossy.

18.3.16 Shellac

The material conforming to IS: 16-1973 shall be used for preparation of french polish.

18.3.17 Denatured Spirit

The denatured spirit is an organic solvent. It shall conform to IS:324-1959.

18.3.18 French Polish

It shall be of specified quality and make and shall conform to IS 348-1968. It shall be free from visible impurities and shall be composed of 150 g of shellac {conforming to IS:] 6 (Pt. 1 &2) - 1973} per litre of solvent. Pure shellac conforming to IS: 16 (Pt. 1&2) - 1973 varying in colour from pale orange to lemon yellow, free from resin and dirt shall be dissolved in methylated spirit conforming to IS:324-1959 or isopropyl alcohol conforming to IS:2631-1976 or a mixture of two together, with other alcohol soluble ingredients as may be necessary, so as to improve the performance of the material-'The tolerance of shellac shall be 25 $\pm$1 percent by weight.

18.3.19 Ready Made Wax Polish

In case of ready made wax polish, it shall be of approved brand and manufacture as stipulated in the item.

18.3.20 Raw Linseed Oil

It shall be of approved brand and manufacture and shall conform to IS:75-1973. It shall be lightly viscous but clear, sweet to taste, yellowish with light brownish shade, and with very little odour. It shall be clear and nee nom rancidity, adulterants, suspended sediments, and other foreign matters. Suitable pigments for colouring, and flavouring substances may be added if required.

18.3.21 Isopropyl Alcohol

The material shall conform to [S:2631-1964.

18.3.22 CNSL Epoxy Coal Tar Pitch Paint

Cashew Nut shell Liquid epoxy coal tar pitch paint (I.P. No. 127126) shall be of approved brand and manufacture.

18.3.23 Shellac Knotting

The material as specified in IS:347-1975 shall be used for knotting and finishing work.

18.3.24 Ready Mixed Paint, Grey Filler for Enamels and for Use Over Primers

The Material is .used as a filler over the primer in the painting system normally followed by enamels. This shall conform to IS: 110-1983.

18.3.25 Transparent Wood Filler Liquid

The material is used for filling wood surfaces prior to the application of undercoating varnish in the varnishing system normally followed for finishing wood work. Commercially, the material is known as 'Wood Filler Transparent Liquid'. It shall conform to IS:345-1952.

18.3.26 Mordant Solution

The solution shall be composed of by weight of the following:

Soft water	64 part
Copper chloride	1 part
Copper nitrate	1 part
Ammonium chloride	1 part
Hydrochloric Acid	1 part

18.4 WORKMANSHIP

18.4.1 General

18.4.1.1 The materials required for the execution of painting work shall be obtained in specified containers with seals unbroken. All paints shall not be inferior to relevant Indian Standards as mentioned in para 18.3 The material shall be brought in at a time in adequate quantities to suffice for the whole work. All materials not in use shall be kept properly protected. Lids of containers shall be kept closed and surface of paint in open containers shall be covered with a thin layer of turpentine to prevent formation of skin. Materials which have become stale or fat due to improper and long storage shall not be used The paint shall be stirred thoroughly in its container before pouring into small containers. While applying also, the paint shall be put back into stock tins. The containers when not in use., shall be kept properly closed and free from air, so that paint does not thicken and shall also be kept guarded from dust. When the paint has been used, the container shall be washed with turpentine and wiped dry with soft clean cloth, before they can be used again. The empty containers shall not be removed from the site of work tm the relevant work has been completed; and the permission obtained from Engineer-in-Charge.

18.4.1.2 ***Commencing Work -*** Painting shall not be started until the Engineer-in Charge has inspected the items of work to be painted, satisfied himself about their proper quality and given his approval to commence the painting work. Painting except the primary coat shall generally be taken up in hand, after all other builder's work is practically finished. The rooms shall be thoroughly swept out and the entire building cleaned up atleast one day in advance of the start of painting work.

18.4.1.3 The surface to be painted/primed shall be thoroughly cleaned and dusted. All rust, dirt, scales, smoke and grease shall be thoroughly removed before painting is started. No painting on exterior or other exposed parts of the works shall be carried out in wet, humid or otherwise unfavourable weather and all the surfaces must be thoroughly dry before painting work is started.

18.4.1.4 If for any other reason, thinning is necessary in case of ready mixed paint, the brand of thinner recommended by manufacturer or as decided by the Engineer-in-Charge shall be used.

18.4.1.5 ***Application of Paint***

18.4.1.5.1 ***Brushing of Paint -*** The brushing operations are to be adjusted to the spreading capacity advised by the manufacturer of the particular paint. The painting with brush shall be applied evenly and smoothly by means of crossing and laying off the later in the direction of the grain of wood. The crossing and laying off: consists of covering the area covered with paint, brushing the surface hard for the first time over, and then brushing alternately in opposite directions two or three times and then finally brushing lightly in a direction at right angles to the same. In this process, no brush marks shall be

left the laying of is finished. The full process of crossing and laying off will constitute one coat. During painting, every time after the paint has been worked out with the brush (which are down together due to the high surface tension of the small quantities of paint
left in between the bristles) shall be opened up by striking the brush against a portion of the unpainted surface with the end the bristles held at right angles to the surface, so that bristles thereafter will collect the correct amount of paint when dipped again into the paint container.

18.4.1.5.2 ***Spraying*** **-** Where so stipulated, the painting shall be done with spray. Spray machine used may be (a) high pressure (small air aperture) type, or (b) a low pressure (large air gap) type, depending on the nature and location of work to be carried out. Skilled and experienced workmen shall be employed for this class of work. Paints used shall be brought to the requisite consistency by adding a suitable thinner. Spraying shall be done only when dry condition prevails. During spraying the spray-gun shall be held perpendicular to the surface to be coated and shall be passed over the surface m a uniform sweeping motion. Different air pressures and fan adjustment shall be tried so as to obtain the best application with the minimum wastage of paint. The air pressure shall not be kept too high as otherwise the paint will log up and will be wasted. Spots that are inaccessible to the spray painting shall be touched up by brush after spraying. At the end of the job, the spray-gun shall be cleaned thoroughly so as to be free from dirt. Incorrect adjustments shall be set right, as otherwise they will result in variable spray patterns, runs, sags and uneven coats.

18.4.1.5.3 Each coat shall be allowed to dry completely and lightly rubbed with very fine grade of sand paper and loose particles brushed off before next coat is applied. Each coat shall vary slightly m shade and shall be got approved from the Engineer-in-Charge before next coat is started. Each coat except the last coat shall be lightly rubbed down with sand paper or fine pumice stone and cleaned off dust before the next coat is applied. No hair marks from the brush or clogging of paint puddles in the corner of panels, angles of mouldings, etc. shall be left on the work. In painting doors and windows, the putty round the glass panes shall also be painted but care must be taken to see that no paint stains, etc. are left on the glass. Tops of shutters and surfaces m similar hidden locations shall not be left out in painting. In painting steel work, special care shall be taken while painting over bolts, nuts, rivets, overlaps, etc. The additional specifications for primer and other coats of paints shall be as according to the detailed specifications under the respective headings.

18.4.1.5.4 After work, the brushes shall be completely cleaned off from paint, by washing with turpentine. After cleaning, the brushes are wrapped in heavy paper or water proof paper for storage. If it is to be used the next day, it shall be hung in a thinner or linseed oil in a container. On no account, brushes shall be made to stand on the bristles. A brush m which paint has dried up is ruined and on no account shall be used for painting work. The brushes used for painting work shall conform to IS:384-1979, IS:486-1983 and IS:487-1985.

18.4.2 Steel and Other Metal Surfaces

18.4.2.1 Reference shall be made to the IS: 1477 (Pt. I) - 1971, IS: 1477 (Pt. II)

1971, IS:2524 (Pt. I) - 1968 and' IS:2524 (Pt. II) - 1968.

18.4.2.2 ***Preparation of Surfaces***

18.4.2.2.1 ***New Surfaces***

(a) The surfaces before painting shall be cleaned of all rust, scale, dirt and other foreign matter sticking to it, with wire brushes, steel wool, scrapers, sand paper etc. This surface shall then be wiped finally with mineral turpentine which shall also remove grease and perspiration of hand marks. The surface shall then be allowed to dry.

(b) The painting of new G, S. sheets shall not usually be done till the sheets have weathered for about a year. When new sheets are to be painted before they have weathered, they shall be treated with a mordant solution as specified in para 18.4.2.3 below. Before painting on new or weathered G. S. sheets rust patches shall be completely cleaned with coarse emery paper and brush. Rusted surface shall be touched with red mixed paint of red lead and the procedure at 18.4.2.2.1 (a) above shall also be followed.,

18.4.2.2:2 ***Previously Painted Surfaces -*** Where old paint is not deteriorated and is in good condition, the under-lying surface being tree from corrosion, the surface shall be rubbed down with sand paper and other abrasive materials. The surface shall then be wiped finally with mineral turpentine to remove grease and perspiration of hand marks, etc. and then allowed to dry. Rusty patches on G. S. sheets shall be cleaned up and touched with lead.

18.4.2.2.3 ***Removal of Old Paint -*** Where complete removal of old paint is necessary, the surface shall be thoroughly cleaned of all old paint, rust, scales. dirt, etc. by one of the following methods as required.

(a) Hand Scraping - The surface shall be scraped thoroughly with hand scraper followed by wire brushing (first with coarse and then with fine brushes) and finally sand papering with coarse sand paper (No.3), steel wool (No.2) or emery paper (No.3) or emery clothes. This shall then be wiped finally with mineral turpentine to remove grease and perspiration of hand marks etc. and allowed to dry.

(b) Flame Cleaning - Flame cleaning is not suitable for use in confined spaces where there is a fire risk, or where inflammable materials adjoining the surface being cleaned. Flame cleaning is restricted to heavy steel, as it may lead to buckling of light gauge materials.

Prior to flame cleaning oil, grease or similar adherent matter shall be removed by washing with suitable solvents and surface shall be allowed to dry. Then oxy acetylene

flame shall be traversed on the surface so as to bum off the old paint and the rust, scales, etc. loosened. The flame shall not be traversed too slow to create high temperature and number of passes of flame on the surface should not exceed 3. The primer coat of paint shall be applied immediately after the flame cleaning has been carried out when the surface is still warm.

(c) Paint Remover - Paint removers shall be used as per manufacture's instructions. The surface shall then be rubbed with wire brushes, abrasive paper and dusted off After stripping of the paint, the surface and the surrounding shall be left clean until the approval of Engineer- in-Charge.

18.4,2.3. ***Application of Mordant Solution Over*** **G.** ***I. Surface*** - The surface shall be prepared in the manner described above in para 18.4..2.2.1 and then shall be treated with Mordant Solution (5 litres for about 100 sqm) by rubbing the solution generously, with a brush or bundle of rags on a stick. After about half an hour, the surface will turn grey and parts remaining bright shall be retouched and the extra surface shall be washed dOWl1 thoroughly with clean cold water and allowed to dry.

18.4.2.4 ***Application of Primers and Paints -*** After preparation of the surface, the primary coat shall be applied immediately. The specifications for application shall conform to para 8.4.1.5 above. In the case of G.S. sheets, new or weathered G.S. sheets shall be painted with a priming coat of one coat red oxide zinc chromate paint conforming to IS:2074-1979, which shall be applied before fixing sheets in place. The ridges of the corrugations shall be painted first and when these get dried, the general coat shall be given to ensure uniform finish over the entire surface without the crown showing signs of thinning. The second or additional coats shall be applie4 when the previous coat has dried. The spe9ifications described under 18.4.1.5 shall also hold good so far as they are applicable.

18.4.3 Wood and Wood Based Material Surfaces

18.4.3.1 Reference shall be made to the IS: 110-1983, IS:2338 (Part I) - 1967 and

IS:2338 Part ll) - 1967.

18.4.3.2 ***Preparation of Surface***

18.4.3.2.1 (a) ***New Surfaces of Wood Work -*** All wood work shall be well seasoned, dry and free from discoloured sapwood, and from large resinous or loose knots, or from any foreign matter, incidental to building operations. Nails shall be punched well below the surface to provide a firm key for stopping. Mouldings shall be carefully smoothed with abrasive paper and projecting fibres shall be removed. Flat portions shall be smoothed off with abrasive paper used across the grain prior to painting and with the grain prior to staining or if the wood is to be left in its natural colour. Wood work which is to be stained may be smoothed by scraping instead of by glass papering, if so required.

Any knots, resinous streaks or bluish sap-wood that are not large, enough to justify cutting out, shall be treated with two coats of pure shellac knotting, applied thinly and extended about 25 mm beyond the actual area requiring treatment. Aluminium primer may be used in the place of shellac knotting. If the area is small and if the wood is not highly resinous, it is permissible instead of applying two coats of knotting, to apply one coat of slightly pigmented with aluminium powder.

(b) ***New Wood Based Material Surfaces***

I. Plywood and Block Board - This shall be treated as for solid wood as per para 18.4.3.2.1 (a) above.

II. Particle Board - The surface shall be filled with a thin brushable filler and finished as for solid wood.

18.4.3.2.2 ***Previously Painted Surface*** **-** If the old paint is oily and dirty but is finm and has hot disintegrated, it shall be cleaned down by washing with solution of soap and water. The surface shall then be thoroughly rinsed with clean water to remove all soap allowed to dry and rubbed down with abrasive paper or pumice stone.

18.4.3.2.3 ***Removal of Old Paint*** - If the old paint film is flaky, shows cracks, blisters, it shall be completely removed by one of the following methods:

(i) Paint Removers - Paint removers of approved brand and manufacture shall be used as per manufacturer's instructions. The paint remover shall be applied liberally with a brush and allowed to remain on the surface for a period depending on the particular brand or remover used and 011 the thickness of the paint coating to be removed. When the paint film lifts and wrinkles under the action of the remover, it shall be stripped with a sharp instrument. If the film is not thoroughly removed, a second coat of remover may be applied, if necessary over such patches, and then the film thoroughly scrapped off. The surface then shall be washed thoroughly with mineral turpentine and made smooth by rubbing abrasive paper Grade I.

(ii) Blow Lamp - The paint shall be removed either with a blow lamp or with an air acetylene equipment. The flame shall be allowed to play upon the paint just enough to soften it without cleaning either the paint or the background. The softened paint shall then be removed with a stripping knife, following flame, as it moves up the surface. Burning off shall begin on the bottom of the vertical surface and proceed upwards. Moulding shall be burned up first, and flat areas last.

Removal with blow lamp shall not be done on narrow or carved cut surfaces, or where there is risk of damage to neighboring materials such as panes in glazed windows. In burning off paint from wood work care shall be taken that wood is not burnt in spots.

(iii) Caustic Soda Solution - Caustic soda dissolved in 48 times its volume of water shall be applied to the old paint with a brush and when the paint film lifts and wrinkles, it shall be thoroughly scrapped off with a sharp instrument. After the surface has been stripped thoroughly, it shall be rinsed with several changes of clean water to remove all traces of alkali. A little acetic acid or vinegar shall be added to the rinsing water which helps to neutralise any remaining alkali.

18.4.3.3 ***Priming Coat -*** If there is dirt or any other extraneous material this shall be removed. If the wood work is not already primed, a priming coat shall be applied. In case there is already a primer coat but an unsatisfactory one, it shall be rubbed down to bare wood and the surface reprimed. Primer shall be applied by brushing. Care shall be taken to prime not only the surface of wood that will be visible after fixing but also any surface which will be in contact with materials, such as brickwork or concrete from which the wood may absorb moisture. It would be an advantage to give such surfaces a further coat of primer, before' fixing.

Unless specified otherwise, all joinery work which is intended to be painted shall receive at least two priming coats. It is particularly important that end grains be so treated and, if it is necessary to cut the joinery before fitting, all cut ends shall be painted with two priming coats.

18.4.3.4 ***Stoppers and Filler Material*** - For deep holes, plastic wood conforming to IS:423- 1 961 shall be used. Stopping may be generally confined to large holes or cavities. Shallow indentations shall be made up with the paste filler conforming to IS:426
1961.

For high class work filling operation shall be done over the whole surface by using the filler conforming to IS:110 - 1983. For clear finishes, filler conforming to IS:345 - 1952 shall be used

18.4.3.5 ***Application of Stopping and filling*** - Stopping and filling should be done after priming. If the surface is not first primed, the filler or stopping may shrink and fall away, owing to absorption of some of the binder. Stopping is made to the consistency of stiff paste and is used to fill holes and cracks, while the function of the filler is to level up slight irregularities of surface. Filler is usually applied with a putty knife and is subsequently rubbed down to a level surface with abrasive paper, pumic stone or other suitable abrasive. For certain work. fillers are mixed to the consistency of thick paint and applied with a brush. 'The filler coat should be of an optimum thickness and should be allowed to fully harden and flatten before subsequent coat is applied. Apply as many layers as necessary allowing the coats to harden and flatten between coats.

18.4.3.6 ***Application of Undercoat -*** Undercoat shall be applied after the surface has been primed, stopped, filled and rubbed down to a smooth surface. Undercoat may be brushed or sprayed. After drying the coat shall be carefully rubbed down and wiped clean before the next coat is applied.

18.4.3.7 *Application of Paints* - The application of finishing paint varies according to the type of paint employed. Cleanliness is essential and as far as possible the application shall be carried out in normal dry conditions. The finishing paint coat shall be applied either with the brush or sprayed as described in para 18.4.1.5 above.

18.4.4 Concrete / Masonry/Asbestos Cement / Plastered Surfaces

18.4.4.1 *General* - References shall be made to the IS:2395 (Pt. I) - 1966 IS:2395
(Pt. II) - 1967 and IS:3140-1965.

18.4.4.2 *Preparation of Surface*

18.4.4.2.1 *General* - The surface to be painted shall be allowed to dry for at least three months. Any existing fungus or mould growth shall be completely removed. All major cracks or defects in the plaster shall be cut out and made good. Before primer is applied, holes and undulations shall be filled up with plaster of Paris and rubbed smooth.

18.4.4.2.2 New Surfaces - Before painting, the surface shall be thoroughly brushed to remove all dirt and remains of loose or powdered material.

In case of new brick work, painting shall be deferred for at least three months after completion of the masonry work and longer if the weather during the period has become unfavourable for drying. The surface shall be cleaned of dirt by washing with water.

Asbestos cement .surface shall be cleaned by rubbing with sand paper. Any glazed area shall be roughened. Wire brushes shall be avoided in cleaning operations as these shall lead to difficulties from deposited particles of iron causing iron stains.

18.4.4.2.3 *Previously Treated Surfaces* - If the old paint is firm and sound, it shall be cleaned of all dust, dirt, smoke, grease, etc. and then all dust; dirt and loose paint removed by rubbing with pumic stone and then by washing with soap and water. The surface shall be allowed to dry.

18.4.4.2.4 *Removal of old Paint* - If the old paint is badly blistered and flaked, it shall be completely scraped off and rubbed down with bristle brush and sand paper and then washed down with clean water and allowed to dry and then the surface shall be coated with a suitable sealer before applying new paint.

If, before painting, any portion of the wall shows sign of dampness, the causes shall be investigated and the damp surface shall be properly treated.

18.4.4.3 *Application of Primers and Paints* - This shall conform to specifications under para 18.4.1.5.

18.5 WALL PAINTING WITH PLASTIC EMULSION PAINT

18.5.1 Materials

Plastic emulsion paint as per specifications given at para 18.3.8 shall be used. This paint is not suitable for application on extemal wood and icon surface and surfaces which are liable to heavy condensation and are to be used on internal surfaces except wood and steel which are liable to condensation. No priming coat is required for the later.

18.5.2 Painting on New Surface

18.5.2.1 ***Preparation of Surface*** **-** The wall surface shall be prepared as specified in para 18.4.4.2.1 and 18.4.4.2.2. The other details, as far as, applicable shall be as specified in para 6 ofIS:2395 (Part I) - 1967.

18.5.2.2 ***Application*** **-** The number of coats shall be as stipulated in the item The paint will be applied in the usual manner with brush. The paint dries by evaporation of the water content and as soon as the water has evaporated tae film gets hard and the next coat can be applied. The time of drying varies from one hour on absorbent surfaces to 2 to 3 hours on non-absorbent surfaces. The thinning with water will be particularly required for under coat which is applied on the absorbent surface. The quantity of water to be added shall be as per manufacturer's instructions. The material after recommended thinning shall be suitable for application by brush, the resulting film shall not show pigment flocculation, coarseness or other undesirable characteristics. The surface on finishing shall present a smooth and matt, or egg shell gloss finish. If necessary more coats will be applied till the surface presents a uniform appearance. Other details shall be as specified in 18.4.1.5 as far as they are applicable.

18.5.2.3 ***Precautions***

(a) Old brushes if they are to be used for emulsion paints, shall be completely dried of turpentine or oil paints by washing in warm soap water. Brushes shall be quickly washed in water immediately after use and kept immersed in water during break periods to prevent hardening the paint on the brush.

(b) In the preparation of walls for plastic emulsion painting, no oil base putties shall be used in filling cracks, holes, etc.

(c) Splashes on floors etc. shall be cleaned out without delay as it will be difficult to remove them after hardening.

(d) Washing of surfaces treated with emulsion paints shall not be done within 3 to 4 weeks of application.

Other details shall be as specified in para 18.4.1.1 to 18.4.1.5 as for as they are applicable.

18.5.3 Painting on Old Surface

18.5.3.1 ***Preparation Of Surface*** **-** This shall be done generally as specified in 18.4.4.2.3 and *18.4.4.2.4* except that the surface before application of paint shall be flattened well to get the proper flat velvety finish after painting.

18.5.3.2 ***Application*** **-** The number of coats to be applied shall be as in description of item. The specification shall be as specified in 18.5.2.2 except that thinning with water shall not normally be required.

18.5.3.3 Other details shall be as specified in para 18.4.1.1 to 18.4.1.5 as far as they are applicable.

18.6 PAINTING WITH ALUMINIUM PAINT

18.6.1 Materials

Aluminium paint as per specifications given at para 18.3.9 shall be used. The paint is used for protective and decorative purposes particularly where a heat reflecting surface is required.

18.6.2 Preparation of Surface

18.6.2.1 ***Steel Work (New Surfaces)*** **-** All rust and scales shall be removed by scraping or brushing with steel wire brushes and then smoothened with sand paper. The surface shall be thoroughly cleaned of dust. Other details for preparation of surface shall be as specified in para 18.4.2.2.1 (a) as far as they are applicable.

18.6.2.2 ***C.G.S. Sheets (New Surfaces)*** **-** The preparation of surface shall be as specified in para 18.4.2.2.1 (a) and (b).

18.6.2.3 *Steel Work or C.G.S. Sheets (Old Surfaces)* - The specifications shall be
as described in para 18.4.2.2.2.

18.6.3 Application

The number of coats to be applied shall be as given in the item Each coat shall be allowed to dry for 24 hours and lightly rubbed down with fine grade sand paper and dusted off before the next coat is applied. The finished surface shall present an even and uniform appearance. As aluminium paste is likely to settle in the container, care shall be taken to frequently stir the paint during use. Also the paint shall be applied and laid off quickly, as surface is otherwise not easily finished.

Other details shall be as specified in para 18.4.1.1 to 18.4.1.5 as far as they are applicable.

18.7 PAINTING WITH ANTI-CORROSIVE BITUMINOUS READY MIXED PAINT

18.7.1 Materials

Materials of specifications given at para 18.3.10 shall be used.

18.7.2 General

The specifications of para 18.4.1.1 to 18.4.1.5 shall be followed as far they are applicable.

18.7.3 Preparation of Surface

The surfaces in case of new surfaces and old surfaces, requiring one or more coats with anti-corrosive ready mixed paint shall be prepared as per para 18.4.2.2.1 and 18.4.2.2.2 with 18.4.2.3 respectively.

18.7.4 Application

After the surfaces are prepared as above, a coat of the paint shall be applied by brushing to give a dry film mass. Air drying shall be allowed for 24 hours. The paint should remain firmly adherent and should not show sign of cracking, blistering, flaking. Formation of hair lines shall not be a cause for rejection. In case of second coat, it shall be applied as for the first coat after drying the first coat by minimum 3 hours.

18.8 PAINTING WITH COAL TAR BLACK PAINT

18.8.1 Materials

Coal tar paint as per specifications given at para 18.3.11 shall be used. Coal tar black paint when applied over iron and steel surfaces provides protection against corrosion. In case of timber also its application gives a good protection mainly due to its creosote content.

18.8.2 Preparation of Surfaces

18.8.2.1 ***Preparation of New Surface*** - In case of iron and steel surfaces, the surface shall be clean from dirt and grease and any loose or broken mill scale. Where in case of wooden or plastered surface, the surface shall be brushed out to remove all dirt and grease and all extraneous material adhering to the surface. If required, the washing shall be done. The surface shall be dried.

18.8.2.2 ***Preparation of Old Surface -*** In case of surfaces which are previously painted with coal tar paint, the cleaning of the surface to remove dirt, grease, loosely adhered paint shall be done by washing or by other suitable treatment. The surface shall be dried, for this, adequate time shall be allowed for evaporation of moisture. In the first instance, spot prime bare metal patches with the paint and subsequently apply the general coating. .

18.8.3 Application

18.8.3.1 The paint is recommended for application by brushing only. Application of
the paint shall be done immediately after cleaned and dried surface. Humid weather conditions shall be avoided since these are likely to cause condensation.

18.8.3.2 *Iron and steel New Surface* - Brush the paint well into the surface and on all irregularities in order to obtain a continuous film at a recommended spreading rate of 0.16 and 0.12 litre per sqm for first and second coat. No second coat shall be applied until the previous coat has dried thoroughly and can be recoated without 'picking up'.

18.8.3.3. *Wooden / Asbestos Cement Surface*

18.8.3.3,1 *New Surfaces* - For new surfaces like asbestos cement and wood, at least two coats of coal tar paint are necessary, the second applied after the first has thoroughly dried. For every porous surface, third coat may be necessary. In case of concrete surfaces which are very rough plastered surfaces, brick work, which is jointed and irregular, the method of application shall be decided separately.

18.8.3.3.2 *Old Surfaces* - The work shall be done in the same manner as specified above in para 18.8.3.3,1 except that only one coat shall be done using 0.12 litre per sqm of the paint.

18.8.4 Precautions

Coal tar paint is not recommended for use in locations which are not likely to be well ventilated. In view of the risk associated with breathing the fine mist which accompanies application of paint by spraying, the paint is recommended for application by brushing. only. A suitable barrier skin preparation may be used to protect the hands of painter working with this paint. If thinning becomes, essential especially in cold weather, coal tar solvent napthas as specified in para A - 1.4 of IS:209 - 1961 may be used.

18.9 PAINTING WITH BLACK JAPAN PAINT

18.9.1 Materials

Black Japan paint as per specification given at para 18.3.12 shall be used

18.9.2 Preparation of Surface and Application of Paint

Specifications regarding preparation of surface, application and precautions of the paint on new and old surfaces shall be as specified in para 18.8.2, 18.8.3 and 18.8.4 respectively.

18.10 PAINTING WITH OIL-TYPE WOOD PRESERVATIVES

18.10.1 Materials

Materials as per specifications given at para 18.3.13 shall be used. It is used as wood preservative mainly for wooden karries and for timber in general use.

18.10.2 Painting on New Surface

18.10.2.1 ***Preparation of Surface*** - Painting shall be done only when the surface is perfectly dry to permit good absorption. All dirt, dust or other foreign matter shall be removed from the surface to be painted. All roughness shall be sand papered and cleaned.

18.10.2.2 ***Application*** - The preservative shall be applied liberally with a stout brush and not daubed with rags or cotton waste. It shall be applied with a pencil brush at the joints of wood work. The first coat shall be allowed at least 24 hours, to soak in, before the final coat is applied. The second coat shall be applied in the same manner as the first coat. The excess of preservative which does not soak into the wood shall be wiped off with a clean dry piece of cloth. The specification described in para 18.4.1.1 to 18.4.1.5 shall hold good as far as they are applicable.

18.10.3 Painting on old Surfaces

The work shall be done in the same manner as on new surface described in para 18.10.2 above except that only one coat shall be done.

18.10.4 Precautions

The following precautions for safety of the workmen, and in case of hazards, the first and treatment are suggested as under:

18.10.4.1 ***Safety*** **-** All persons handling the creosote shall be fully aware of the hazards involved in handling. Skin should be protected from coming in direct contact with the liquid. Eyes shall be protected by using safety goggles, while handling the material

18.10.4.2 ***First Aid Treatment***

18.10.4.2.1 ***Skin*** **-** The effected area may be washed immediately with industrial methylated spirit followed by a wash with soap and water.

18.10.4.2.2 ***Eye*** **-** Immediate treatment is vital. Eye/eyes may be washed thoroughly with ruining cold water. Alternatively, if quick application is possible use copious quantities of buffered phosphate solution prepared by mixing 700 g anhydrous potassiumdi-hydrogen phosphate (KH_2PO_4 12 H_2O) in 850 ml distilled water. The solution can be stored for three months only. For use, it should be diluted with three times of water. Along with the phosphate solution appropriate medicine for immediate use may be kept at site.

18.11 VARNISHING WITH SYNTHETIC / COPAL VARNISH

18.11.1 Materials

Synthetic Varnish as per specifications given at para 18.3.14 for exterior finishing and copal varnish as per specifications given at para 18.3.15 for interior finishing shall be used. The varnish prescribes for protection and decoration of wood surfaces.

18.11.2 Preparation of Surfaces

18.11.2.1 Surfaces to be varnished shall be prepared to produce a smooth, dry, matt surface, previous coats of paint or stain, if any, shall be allowed to dry, and rubbed down lightly, wiped off and allowed to dry. All dust and dirt shall be removed from the surface to be varnished and also from the neighborhood. If any surfaces are dampened to avoid raising of dust, they shall be allowed to dry thoroughly before varnishing is commenced.

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18.11.2.2 *New Surfaces* - New wood work to be varnished shall be finished smooth with a carpenter's plane. Knots, shall be cut .to a slight depth. Cracks and holes shall be cleaned of dust. The Knots, cracks, holes etc. shall then be filled in with wood putty made by pouring a small quantity of glue size on apiece of wood say 20x 15 cm face and on the side where cross grains appear and by scraping the surface with the edge of a fine carpenter's chisel. Very fine powder shall then be mixed with the glue and the paste thus formed shall be used for the filling. The fillings when dry shall be rubbed down with a carpenter's file and then the entire surface shall be rubbed down perfectly smooth with medium grained and fine sand papers and wiped with .dry clean cloth. In no case sand papers shall be rubbed across the grains as in this case even the finest marks will be visible when the varnishing is applied.

18.11.2.2.1 *Sizing or Transparent Wood Filler Coat* - The surface shall then be treated with either glue sizing .or with transparent wood filler coat as stipulated in the description of item. The object of application of the glue size is to seal the pores in wood so as to prevent the absorption of the oil in the varnish. When sizing is stipulated a thin clean glue size shall be applied hot on the surface. When dry, the surface shall be rubbed down smooth with sand paper & cleaned. The surface shall then be given another application of glue size nearly cold. The sized wood work shall again be rubbed down smoothly with fine sand paper and cleaned. Glue sizing is inadvisable on floors, table tops and other horizontal surfaces likely to carry wet house held utensils which are likely to disturb the size coatings and thus expose bare wood.

18.11.2.2.2 *Transparent Wood Filler* - Where instead of glue sizing, transparent wood filler application is stipulated, it shall be applied as specified in para 18.4.3.4.

18.11.2.3 *Old Surfaces* - In case, if old varnished surface is firm and sound, it shall be cleaned of grease and dirt with turpentine and water, and then rubbed with wet sand paper until the surface is dean and smooth. It shall be dried and wiped clean with a soft cloth. Knots, boles and cracks shall be stopped as specified in para

18.11.2.2. The entire surface shall then be rubbed down smooth with sand paper and wiped clean. In case old varnished surface requires tbe removal of entire varnish it shall be done by any method as described in para 18.4.3.2.3 and on removal of the old varnish the surface shall be treated as new surface.

18.11.3 Application of Varnish

18.11.3.1 ***General*** **-** The number of coats to be applied shall be as stipulated in the description of item. During application period, damp atmosphere and droughts shall be avoided. For exterior work, a normal dry day shall be chosen. Exposure to extremes of heat or cold or to a damp atmosphere will spoil the work. Special fine haired varnishing brushes shall be used and not ordinary paint brushes. Brushes shall be well worn and perfectly clean. In general, the specifications of para 18.4..1.1 to 18.4.1. 5 shall hold good as *far* as they are applicable.

18.11.3.2 ***Varnishing on New Surfaces***

18.11.3.2.1 ***One Coat Varnish*** **-** The varnish shall be applied liberally with a full brush and spread evenly with short light strokes to avoid frothing. In handling and applying varnish care shall be taken to avoid forming of froth or air bubbles. If the work is vertical, the varnish shall be crossed & recrossed and then laid off, latter being finished on the upstrokes so that varnish as it sets flows down and eliminates brush marks. If the surface is horizontal varnish shall be worked in every direction, with light quick strokes and finish in one definite direction. so that it will set without showing brush marks. Too much or too little varnish left on the surface will mar the appearance of the finish. The varnish, once it has begun to set. shall not be retouched. If a mistake is made, the varnish shall be removed and the work shall be started afresh. The work shall be allowed to dry. The finished surface shall then present a uniform appearance and fine smooth and glossy surface free from streaks. blisters etc. The above process shall constitute one coat.

18.11.3.2.2 ***Two Coat varnish*** **-** In case of two coat varnish work the under coat of varnish conforming to specifications given at para 18.3.14 shall be applied as for one coat varnish specified at para 18.11.3.2.1 above. This shall be allowed to dry hard and then be flatted down to produce a smooth and glessy surface finishing. On c2ompleting the under coat, finishing coat of stipulated brand varnish shall be applied as per para 18. 11.3.2.1 above. Sufficient time shall be allowed between two coats.

18.11.3.3 ***Varnishing on Old Surfaces*** **-** The specifications shall be same as described in para 18.11.3.1 and 18.11.3.2 above as for new surfaces.

18.12 POLISHING WITH FRENCH SPIRIT POLISH

18.12.1 Materials

French spirit polish of specifications given at para 18.3.18 shall be used.

18.12.2 General

The specifications of 18.4.1.1 to 18.4.1.5 shall hold good as far as they are applicable.

18.12.3 Polishing New Surface

18.12.3.1 *Preparation of Surface* - The surface shall be cleaned all unevenness shall be rubbed down smooth with sand paper and well dusted. Knots if visible shall be covered with a preparation of red lead and glue size laid on while hot. Holes and indentations on the surface shall be stopped with glazier's putty. The surface shall then be given a coat of wood filler made by mixing whiting (ground chalk) in methylated spirit at the rate of 150 g of whiting per litre of spirit (with a suitable pigment if required) otherwise the french polish will get absorbed and a good gloss will be difficult to obtain. The surface shall again be rubbed down perfectly smooth with glass paper and wiped clean.

18.12.3.2 *Application* - The number of coats of polish to be applied shall be as described in the item. A pad of woollen cloth covered by a fine cloth shall be used to apply the polish. The pad shall be moistened with the polish and rubbed hard on the wood, in a series of over-lapping circles applying the polish sparingly but uniformly over the entire area to give an even level surface. A trace of linseed oil on the face of the pad facilitates this operation. The surface shall be allowed to dry and the remaining coats applied in the same way. To finish off, the pad shall be covered with a fresh piece of clean fine cotton cloth slightly damped with methylated spirit and rubbed lightly and quickly with circular motions. The finished surface shall have a uniform texture and high gloss.

18.12.4 Polishing Old Surface

18.12.4.1 *Preparation of Surface* - If the old polished surface is not much spoiled, it shall be cleaned of grease and dirt by rubbing with turpentine and then rubbed with the fine sand paper. If the old polished surface is much spoiled then it will be necessary to remove the entire polish as per the procedure and specifications described in 18.4.3.2.3.

18.12.4.2 *Application* *:* The specifications shall be same as described in para 18.12.3.2 above

18.13 POLISHING WITH READY MADE WAX POLISH

18.13.1 Materials

The polishing shall be done with bees waxing prepared locally or with ready made wax polish of approved brand and manufacture, as stipulated in the description of item. Where bees waxing is to be prepared locally the following specifications for the same shall apply:

Pure bees wax free from paraffin or stearine adulterants shall be used. Its specific gravity shall be 0.965 to 0.969 and melting point shall be 63 C. The polish shall be prepared from a mixture of bees wax, linseed oil turpentine and varnish in the ratio of 2: 1.5: 1: 0.5: by weight. The bees wax and boiled linseed oil shall be heated over a slow fire. When the wax is completely dissolved the mixture shall be cooled till it is just warm and turpentine and varnish added to it in the required proportions and entire mixture shall be well stirred.

18.13.2 General

The specifications of para 18.4.1.1 to 18.4.1.5 shall hold good as far as

they are applicable.

18.13.3 Polishing New Surfaces

18.3.3.1 ***Preparation of Surface*** **-** Preparation of surface shall be as described in para 18.12.3.1 with the exception that knotting, holes and cracks shall be stopped with a mixture of fine saw dust formed of the' wood being treated, beaten up with sufficient bees wax to give it cohesion.

18.13.3.2 ***Application*** **-** The polish shall be applied evenly with a clean soft pad of cotton cloth in such a way that the surface is completely and fully covered. The surface is then rubbed continuously for half an hour. When the surface is quite dry, a second coat shall be applied in the same manner and rubbed continuously for one hour or until the surface is dry. The final coat shall then be applied and rubbed for two hours (more if necessary) until the surface has assumed a uniform gloss and is dry, showing no sign of stickness. The final polish depends largely on the amount of rubbing which should be continuous and with uniform pressure with frequent changes in the direction.

18.13.4 Polishing Old Surfaces

18.13.4.1 *Preparation of Surface* - The wood work shall be cleaned of all smoke and grease by washing with lime water. The surface shall then be washed with soap and completely dried. Then it shall be prepared smooth as specified in 18.13.3.1.

18.13..4.2 *Application* - The polish shall be applied in the manner specified in 18.13.3.2. In this case one or two coats shall be applied as necessary to get uniform gloss, instead of three coats in the case of new work.

18.14 OILING WITI(RAW LINSEED OIL

18.14.1 Materials

Raw linseed oil of specifications given at para 18.3.20 shall be used.

18.14.2 General

The specifications of para 18.4.1.1 to 18.4.1.5 shall be followed as far as they are applicable.

18.14.3 Oiling New Surface

18.14.3.1 *Preparation of Surface* - This shall be done as described in para 18.11.2.2 except that no sizing will be done on the prepared surface.

18.14.3.2 *Application* - The number of coats to be applied shall be as stipulated in the description of item. The oil shall be applied freely with brushes (no rags) and spread evenly and smooth, until no more oil is absorbed. Each subsequent coat shall be applied after the previous coat is thoroughly dried and in any case not before 24 hours after the application of first coat. Work after completion shall not be patchy and sticky to touch and shall present a uniform appearance.

18.14.4 Oiling Old Surface

18.14.4.1 *Preparation Of Surface* - The wood work shall be cleaned of all smoke and grease by sand papering or by washing with lime and water. The surface shall then be washed with soap and water and then completely dried.

18.14.4.2 *Application* - The specification for application shall be as described in para 18.14.3.2 above.

18.14.3.2

18.15 PAINTING WITH C.N.S.L. EPOXY COAL TAR PITCH PAINT

18.15.1 Materials

Cashew Nut Shell Liquid (CNSL) epoxy - coal tar pitch paint (IP No. 127126) of approved brand, manufacture and of the required shade shall be used. This shall conform to the Research Design and Standard Organisation, Ministry of Railways. It has the life expectancy of 15 years.

18.15.2 General

The specifications of para 18.4.1.1 to 18.4.1.5 as far they are applicable shall be followed.

18.15.3 Preparation of Surface and Priming

The gates of the dams and canals, shall be cleaned by appropriate method applicable out of para 18.4.2.2 and 18.4.2.2.3. The surfaces which have been cleaned to bare metal shall be primed with one coat of red oxide, zinc chromate as specified m IS:2074-1979 within 4 hours. The appropriate method of application for priming shall be as specified m para 18.4.1.5. The primer shall be allowed to dry thoroughly before
application of under coat, finishing coat of the paint.

18.15.4 Application of Paint

The CNSL epoxy coal tar pitch paint shall be applied by spraying as per the specifications under para 18.4.1.5.2 as far as they are applicable. Also specifications under paras 18.4.1.5.3 and 18.4.1.5.4 shall be applicable. Minimum 12 hours shall be allowed before application of the subsequent coats.

SECTION - III

CHAPTER - 19

DISMANTLING

CHAPTER - 19 DISMANTLING

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CHAPTER - 19

DISMANTLING

19.1 REFERENCE

Standard specifications; Building and communications Department; Government of Maharashtra - 1972.

19.2 GENERAL

The item provides for the complete removal of the existing structure after dismantling except such portions as portions as may be required or permitted to be left in place as shown on the drawing or as directed by the Engineer-in-Charge, clearing the site sorting out useful materials and stacking them neatly within the specified distance and disposing off the non-serviceable material as directed by the Engineer-in-Charge.

19.3 PRELIMINARIES

19.3.1 Where necessary and if so directed by the Engineer-in-Charge the screens of canvas or other suitable materials shall be erected and / or the structure and the area shall be watered to avoid the nuisance of dust before and during dismantling Care shall be taken to see that the dismantling is done in such in sequence and manner as to prevent all avoidable damage to usable materials and any damage to nearby property or injury to life.

19.3.2 The dismantling work shall always be planned before hand and shall be done in reverse order of the one in which the structure was constructed. The scheme shall be got approved from the Engineer-in-Charge before starting the work.

19.3.3 In case of structures, which are to be moved for re-erection, all members shall be properly match - marked with paint. The pins, nuts, plates, structural steel members, timber etc., shall be similarly marked for identification of their position in the entire assembly. All machined surfaces, pin holes, pins, etc., shall be coated with grease.

19.3.4 In case of fixing done by nails, screws, bolts, rivets, etc., dismantlings shall be done by taking out the fixing with proper tools and not by tearing or ripping off.

19.3.5 Necessary propping, shoring and/or under pinning shall be provided for the safety of the adjoining work or property before dismantling is

taken up and the work shall be carried out in such a way that no damage is caused to the adjoining work or property,

19.3.6 An inventory of all possible serviceable materials shall be prepared. This record shall be kept for proper control during execution of work.

Portions required to be retained shall be marked before starting dismantling.

19.3.7 Where so required, for diverting the traffic adequate barriers with watchman and / or lights at the ends of portions of the road required to be closed if any, shall be constructed and maintained during dismantling operations.

19.3.8 A register shall be kept at the work site in which day-to-day account of the turn out and the salvaged materials shall be maintained. This register shall also show whether dismantled material is properly stacked or wasted.

19.4. DISMANTLING AND REMOVAL

19.4.1 The structure shall be dismantled carefully and the materials removed without causing damage to the serviceable materials to be salvaged, the part of the structure to be retained and any properties or structures nearby.

19.4.2 Unless otherwise specified, the structure shall be removed upto 45 cm. below the ground level and the portion which interferes in any way with the new construction shall be removed entirely.

19.4.3 Where existing structure is to be extended or otherwise incorporated in the new work, only such part or parts of the existing structure shall be removed as are necessary to provide a proper connection to the new work. The connecting edges shall be cut, chipped and trimmed to the required lines and grades without weakening or damaging the part of the structure to be retained.

19.4.4 Blasting if required, may be resorted to with the written permission of the Engineer-in-Charge. All blasting operations shall be finished before the new constructions is commenced.

19.4.5 Equipment or methods which might damage members, portions of the structure to be preserved or adjacent construction or structure shall not be used.

19.4.6 If sewers or drains are removed or disturbed, the foul matter shall at once be removed. If sewers, drains or electric lines have to be temporarily removed, a temporary passage for the flow shall be provided till sewer, drain or electric line are restored.

19.5 DISPOSAL

19.5.1 All the materials obtained from the removal of the structure shall be the property of Government. Serviceable materials shall be stacked neatly in such a manner as to avoid deterioration and in places directed by the Engineer-in-Charge within a specified lead, Different categories of materials shall be stakced separately.

19.5.2 Unless otherwise provided, excavated materials shall be used in back filling the excavation made in removing the structure in leveling ground or otherwise disposed off as directed within specified lead.

19.5.3 Non-serviceable materials shall be disposed off without causing any damage or inconvenience.

19.6 FINAL CLEARANCE

All rubbish shall be cleared off the site and the ground left clean and clear.

SECTION – IV

CHAPTER – 22

DRILLING AND GROUTING

CHAPTER – 22 DRILLING AND GROUTING
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CHAPTER – 22

DRILLING AND GROUTING

22.1 REFERENCES

IS : 269-1989	Ordinary and low heat portland cement (III revision)
IS : 455-1989	Portland slag cement
IS : 1489-1991	Portland pozzolana cement (II version)
IS : 2131-1992	Method of standard penetration test for soils (first revision)
IS : 2132-1992	Code of practice for thin – walled tube sampling of soils (First revision)
IS : 4078-1990	Code of Practice for indexing and storage of drill cores (first revision)
IS : 4464-1990	Code of practice for presentation of drilling information and core description in foundation investigation.
IS : 4999-1991	Recommendations for grouting of pervious soils.
IS : 5313-1989	Guide for core drilling observations (first revision)
IS : 5441-1991	Portable pneumatic drilling machine (first revision)
IS : 5529 – (Pt.I) 1990	Code of Practice for insitu permeability tests-tests in overburden.
IS : 5529 (Pt. II) 1990	Code of practice for insitu Permeability tests – tests in bed rock. (Reaffirmed 1984)
IS : 6066 – 1990	Recommendations for pressure grouting of rock foundations in river valley projects (first revision)
IS : 6909-1990	Super sulfated cement .
IS: 6926- 1990	Code of practice for diamond core drilling for site investigation for river valley projects.
IS: 6935-1973	Method of determination of water level in bore hole.
IS: 10135-1982	Code of practice for drainage system for gravity dams.
IS: 12330-1988	Sulfate resisting cement.

22.2 TERMINOLOGY

22.2.1 **Blanket or Consolidation (Are.) grouting –** Blanket or area of consolidation grouting refers to grouting of an area through shallow holes for improving the foundation condition by bonding together the jointed or shattered rock into more or less a monolithic mass.

22.2.2 **Curtain Grouting –** Curtain grouting refers to grouting of one or more lines of deep holes in order to create a barrier against seepage. This is sometimes referred to as high pressure grouting.

22.2.3 **Full depth grouting –** A method of grouting in which the entire depth of a hole is grouted in one operation by connecting the grout supply line to the manifold at the top of the hole.

22.2.4 **Stage –** A partial depth of hole, treated or to be treated.

22.2.5 **Stage Grouting -** A method of grouting in which a hole is deepened and grouted in a descending sequence of stage

22.2.6 **Packer-** The device used in the hole to segregate a part of hole for grouting installed at suitable elevation for maintaining pressure in the hole.

22.2.7 **Packer grouting –** A method of grouting of a hole, which been drilled to its final depth, in any desired sequence of sections which are isolated by use of packers from the ungrouped sections.

22.2.8 **Single Packer Method –** Method in which one packer is used in the drill hole. In this case the test section is between the bottom of the bore hole and the packer (see Fig. IA)

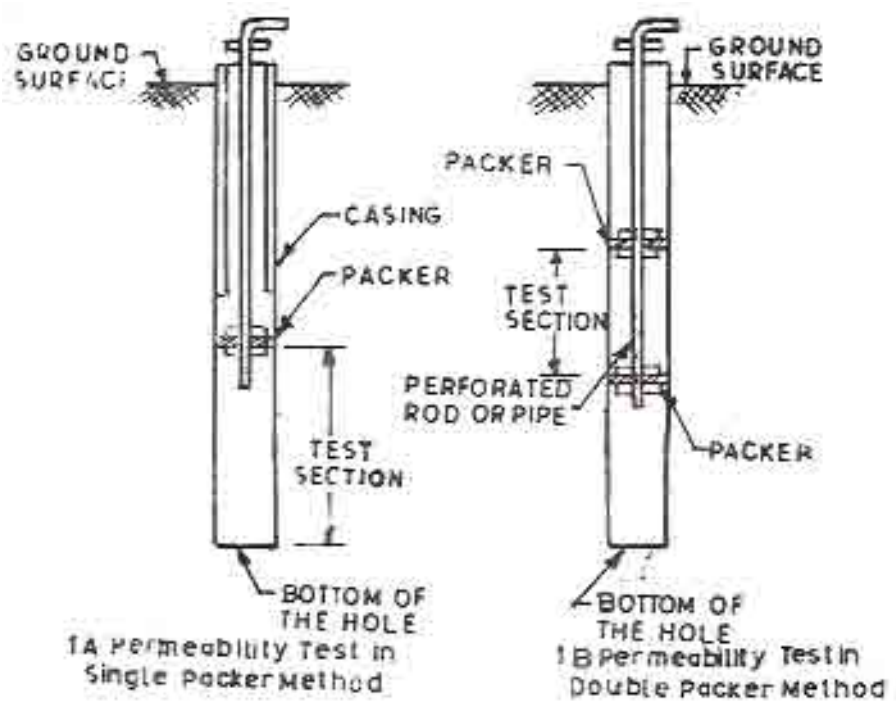


Fig 1. Permeability Test Both in Single and Double Packer Method

22.2.9 **Double Packer Method –** Method in which two packer are used in the drill hole. In this case the test section is between the two packers (see fig. IB).

22.2.10 **Split Spacing Grouting Method -** A sequence of drilling and grouting holes in which widely spaced holes are drille and grouted initially and the spacing is subdivided by intermediate holes. The initial set of holes are called primary holes and intermediate holes are termed secondary, tertiary, etc.

22.2.11 **Slush Grouting –** Application of cement slurry to surface rock as a means of filling cracks and surface irregularities or open joints to prevent leakage and slacking.

22.2.12 **Contact Grouting -** Contact grouting is a sealing operation intended to bring about as nearly as possible a fully bonded contact between any concrete structure and the adjacent rock.

22.2.13 **Washing -** Washing of the walls of the walls of the grout hole by water under pressure after completion of drilling but before grout injection.

22.2.14 **Jetting –** Systematic washing of groups of holes in order to remove the erodible material in the intervening rock mass.

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

22.2.16 **Single Line System –** The piping arrangement by which grout is conveyed from a grout pump to the grout hole through a single line of pipe without a return line of pipe without a return line.

22.2.17 **Collar of Hole –** The opening of hole at surface or opening of standpipe, protruding out of ground level is called collar of hole.

22.2.18 **Grout Nipple –** A short length of pipe, installed at the top of a grout hole through which drilling is done and/or to which the grout header is attached for the purpose of injection by grout.

22.2.19 **Agitator-** A machine employed for agitating an already mixed grout maintains the grout in Colloidal/suspended State, during storage or grouting operation.

22.2.20 **Manifold or Header –** The piping arrangement at the top of the hole for connecting the supply line to the hole.

22.2.21 **Patterns –** Arrangement of holes in plan and vertical section.

22.2.22 **Grout Refusal –** When rate of grout intake of a hole or stage reduces beyond a specified limit, averaged over a given time, at a particular pressure, the hole is said to have attained a state of grout refusal and grouting of a hole is said to be completed.

22.2.23 **Percolation Test –** Pumping of water into a hole through a direct connection or a packer to measure water acceptance under pressure.

22.2.24 **Lugeon –** It is the water absorption during the test in lit/min/metre./ depth conducted under a standard pressure of 10 Kg./ cm2 normalized value in proportion to the test pressure when tested at lower pressure.

22.3 DRILLING

22.3.1 General

Drilling shall be done by one of the following method as a specified: -

(A) **Percussion Drilling –** In this method rock is broken by impact from the repeated blows. It includes drilling using jackhammer, drifter, Wagon drill.

(B) **Rotary Drilling –** In this method the drill grinds the rock into small particles through abrasive effect of bit that rotates in the hole. In includes drilling rigs using diamond bits, etc. and calyx drilling.

22.3.2 Guideline Factors Affecting Selection of drilling Equipment:

Holes are drilled for several purposes such as for exploration, for injection of grout and for receiving charge of explosive for blasting etc. Among the many factors that affect the selection of equipment, the important ones are as follows:

(i) The purpose of the hole, such as blasting, grout injection, etc.

(ii) The size and required depth of hole.

(iii) The nature of terrain. Rough surface may require jackhammer.

(iv) The type and hardness of rock.

(v) The extent to which the rock is broken or fractured.

(vi) Overall size of the project

(vii) Availability of water for drilling purposes, lack of water favors dry drilling.

(viii) The extent to which rock is to be broken for handling.

(ix) Overall economy.

22.3.2.1 Percussive drilling methods are generally more economical in all types of rocks. For deep holes it may be advantageous to use the 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 the greater rigidity of the 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 cutting forms slush in soft saturated strata and cannot be removed by air flushing.

22.3.2.2 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.

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

22.3 DIAMOND CORE DRILLING

22.4.1 Equipment

22.4.1.1 ***Rotury Diamond Core Drilling Machine*** **–** The machine shall be capable of providing a rotary motion and using drilling bits. The feed or thrust to the drilling tool is actuated by hydrant i.e. mechanical, manual or other suitable means. The machine shall also be capable of drilling angular holes where required by prevailing geological site conditions.

22.4.1.2 ***Water Pump or Drilling Mud Pump*** **–** The pump shall be capable of delivering sufficient volume and pressure for the size of the hole to be drilled.

22.4.1.3 ***Core Barrels*** – The type of core barrels shall depend upon the type of formation to be drilled through. For soft rock or fractured hard rock the use of the double tube core barrel is recommended.

Note :- The outer diameter of single and double tube core barrels and the corresponding hole and core diameters shall be as given in table below :

TABLE – 1 CORE BARREL OUTER DIAMETERS AND HOLE AND CORE DIAMETERS

Size designation Single Tube Type A or Type B (G or M Design)	Outer Diameter of core barrel mm	Hole Diameter mm	Core Diameter mm
(1)	(2)	(3)	(4)
AW	46.0	48.0	30.0
BW	57.9	59.4	42.0
NW	73.8	75.6	54.7

Note :- Larger core barrels to give core diameters up to 151.6 mm are available form manufacturers.

22.4.1.3.1 *Single Tube* –This shall consist of a hollow steel tube, with the head at the upper end threaded for drill rod, and fitted at the lower end with a blank or set reaming shell, a core lifter, and a core bit.

22.4.1.3.2 *Double Tube Swtvel Type, Type A* - (Commonly referred to as G design) - The double tube, swivel tube, Type A shall have an outer tube and a concentric inner tube. The latter is suspended from the core barrel head on ball or roller bearing and is positioned at the bottom by the reamer shell. Ball or roller bearing suspension of the inner tube makes rotation of inner tube independent of the barrel.

22.4.1.3.3 *Double Tube Swivel Type, B* (Commonly referred to as M design) This is similar to double tube type A with the important difference that core lifter is contained in a lifter case attached to the bottom of the inner barrel. The lifter case extends down close to the bit face for protecting the core form water washing at any time. To accommodate this additional length on the inner tube, the bit is longer and has a female connection. The short length reamer shell has male threads on both ends.

22.4.1.3.4 *Triple Tube* - With split inner tube or plastic inner tube.

22.4.1.4 ***Core Bits*** **-** These shall be set with diamonds, tungston carbide or similar hard materials or impregnated bits appropriate to the hardness of materials being drilled.

Note :-In a set bit as the name indicates the diamonds are set in a material embedding material on the surface and the diamonds protude out from the matrix. Impregnated bits contain uniformly sized and graded diamonds evenly distributed through - out the matrix. Impregnated bits are "throw away" type and they should be used until all the diamonds are consumed.

22.4.1.5 Reaming Shell - It joints the drill bit to the core barrel. It is either blank or set either with diamonds or tungston carbide appropriate to the hardness of the materials being drilled, to act as a reamer and so enlarge the hole slightly. The outer diameter over the diamonds set on the reamer shells will be slightly more than the outer diameter of the core barrel so that the diamonds on the reamer shell may ream the drill hole sides and thus prevent the barrel rubbing against the wall rock and wear prematurely.

22.4.1.6 Drive Pipe Or Casing - Standard weight or extra heavy pipe, as required by the nature of overburden or the drilling method shall be furnished, where necessary for driving through overburden to bedrock. The casing or pipe shall be of a deameter to take the largest size core barrel to be employed. The inside of the casing or pipe shall be free of burrs and obstructions.

22.4.1.7 ***Casing*** **-** The casing pipe shall be of mild steel and seamless. When it is necessary to case through formations already penetrated by the drill or when no drive casing has been employed, auxiliary casing shall be provided that will fit inside the hole and permit the sue of the next smaller bid and core barrel.

NOTE : The outer and inner diameters of casings are given in Table 3.

TABLE : 3 DIAMETERS OF CASINGS

Size Designation	Outer Diameter mm	Inner Diameter mm
(1)	(2)	(3)
Ex	46	38
AX	57	48
BX	73	60
NX	89	76
44 x 37 mm	44	37
54 x 47 mm	54	47
64 x 57 mm	64	57
74 x 67 mm	74	67
84 x 77 mm	84	77

22.4.1.8 Drill Rods - The drill rods shall be of such diameter to permit adequate flow of the drilling fluid (drilling mud or water) and to provide sufficient upward velocity of the fluid between the rod and the hole wall, to remove and recover the cuttings effectively and completely.

NOTE :- The outer and inner diameter of drill rods are given in Table 4.

TABLE 4 : DIAMETER OF DRILL RODS

Size Designation	Outer Diameter mm	Inner Diameter mm
(1)	(2)	(3)
EW	34.9	25.4
AW	43.6	34.1
BW	53.9	44.4
NW	66.6	57.1

NOTE :- Larger drill rods upto 88.9mm outer diameter and 77.7 mm inner diameter and available.

22.4.1.9 ***Retrieving Tools*** **-** Special retrieving tools for casing, rods, core barrels, bits, other small objects, lost pieces of core etc. shall be furnished.

22.4.1.10 ***Auxiliary Equipment*** **-** Auxiliary equipment shall be furnished as required by the work including tripod, roller bits, fishtail bits, wrenches, equipment for mixing the drilling mud, etc.

For inclined bore holes it will be necessary to obtain suitable equipment for measuring the inclination of bore holes. In the absence of this equipment the method of etching by glass tube with hydrochloric acid lowered in the hole shall be followed :

22.4.2 Drilling Procedure

22.4.2.1 In any drilling for surface exploration the endeavour should be to get the maximum core size to maximum depth for obtaining maximum core recovery as well as optimum data for interpretation.

22.4.2.2 The core drilling procedure shall be used when formations are encountered which are too hard to be sampled by soil sampling methods. A penetration of 30cm or less for 50 blows according to IS:2131-1992 "Method for Standard penetration for soils" shall be considered as indicating that soil sampling methods are not applicable and core drilling shall be adopted. In some cases the use of dry drilling techniques with Tungston carbide bits may be advantageous. If even this technique indicates no penetration wet drilling techniques shall be adopted with diamond bits.

22.4.2.3 The casing shall be seated firmly on the bed rock or the hard material where found necessary to prevent caving of the hole, to prevent loose materials from entering the hole, and to prevent the loss of drilling fluid. The surface of rock or hard

material shall be levelled when necessary by the use of a fish tail or other bits for proper seating of the casing.

22.4.2.4 Core drilling shall begin using the Type A or Type B (NWG or NWM) double tube swivel core barrel. After drilling the required run, the core barrel shall be removed from the hole and core shall be taken out. If the core blocks the flow of the drilling fluid during drilling, the core shall be removed by withdrawing the core barrel immediately.

22.4.2.5 The core and the cuttings shall be logged by a geologist.

22.4.2.6 The core cuttings shall be placed in the core box in accordance with specification under para 22.5.1.

22.4.2.7 When soft materials are encountered which produce less 50 perent recovery, core drilling shall be stopped. If soil samples are desired, such samples shall be secured in accordance with the procedures described in IS:2131-1963 or IS:2132-1992. Diamond core drilling shall be resumed when refusal materials are again encountered.

22.4.2.8 Special care shall be taken to record occurrence of seams, fissures, cavities and broken areas etc. If such broken rock or cavities prevent the advance of the boring, action shall be taken to (a) cement the hole, or (b) ream and case, or (c) case and advance with next smaller size core barrel as the conditions warrant. Same procedure shall be followed where fissures are encountered causing loss of drilling water return.

22.4.2.9 In soft, seamy or otherwise unsound rock, where core recovery is poor, the Type B(M design) or the triple tube core barrel with bottom discharge bits shall be employed. In hard, sound rock, the single tube core barrel shall be employed, if the core recovery is poor double tube core barrel shall be preferred.

22.4.3 Drilling Observations

22.4.3.1 Behaviour of Drill Water

22.4.3.1.1 The colour of the return drill water and the depth at which changes in regard to these characteristics shall be recorded at frequent intervals. The return water brings with it the cuttings of the strata through which the drilling is in progress and provides information with regard to the lithology and the general nature of the strata through which the drilling bit is progressing. For example, drilling through hard and structurally sound quartzites may, generally, give clean water, with only a few particles, whereas, return drill water thickly laden with cuttings, may be recovered while drilling through comparatively fort, interbedded shale strata or clay filled seams or shear zones. Excessively mud-laden water, containing a lot of cuttings, may also be corelated with poor recovery of core at that depth and indicate probable reason for the core loss.

22.4.3.1.2 The depth at which drill water is lost or returned fully or partially shall also be recorded, as it may indicate the existence of open joints or any other special geological feature, such as cavities and faults which may have caused the loss of water in the drill hole at the specified depths, subsequent recovery of drill water, especially upon placement of casing and/or grouting across the leaky zone, may indicate the extent of the leaky zones. Approximate water intake values in the zone where total or partial water loss is observed shall be assessed and recorded.

22.4.3.1.3 Where hot water is encountered during drilling, the temperature of the water, depth of occurrence and amount of flow shall be recorded in remarks column of daily drilling report Appendix I.

22.4.3.2 Rate of Penetration

22.4.3.2.1 The rate of penetration gives indication as to the comparative physical nature of the strata through which the bit is passing. For example, in hard quartzite bands, the rate of penetration is generally slow compared to the progress in shale bands. Therefore, the depth through which a uniform rate of penetration was maintained and the depth at which it showed a marked change shall be noted as this will help in locating the depth at which the actual change of strata occurred, although,

due to the loss of core in the softer formation, it may not be possible to precisely locate its vertical extent from the examination of the core alone.

22.4.3.2.2 Any sudden fall of the drill rod and the depth at which such a fall occurs shall also be carefully recorded. This may give an indication of the existence of any open seam or cavity in the drilled strata or of any markedly weak or softer zone therein, if the fall of the drill rod is also accompanied by highly muddy return drill water.

22.4.3.3 Core Loss

22.4.3.3.1 The depth at which a core loss might have taken place, adjudged by the behavior of the drill machine while drilling, shall be recorded. This will enable the geologist interpreting the observations to give probable reason for the loss. In this connection, blockage of drill bit during and the recovery of redrilled and rounded core pieces shall be recorded in the daily drill report.

Poor core recovery may be due to various causes, such as poorly consolidated nature of the rock, presence of highly sheared zones, clay-filled seams, as well as inclination of the hole with respect to the foliation of the rock and even due to the techniques of drilling.

Sludge samples often give important clues to adjudge causes for poor core. These sample shall be kept for all runs where poor core recovery is anticipated (see para 22.4.11.3.4)

Core recovery may be ruined by careless operation by drilling too fast, over drilling a run, dropping core and grinding it or not pulling out the tools when the barrier jammed and thereby grinding the core. Vibration in the drill string also causes poor cost recovery.

22.4.3.4 Vibration and Torque - Any heavy vibration or torque noted during the drilling shall be recorded together with the depth of drilling at which these phenomenon are noticed. Any remedial measures taken and their effect on vibration

and torque shall also be recorded. The record of vibration and torque shall be integrated with the type of formation crossed, nature of core breakage and the amount of core recovered.

22.4.3.5 Ground Water Level In the Hole - The ground water level in the drill holes shall be recorded every day, both before and after the drilling and any fluctuations in the levels observed therein shall be noted. In cases where considerable divergence in the levels is noticed it may be necessary to bail out the water and record the level as recuperated to equilibrium value. This information will give an indication as to the ground water table conditons, if this intercepted by the drill hole. It may also indicate the degree of tightness or otherwise of the rocks drilled through, when studied in conjunction with the pressure percolation test data.

22.4.3.6 Other Special Condition to be Noted - Any other conditions which may be peculiar to individual cases shall be noted. Some of the special conditions which are likely to occur are given in 22.4.3.6.1 to 22.4.3.6.5 (see also Drill Observer's Remarks under Appendix I).

22.4.3.6.1 Depth at Which Hole was Grouted - The depth at which grouting of the hole had to be done shall be recorded for effectively interpreting the foundation conditions under an engineering structure. Grouting of the hole may sometimes be necessary while the drilling is being done through broken strata, as the sides of the hole collapse frequently due to the poor physical conditions of the substrata. Also, in those cases where the drill water is continuously being lost and a flushing of the cutting from the drill hole is not observed, grouting of the hole may have to be resorted to avoid the jamming of the bit inside the hole in either case. Necessity for grouting is an important indication of the lithological and the physical nature of rock being drilled through. If the hole is grouted or stabilized by using bentonite slurry the fact shall be recorded.

22.4.3.6.2 Artesian Conditions - Where artesian conditions are observed, they shall be recorded carefully. As far as possible accurate observations shall be made with regard to the depth, the pressure and the volume of outflow of water such artesian horizons, by using water meters or by diverting the flow to a measured

container. The piezometric head of each horizons as observed at the ground surface at each drilling point shall also be noted.

The piezometric head shall be determined by using a sensitive pressure gauge to the drill pipe or casing. The alternative but approximate, method of determining the piezometric head by fixing a pipe above the top of the hole as soon as an artesian horizon is encountered and recording the rise of water level in the pipe may also be used. In order to accurately determine the piezometric head of individual artesian horizons pierced by the hole, packers shall be fixed at the top and bottom of the horizon in the hole prior to the recording of the piezometric head above the ground surface at the drilling point.

22.4.3.6.3 **Gas Discharge** - Where subterranean gases like methane are encountered either with the return water or gas bubbles or as gas shown at specific depths this information shall be recorded. Samples of gas shall be collected and preferably analyzed at site. Where this is not possible special precautions shall be taken to send the samples in hermetically sealed containers for subsequent chemical analysis.

22.4.3.6.4 **Permeability Test:** - These tests are necessary for properly evaluating the permeability of the strata over which the proposed engineering structure will be founded and to plan seepage control measures. These tests shall be conducted in accordance with IS:5529(Part I) –1990., IS:5529(Part II) –1990 (Also refer Appendix IV).

22.4.3.6.5 **Deviation of Inclined Drill Holes**- The deviation of inclined drill holes, if any, during drilling shall be recorded in each run by using a bore hole clinometer. In the absence of a bore hole clinometer. measuring of inclination of the hole with the help of etching by hydrofluoric acid of a glass tube suitably in the hole, shall be undertaken.

22.4.3.7 **Other Observations -** Details of casings and bits used, depth at which blasting was done, if any, for driving of casing, types of barrel (single, double or triple) and bits, depth at which in situ tests were done mineralization, if any,

encountered, supplies like petrol, diesel etc. used and other details given in Appendix I Shall also be recorded.

22.4.4 Record of observations

22.4.4.1 The observations and other details shall be recorded in the proforma given Appendix I. Suitable notes shall be recorded for special observations.

22.4.4.2 One sheet of the proforma given in Appendix I shall be used for one shift of drilling only. Drilling observers shall be present whole time on the drilling job. Copies of the proformas duly filled in, shall be kept with the cores and shall also be sent to the concerned engineering geologist through the Engineer-in-Charge.

22.4.5 Selection and care of core bits :

22.4.5.1 Fast progress and good core recovery are not combined. In foundation investigations, the emphasis shall be on good core recovery.

22.4.5.2 Diamond Set Bits :

22.4.5.2.1 The harder and more fine grained the rock is, the smaller diamonds shall be used. Bits with big diamonds (5 to 15 stones per carat) are suited for soft rocks and for fractured rocks of all types. Bits with 15 to 30 stones per carat are intended for hard fractured rocks and bits with 30 to 60 stones per carat are mostly used in hard solid rocks. The diamonds that may be used for different types of rocks are given in Appendix II for guidance. The bits indicated with cross (X) shall normally be used. In some cases other types of bits may be considered.

22.4.5.2.2 Bits of bigger diameter give a better core recovery and less disturbed core. The diameter of the bits shall be decided by the demands of the drilling programme.

22.4.5.2.3 Precautions to be taken with new bits :

(a) It is preferable to use an old bit to start a hole.

(b) Speed and bit pressure should be low to avoid vibration, and loss of diamonds (See also para 22.4.7 & 22.4.8)

(c) As tools are lowered near bottom of the hole, water circulation should be started to washout settled cuttings which usually extend up some distance from bottom.

(d) A new bit should never be pushed to the bottom of a hole, since an old bit is usually under gauge, a new bit should stopped 5 to 10 cm from the bottom and drilled. When the bottom is reached, the new bit should be run at a moderate rate and slow feed for 3 to 5 cm to give the diamonds a chance to seat themselves. This prevents the sharp points from being broken off.

(e) Wrench Jaws should not be allowed to touch the diamonds in a bit. This applies also to the reaiming shells.

(f) When bits and shells are not in use they should be well oiled over their entire surface and packed in a separate box used only for this purpose. Each diamond set tools should be protected by waste, rags or other soft packing to prevent damage to the diamonds.

(g) When drilling through very hard, fine-grained, siliceous rock, the diamonds may get polished after drilling only about a meter or more. When this happens the diamond bit cannot be expected to make any further progress in that particular kind of rock and should be removed from service and used later, either in another hole or in that same hole in some different kind of formation. Very often a slight change in the grain r hardness of the formation will remove the polish from the stones and render the bit useful for much additional drilling.

(h) When drilling through highly abrasive rocks, there is tendency for the metal to wear away from the diamonds. In these cases when the diamonds become exposed approximately one-third of their size, the bits should be removed and reset. After one-third of the bulk of each of the diamonds extends from the metal, there is danger of further wearing away of the metal to the point where the diamonds will drop out.

(i) Burnt bits are sometimes caused by not tightening drill rods before lowering into the hole and depending on torque when starting to drill to do so. Because of wash water escaping through the joints the bit may run dry and hot in the mud and sludge at the bottom of the hole. The bit will also get burnt if it gets into the accumulated sludge at the bottom of the hole and drilling is started without cleaning the bottom of the hole.

22.4.5.2.4 Resetting of Bits - Items containing diamonds should be properly handled and maintained as any erroneous use may easily cause expensive damage to the equipment and/or hamper drilling operations. Diamond set bits have to reset at intervals, that is the diamonds are salvaged and replaced in a fresh matrix. Bits shall be checked after each run. Resetting should be done on any of the following indications :

(a) If the matrix is worn out to the extent that more than 30 to 40 percent of diamonds are exposed. This may indicate that too soft matrix has been used; the bit may be reset in a harder matrix.

(b) If the cutting edges of the diamonds are polished, the diamonds have a glare and are shiny. This is an indication that the bit has been run with insufficient water pressure. In such cases water pressure should be adjusted.

(c) If more than 30 percent. of the diamond points are broken. This often occurs in highly fractured rock where the diamonds are exposed to

impacts which will break their points. In hard rock, vibrations in the rod string may have the same results. In such cases the spindle speed should be reduced or impregnated bits should be used.

(d) If some diamonds are missing. If the bit is continued to be used without resetting, more diamonds will fall out and the rolling at the cutting face and destroying this bit as well as other bits inserted in the hole. Further more the diamonds are lost and have to be replaced at great cost.

22.4.5.2.5 Impregnated Bits : These bits are self sharpening and are designed to be run to destruction. They are mostly used in very hard rock, for example hard granite, gneisspegmatite, hard stand stone, quartzite, and flint stone (see also appendix II) In highly fractured rock the impregnated bits are often more resistant then diamond set bits. The pre-requisite for the use of impregnated bits is that the drilled rock is abrasive, that is, hard particles of the sludge will wear away the metal of the matrix thus exposing the embedded diamonds. Impregnated bits will become polished if used in wrong type of rock crystalline rocks they may get polished by using a too high spindle speed. Impregnated bits should never be run in rocks like limestone, marble, dolomite, or serpentine which create an adhesive sludge without any abrasive particles. If an impregnated bit does not cut, it can be sharpened by a gentle tapping of the cutting surface with the edge of a big file.

22.4.5.3 Tungston Carbide Tipped Bits (Saw-Tooth)- These are used for planning of the rock surface before the more expensive diamond bits are used. They can also be used for drilling in very soft rock and in overburden (See Appendix II). They should be resharpened at intervals with silicon carbide disc.

22.4.5.4 Reaming Shells and Casing Shoe Bits - These should be reset under the same conditions.

22.4.5.5 With each order for resetting there shall be indication for the matrix (its hardness), carat content of diamonds in the bit (to define amount of additional diamonds) and diamond size (stone per carat).

22.4.6 Core Barrels :

Single tube core barrels shall be used only in solid unfractured rock and for the first 25 to 70 cm when a new hole is started. In fractured and/or soft rock, the use of single tube core barrel will cause the core to be grounded jammed or washed away. Double tube core barrels shall always be used in fractured and/or soft rocks. In very friable rocks Type B core barrels with bottom discharge bits shall be used at slow speed and low bit and water pressures. Long core barrels may be used in rocks and short ones in fractured rock. The runs shall never completely fill the core barrels but leave a few centimeters.

22.4.7 Spindle Speed :

22.4.7.1 Diamond Set Bits - High spindle speed gives rapid progress but the core recovery will be hampered, especially in soft rocks, The spindle speed should therefore be regulated to the properties of the rock. At small diameters and holes down to 180 m the spindle speed may reach but should rarely exceed 1500 rev/min while 100 to 200 rev/min is average at great diameters and for deep holes. As an spindle speed should be 100 to 750 rev/min for NX bits and 5 to 15 stones/carat; and for small diameter bits with 30-60 stones/carat, spindle speeds of 500 to 1500 rev/min are suitable. The bit speeds suitable for various types of rocks are give in Appendix II.

22.4.7.2 Impregnated Bits - The impregnated bits can work within a large range of spindle speeds and high speeds give more rapid progress. However, the spindle speed should never be so high as to cause vibration in the rods. The highest spindle speed should not exceed that giving a periphery speed of the bit equal to 2.3 m/s, which gives maximum speeds of 1000 rev/min for AX bits, 700 rev/min for BX bits and 550 rev/min for NX bits.

22.4.8 Bit Pressure and Water Pressure :

The bit pressure (feed pressure plus weight of the rods) should be low (160 to 315 kg) when a new bit is put into operation to prevent too rapid wear or

break of the cutting points of the diamonds. As the polishing of the diamonds proceeds the cutting speed is reduced which can be made up for by increasing the feed pressure. The requirement for resetting the bit gives generally the limit for the pressure. However, the strength of the rods and the rig itself will mostly impose the maximum pressure, 900 to 1130kg with A-rods. If a worn out bit is operated at high pressure, there is a danger of deviation of the hole. Guidance on bit pressure and water pressure for various rock types is given in Appendix II.

22.4.9 Core Recovery :

Regardless of the careful supervision an engineer may give to the driller the responsibility for good core recovery which is largely in the hands of drill operators. Generally this may be assured by adopting correct drilling techniques and special coring equipment. In this connection the use of double tube or triple tube core barrel with bottom discharge bits would be found useful in ensuring the maximum possible core recovery in soft rock or fractured hard rock. Special drilling techniques in such cases may call for short runs of drilling and judicious control of water supply and speed of drilling. Core recovery may be ruined by drilling too fast, over drilling a run, or dropping core and grinding it, or not pulling out the tools when the barrel is jammed and thereby grinding the core. This also damages the bit. Vibration in the drill string causes poor core recovery, diamond wear and diamond losses in bits and shells, wear and tear on drills and loss of footage. Guidance on the causes of vibration and the measures to be taken for controlling vibration are given in Appendix III.

22.4.10 Handling of Equipment :

22.4.10.1 All equipment whether at store or at work site shall be kept in a shed in proper order, preferably in racks and protected by grease. Expensive equipment shall be kept under lock when not used. Diamond items and all threads shall be first protected by soft wrapping.

22.4.10.2 Tools shall be used with care and for the intended purpose. There are special wrenches for core barrel outer and inner tubes, for core barrel head coring bits and reaming shells. Pipe wrenches are used for pipe & casings. Wrenches shall not be

used for holding the drill string as they will be damaged if used for this purpose. Use of wrenches also includes a risk of dropping the drill string with consequent damage to bits and difficulties for retrieving the dropped equipment. Safety footclamps shall always be used at lifting and lowering operations.

22.4.11 Core Box arranging and indexing of Cores :

22.4.11.1 General - At the site of drilling, the cores, immediately on their withdrawal from the core barrel shall be placed in core tray and then transferred to core boxes specially made for this purpose.

22.4.11.2 Core Box - These boxes should be made of seasoned specified timber or any other durable material. If made of timber the top lid of the box shall be made up of a maximum of two planks. If two planks are used the lid should be strengthened by means of battens. Battens should also be provided at each end at the bottom to facilitate handling. There should be different sizes of compartments to accommodate different sizes of cores. It is desirable to provide grooves on the inside of the widthwise sides of the box corresponding to the widths of compartments for the AX, BX and NX size cores (see Note 2 under fig 2) so that the partitions for the compartments can be slide in easily. The boxes will be of good workmanship, doors fitting snugly with hinges and locks of specified quality approved by engineer-in-charge.

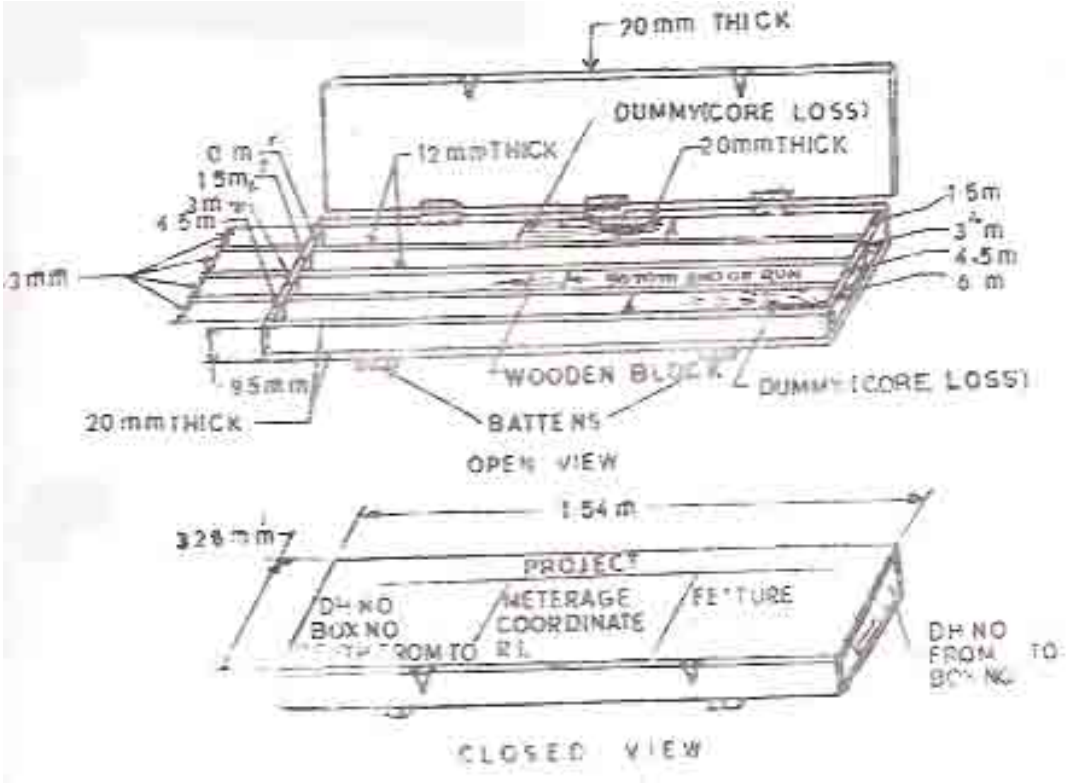


Fig. Typical Details of Core Box For 54.7 MM Dia Core

Note :- 1- indicates depth at which cores were obtained.
DH = drill hole
RL = reduced level

Note :-2- This figure gives typical details of a box for 54.7 mm diameter core. The box with the same overall dimensions may be used for cores of diameter 42.0 and 30.0 mm. by dividing the inside of the box into 5 or 6 compartments respectively instead of the 4 compartments shown in the figure for 54.7 mm, core giving the following compartment width :

Core Diameter (mm)	**Width of Compartment in Core Box (mm)**
54.7	61
42.0	48
30.0	36

The 54.7, 42.0 and 30.0 mm are generally designated as NX, BX and AX cores respectively.

22.4.11.3 Arranging and Indexing of Cores :

22.4.11.3.1 The cores shall be arranged starting from the side nearest to the hinge from the left to the right end of the box in the order of increasing depth from the surface, in a manner very similar to the lines on the pages of a book (see Fig 2). All core pieces shall be numbered serially, omitting very small pieces in the run. An arrow mark (---->) towards increasing depth shall be marked on every piece of core.

22.4.11.3.2 The core shall be separated at the end of the runs, either by inserting cross partitions of wood or by using the side supports in the case of the end of the core box, and the depths shall be clearly marked with paint, indelible ink or copying pencil. For each run, the pieces of core should be tightly packed together, as nearly as possible to its original condition in the ground. The cross partitions of wood wherever used, shall be of suitable size and fixed tightly to fit in the longitudinal partitions in the core box. (The cross partitions should be about 50mm in width and of length and depth to fit tightly into the compartments.)

22.4.11.3.3 In case there is no core recovery in an entire run, part of a run or in consecutive runs, separate wooden filler blocks, preferably a wooden dummy equal in length to the core loss, shall be inserted for each of the core loss sections and marked with paint, indelible ink or copying pencil thereon. The appropriate depths shall be marked on the wooden partitions on each flank of the core loss run. Each care loss dummy filler shall be arranged in a position in the core box corresponding with the position of core loss in the ground. If the position of a core loss within a run is not known (and this is often the case) then, by convention, the core loss dummy filler may be placed at the bottom of the run.

22.4.11.3.4 For reaches where core recovery is anticipated to be poor, the return drill water shall be collected in bowls and the settled sludge shall be recovered and suitably packed in polythene bags and kept in the core box with separating wooden blocks on either side marked with the depths and the inscription 'Washings'. Attempt

shall be made to collect the cores, as far as possible, even in the runs made in the overburden section at a drilling site.

22.4.11.3.5 Cores at the drilling sites shall be kept at a clean and dry place. The core boxes shall be closed immediately after a core run is kept and the necessary indexing has been done in order to avoid any infiltration of extraneous material and the consequent spoiling of the core surfaces, all of which may render proper interpretation of the cores difficult later on. The cores shall be so packed in the core boxes that they are not damaged in transit. Packing material like dry straw, cotton waste etc; shall be used to make the cores tight in the box. Latches shall then be secured on each of the core boxes and, before they are transported to the place of detailed examination and storage, it shall be ensured that the latches are well fixed and that there is no possibility of mixing of the cores during their transit form the field to the place of examination and then to the core shed.

22.4.11.3.6 The drill hole number, the box number and the engineering feature for which the hole had been made shall be noted on the top of the lid of the individual core boxes at the drilling site itself so as to avoid any possibility of the mixing - up of the core boxes. A suitable core boxes for each bore hole shall be kept to avoid mixing of cores from different holes. when there are more than one core box for a single hole, these shall be numbered indicating the numerator as serial number and denominator as total number of core boxes for that hole (for example 1/3, 2/3 and 3/3 for three core boxes for a hole).

22.4.11.3.7 The engineer-in-charge shall arrange, if possible, a Geological Assistant to supervise and log when the drilling is in progress. The Agency for drilling shall afford all facilities for his logging and collecting information. in cases, a geologist cannot be arranged to be present during drilling, on completion of drilling of each hole, the cores shall be logged by an engineering geologist who should also check the 'Daily Drill Report ; and discuss with the concerned driller any peculiarities or uncertainties recoreded during the drilling of the hole. The core boxes shall be finally shifted to a place of storage (a shed or building equipped with racks, etc) for the purpose.

22.4.11.3.8 Three copies of each of the daily drill reports shall be sent along with the core boxes, one for study in connection with the preparation of the detailed geological logs of the drill holes by the site geologist and another for being kept as a record in the place of storage for cores and the third for recording in Engineer-in-Charge office.

22.4.12 Storage of Cores

22.4.12.1 Cores shall be maintained at major river valley projects for at least 10 years after the completion of construction of the project so that it may be possible to check the sub-surface conditions and to study the problematical foundation features which may occasionally arise during the construction phase or the post - construction maintenance phase of the project. After this period, cores may be destroyed only on the Specific orders of Chief Engineer. The place of storage shall be well ventilated and lighted to facilities proper examination o cores. Space core boxes and painting materials shall be stored in convenient place in the place of storage of cores for ready use.

22.4.12.2 Immediately on their arrival in the place of storage the core boxes shall be cleaned and painted. The paint shall be of such a nature as to be durable and water resistant. After primary coating of the paint on the outside surfaces of the core boxes the top lid of the boxes shall be inscribed in a well contrasted paint colour with the feature of the project for which the drill hole, total length of the cores contained in the box and the box number (sse fig. 2). The sides of the core boxes shall further be inscribed with the drill hole number, the length of the cores contained in the box and the serial number of the box, for easy reference when the boxes are kept in the racks. No painting is necessary inside the core box, except along the rim of the box, on the inserted dummy blocks and the partitions separating the individual runs, which should be inscribed with the reason for core loss and the lengths of the runs as marked earlier on the field.

22.4.12.3 In the case of cores, which are liable to disintegrate on exposure suitable representative samples as instructed by Engineer-in charge shall be taken and preserved by waxing or by any other suitable method. A copy of record of drilling

information of the bore hole and the details of cores suitably prepared using the proforma given in Appendix IV, shall be compiled and kept in the place of storage (Core library). If such samples are taken, a record to that effect shall be kept at the corresponding section of the run in the core box.

22.4.12.4 If any portion of the core is removed from the box for testing or other examination this should also be recorded by insertion of suitable remarks on a square section of timber painted white, kept in the core box.

22.4.12.5 A series of racks shall be arranged at the place of storage (core library) and the boxes after being painted and suitably captioned, shall be arranged in the racks according to the serial order and area of exploration.

The daily drill reports received from the field shall also be available for ready reference in the place of storage.

22.4.12.6 A certificate as follows shall be furnished by S.D.O. incharge for every calendar year before end of December -

"Certified that I have personally inspected the upkeep of core boxes are counted by me and no box is missing".

22.5 **CALYX DRILLING**

22.5.1 This is a rotary abrasive type drill in which core can be obtained.

22.5.5.2 For drilling in hard rock shorbit is used. The shorbit at the bottom of the drill pipe assembly is connected to a core barrel. The core barrel plug is between them. The drill rods are hollow seamless steel tubes available generally in lengths varying from one of three meters. The core drills incorporate all other all other features of the rotary rig, the rotating mechanism, the derrick, the winch drum operated by by the main shaft the mud pump and the mechanical arrangement for applying pressure on the bit. The drilling outfit, however, is generally lass sophisticated than a conventional direct rotary rig. The chilled steel shots (calyxite) are fed through the water line. During drilling the calyxite is ground by the shot bit. Pressure is applied on the bit in addition to the weight of the drill pipe assembly.

Water is used as a drill fluid to lubricate the drill and remove loose debris. As the drilling proceeds, cylindrical rollers are cut through and collected in the core barrel, which is removed at frequent intervals. The operation is not continuous and hence it is time consuming.

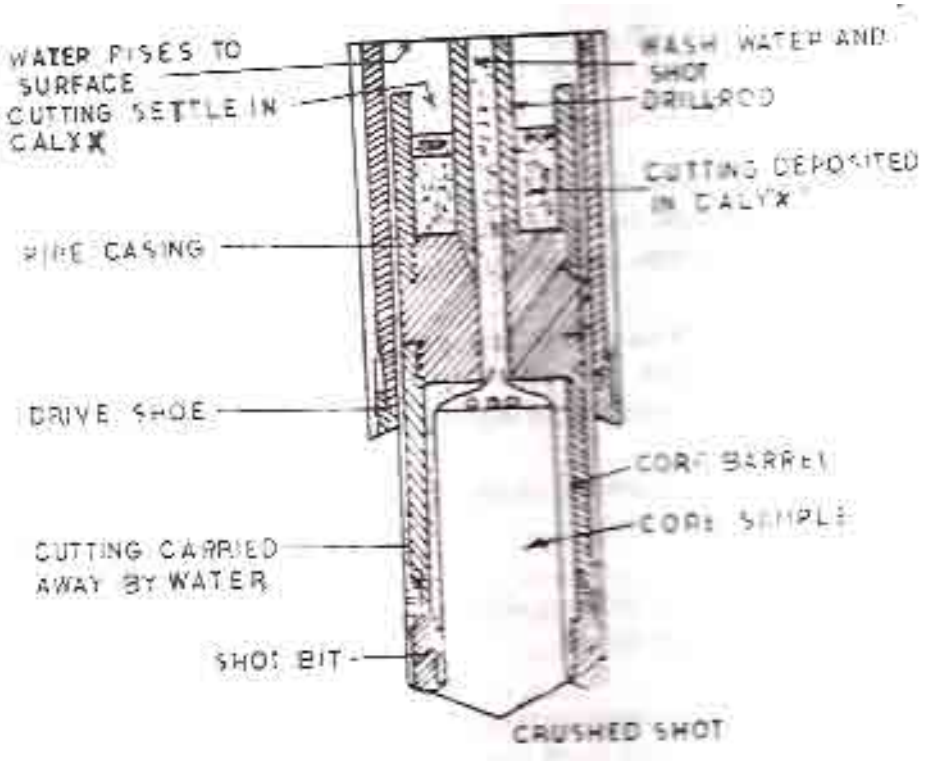


Fig. 3 Shot Drill.

22.5.3 For arranging & indexing of cores and storage of core boxes, specifications under Para 22.4.11 shall be applicable .

22.6 PERCUSSION DRILLING

In this type of drilling process the rock is broken by impact from repeated blows. Therefore, core cannot be obtained by this method.

22.6.1 DRILLING WITH JACK HAMMER

It is an air operated percussion type portable drill. It is mostly used for drilling vertical shallow holes up to 6 min depth.

A complete drilling unit consists of a hammer, drill-steel and a bit. As the compressed air flows through a hammers for occasional use may be used dry, but for a continued use "wet" drilling is used to keep down the dust.

22.6.2 Drilling with Wagon Drill

The wagon drill is a larger jack hammer mounted on a mast supported by two or more wheels to provide portability. Their performance is better than jack-hammer. They are used to drill at any angle from vertical to slightly above horizontal. They are self feeding and automatic rotating and can be operated wet or dry.

22.6.3 Drilling With Drifters

A drifter is an air operated percussion type drill similar to a jack hammer, but so large that it requires mechanical mounting. They are used for drilling vertical, horizontal or up holes.

They are capable of drilling holes upto 12cm diameter. It is extensively used in tunnel work. Either, air or water may be used to remove the cutting. They are mounted on columns or bars.

22.7 GROUTING OF ROCK

22.7.1 Co-ordination with Design Requirement

22.7.1.1 Rock grouting is normally carried out to fill discontinuities of cavities or voids in rock mass by a suitable material. The grouting programme should aim at satisfying the design requirement economically and in confirmity with the rest of the construction schedule. The basic design requirement generally involve the following :

(a) Impermeabilization of the rock mass to control the quantity of the seepage and/or to help control the hydrostatic uplift by means of grouting above or in conjunction with drainage measures :

(b) Reduce the deformability of jointed or shattered rock; and

(c) To fill construction voids i.e. to seal the gap between concrete structure and the adjacent rock, e.g. abutments, tunnel crowns, etc.

22.7.1.2 Before deciding upon details for any particular job, the design requirement shall be established and the primary objective defined, as described in preceding para. The depth, spacing and pattern of grout holes, the choice of method of grouting, materials injected and consumption limit as well as control on pressure depend on the objective as described in preceding para. These controls and criteria shall have to be established by trials.

22.7.1.3 The criteria for appraisal of efficacy of grouting are results of water percolation test in bore holes and specific absorption of the grout material per stage or per metre of the hole. Percolation tests (see Appendix V) may fail to provide a reliable indication unless they are standardized and uniform procedure are used in testing rock before and after grouting. In no case shall testing be done in holes where grout had entered due to leakage or grouted for integration of the water loss or lugeon value.

22.7.1.4 The following criteria are suggested for deciding whether to grout any particular zone or portion of rock. The criteria described in 22.7.1.4.1 and 22.7.1.4.2 are to be used with caution and overall design requirements as well as geological conditions shall be kept in mind before applying the criteria in any given case.

22.7.1.4.1 Curtain Grouting

(a) Dam exceeding 30 m height, curtain grouting should be carried out when the water absorption exceeds one lugion; and

(b) Dams under 30 m height, curtain grouting should be carried out where the water absorption exceeds 3 lugeon.

(c) Curtain grouting should be aserted to after carrying out experimental grouting on a test patch with set of holes depending upon geological formation.

22.7.1.4.2 Consolidation Grouting - The extent of consolidation grouting will be governed by the presence or otherwise of filing material in the joints or seams and nature of filling materials. When it is decided to remove the filling material by washing, the extent of the zone grouted will be determined by the efficacy of the washing procedure. On the other hand, if it is decided not to wash and remove the material filling the joints or seams; the criteria for grouting will be the grout ability of the stratum.

22.7.2 Co-ordination with other construction activities.

22.7.2.1 Grouting operation are generally interdependent 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. In other cases, it may be necessary to complete the grouting operations to enable 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 case removal of the obverburden may be necessary to facilitate sealing of the cracks prior to grouting. Drainage holes shall always be drilled only after grouting is completed within the expected distance of grout level. Generally it is preferable to complete blasting before taking up grouting operations. If blasting after grouting is unavoidable, through testing and regrouting shall be essential after blasting.

22.7.2.2 A drainage and grouting gallery is a device commonly used to facilitate grouting after placing the masonry or concrete in the foundation and ensure that the necessary cover of concrete is obtained to enable the desired grouting pressure to be developed. Sometimes holes are drilled in the foundation, black steel pipes are left in place through the masonry or concrete which is raised and the foundation grouted through these pipes later.

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

22.7.3 Relation of Geology to Grouting the importance of Foundation Exploration and Initial Experimentation :

22.7.3.1 The sub-surface conditions shall be investigated by core drilling the number of holes in the foundation area. Percolation tests should be conducted in the holes and the open area of the foundation chartered for use in planning the grout treatment. When investigation holes have served their purpose, they shall be completely filled with grout.

22.7.3.2 The grouting programme shall be conducted in such a manner that the initial experimentation covers all the typical geological situations.

22.7.3.3 The depth, spacing and orientation of grout holes shall be related to the geological features; for example inclined holes shall be preferred when the rock permeability is due to closely spaced 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, systems of joints and lava contacts.

22.7.4 Grouting Methods

22.7.4.1 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 shall normally proceed from river bed towards abutments.

22.7.4.2 Full Depth Grouting - In the full depth method each hole shall be 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 upto 10 m that have only small cracks and joints and there is no risk of surface leakage. In deep bore holes high grouting pressures may 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.

22.7.4.3 Stage Drilling And Grouting

22.7.4.3.1 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 following procedure.

22.7.4.3.2 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 heave and upheaval in the higher stages.

22.7.4.3.3 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 occures, 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.

22.7.4.4 Choice of Method of Grouting

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

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

22.7.4.4.3 However, it is frequently the experience that 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.

22.7.4.4.4 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 upto the bottom of the stage in progress.

22.7.4.4.5 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.

22.7.5 Pattern and Depth of Holes and Sequence of Grouting

22.7.5.1 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.

22.7.5.2 Pattern of Holes for Curtain Grouting

22.7.5.2.1 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 with can be achieved by grouting a single line of holes. In massive rocks with fine fissures, uplift contorl is primarily achieved by drainage and the grout curtain is used only as a supplementary measures 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.

22.7.5.2.2 In single line curtains it is customary to drill a widely spaced system of primary holes, subsequently followed by secondary an\d 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 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 pattern 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. 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 20.0 m of the hole to be grouted.

22.7.5.2.3 Multiple Line Curtains - In rocks with a wide range of sizes of openings, cavities and discontinuities which are also irregularly distributed, a single line curtain may not be effective. The larger openings may absorb excesive volumes of grout if high pressures and thin grouts are used. On the other hand thicker grouts (1:1 or thicker or grout with fillers) used for sealing the larger openings may block the sides of holes and prevent penetration of 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 the 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 impermebilazation is achieved.

22.7.5.3 Pattern of Holes For Consolidation Grouting

22.7.5.3.1 The choice pattern of holes, for consolidation grouting depends on whether it is necessary to wash and jet the hole systematically (see 22.7.9.3). When washing has to be carried out in a hexagonal pattern (see fig.4) it 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.

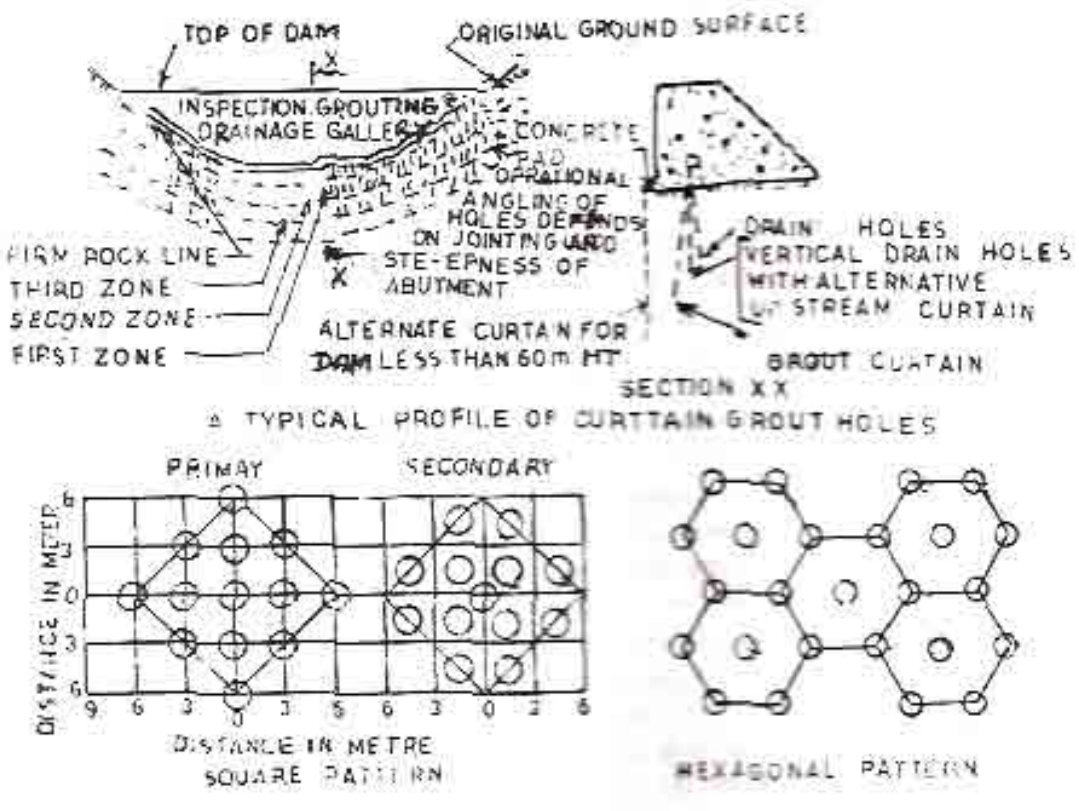


Fig. 4 Consolidation Grouting Pattern of Grout Holes.

22.7.5.3.2 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.4) 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.

22.7.5.4 Numbering of Grout Holes :

22.7.5.4.1 Each hole would be assigned a number which would be used for all future references. Number would details viz. block number, stage, serial number of the hole and phase (Primary secondary - tertiary etc.) For an example; a grout hole in Masonry block 17 is numbered as under :

17/G15(P)

Where :	17	=	Block 17,
	G	=	Grout hole
	I	=	Ist stage
	5	=	Serial number of hole
	P	=	Primary hole (Thus their would be Secondary, S, and Tertiary, T, if deemed necessary).

In addition the holes (primary, secondary & tertiary) shall be shown on a drawing showing location and number of these holes in plan.

22.7.5.4.2 Special grout holes proposed on geological consideration would have prefix 'RG' instead of 'G'.

22.7.5.4.3 All grouting operations would follow in sequence according to serial numbers of the hole.

22.7.5.5 Sequence of Grouting

22.7.5.5.1 While carrying out grouting operation it is necessary to ensure that no hole is drilled so 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 be not taken until sufficient cushion of already grouted stages of primary holes in the same area is not available.

22.7.5.5.2 In multiple line curtains relative sequence of outer and inner rows shall also be strictly followed as described in 22.7.5.2.3

22.7.5.5.3 When grouting in rock overlain by pervious soil it is necessary to complete grouting of the contact zones of the rock and solid before commencing the grouting of the rock otherwise grout would escape into the soil and it may be possible to control or detect excessive leakage.

22.7.6 Materials

22.7.6.1 Grouting Materials

(i) **General -** Rock grouting shall be performed with a mixture of neat cement and water. Other solid materials as well as soluble chemicals has also been used for economic or other reasons.

(ii) **Cement -** The cement to be used should be ordinary portland (IS:269:1989) or IS 8112:1989 or IS:12269:1987, portland pozzolana IS 1489 (Pt. 7th):1991, Portland slag (IS:455:1989), supersulphated plated cement (IS 69009:1990), sulphate resisting cement (IS:12330:1988)

(iii) **Sand -** Coarse & fine sand sometimes required as filter in the grout shall conform to the specifications of sand for concrete as given in specifications of Chapter 7 & 16 with the limitation that sizes above No. 10 IS sieve shall be excluded.

(iv) **Water -** Water for mixing grout shall be clean & free from injurious amounts of oil, acid, alkali, salts, silt, organic matter and other deleterious substances.

(v) 1 kg of 200 mesh bentonite per sack of cement may be used with bentonite as admixture where required.

(vi) Pipe and pipe fittings for grouting permanently incorporated into the work shall be of standard weight black steel pipe and fittings conforming to IS:1239(Pt.I)1979.

22.7.7 Drilling and Grouting Equipments

22.7.7.1 **General -** Sufficient drilling and grouting equipment with necessary auxiliary equipment and accessories to complete the various types of drilling and grouting required shall be arranged. The equipment shall bve maintained in first class operating conditions at all times.

22.7.7.2 Percussion drills for drilling grout holes shall be capable of drilling holes of the sizes and to the depths specified in rock or through concrete while continuously washing the holes during drilling. Such drills shall be provided with the following :-

(i) A water supply at a minimum pressure of 8.5 kg/cm^2 at the drill with the drill operation;

(ii) An auxiliary water swivel installed between the drill chuck and the rods;

(iii) Drill rods and bits having oversize water passages.

22.7.7.3 Grouting Equipments

22.7.7.3.1 **General Equipments -** The grouting equipment should meet the following requirements :-

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

(b) Be capable of prolonged operation at anticipated maximum pressures;

(c) Be of sufficiently rugged construction to minimize delays from failure of some essential part;

(d) Permit quick cleaning by washing; and

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

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

22.7.7.3.2 Grouting equipments shall be capable of effectively batching, mixing and maintaining grout mixes in suspension as specified, and of delivering and pumping grout into the grout holes and concrete joints through grout connections in a continuous uninterrupted flow at any constant pressure upto the limiting pressures specified. However each grouting installation supplied for the work shall include the following minimum equipment :-

(i) Operating and one stand by pump each capable of operating at a maximum discharge pressure of 25 kg/cm^2 and of pumping and injecting grout, including grout to which sand has been added if required as specified, at rates upto atleast 0.15 m^3 per minute without pressure fluctuations at the collar of the hole. A suitable water connection shall be installed on the intakes of the pumps to facilitate flushing of the system and injection of water into the grout holes.

(ii) A high speed (colloidal) type mixer designed primarily for mixing grout materials, including grout to which sand has been added if

required and capable of mixing a minimum of $0.3m^3$ per minute of grout mixture.

(iii) A agitator consisting of a mechanically agitated sump graduated in cubic meters and measuring to an accuracy of .01 cum and capable of maintaining the solids in the grout in suspension. The agitator shall be equipped with adequately sized screens to remove from the grout entering the agitator from the mixers and the grout return line any hardened grout or foreign material not passing a 150 micron Indian standard sieve if a non-sanded mix is being used or a 1.18 mm Indian standard seive if statdard mix is used. The capacity of the agitator shall not be less than that of the mixer.

(iv) An approved water meter graduated in tenths of $0.03m^3$.

(v) All valves, water flow meters, grout flow meters, pressure gauges including pressure hosepipe, flush-coupled diamond drill casing where applicable, sleeves, packers, fittings and small tools necessary to complete the grouting as specified. An accurately calibrated high precision pressure gauge shall also be arranged for checking accuracy of all pressure gauges used in the grouting system.

(vi) Packers consisting of pneumatic or hydraulic expansible tubes, or of mechanically manipulated rings of rubber, leather or other suitable material which can be set singly in a grout hole at any depth required upto a maximum of 76 m or , where required by the Engineer-in-Charge in pairs to isolate a section of hole. Packers shall be so designed that they can be expanded to seal the holes at the specified elevations and that when expanded, they shall be capable of withstanding without leakage, for a period of at least 10 minutes, water pressures equal to the maximum expected grout pressures which they will have to withstand.

The arrangement of the grouting equipment shall be such as to provide a continuous circulation of grout of uniform consistency through out the grouting system and to permit accurate pressure control at the collar of the hole being grouted at all rates of grout in take. Pressure gauges and valves shall be supplied at the pump, at each hole being grouted and elsewhere as required to ensure the necessary control of grouting.

A flow meter in the supply line and flow meter in the return line shall be arranged in such a manner that a continuous and accurate record of the amount of liquid flowing to the each hole and being returned to the agitator can be obtained.

22.7.8 Drilling

22.7.8.1 Holes for grouting shall be drilled at the location, to the depths (and of sizes) shown on the relevant drawing and as required by site conditions.

22.7.8.2 The minimum diameter of each grout hole shall not be less than that produced by the commercial standard Ex-size drill i.e. approximately 38 mm. The size of the holes specified are the minimum diameters required at the bottom of the holes. The grout holes may be drilled using either diamond or wet percussion drills as specified. Whenever diamond core drilling is carried out for grouting, cores from such holes shall be recovered, logged properly and preserved in core boxes as specified in para 22.4.11.

22.7.8.3 Holes shall be drilled vertically or at an inclination to the vertical as shown on the drawings, or as directed by the Engineer-in-Charge. Exploratory holes shall not deviate from the required directions by more than one per cent of the length of the holes, as measured at the point of maximum penetration. All measurements relating to the depth of the hole shall be made from the ground collar of the hole.

Grout hole and check holes shall be drilled wet and a constant flow of return water shall be maintained at all times. Use of lubricants other than water as an aid to drilling grout holes shall not be permitted.

Where packers are to be used any hole for grouting or water testing every precaution shall be taken during drilling to maintain a smooth wall in the hole, in order that the packers can be set properly at any desired location.

22.7.8.4 When drilling of a grout hole or, check hole, has been completed to its final depth or to the bottom of a stage, the hole shall be washed to remove all drill cuttings sediments, sludge and other loose or foreign materials.

22.7.8.5 Each grout hole and check hole shall be protected from becoming clogged or obstructed until it is grouted, by wooden plug or steel cap and where a grout pipe nipple or pipe fitting is permanently embedded in rock or concrete, a suitable cap for such grout pipe nipple or pipe fitting shall be provided.

22.7.8.6 Each grout hole and check hole shall be labeled with a metal or plastic tag and each tag shall be numbered.

22.7.9 Washing Holes.

22.7.9.1 General - The purpose of washing is two fold. First to clean the hole to remove material deposited on the surface during the drilling operation second to provoke deliberate inter connections between adjoining grout holes to remove known seams end layers or credible 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 interconnections 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 routine washing of holes at the end of the drilling operation (see 22.7.9.2) and systematic washing of groups of holes in order to remove the erodable material in the intervening area for which the term jetting or special washing is used (See para 22.7.9.3).

22.7.9.2 Routine Washing

22.7.9.2.1 On completion of the drilling of a stage and before injection the holes shall 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 shall be adequate and generally not less than 15 lit/min.

22.7.9.2.2 When no return of drilling or washing water occurs, the holes shall 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.

22.7.9.2.3 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 connections were made is clear. Such inter connections between the various holes shall be shown on the drawing showing location of holes has described in para 22.7.5.4.1 showing the interconnection between holes. The direction of flow of water or grout shall also be indicated with an arrow in the appropriate direction on the lines showing such interconnections.

22.7.9.2.4 Where deliberate attempts to obtain connections between adjacent holes are required in order to remove known deposits of erodable materials the jetting procedures described in para 22.7.9.3 should be used instead of the washing procedure described in 22.7.9.2.

22.7.9.2.5 In case, reasonably clear water is not obtained on return on washing of a hole within 30 minutes of washing, it may be presumed that the hole needs special washing. The special washing as per para 22.7.9.3 shall then be taken up.

22.7.9.3 Special Washing (Jetting)

22.7.9.3.1 The results of routine washing in many cases indicate that special washing procedure are required in order to remove more intensive deposits of loose or cloyey materials from fissures fractures or other zones intercepted by grout holes. Special washing or jetting operations are carried out in order to deliberately provoke connections between boreholes and to remove known deposits of erodable materials.

22.7.9.3.2 Special washing or jetting shall be carried out on groups of holes arranged on a square, trangular or hexagonal pattern known as cells.

22.7.9.3.3 Experience has indicated that the hole spacing within each cell should not exceed about 1.5m for successful jetting. The optimum spacing at any site can be arrived by washing holes in pattern of primary and secondary cells.

22.7.9.3.4 All holes in a cell shall 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 shall be drilled to the short first stage depth of 3 to 6 meters. The stand-pipes shall then be capped with three-way plugcocks and the cell is then ready for jetting.

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

22.7.9.3.6 All other cocks in the cell shall then be opened and water followed by air applied alternately until a connection is made. Jetting shall continue on this connection until no further erodible matter can be removed. Where any other hole connect to the manifolded hole during the operation, its cock should be closed. All the interconnections between various holes shall be shown in the manner specified in para 22.7.9.2.3.

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

22.7.9.3.8 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 connection are changed at frequent intervals to

cause the water flow in every possible direction through the seam. Application of air and water pressure is continued until all possible inter connection between adjacent holes are established.

22.7.9.3.9 As many combinations of holes as necessary shall be used to ensure the cleaning of all seams. The washing of any set of holes shall be 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 shall be continued till reasonably clear water emerges from the holes. Washing shall be 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.

22.7.10 Water Testing of Holes

22.7.10.1 In order to determine the permeability of the rock the effectiveness of grouting operations, water tests in exploratory holes, grout holes and check holes shall be made in conjunction with drilling and grouting operations.

22.7.10.2 When during drilling, abnormal gain or loss of drill water is observed or caving of the hole occurs, or the bit and drill rod falls through an open crack or cavity or when unusually low core recovery is obtained, drilling shall be discontinued and hole shall be water tested.

22.7.10.3 The procedure for water pressure testing shall be as follows :

(i) Immediately prior to being tested, each hole shall be thoroughly flushed to remove all drill cuttings, sediments, sludge or other materials form the hole and such flushing shall be continued until the wash water returns clear.

(ii) If a hole is drilled to full depth, the section of the hole to be tested shall be isolated by sealing it off with packers set at the bottom as well as at the top of the section. If stage drilling method is used, a single packer shall be, used to isolate the section to be tested.

(iii) The existing water level in the hole to be tested shall be recorded before commencement of the pressure testing. The hole shall be filled with clean water and the packers tightened.

(iv) Clean water shall be pumped into the hole through such valves and flow meters as are required to regulate the pressure of the water being injected and to measure the flow into the hole. The pressure testing apparatus shall be tested before use and shall be periodically tested for accuracy and satisfactory operations.

(v) Pumping shall be continued until the pressure of water to be injected is maintained with flow into the hole in a steady state. The pressure test shall be performed in one continuous operation using the following steps of pressure and times.

Step No.	**Pressure (P)**	**Elapsed time minutes**
1.	P1 = 1/3 P3	5
2.	P2 = 2/3 p3	5
3.	P3 = Maximum pressure attainded limited to Prescribed grouting pressure.	10
4.	P4 = 2/3 P3	5
5.	P5 = 1/3 P3	5

In some cases after steps 4 & 5 , the hole valve shall be closed and the pressure drop observed and recorded for a maximum period of 3 minutes in each instance.

22.7.11 Grout Connections :

Connections for doing grouting shall be made using expansion type packers specified in para 22.7.7.3.2 (VI) except that :-

(a) Connections for doing grouting shall be made using removable pipe nipples attached to pipe fittings embedded in concrete.

(b) Connection shall be made using grout pipe, grout nipples where, in the opinion of the Engineer-in-Charge, rock conditions are such that packers can not be set directly in holes and where such nipples are required to be set into springs, crevices in the rock, faults or other foundations anomalies.

Where grout pipe nipples are used for connections to holes in rock, the size of the pipe nipple for each hole and the depth into the hole to which it is set shall be adjusted to suit the size and type of hole drilled and the surface work conditions. Prior to grouting, the space around the nipple shall be carefully sealed with a quick setting mortar.

Where grout pipe nipples or fittings for grout connections are permanently embedded in concrete such pipes, nipples or fittings shall be so embedded that they terminate not less than 7.5 cms from the finished surface of the concrete. The pipe shall be standard black (iron) pipe confirming to IS:1239(Pt.I)1979 for class I weight A type. The pipe fittings shall be of malleable iron confirming to IS:1239 (Pt,I) 1979.

All pipes and fittings to be embedded in concrete shall be cleaned thoroughly of all dirt, grease, grout and mortar, immediately before being embedded in the concrete. They shall be carefully assembled and placed, and shall be held firmly in positions and protected from damage until the concrete has set.

Grout pipes which leak during grouting operation shall be reset.

22.7.12 Grouting or Rock Foundations

22.7.12.1 The grouting shall be carried out using packer grouting technique or stage grouting technique as desired by the Engineer-in-Charge depending upon the rock conditions and results of earlier grouting.

22.7.12.1.1 Packer grouting shall be performed by attaching a packer to the end of a grout supply pipe into the drill hole until it reaches the nearest part of the farthest stage to be grouted at specified pressure, setting the packer and grouting the stage beyond the packer at the required pressure, allowing the packer to remain in place until there is no back pressure, with drawing the grout supply pipe to the nearest part of the next stage required and grouting the hole in successive stages as required, by the Engineer-in-Charge.

22.7.12.1.2 In stage grouting the hole will be drilled to a limited depth, pressure tested if necessary, and then grouted at that depth. After the hole has refused grouting (to the extent specified hereinafter), it shall be flushed out by washing to its final set (within 2 to 4 hours). Alternatively the grout may be allowed to harden and redrilling carried out through the hardened grout as directed by the Engineer-in-charge.

After the grout surrounding the grouting hole has set, the hole may be tested for water pressure if required. Thereafter successively deeper stages shall be drilled, grouted (and tested if required) at increasing pressures until the required depth of the hole is completely drilled and grouted.

22.7.12.1.3 The packers shall be so designed that they can be expanded to seal the drill hole to a specified elevation and when expanded shall be capable of withstanding without leakage, water-pressure equal to the maximum grout pressure to be used.

22.7.12.1.4 The depth of each stage shall be 6 to 10m. but may vary as required by site conditions. The grouting shall begin with low pressure, say 0.10 to 0.25 kg/cm^2, per meter depth of packer or grout zone measured on the back pressure gauge located at the header. The pressure will be built up gradually. In no case the pressure will be such as to cause upheaval of the bed rock. Sensitive upheaval indicators (see para 22.7.11) shall be installed at suitable locations and shall be carefully watched for any indications of uplift during water pressure testing and grouting operations.

22.7.12.2 Once the grouting of a stage or group of holes has been commenced it shall be continued without interruption until completion. In general a stage may be considered complete when the absorption of grout at the desired limiting pressure is less than 2 lit./min averaged over a period of 10 minute.

22.7.12.3 As far as practicable a continuous flow of grout shall be maintained at the desired pressure and the grouting equipment shall 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 shall respond quickly and effectively to manipulate the desired changes in the grout mix consistency rate and pressure of injection etc. as directed by Engineer-in-Charge during grouting operation.

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

If any stage continues to absorb large quantities of the thickest pump able grout at nil pressure, grouting shall 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 than the limit of consumption shall apply. When any of the procedures recommended is adopted the grouting operations should be controlled in accordance with para 2.2 and 3 of Appendix VI.

22.7.12.5 When any hole connect to another during injection, the grout shall be allowed to escape from the coupled hole until it is of the same consistency as that being injected, the coupled hole shall then be capped and the combined holes brought up to pressure. After the first hole has ben grouted all the other holes shall be successively connected to the grouting header to subject them to full pressure.

Where leakage of grout occur on the ground surface, they shall be restricted by caulking with wooden wedges, lead wool, etc. or by thickening the grout followed by re-treatment with thinner grouts and through fresh holes, if necessary, as directed by Engineer-in-Charge.

22.7.12.6 Grouting shall be stopped whenever pressure gauges register a sudden drop of pressure or the rate of grout absorption increases abruptly or there is any indication of upheaval, disturbance or leakage. 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.

22.7.12.7 The control of grout mixtures is not amenable to rules which can be fixed in advance and sufficient discretion has to be exercised by the Engineer-in-Charge. Grouting should normally start 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 should be replaced with thinner grout and used until the hole refuses. In appendix VI the guiding principles for controlling pressures and selecting grout mix proportions are discussed. As a general principle grout mixture shall not be thickened if pressure starts to rise afterr continuous injection over a period of 10 minutes. Hasty changes in the mix proportions are not desirable and the response of the hole to the selected mix proportion or pressure should be judged only after observing for a sufficient period. The choice of initial mix proportions should be based on the water intake test. Experimentation, at the start of the work, should be used to establish the guideline for choice of mix proportions. Use of excessively thin mixes in the initial stages is generally wasteful & may some times cause softening of rocks like shale. Therefore, a starting mix of 5:1 is recommended and in exceptional cases 10:1 may be adopted.

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. 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.

22.7.12.8 Should conditions warrant, grout mixes shall be thinned after thickening, and if necessary to prevent premature stoppage, periodic application of

water under pressure may be made, However, no prolonged application of water shall be permitted.

22.7.12.9 If it is found that a hole will take grout at the rate of the maximum capacity of the grout pump and no decrease in the rate of grout intake is observed while pumping a mixture having a water cement ratio of 0.5:1 or, that no resistance can be built by reducing the pump speed, the grouting of the hole shall be continued for a maximum I hour at minimum pump speed. If the rate of grout intake still does not decrease, the grouting of that hole shall be discontinued for a minimum of 2 hours to allow the grout to attain initial set. Thereafter the hole shall be cleansed and after a period of, 6 hours grouting shall be resumed. If it is found that certain holes cannot be effectively grouted with particular water cement mixture due to very large cavities or excessive grout intake, thicker grout mixtures may be used when directed.

22.7.12.10 The amount of sand used in the mix will be increased progressively until the maximum amount, which the equipment can handle successfully, has been reached. If the desired results are not obtained with this mix. grouting will be discontinued. In such event the hole shall be cleaned the grout allowed to set, and additional drilling and grouting shall then be done in this hole or, in the adjacent area, as directed, until the desired pressure is built up.

22.7.12.11 the grouting of each hole shall be continued until the hole refuses to take grout mixes of 3 to 1 or thicker at the maximum pressure required, or until the hole takes grout mixes thinner than 0.03 in^3 of grout mixture, in 20 minutes if effective pressure of 3.5 Kg/cm^2 or less are being used, in 15 minutes if effective pressure of 3.5 Kg/cm^2 or less are being used, in 15 minutes if pressure between 3.5 and 7.0 and Kg/cm^2 are being used, in 10 minutes if pressure between 7.0 and 14.0 Kg/cm^2 are being used, and in 5 minutes if pressure in excess of 14.0 Kg/cm^2 are being used. As far as practicable, the maximum required grouting pressures shall be maintained constant during grouting injections.

22.7.12.12 After a stage of grouting is completed in any hole or set of holes, the pressure shall be maintained by stop cocks or other suitable valve devices until the

grout has set sufficiently that it will be retained in the holes. Higher grout pressure may be used in final reading.

22.7.12.13 The following requirements shall also be met during groutings :-

(1) Drilling, washing pressure testing or grouting shall not be performed within a distance of 12m. or as may be considered suitable for the site conditions, from a hole being pressure tested or grouted unless at least one grout hole in between these holes, has been completely grouted and a period of, 6 hours has elapsed since the completion of such grouting.

(2) On steeply sloping ground, grouting shall invariably proceed from the lower elevation to the higher.

(3) The arrangement of the grouting equipment shall be such as to provide a continuous circulation of grout throughout the system and to permit accurate pressure control by operation of a valve on the grout return line, regardless of how small the grout take may be.

(4) The grouting equipment shall be so located that agitator is within 30 m of any hole being grouted. Pressure gauges gauges and adequate valves will be required to control bye-passes and shut off.

(5) The equipment and lines shall be prevented from becoming fouled by constant circulation of grout and by the periodic flushing out of the system. With water. Flushing shall be done with the grout intake valve closed, the water supply valve open, and the pump running at full speed.

(6) Any grout which has not been used within 1 hour of the time of mixing shall be wasted.

22.7.12.14 The holes drilled for curtain grouting shall be packer grouted or stage grouted at pressures which will give an effective pressure at the top of the stage being grouted of 0.23 Kg/cm^2 per meter of depth below the nearest rock surface, except as otherwise required by the Engineer-in-Charge. In determining such pressure, the

Engineer-in-Charge will take into consideration the elevation the elevation of the grout water and the pressure losses in the grout pipes. The deep grouting shall be completed by grouting the holes by progressively working up the abutments.

22.7.12.15 The effectiveness of the grouting work shall be checked as work progresses by tests performed in a series of vertical and/ or inclined holes drilled along the grout curtain every 15 m or nearer if required. Pressure tests in these holes, and core recovery, may indicate that parts of the foundation already grouted required additional grouting. In such event additional holes shall be drilled and grouted as and when required.

22.7.13 Backfilling / Packing of Grout Holes

Grout holes shall be backfield with grout having a water–cement ratio of 0.7.1 with 3 per cent. of bentonite. A minimum 25-mm dia delivery pipe shall be lowered to the bottom of the hole. Grout shall be pumped in the delivery pipe until it flows from the hole, then the delivery line shall be slowly withdrawn while pumping continues. If settlement of grout occurs after initial set, the holes shall again be backfield with grout.

22.7.14 Uplift Gauge (Up Heave Gauge Or Foundation Displacement Indicator).

The surface bed rock may be particularly sensitive to displacement due to hydraulic pressure developed during pressure testing or grouting. Such displacement shall be controlled with the aid of careful observations of uplift gauges specifically installed for the purpose. For this 12mm diameter pipe or 15mm dia M.S. bright bar shall be anchored by grouting to the bottom of holes drilled at specific locations indicated at site 3 meters deeper than the proposed grout holes in the area. Above the anchorage, the pipe shall be encased in a 40-mm asphalt dipped M.S. conduit and the hole filled up with lean mortar. An iron yoke or bridge shall be anchored to the surrounding rock or masonry. Measuring tips shall be set at the top of the pipe and on the underside of the yoke. A standard strain gauge with 0.01 mm least count may be used for this purpose (Fig. 5) the gap between the tips shall be frequently measured during grouting and pressure testing operations. For any progressive upheaval greater than 0.0254 cm the pressure shall be reduced and grouting operation continued

thereafter. If necessary, the pressure shall be relieved by allowing the grout to flow out of the holes until the gauge show the settlement has ceased, before continuing the operations. Such instruments may have to be installed at a minimum interval of 20 meters.

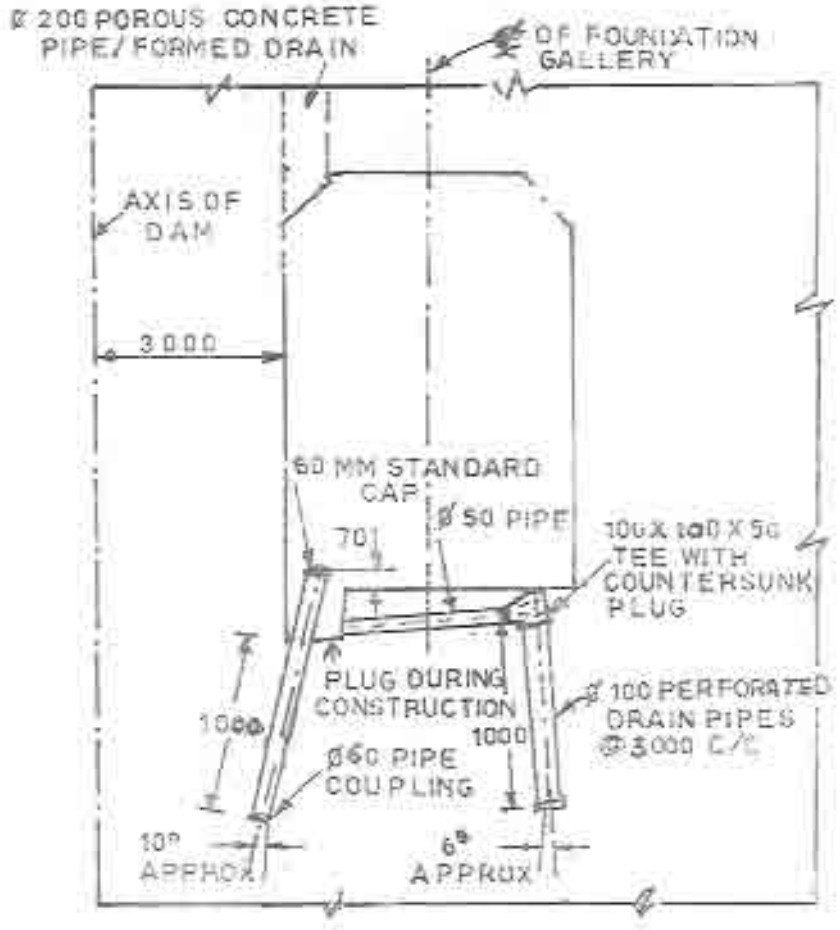
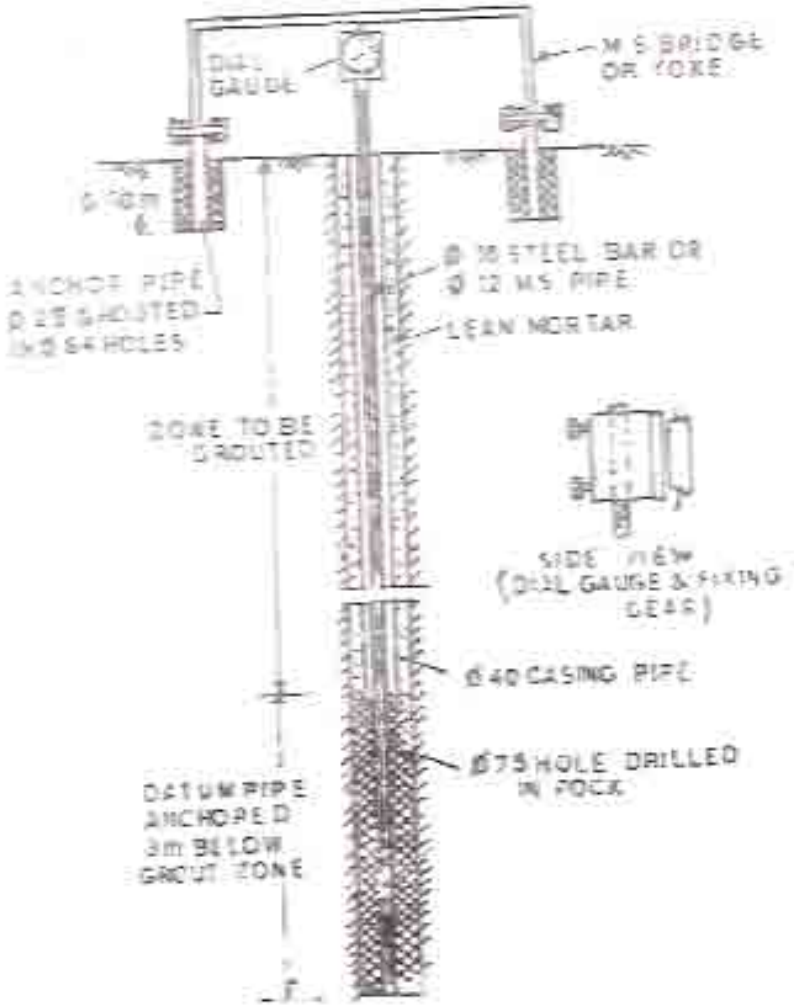


Fig. 5. Uplift Gauge

22.7.15 Drainage Holes

22.7.15.1 Drainage of dam foundation shall be accomplished by a line of holes drilled from the foundation gallery into the foundation rock. The diameter of the hole shall generally NX drill which is 75 mm. The spacing of the hole shall be initially kept as 6m centre to centre and may be reduced as required or as decided by the Engineer-in-Charge. If not otherwise specified, the depth of drainage holes shall be decided by the Engineer-in-Charge on the basis of the geological conditions and that

it would be 20 to 40 per cent of the maximum reservoir depth and between 30 to 75 per cent of the curtain grouting depth for preliminary design. These shall further be reviewed and holes provided at closer intervals are further deepened on the basis of actual observations after the reservoir is filled. To facilitate this, additional nipples/ pipes as directed shall be embedded in the gallery / concrete.



ALL DIMENSION IN MILLIMETRES

Fig.: 6A Foundation Drainage Gallery (In Rock)

(All Dimensions in MM)

22.7.15.2 The drainage holes of 75mm dia shall be drilled through 100 mm dia black steel pipe embedded in the masonry / concrete portion in the gallery. When drainage holes are drilled through soft foundations, a perforated pipe shall be placed in the drainage holes and the space between walls of holes and this pipe shall be filled with pea gravel (passing 10 mm sieve and retained on 4.75mm sieve) (see fig. 6 B).

This arrangement would avoid caving – in of walls and the holes could be got washed, if required.

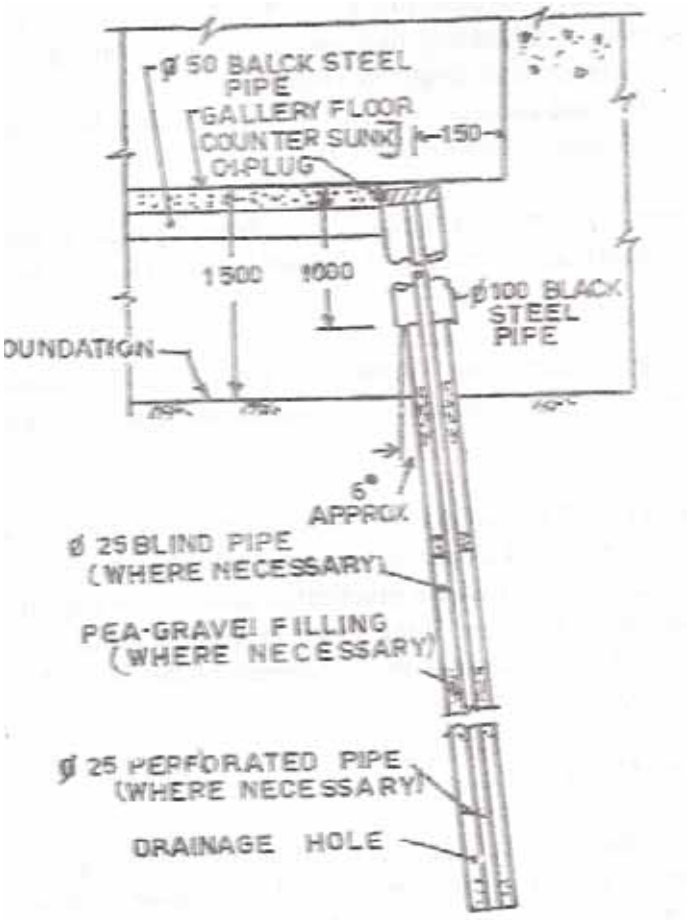


Fig. 6 B. Foundation Drainage Pipe (In Soft Foundation)

(All Dimensions In MM)

22.7.15.3 Drainage holes shall be drilled after all foundation grouting has been completed within minimum horizontal distance of 15m. the drainage holes shall be drilled through the drainage gallery through previously installed black steel pipe extending down to the foundation rock. Additional drainage holes or curtain grouting shall be provided if uplift pressure higher than designed values is observed. After drilling, the pipes shall be plugged at top and seepage water from the hole shall be taken off at a T-joint and led to the gutter of gallery. (See fig. 6 A & B).

22.7.15.4 Where cross galleries, additional foundation galleries and drifts are introduced, necessary drainage arrangements shall also be provided as directed by the Engineer-in-Charge.

22.7.15.5 The seepage water from drainage holes shall be monitored from consideration of quantity, contents of fines and chemicals and remedial action taken, if warranted.

22.7.15.6 All the water shall be removed from the hole when grout is placed. The anchor bars if required to be provided as per the design shall be forced into place before the grout has taken. Its initial set, and where practicable shall be vibrated or tapped until the entire surface of the embedded portion of the bars is in intimate contact with the grout. Special care shall be taken to ensure against any movement of the bars which have been placed.

22.7.16 Repair and Clean up

Concrete surface and foundation surfaces over which grout has flowed shall be cleaned and restored to their original condition. Upon completion of the grouting all removable grout nipples shall be removed from grout pipes embedded in concrete. Holes in concrete for such connections shall be filled and finished as specified. Any grout pipe nipples extending above the dam zone foundation and, if required by the Engineer-in-Charge any other foundation, shall be cut flushed with the foundation surface.

22.7.17 Technical Field Records

An accurate and up-to date technical field records of all survey, drilling testing, grouting, and control operations and observations required to be performed in connection with this work, shall be maintained for each hole in a chronological order in the proforma given in Appendix VII. Suitable forms shall be used for recording other relevant information not covered by the proforma given in Appendix XII.

APPENDIX – I
(Para 22.4.3.6, 22.4.3.7 and 22.4.4.1)

DAILY DRILL REPORT

Project Date
Location Shift : from h to h
Feature
Drilling machine Drill hole
Machine No : Hole No.
Type : Coordinates : Coller elevation :

Feed : Screw / hydraulic Bearing hole : Ground elevation

Angle with horizontal : Depth of water level in the hole
Depth drilled during the shift At start of shift (m) :
At end of shift (m) :

Pump :
Pump No :
Capacity : From to
(N/mm^2) (m) (m)

Casing Lowered			Run		Length Drilled (m)	Rate of Penetration (mm/minute)	Water Loss (See Drill Observer's Remark 1)	Colour of Return Water	Core Recovery		Type of Rock	Remarks
Size (mm)	Depth		From (m)	To (m)					Length (m)	Percentage of core recovery		
	From (m)	To (m)										

Supplies				Bits used					
Petrol (It)	Diesel (It)	Motor Oil (It)	Misc	Types and Size	Depth		(Old/New) with Number	Carate lead and make	Stones per carat
					From (m)	To (m)			

Drill Foreman / Superviser

Operator

Office – in – Charge

Drill observer

DRILL OBSERVER'S MARKS

1. Water loss during drilling may either be recorded as (a) complete, when no water is coming out, partial or nil water loss; or (b) in percentage of return water (100 per cent, loss when no water is coming back and no water loss or 0 per cent. When all the drilling water is coming back) (See 22.4.3.1.2)

2. Rate of penetration in special zones (soft or broken zones) (see 22.4.3.2) and other details of drilling like heavy vibration and torque (See 22.4.3.4) recorded during drilling.

3. Reason for heavy core loss (See 22.4.2.3) as integrated with rate of penetration.

4. Any special conditions not recorded, for example, depth at which blasting was done while driving casing depth at which hole was grouted (See 22.4.3.6.1), artesian water conditions if any observed during drilling (See 22.4.3.6.2), gas discharge (See 22.4.3.6.3).

5. If water flows are encountered at the collar of the drill, then the pressure head and discharge at the collar should be recorded. On completion of the hole, the pressure decline over a period of time should also be recorded.

6. Other details given at 22.4.3.7 should also be observed and recorded.
7. The feel of the driller may be suitably recorded in remarks column.

APPENDIX – II

(Para 22.4.5.2, 2.4.5.2.5, 22.4.5.3, 22.4.7.1 and 22.4.8)

Average data for drilling with N size tools to achieve a concurrence of rapid progress and good core recovery.

Rock Type	Bit Type				Diamond Impregnated Bits	Core Barrel Type B	Bit Spped Rev/min	Bit Pressure	Water pressure Kg/cm^2
	T.C.	Diamond	Set	Bits					
		5 15	15 30	30 60					
1	2	3	4	5	6	7	8	9	10
Laterite		X				X	100	Light	3.5 to 7
		X				X			
Weathered granite and soft gnaiss							200	Light	3.5 to 7
Sandstone		X				X	200	Light Medium	9 to 12.5
Clay shales	X					X	200	Light	9 to 12.5
Other bedded Sediments	X	X				X	200	Light Medium	9 to 12.5

Rock Type	Bit Type				Diamond Impregnated Bits	Core Barrel Type B	Bit Spped Rev/min	Bit Pressure	Water pressure Kg/cm^2
	T.C.	Diamond	Set	Bits					
		5 15	15 30	30 60					
1	2	3	4	5	6	7	8	9	10
Hard sandstone		X					200	Medium	10.5 to 14
Black Schist			X				400	Medium	10.5 to 14
Basalt (green stone)			X				400	Medium	10.5 to 14
Prophyry			X	X			400	Medium	10.5 to 14
Diorite			X	X			400	Medium	12 to 15.5
Hard basalt (green stone)				X			600	Medium heavy	14 to 17.5
Hard perphyry				X	X		600	Medium heavy	14 to 17.5
Hard diorite granite, gneiss				X	X		600	Heavy	14 to 17.5

Bit Type : TC = tungsten carbide saw tooth bits.

5.15, 15, 30, 30, 60 = Diamond set bits with stones per carat within the limits indicated.

The bits indicated with a cross (x) should normally be used.

When using other size of coring equipment, multiply with factor given below :

Size	Factor		
	Feed Pressure	Water Pressure	Bit Speed
NX	I	I	I
BX	0.7	0.7	1.3
AX	0.5	0.5	1.6
EX	0.3	0.3	1.9

APPENDIX- III

(Para 22.4.9)

VIBRATION IN DRILLING

1. CAUSES OF VIBRATION

1.1 Causes of vibration for which the operator is responsible are the following.

(a) Excessive rotational speed;

(b) Excessive feed rate of pressure;

(c) Excessive water pressure or volume;

(d) Low water pressure or volume, resulting in show removal of cuttings,

(e) Drilling when the core barrel is filled;

(f) Drilling over dropped core; and

(g) Careless handling of drill rod. Bent rods cause vibration deviation in holes and damage to bits.

Rods can be bent through:

(1) Rough handling of rods;

(2) Their improper use as crow bar or as lever arm, and

(3) Hoisting and lowering rods with pipe wrench instead of using safety clamps.

1.2 Causes of vibration controllable by the operator are the following ;

(a) Unsatisfactory setting up of drilling rig;

(b) Incorrect size of rods and core barrel in relation to the size of hole;

(c) Bent core barrel and rods;

(d) Bit with missing stones or damaged bits;

(e) Lack of rod grease;

(f) Unsatisfactory condition of drilling equipment, such as worn out spindle and bearing of swivel head; and

(g) Off-center tightening of the chuck.

1.3 Causes of vibration not fully controllable by drolleries are the following :

(a) Worn out rod couplings;

(b) Core bits with flat faces that ‘walk’ in certain formation;

(c) Crooked drill holes due to unfavorable geological featured;

(d) Cavities in the rock, allowing wide sway of the rod string; and

(e) Variable hard and soft layers, such as lime- stone with chert or shale with hard quartzite layers.

Note: - All causes of vibration listed have serious effects on core recovery and wear on bits and equipment.

2. REMEDIES FOR VIBRATION

2.1 Remedies for vibration are the following:

(a) The use of rod grease on bottom rods;

(b) Drill rods of maximum size for hole being drilled;

(c) Use of drill collars;

(d) The use of sharp bits;

(e) The use of straight rod and core barrel, concentrically threaded;

(f) Maintenance of rods, coupling, core barrel and drill itself in first class condition; and

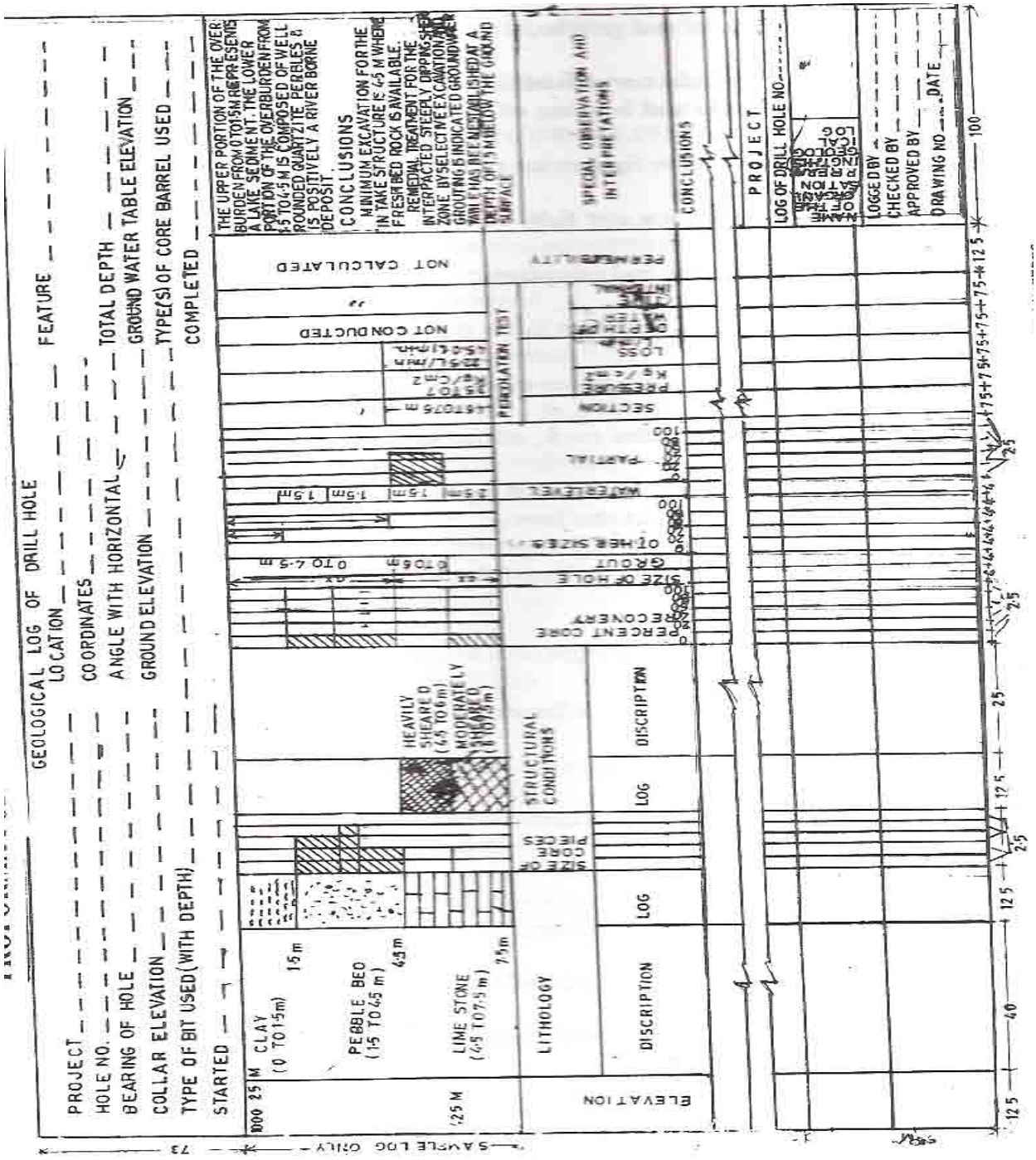
(g) Proper control of feed, rotational speed and drill bit pressure.

In coring operations as many of the adverse conditions which tend to induce rod vibrations as is physically and economically possible shall be eliminated.

APPENDIX – IV

(Para 22.4.12.3)

PROFORMA FOR PRESENTING DRILLING INFORMATION



ALL DIMENSIONS REGARDING SIZES OF COLUMNS IN THE PROFORMA ARG IN MILLIMETRES

NOTE : - A SAMPLE LOG FOR 7.5 M DEPTH IS FILLED IN THE PORTICN ABOVE THE TITLES OF COLUMNS THIS IS TO SERVE UNLY AS GUIDE FOR FILLING THE LOGSHEET AND IN NOT A PART OF THE PROFORM.

APPENDIX – V

(Para 22.7.3)

IN SITU PERMEABILITY TESTS IN BED ROCK IN DRILL HOLES

(Pumping – in Type Test)

1. EQUIPMENT

The following equipments shall be used for water percolation tests in drill holes :-

1.1 Drilling Equipment:- A drill rig and/or accessories for lowering and driving the casing pipe.

1.2 Water meter: - Capable or reading up to 0.5 of a liter. The water meter should be periodically checked and calibrated.

1.3 Pressure gauge :- Choice of pressure gauge of range 4 or 10 or 16 kg/cm^2 should be made dependent on the maximum pressure desired for testing. This will give suitable least count reading for test accuracy. Where centrifugal pumps are not available and reciprocating pumps have to be used, they should be used with siphon or air - dome attachment in order to enable correct measurement of testing pressure.

1.4 A pump:- Preferably a centrifugal pump of minimum capacity 500 It/min capable of producing pressure up to 30 kg/cm^2.

1.5 Water pipes, connections and swivels. - See Note under 1.8.

1.6 Drill Rods, Perforated Rods and Other Fittings. - See Note under 1.8.

1.7 Packers (Washers, Pneumatic or Hydraulic Type). See Note.

Note:- Leather cup packers are generally used in rock formation where holes drilled their proper size. Mechanical packers are commonly used in moderately hard formations wherein the holes drilled are upto 20% over size.

Pneumatic packers, can be used for all types of formations, are generally preferred for soft rock formations wherein the holes drilled are 20% over size.

1.8 Equipment for Measuring Water Level in the Drill Holes: - See IS : 6935 – 1973.

Note:- When drilling is in progress, no additional water pipes, swivel, etc. will be necessary. The drill rods and other equipment as used in drilling may be used for conducting percolation tests.

1.9 A Stop Watch:- Having a measuring capacity up to one hour and a least count of one second.

2. QUALITY OF WATER TO BE USED FOR THE TEST

In the pumping in test, unless clear water is used, the tests are invalid and may be grossly misleading. The presence of even small amounts of silt or clay in water used in the test will result in plugging of the test section and give permeability results that are too low.

By means of settling tank or a filter, efforts should be made to assure supply of clear water. It is also desirable, where the climatic conditions demand, to raise the temperature of added water to one higher than ground temperature so as to preclude the creation of air bubbles in the ground which may greatly reduce the acceptance of water by the test section.

3. PROCEDURE PUMPING – IN TYPE OF TESTS

The water percolation tests should be conducted in uncased and ungrouted sections of the drill holes.

3.1 Single (‘Single packer’- method) or double ('double packer' method) packers are employed to conduct these tests (See fig.1). Examination of drill cores and the results of water tests obtained during drilling will usually indicate whether a double packer test in any isolated section or sections of the drill hole is required. (In certain form actions, it may not be possible to use the packer or there is a danger of the packer being stuck in the holes. In such cases, a better method will be to grout the earlier stage, extend the bore and carry out the test. The tests are based on measuring

the amount of water accepted by the test section (of the hole) confined by a packer/packers while water is pumped into it. The lay out for the test is shown in figure 7.

The single packer method (Fig. 1A) is useful the full length of the hole cannot stand uncased/ un grouted in soft rocks, such as sand rock (soft and stone), clay shale or due to highly fractured and sheared nature of the rocks or where it is considered necessary to have permeability values side by side with drilling (for example where multiple aquifers are present). Where the rocks are sound and the full length of the hole can stand without casing/grouting double packer method (Fig. IB) may be adopted. The specific advantage of double packer method is that critical rock zones can be tested by confining them along with packers. The disadvantage of the double packer method is that leakage through the lower packer can go unnoticed and lead to over estimation of water loss. Wherever time permits, single packer method would be preferable.

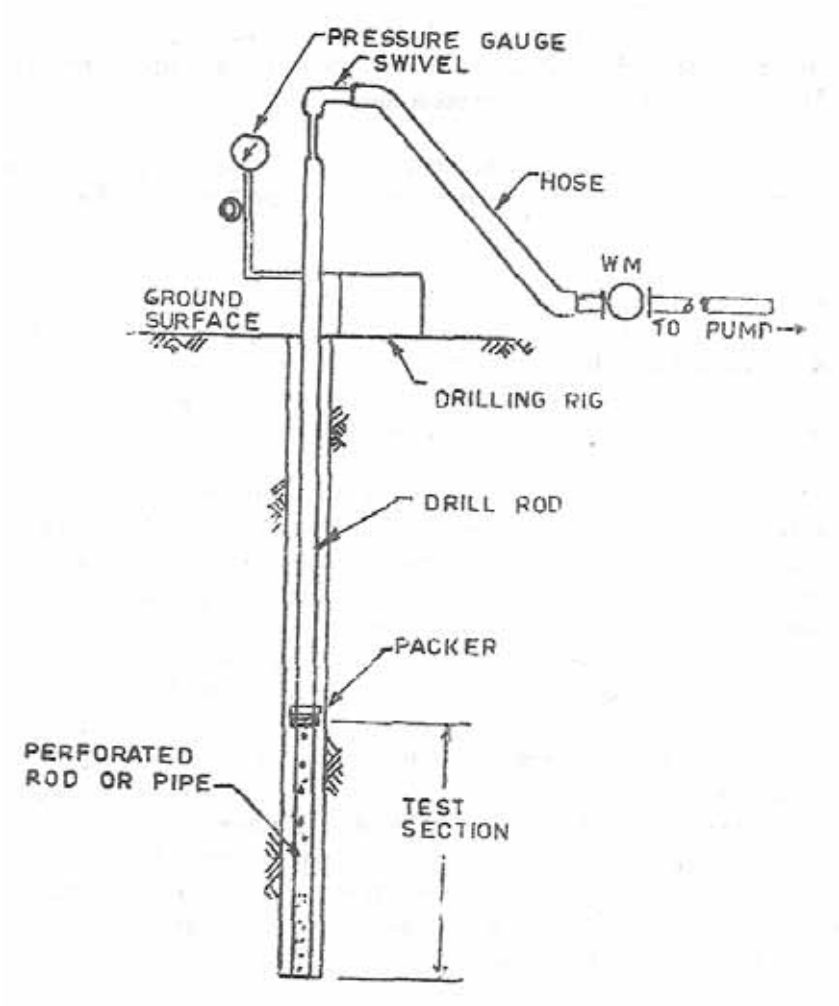


FIG 7 : SKETCH SHOWING LAYOUT OF EQUIPMENT FOR PERMEABILITY TEST IN DRILL HOLE (SINGLE PACKER METHOD)

3.2 Single packer method: - In this method the hole should be drilled to a particular, depth desirable for the test. The core barrel should then be removed and the hole cleaned with water until, clear water returns. The packer should be fixed at the desired level above the bottom of the hole and the test performed in accordance with the procedure laid down in Para 3.5, after performing the test, the entire assembly should be removed. The drilling should then be proceeded with till the next test section has been drilled for performing the next test. In this manner, the entire depth should be tested side by side with the drilling.

3.3 Double packer method:- In this method the hole should be drilled to the final depth desired and cleaned with water until clear water returns. Two packers connected to the end of a perforated drill rod of a length equivalent to the test section should be fixed in the drill hole. The bottom of the perforated rod should be plugged before the double packer tests are proceeded with.

The tests may be done from bottom upwards or from top downwards. **However,** it is convenient to start the test from the bottom of the hole and then work **Upwards.**

3.4 To verify the presence of ground water table the water level in the hole should be depressed either by evacuation with compressed air or boiling by sand. After the operation is completed, if three consecutive readings of the water level taken at 10 to 15 min intervals is constant, then this water level may be taken as the ground water level. The time interval may have to be increased to 30 min in less permeable formation.

3.5 The tests are recommended to be performed in 1.5 or 3m test sections so that that the entire hole is covered, depending upon the geological conditions; as for example in sections passing through a shear zone or a highly jointed zone, a lesser length of section should be used (see also para 4.3). The test length should not, however, be less than 5 times the diameter of the bore hole. The test section should be confined by means of a packer or packers (see para 3.2 & 3.3). The water level in the hole/test section should be determined using electrical device as given in IS : 6935 - 1973.

The measurements of the water level should be noted at short intervals of time (usually 10 to 15 min) till three consecutive readings show constant values. The constant readings should be taken as the depth of water table. This measurement is done for determining the hydrostatic pressure in the test zone and this value is used for calculating the permeability of the horizon. If these measurements indicate that there is no water table or piezometric, head, this fact should be mentioned in the report/ noted on the Drg. showing the logs of bore holes.

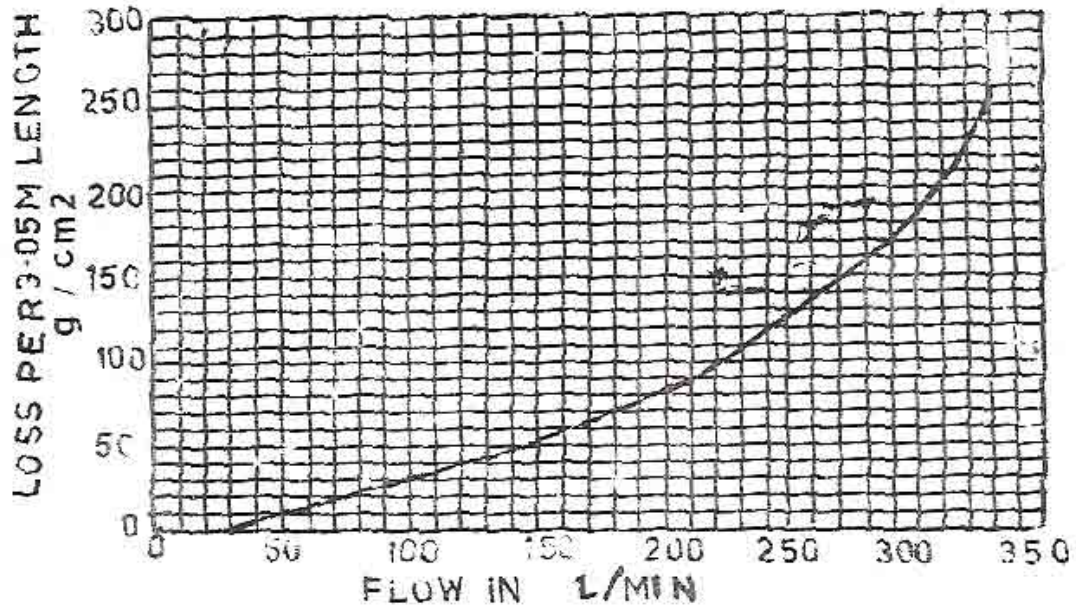
Under piezometric conditions, the piezometric head in separate horizons shall be ascertained by measurement of water level after installation of packer in the hole.

3.6 Water should then be pumped into the section under pressure. Each pressure should be maintained until the readings of water intake at intervals of 5 min show a nearly constant reading of water-in-take for one particular pressure at the collar. The constant rate of water intake should be noted. It is recommended that the tests be commenced with a low pressure at the collar and increased limited to the availability of suitable rock cover to prevent uplift or to a maximum equivalent to H + X (where H is the hydraulic head to which the strata would be subjected due to contemplated structure and X is the loss due to friction) in achieved. Frictional loss may be determined by means of charts given in fig 8A, 8B and 8C and added to the test pressure. In order to avoid upheaval of the rock foundation test pressures are generally limited to the following :-

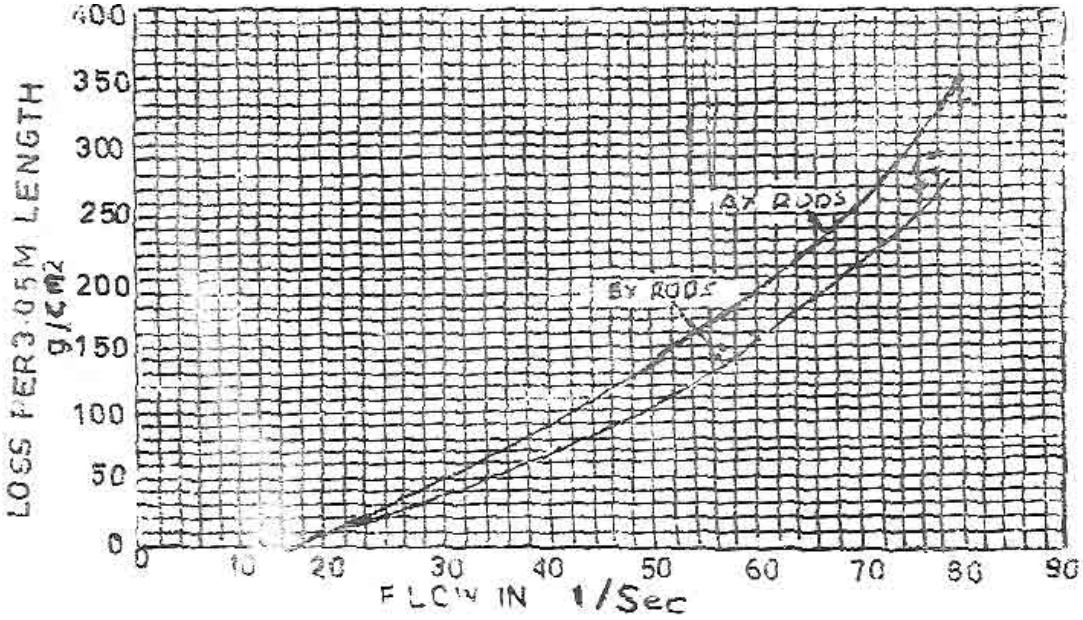
	Rock Type	Limit of Test pressure applied to the Test Zone in g/cm^2 per metre of Rock Load (See Note)
(i)	Unconsolidated or poorly consolidated sedimentary formations.	115
(ii)	Consolidated horizontally bedded sedimentary formations.	175
(iii)	Hard igneous and metamorphic rocks	230

Note :- These pressure are applicable for testing in exploratory holes for determining the in-situ permeability. For testing to determine the grout ability of the formation higher pressure may be needed (see IS:6066-1984) .

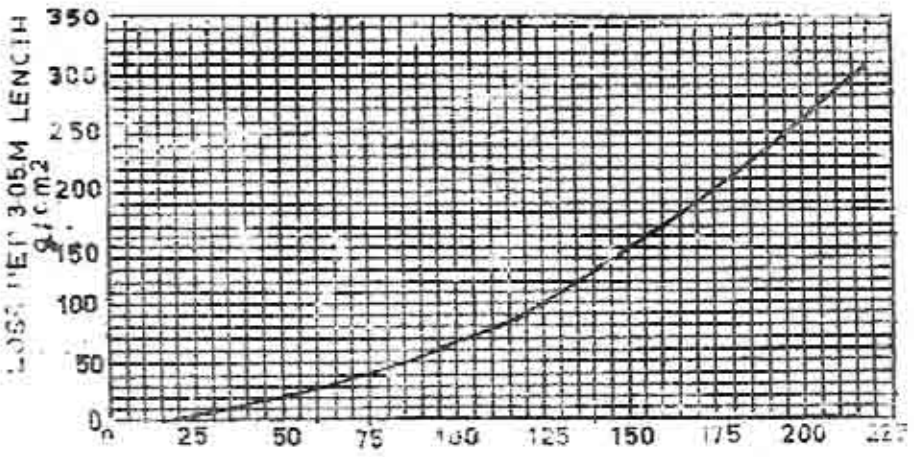
IS:6066-1984).



8A : HEAD LOSS PER 3.05 M. LENGTH IN 32 MM PIPE



8B : HEAD LOSS PER 3.05 SECTION IN AX AND BX RODS



8C : HEAD LOSS PER 3.05 M SECTION OF BX DRILL ROD

FIG. 8 : HEAD LOSS IN PIPE AND DRILL RODS

3.7 Cyclic Test - In special circumstances cyclic tests are performed to evaluate the wash ability and grouting of joints of rock or their extent. Cyclic tests for assessment of permeability are useful in competing lugeon value. These tests are started at low pressures, the test pressures built up to the maximum capable pressure by increments and decreased in the same order until the original pressure is reached. Generally, for the performance of the cyclic tests, 4 ranges of pressure should be chosen which may be fixed at 25 per cent , 50 per cent 75 per cent and 100 per cent of the pressures selected for the test section based either or suitable rock cover or maximum equivalent of reservoir head whichever is applicable (see para 3.6)

In addition to performing the permeability tests at regular intervals of the strata, it is desirable to test critical bedrock zones by confining them alone with packers.

4. Precautions in Conducting the Test

4.1 On completion of drilling, the holes shall be immediately capped or plugged and shall be protected from entry of dirt, muck, grout or any kind of waste.

4.2 Water level in the drill shall be recorded before proceeding with the water percolation tests.

4.3 Normally a 1.5 or 3m section is considered suitable for performing the tests. However, the length of the test section should be selected according to the total thickness of the permeable stratum and geological conditions and varied locally to seat the packer (s) properly. Short test sections of 1.5 m would be preferred in thin bedded and heterogeneous strata. When the intake of water in the test section is more than that which the pump can deliver it is advisable to reduce the section. Under normal circumstances test sections longer than 3m are not recommended.

4.4 The hole should be thoroughly flushed with clear water before the tests are commenced. Where core recovery is good (greater than 70 per cent) holes should be flushed with water under pressure, until the wash water is clear. When the recovery is poor (less than 70 per cent) and the holes are liable to collapse by the disturbance caused by washing the holes may be cleaned by gentle surging (by moving a rubber block up and down the hole) followed by gentle flushing.

4.5 Drill rods or 32 mm pipes may be used for conducting the permeability tests. It would however, always be better to use a large diameter rod when the alternative is available so that friction losses may be reduced to the minimum possible.

4.6 The water swivel used in the test should preferably have a uniform inside diameter to minimize loss of head.

4.7 Locations of the pressure gauge between the pump and the water meter or the water meter and the swivel may not measure the actual pressure acting in the test. In order to get better and representative figure of the pressure acting, it is recommended that the gauge be located between the swivel and the packer (see Fig. 7).

4.8 Unnecessary bends in the pipe lines from the pump to the swivel should be avoided.

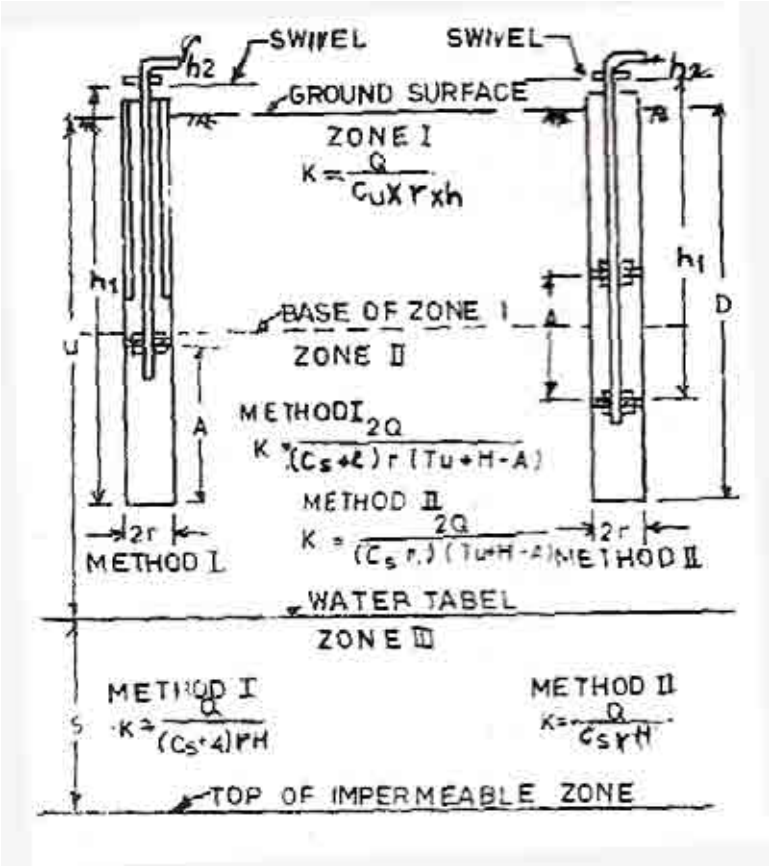
4.9 The water used for the test should be clear and free form silt (see para 2).

4.10 All joints and connections between the water meter and the packer, it should be assured that the packer/packers are not, leaking. A leaking packer usually causes the rise of water level in the hole or even the water strata overflowing from the nipple.

4.11 Every opportunity should be taken of comparing the permeability observations in open pits, shafts and trenches with the results of tests in bore holes.

5. COMPUTATION OF EQUVALENT PERMEABILITY FROM PERMEABILITY TEST DATA.

5.1 The coefficient of permeability should be computed using the formulae given in fig.9. The coefficient Cu and Cs in these formulae may be taken from the graphs given in Fig. 10 and Fig. 11. For water percolation tests conducted above the water table, the position of the base of Zone I should be found from the curve given in Fig. 12. The friction loss of head (L) should be calculated or obtained from Fig. 8A, 8B or 8C. This head should be deducted from the combined head due to gravity and that due to applied pressure. Numerical examples illustrating the use of the formulae are given in para 5.2.



Q

Limitations <0.10; S>10 in method II: thickness of each packer should be 10.

a

A = length of test section in m.

a = surface area of test section in m2 (in method I, a is area of wall plus area of bottom)

Cu= conductivity coefficient - unsaturated bed (see Fig. 10)

Cs= conductivity coefficient - saturated bed (see Fig. 11)

D = distance from ground surface to bottom of hole, in m.

H = effective head = h1 + h2 - L,in m.

h1= in test above water table, distance between swivel and bottom of hole in m. in test below water table, distance between swivel and water table, in m.

h2= applied pressure at collar, in m of water.

K = coefficient of permeability in m/s under unit gradient (multiply by 100 to get the value in cm/s)

L = head loss in pipe due to friction in m of water (for quantities less than 181/min in 32mm pipe, it may be ignored.)

Q = steady flow into well, in m3/s

r = radius of test hole, in m.

S = thickness of saturated material, in m.

Tu= U - D + H

U = thickness of unsatureated material, in m.

$$X = \text{percent of unsaturated stratum } \frac{H}{Tu} \times 100 \text{ (see Fig. 12)}$$

Fig. 9 Formulae For Calculation of Coefficient Or Permeability .

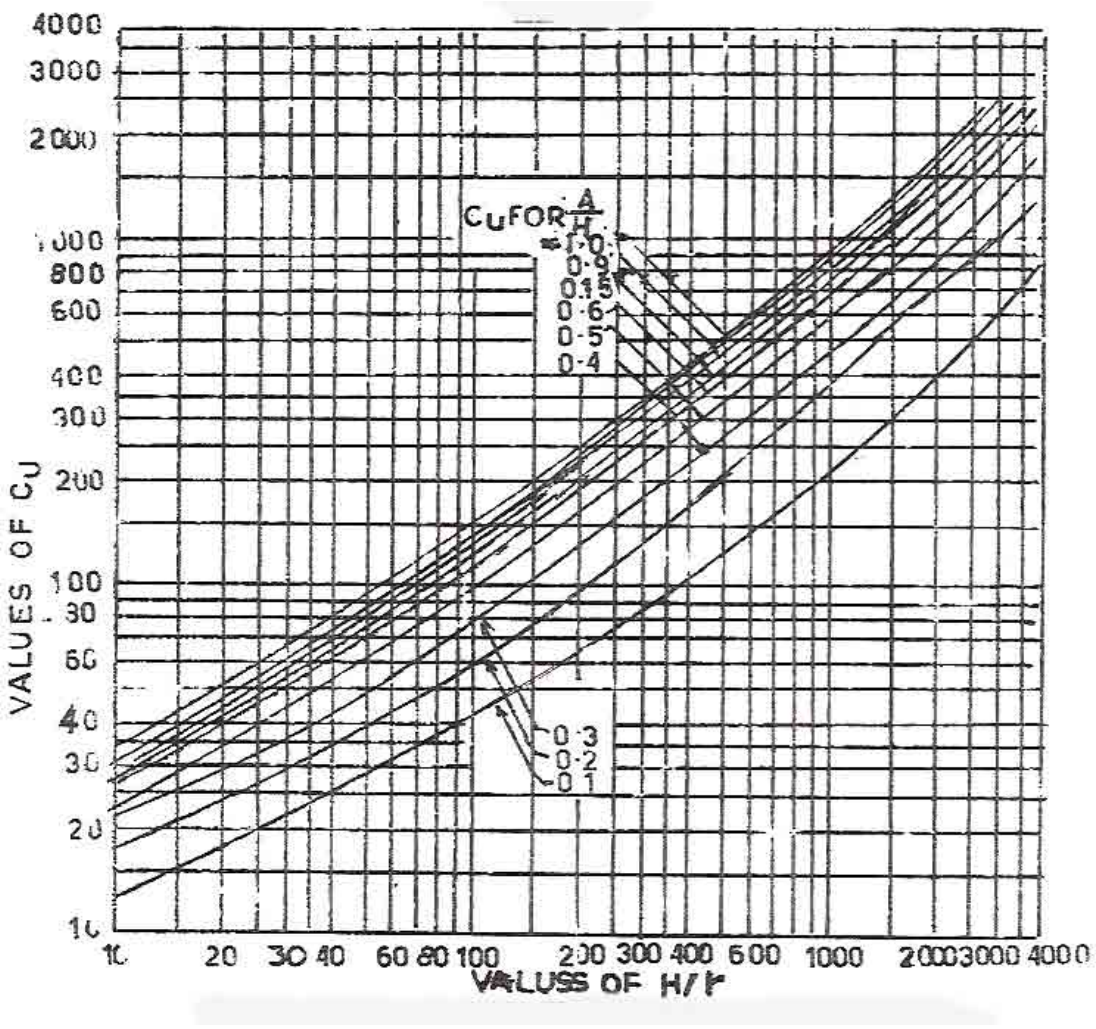


Fig. 10 CONDUCTIVITY COEFFICIENT FOR PERMEABILITY DETERMINATION IN UNSATURATED STRATA WITH PARTLY PENETRATING CYLINDRICAL TEST WELLS

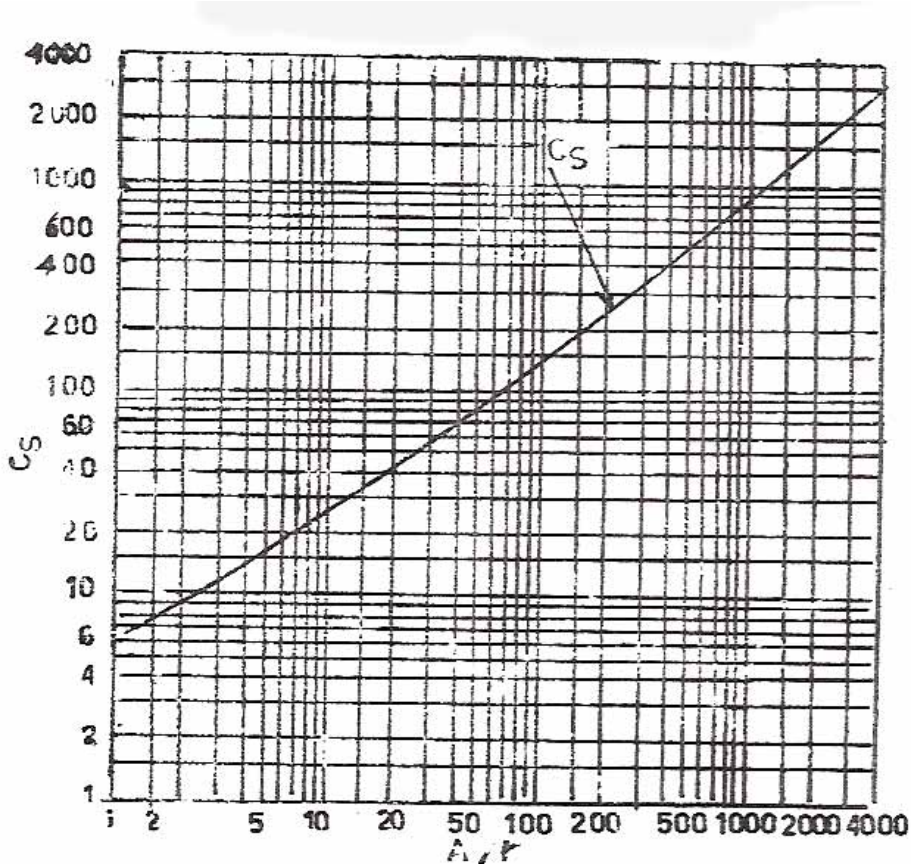


FIG. 11 : CONDUCTIVITY COEFFICIENTS FOR SEMI-SPHERICAL FLOW IN SATURATED STRATA THROUGH PATIALLY PENETRATING CYLINDRICAL TEST WELLS

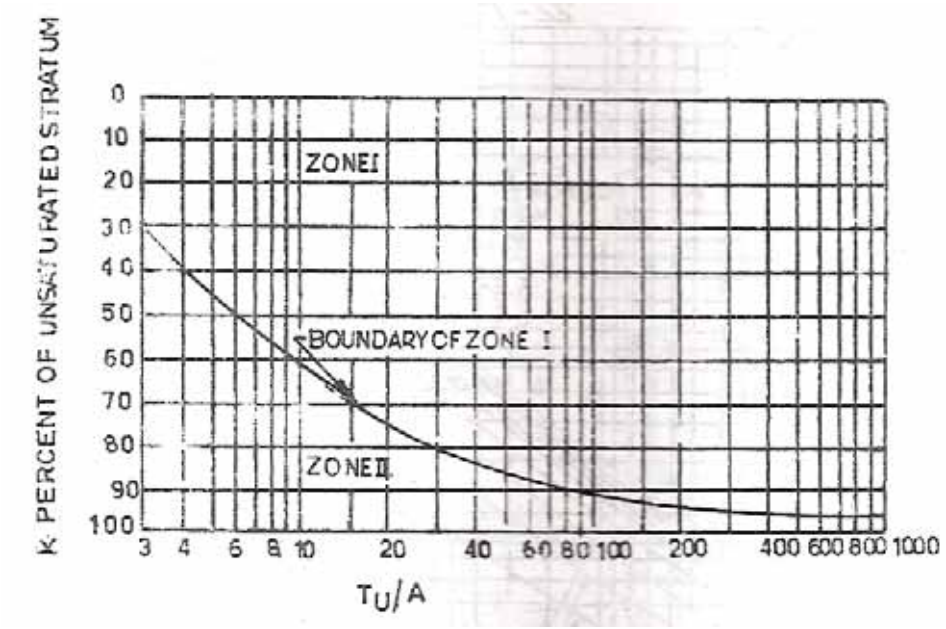


FIG. : 12 LOCATION OF ZONE I LOWER BOUNDARY FOR USE IN PERMEABILITY DETERMINATION

5.2 CALCULATION OF PERMEABILITY COEFFICIENT USING PRESSURE PERCOLATION TESTS IN BEDROCK

Zone I:

U = 23 m D = 7.6 m A = 3m

r = 0.15 m h1 = 10m h2 = 1.75kg/cm^2 = 17.5m

Q = 0.0013m^3/s

L using 32 mm pipe at 0.0013 m^3/s

= 23 cm loss per 3.05 m section

Distance from swivel to bottom of pipe - 6.7 m

$$\text{Head loss} = \frac{6.7 \times 0.23}{3.05} = 0.514\text{m}$$

H = (10+17.5-0.51)m = 26.99m, say 27m

Tu = U-D+H=23-7.6 + 27m = 42.4m

$$x = \frac{H}{Tu} \times 100 = \frac{27 \times 100}{42.4} = 63.6 \text{ percent}$$

$$\frac{Tu}{A} = \frac{42.4}{3} = 14.1$$

Point $\frac{Tu}{A}$, X on fig.12 is in Zone I

$$\frac{H}{r} = \frac{27}{0.15} = 180$$

$$\frac{A}{H} = \frac{3}{27} = 0.11$$

Cu from (Fig. 10)= 62

$$K = \frac{Q}{Cur\ H} = \frac{0.0013 \times 100}{62 \times 0.15 \times 27}\ \text{cm/s per unit gradient}$$

$$= 0.00052\ \text{cm/s per unit gradient}$$

ZONE II:

U = 23 m D = 20m A = 3m

r = 15 cm h1 = 22m

h = 1.75 kg/cm^2 = 17.5m Q = 0.0013m^3/s

L = using 32 mm pipe at 0.0013m^3/s

= 23 cm loss per 3.05 m section

Distance from swivel to bottom of pipe = 19.6 m

$$\text{Head loss} = \frac{19.6}{3.05} \times 0.23 = 1.5\text{m}$$

H = 22 + 17.5 - 1.5 = 38 m

Tu = 23 - 20 + 38 = 41 m

$$X = \frac{38}{41} \times 100 = 92.5\ \text{percent}$$

$$\frac{Tu}{A} = \frac{41}{3} = 13.7$$

$$\frac{A}{r} = \frac{3}{0.15} = 20$$

Cs (From Fig.11) = 39

Point $\frac{Tu}{A}$, X on Fig. 12 is Zone II

Method I

$$K = \frac{2Q}{(Cs + 4)\, r\, (Tu+H-A)} = \frac{0.0026 \times 100}{(43 \times 0.15)\,(41+38-3)}$$

= 0.00053 cm/s per unit gradient

Method II

$$K = \frac{2Q}{(Csr)(Tu + H - A)} = \frac{0.0026 \times 100}{(39 \times 0.15)(76)}$$

= 0.000583 cm/s per unit gradient

ZONE III

U = 23 m S = 18 m

D = 30 m A = 3 m

r = 0.15 m h1 = 25 m

h2 = 1.75 kg/cm^2 = 17.5 m

Q = 0.0013m^3/s

L using 32 m pipe at 0.001 m^3/s = 23 loss per 3.05 m section

Distance from swivel to bottom of pipe = 30 m

$$\text{Head loss} = \frac{30}{3.05} \times 0.23 = 2.26$$

H = 25 + 17.5 - 2.26 = 40.24 m

$$\frac{A}{r} = \frac{3}{0.15} = 20$$

Cs (from Fig.11) = 39

Method I

$$k = \frac{0.0013 \times 100}{(39+4)\ (0.15 \times 40.24)} = 0.0005 \text{ cm /s per unit gradient}$$

Method II

$$K = \frac{0.0013 \times 100}{39 \times 0.15 \times 40.24} = 0.00055 \text{ cm/s per unit}$$

5.3 In hard-rock when the permeability tests are conducted the water intake is generally due to joints and fractures and not due to intergranular voids. In such cases, the permeability computed from these tests would correspond to that of the joints and fractures and would represent the equivalent permeability of a homogeneous isotropic material.

5.4 The water loss may also be expressed in Lugeons which is defined as the water loss of one liter per minute per meter of the drill hole under a pressure of 10 atmospheres maintained for 10 min a drill hole of 46 to 76 mm diameter.

As it is difficult to build up without upheaval / deformation pressure of 10 atmospheres at depths of less than 30 to 45 m in hard massive rock a unit coefficient of water loss (one liter per minute per atmosphere) herein designated as a "deci-Lugeon" may be adopted for direct evaluation of the order of water tightness of the rock.

6 SIGNIFICANCE OF PERMEABILITY VALUE IN BED ROCK

6.1 The direct values of water loss (which may be preferably expressed in Lugeons) is a useful guide to assess the competency of the foundation, determine the necessity or otherwise of grouting requirements and to settle the foundation grades of dam foundation. Therefore, it is customary to note the water loss values along with the plotting of the log of bore holes.

6.2 It is customary also to note the values of water loss at a water pressure of 1.5 to 2 times the reservoir head to which the bed rock at that level is likely to be subjected.

6.3 The water loss indicate the aquifer zones that are more permeable and against which slotted pipes are to be placed in tube well construction.

6.4 The equivalent permeabilities of rock are some guide in ground water yield studies. But in ground water studies more reliance is placed on pumping tests with a mother well surrounded by auxiliary wells.

APPENDIX – VI

(Para 22.7.12.4 & 22.7.12.7)

CONTROL OF GROUTING OPERATION

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.

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.

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 pressure are raised hastily, damage could occur even, at relatively low pressures. In general horizontal particularly stratified or low dipping rocks are more vulnerable to distrubance by grouting pressure than fractured igneous or metamorphic rocks or steeply dipping 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.

1.3 It is always advisable to begin with a low initial pressure say 0.10 to 0.25 kg / cm^2/m of overburden and build up pressure gradually. Initially the rate of intake may be 20 to 30 lit./min. In order to avoid the premature build of high pressure a general guideline should be followed that the pressure shall be raised only when the intake rate falls below 5 liter/minute when surface leaks develop, pressure shall be immediately reduced. Subsurface cracking may sometimes be indicated by as abrupt rise in the rate of intake after grouting at a constant value of pressure for a considerable period.

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 pressure so that even the smaller seams can be grouted effectively,

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/cm^2 may be computed by multiplying the depth of the hole in metres by factors relative to the water – cement ratio given in Table 1 and added to the pressure gauge reading at the top of the grout hole.

TABLE 1 – MULTIPLYING FACTORS

Water – Cement Ratio (1)	Factor (2)	Water – Cement Ratio (1)	Factor (2)
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

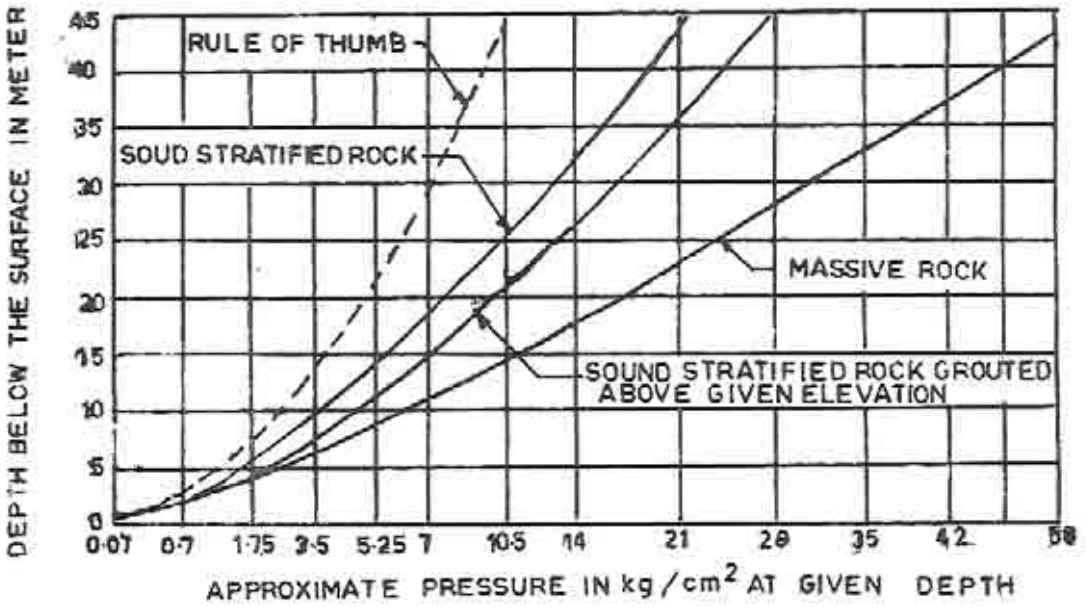
2.00	0.121	10.00	0.102
2.25	0.119		

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

(a) The limiting value of pressure for each zone and depth of stage may be established initially from the results of trial grouting, along with observations of upheaval by uplift gauge. Figure 13 may be used as a guide, subject to verification by trial grouting;

(b) Pressure limits may be decided by analysing the result of Cyclic Percolation Test.

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



APPROXIMATE PRESSURE IN kg/cm^2 AT GIVEN DEPTH

Fig. 13 Guide For Grouting Pressures

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. 13. Pressure limits based on Fig. 13 should be taken as initial values to be confirmed by trial and observations.

The choice of pressures may also be established by examining water test data. The method of interpretation of water test data is described as suggested in Fig. 14 and para 1.4.1.1. These interpretations may be generalized to establish relationship between hydraulic fracturing pressure and overburden depth for various strata encountered. The Pressure limit may be set at 2/3rd the hydraulic fracturing pressure established by analysis of water test data. The water test thus constitutes a basis of verification of rock categorization as per fig. 13.

1.4.1.1 Interpretation Of Water Test

(A) The results of water percolation test should be interpreted on the basis of following principles :

When the rate of flow for a given length of test section varies proportionate to pressure, this is categorized as a condition of laminar flow… In a cyclic test, the flow will increase and decrease in direct proportion of the pressure and lugeon values remain constant all over the cyclic test.

Sometimes the resistance to flow increase disproportionately to the increase in pressure and therefore the rise of flow rates is not commensurate with the increase in pressure. This may be attributed to development of turbulent flow regime and is indicated by bugeon values decreasing with increase of pressure.

(B) Hydraulic fracturing is indicated by a disproportionate increase of flow with reference to pressure and the percolation at the end of the cyclic test is higher than the initial values at equal pressure.

Sometimes, flow rates tend to decrease with passage of time and the flow rate at the end of cyclic test is smaller than the initial flow rate at equal pressure. This is categorized as a condition of void filling.

Sometimes, a phenomena similar to hydraulic fracturing occurs when lugeon values at the end of the test are higher than the initial values at

equal pressures. However, if the test is repeated, a normal trend is indicated. Such cases are categorized as washout. The difference between the hydraulic fracturing and washout category is that in case of hydraulic fracturing a progressive increase of flow rates will occur with each cycle as the cycles are performed.

1.4.2 The pressure limits initially established as per 1.4.1 should be further reviewed by examining trends of grout intake and pressures during initial stage of actual grouting operations. The method of interpretation of trends of grouting pressure is described in para 1.4.2.1 It should be recognized that the resistance to flow of grout pressures are 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 / creacks / cleavages are filled by the grout response. Grouting with ‘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 1.4 should be modified on the basis of the analysis of the trends of grouting pressure and intake. The chosen pressure limits ensure that ‘A’ trends are achieved generally and ‘C’ trends are eliminated.

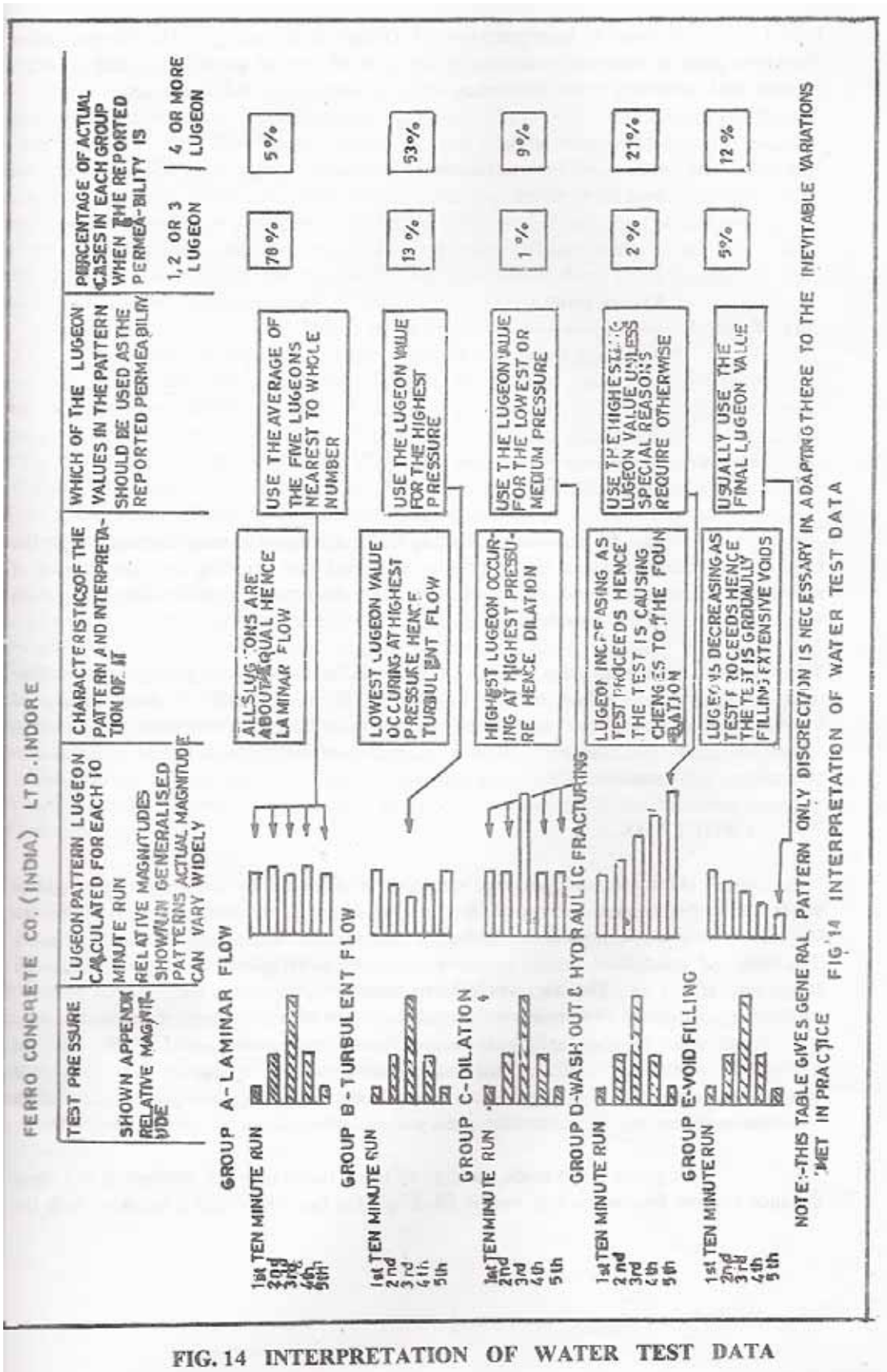


FIG. 14 INTERPRETATION OF WATER TEST DATA

1.4.2.1 **Method of Interpretation of Trends of Grouting -** The categorization should be done as follows by competing the ratio of rate of grout intake and grouting pressure and examining 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 $\frac{\text{Rate of grout intake}}{\text{Grouting Pressure}}$ ---------- Decreasing 'B' trend*

(c) Ratio of $\frac{\text{Rate of grout intake}}{\text{Grouting Pressure}}$ ---------- increasing 'C' trend

* In this case the rate of intake and pressure may fluctuate while the ratio would remain constant for a prolonged period and grouting may be stopped if consumption limit is attained. Alternatively the operation may end with a decreasing ratio which implies 'A' trend towards closer.

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 up heaval may be noted only when sufficient volume of grout is injected into the fractured zones to cause displacements in the surface zones.

2.0 GROUT MIX. -

Grout mixture ranging from mixture of 0.5:1 upto 10:1 (ratios by weight of water and cement) have been used. Recommended range of mixture falls from 5:1 to 0.8:1. It is only in exceptional circumstances that mixtures leaner than 10:1 need be used. The choice of grout mixture may be based on results of percolation tests conducted prior to grouting (See 1.4) . The ideal would be to conduct a percolation tests 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 operation. It is indivisible to relax the requirements of percolation testing in the initial stages of grouting and grout absorptions at low water-cement ratio are a poor substitute for water percolation tests.

2.1 If grout is too thick, passage of grout travel may get obstructed at a short distance and the fine seams may not be filled up. On the other hand if injection with the grout is continued for a too long 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 per cent in a grout mix. will have lubricating action. No general rules can be stipulated regarding. the manner in which the thickening or 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 judgment about the efficacy of a particular sequence may be had by comparing the grout consumption 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 a continuous grouting of about 10 min.

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 over travel and to block the more pervious zones. In the inner or central lines grouts may be thickened very gradually and comparative 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 over travel of grout in the case of wide joints, sodium silicate is sometimes added, while for increasing the flow ability in the case of thin joints 2 to 3 per cent bentonite is added.

2.3 It has been the practice of some organizations to dilute the grout by increasing the water content at the end of the grouting operation. The advantages of this procedure are controversial; however, 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.

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.

2.3.2 While 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 standard grout has been pumped or in zone in which refusal was specially difficult to obtain or again in the case of deep interconnection, this process might not be performed and thin mixes may be omitted for 6 m or so overlying the trouble some zone, or the section might be allowed to rest for a few hours before higher sections are treated.

3. CONTROL OF GROUT CONSUMPTION -

When pressure does not built up even after grouting a thick grout that is, grout with water cement ratio smaller 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 stage and 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 grout in order to penetrate the finer cracks and joints which may not be grouted in the initial operation. In such situations a multiple line curtain may be used with advantages and the sequence of grouting shall be as in 2.2.

APPENDIX VII
(PARA 22.7.17)
PRESSURE GROUTING RECORD

Hole No
Co-Ordinates
Diameter
Elevations
natural Ground
Type of Hole

Grout Cap
Width
Depth
Casing Pipes
Depth
Diameter

Up Lift Gauges
Bottom Elevation
Top Elevation
(Space for Sketch)

Hole log Particulars Log	Type of Grouting	Stages of Grouting	Date	Time	Water Pressure Test			Pressure grouting				Grout Consis-tency	Uplift		Extent of leakage from surface joint & fissures	Leakage	Re ma rks
					Pressure		Intake Litres per minutes	Grout mix by Volume	used pressur e	Intake litres per minute	Cemen t cons-umed		Obs point No.1	Obs point No.2			
					pressure specified	pressure used											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

Notes :

1. Sketch on the top right hand corner shall show the location of the hole belbg grouted together with location and condition of nearby holes. Holes that have been drilled will by "D" with the number showing the depth of the hole, such as 'D-25'. The hole has been grouted will be indicated by the letter 'BG in similar manner'. Position of upheaval indicators shall also be shown.
2. Column 1 & 2 will also show the ground water table level.
3. Column 5 & 6 will record the date & time. of any significant event in the operation. The change pressure & intake in the water pressure test, and each change in grout mix, pressure or intake the grouting operation will be recorded.
4. The rate of intake in column 12 shall be recorded at every 15 minutes interval.
5. Cement consumption in column 13 shall be recorded for each pressure of grout mix change.
6. Column 15 & 16 will show readings of uplift observation points at the beginning of the operations and at every noticeable change.
7. Under "Remarks" in column 19 shall be recorded any change or incident affecting the grouting operation, such as "Tight Hole" "Leak caulked" "Hole No ..... Caped", "Grout pump down", "Grouting suspended due to ..... " Hole Completed and so fort

Section – V

CHAPTER – 25

Canal Lining

LINING OF CANALS

CONTENTS

CHAPTER -25

LINING OF CANALS

25.1 REFERENCES

IS: 651-1980	Specification for salt glazed stoneware pipes and fittings.
IS: 1398-1982	Specification for packing paper water proof bitumen laminated.
IS:2252-1981	Specification of Mortar
IS:2508-1984	Specification for low density polyethylene films.
IS3872-1990	Code of Practice for lining of canals with burnt clay tiles.
IS:3873-1993	Code of practical for laying cement concrete/stone slab lining on canals
IS:4515-1993	Code of practice for stone pitched lining cansls.
IS:4558-1990	Revised draft for under drainage of lined canals, circulated by BiS vide DOC: RVD 13 (63) in Oct. 1993 for revision of IS: 4558-1990.
IS:4701-1990	Code of practice for earthwork on canals
IS:5256-1992	Code of practice for sealing expansion joints in concrete lining on canals
IS:5690-1990	Guide for laying combination lining for existing unlined canals.
IS:5889-1970	Specification for vibratory plate compactor
IS:7246-1974	Recommendation for use of table vibrators for consolidating concrete
IS:9451-1994	Guide lines for lining of canals in expansive soils.
IS:9698-1990	Revised draft for lining of canals with low density polyethylene film circulated by BIS vide DOC:RVD 13 (155) in Oct. 1993 for revision of IS:9698-1991.
IS:10430-1991	Criteria for design of lined canals and guidelines for selection of type of lining.
IS:10646-1992	Specification on canal lining-Cement concrete tiles
IS:11809-1994	Code of practice for lining of canals Stone Masonry
IS:12379-1992	Code of practice for lining water courses & field channels
IS:13143-1991	Specification on joints in concrete lining of canals sealing compound
CWC Report June 1987	Lining of canals in Expansive Soils
Memo No.WB MP-9 of WAPCOS	Lining of main canals and branch canals of M.P. Composite Irrigation Project

T.C. 17	Canals in expansive soils-Identification and Treatment
T.C. 1/84	Concrete lining
T.C. 20	Necessity and type of Drainage Arrangements Behind Lining
CSMRS Report	Report of CSMRS on "Guideline for use of CNS soils" issued vide No. 8120/R-1/86-CSM/356 dated 18-8-87.

CHAPTER – 25

25.1 CANAL LINING

25.2 TERMINOLOGY

Black Cotton Soil - They are a type of expansive soil and form a major soil group in India. The colour of black cotton soil vary from black yellowish to grey. They are characterised by high shrinkage and swelling properties.

Beaching - A protective covering of properly packed or build in materials on the earthen surface slopes of irrigation canals, drainage channels, river banks etc. to protect them from the action of water.

Cohesive Non-swelling soil (CNS) - They are soils possessing the property of cohesion of varying degree and having non-expanding type clay minerals such as illite and kaolimite and their combination with low plasticity with liquid limit not exceeding 50.

Compaction - The densification of a soil by means of Mechanical manipulation.

Consolidation - The gradual reduction in volume of a soil resulting from an increase in compressive stress.

Construction Joint - A joint occurring in a structure composed of homogeneous material such as earth or concrete along a plane or surface formed by cessation of placing of material for a time, such as overnight or for several days.

Expansion Joint - A joint provided in exposed members between fixed point to permit vertical movements where different settlement is anticipated.

Expansive Soil - They are inorganic or organic clays of high plasticity with high compressibility and liquid limit more than 50 and are characterised by shrinkage and swelling properties.

Face - The surface of the slab, which will come in direct contact with either the subgrade or water in the canal.

Lip Cutting - Cutting of extra width provided at the inner face of the bank under compaction to allow for any lapses in compaction due to the inability of compacting rollers to cover the edge of the bank.

Made up ground - Excavated soil or rock deposited for the purpose of filling a depression or raising a site above the natural level of the ground.

Pressure, Relief Valve - A valve provided in a canal lining which opens in to the canal to relieve excess hydrostatic pressure behind the lining. The pressure relief valves shall be such that it will operate by a differential pressure less than that which will be damaging to the lining with safety factor of 2. This should be operative generally with a differential head of 100 mm and above. Pressure relief valves are generally of such material, which will be abrasive resistant and will not be effected due to its presence in the water.

Pipes/drain - Pipes are provided with filter all round so that sub soil water can flow in the pipe; without changing the soil strata beneath the lining. Pipes are kept open so as to facilitate the entry of water.

Sides - All the surfaces other than the faces of the slab.

Slip-Form - A steel plate provided at the leading edge of the slip-form machine extending across the bottom and up the slopes of the canals to form the finished surface of the lining.

Subgrade - The specially prepared surface on which lining shall be laid.

Toe Wall - A shallow wall constructed below the bed or floor level to provide footing for the sloped pitching or the face of an embankment.

25.3 PREPARATION OF SUBGRADE

25.3.1 Expansive Soils

The detailed position in this regard is given in IS 9451: 1985.

25.3.1.1 General

25.3.1.1.1 Expansive soils in side slopes and bed of canal in cutting or embankment when in contact with water swell, exerting a swelling pressure, which may range from 50 to 300 KN/m2 or more. This characteristic of swelling and the swelling pressures of black cotton soil is attributed to the pressure of montmorinolite or combination of montmorinolite and illite clay minerals. A wide range of properties of expansive soils are found in India (see IS 1498: 1992 for identification and properties).

The swelling pressure and free swell index tests should be done in accordance with IS 2720 (Part 40): 1992 and IS 2720 (Part 41): 1992. Expansive soil met within the locality has to be analysed for swelling pressure before deciding the type of treatment. For testing the expansive soil for determination of swelling pressure the expansive soil specimen should be remolded at zero moisture content to the density obtainable at any time in the year in the field at a depth beyond 1.0 m (in expansive soil). The swelling pressure should be determined under no volume change condition when moisture content is increased from zero to fill saturation level.

25.3.1.2 ***Identification of expansive soil:***

25.3.1.2.1 Following indications are generally observed in the case of expansive soil:

(a). During summer wide deep and map type cracking is normally observed in expansive soils.

(b). Walking over such soil is rendered difficult during heavy rains.

(c). Thorny bushes, thorny trees (Babul) and cactus constitute the normal vegetation in such soil in India.

(d). Buildings constructed using conventional methods exhibit heaving of floors, cracking of walls and jamming of doors during rainy season. Retaining structures get tilted and roads get rutted bed heaving and side slips and sloughing are noticed in canal.

25.3.1.2.2 The expansive soils can be identified by following visual properties.

Colour	-	Black, Grey, Yellow and Yellowish Grey
Land slope	-	Normally 0 to 2
Drainage	-	Generally poor

25.3.1.2.3 Physical properties of expansive soils

The grain size and index properties of such deposit expressed in percentage are in the following range.

Gradation:

GRAIN SIZE	**PERCENTAGE**
Clay (less than 2 micron)	50 to 70
Silt (0.06 mm to 0.002 mm).	20 to 35
Sand (2 mm to 0.06 mm)	30 to 50
Gravel (greater than 2 mm)	Less than 10%
Index properties:	
Liquid limit	60 to 100
Plastic limit	30 to 50
Plasticity index	30 to 40
Shrinkage limit:	8 to 12

25.3.1.3 Cohesive Non-swelling Soils (CNS) for Treatment

25.3.1.3.1 (a) They are soils possessing the property of cohesion of varying degree and non-expanding type clay minerals such as illite and kaolinite and their combination with low plasticity with liquid limit not exceeding 50 percent.

(b) Some of the soils which may be considered as cohesive non- swelling soils are all adequately compacted clayey soils, silty clays, sandy clays, gravelly sandy

clays, etc., exhibiting cohesive- properties and containing predominantly non-expanding type clay minerals.

© CNS material should be non-swelling with a maximum swelling pressure of 10 KN/m^2 when tested in accordance with IS 2720 (Part 41): 1992 at optimum moisture content and minimum cohesion (unconfined compression strength on saturated compacted soil, remoulded at OMC and compacted to standard proctor density) should be 10 KN/m2 when tested according to IS 2720 (Part 10): 1991.

(D) If given CNS material is not available, designed mix to produce blended CNS may be used. The artificial CNS should satisfy all the requirements of CNS. If stabilized material is to be used, special mix design needs to be evolved.

25.3.1.3.2 Identification of CNS Material.

The CNS material can be identified by using

(a) Visual properties-

Colour - Red, Reddish, Yellow, Brown, White, whitish, Grey, Whitish yellow, Green and Greenish grey.

Land slope - Normal land slopes are between 2 and 10, though on flatter slopes they are many times encountered within 3m below the overlaying expansive soil

Drainage – Generally good

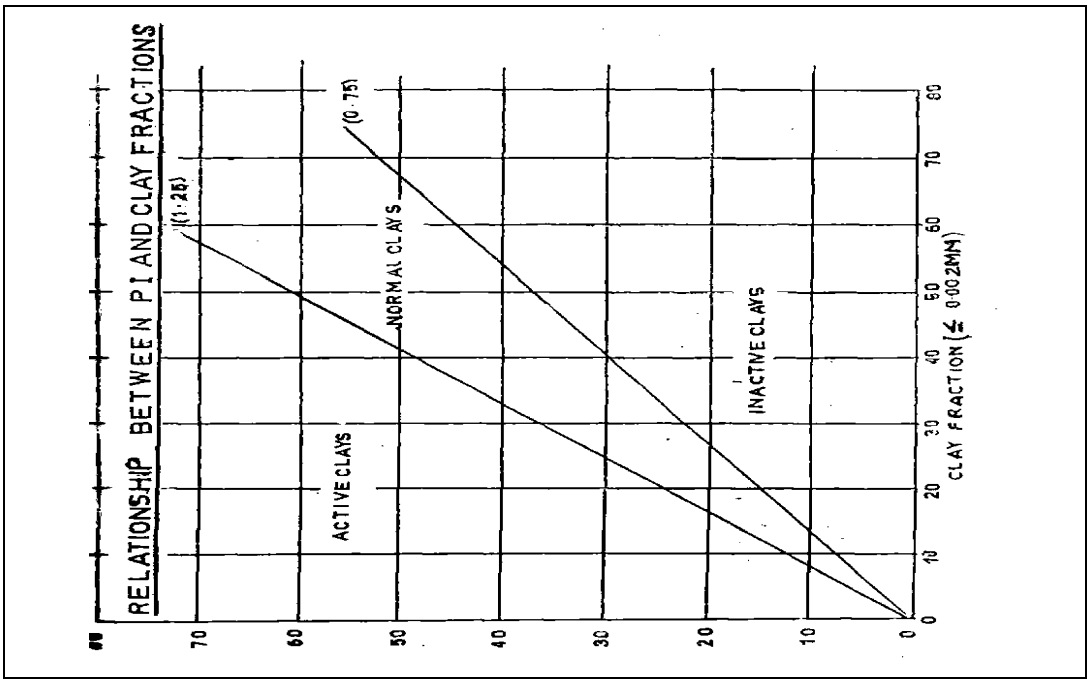


Fig 1 ACTIVITY CHART

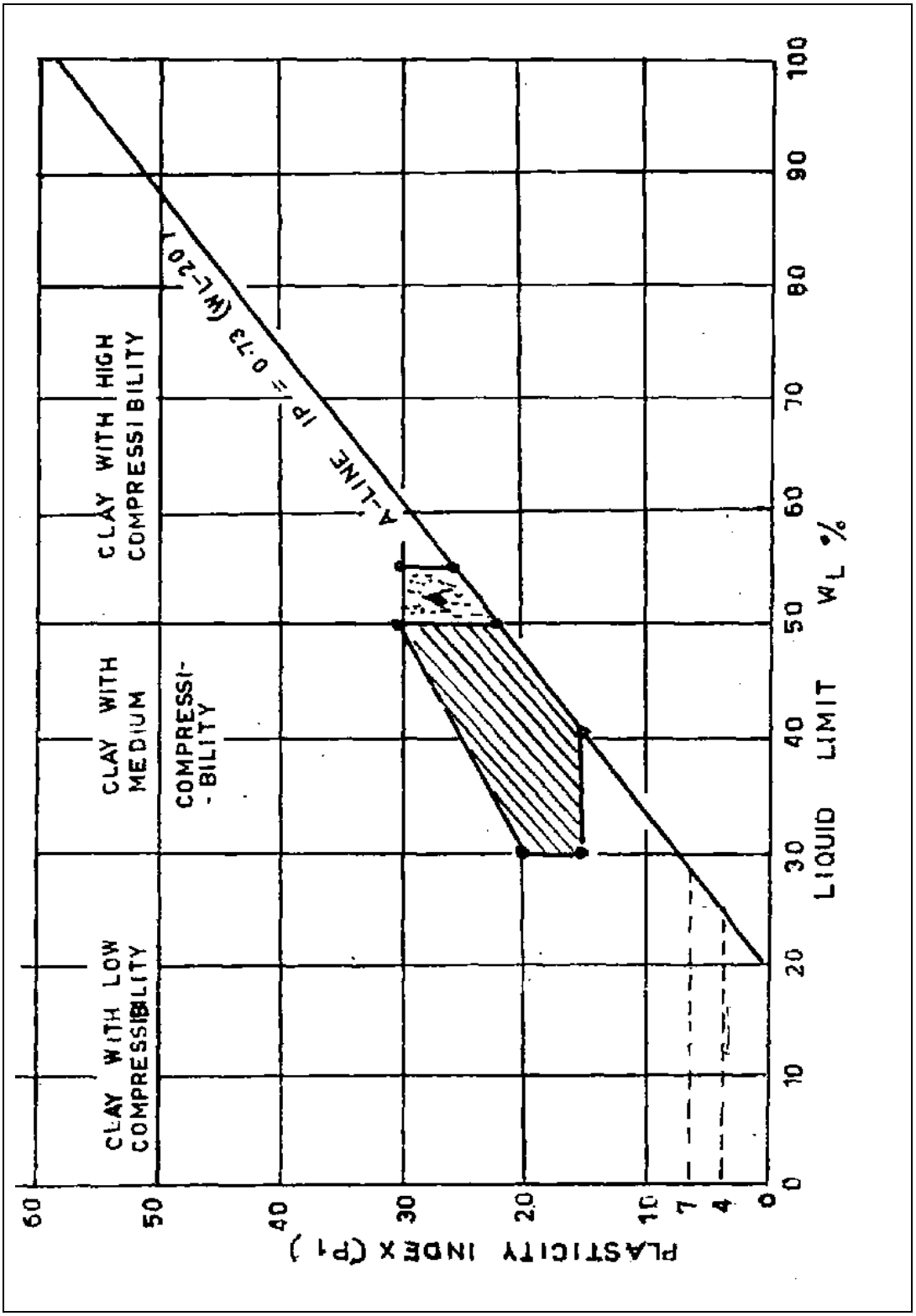


Fig 2 PLASTICITY CHART

(b) Identification using Activity Chart -

This chart (Fig.I) classifies the soil into active" Normal and Inactive soils based on plasticity Index and clay fraction present in the soil.

It is desirable to first check sample on this chart to see that the soil does not fall into active zone. The soil sample identified on this chart as suitable, i.e. not falling into active zone shall only be checked on A-line chart (Plasticity Chart) in accordance with the procedure laid down in para -C below.

(c) Use of A line chart (fig.2) is made for general identification of the CNS material. In this method the data required is only liquid limit (LL) and Plasticity Index (PI). The CNS soil has to resist internal erosion due to seepage and form suitable base for lining the soil with LL less than 30% and P! less than 15% is not considered suitable. The Zone covered between LL 30 to 50% and PI 15 to 30% is shown hatched. Soils falling in this zone can be considered suitable to be used as CNS material.

However, it is desirable to have a few representative samples tested for swelling pressure as a cross check.

In case of samples failing in Zone 'A' of the chart, it would be necessary to ascertain swelling pressure and cohesion of such sample before accepting the same as CNS material.

CNS soil normally should not exhibit swelling pressure, but in exceptional cases swelling pressure less than 0.1 kg/cm2 is acceptable, Minimum cohesion should be 0.1 kg/ cm2 (10 KN/m2).

25.3.1.3.3 ***Physical Properties Of CNS Soils***

Most murums of laterite, laterite type and siliceous sandy clay exhibit CNS characteristics, however some murums may be of swelling type. Unlike swelling soils, they do not exhibit cracking during summer, nor heaving and stickiness during rainy season. Structures constructed on such soil do not exhibit heave though they may sometimes settle. The CNS are generally red, reddish yellow, brown, yellow, white, whitish grey, whitish yellow, green and greenish grey in colour. Although, several soils containing non-expanding type clay mineral, exhibit CNS properties, the following range helps in locating such types :

	Percent
Clay (less than 2 microns)	15 to 20
Silt (0.06 mm-0.002 mm)	30 to 40
Sand (2 mm- 0.06 mm)	30 to 40
Gravel (Greater than 2 mm)	0 to 10
Liquid limit	Greater than 30, but less than 50
Plasticity index	Greater than 15 but less than 30

25.3.1.4 Criteria For Fixing The Thickness Of CNS Layer.

25.3.1.4.1 Thickness of CNS materials is related to swelling pressure and the resultant deformation. The permissible deformation is 2 cm.

25.3.1.4.2 Guidelines for choosing the thickness of CNS materials required for balancing the different swelling pressures is given in Table 1. Slopes should be in accordance with IS 10430: 1982.

Table 1. A THICKNESS OF CNS LAYER CARRYING CAPACITY LESS THAN 2 CUMECS

Discharge in cumecs	Thickness of CNS Swell Pressure 50-150 KN/m2	Layer in cm (Min) Swell Pressure More Than 150KN/m2
1.4-2	60	75
0.7-1.4	50	60
0.3-0.7	40	50
0.03-0.3	30	40

Table 1.B. A THICKNESS OF CNS LAYER, CARRYING CAPACITY OF 2 CUMECS AND MORE

Swelling Pressure of Soil KN/m2 cm (Min)	Thickness of CNS Materials
50 to 150	75
150 to 300	85
300 to 500	100

NOTE: However, optimum thickness of CNS material needs to be determined for different swelling pressures by actual experiments both in field and laboratory: if required.

25.3.1.5 ***Construction Procedure.***

To counteract the swelling pressure and prevent deformation of the rigid lining materials, a CNS material of required thickness depending on the swelling pressure of expansive soil, is sandwiched between the soil and the rigid lining material. The thickness of CNS layer should be measured perpendicular to the surface of expansive soil.

25.3.1.5.1 ***Canal in Cutting***

Long deep cuts in expansive soils should be avoided and where possible a detour should be considered.

In cutting special care will be necessary to compact the CNS materials against the excavated surface of the cuts. The material should be spread uniformly in their horizontal layers of specified thickness (15 cm thick). Care also is necessary in obtaining a good joint between the two materials, by thoroughly wetting the excavated surface, so as to avoid slips at the junction plane. The construction should be carried out in the following step's:

a). While excavating provision should be made for accommodating required thickness of CNS layer on bed and sides. The subgrade on which CNS layer is to be laid should generally not be kept exposed for more than four days, prior to the placement of the CNS layer.

b). Serrations should be :provided in expansive soil to prevent contact slides between CNS

materials and expansive soil.

c). Proper moisture should be added to CNS materials.

d). CNS materials should be compacted in layer by appropriate equipment to ensure proper density.

e). CNS on side slopes should be trimmed to the required thickness. The thickness is measured perpendicular to the surface of expansive soil.

f). Suitable canal lining over CNS material should be provided depending on the site and economic condition.

g). To avoid slipping and rain cuts during the rainy season, it is advisable to provide CNS right up to the ground level.

h). In deep cuts CNS material should be provided not only behind the lining of the canal but also above the canal prism, all along the excavated surface, so as to prevent large scale heaving above the canal level. The CNS material above the canal prism may be of lesser thickness say 15 to 20 cm However, full design thickness behind the lining should be continued at least 100 cm above the top level of lining (illustratory arrangement shown in Fig.3)

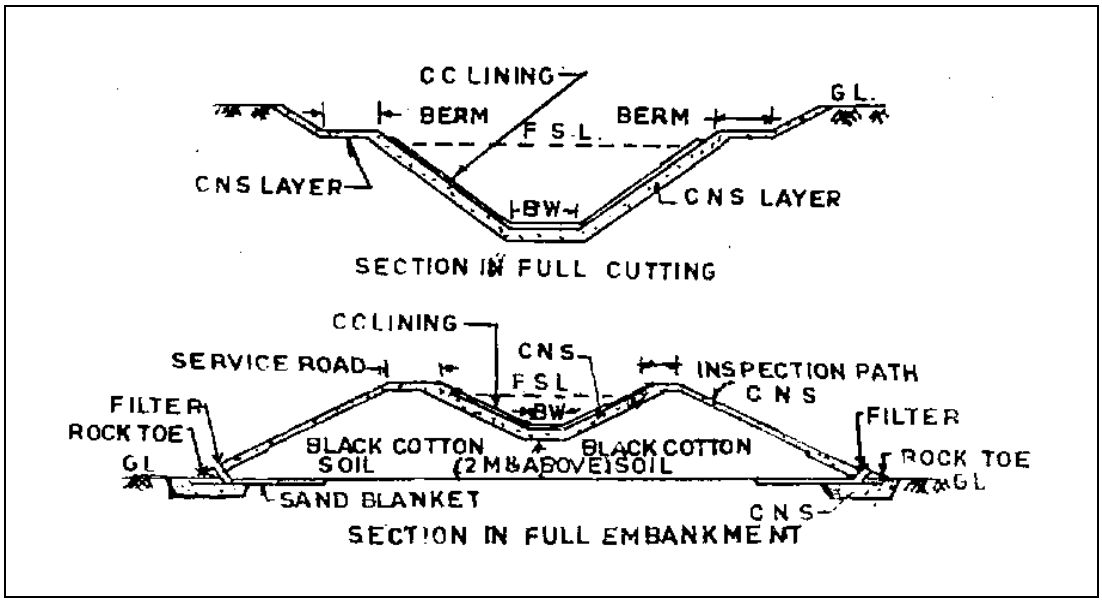


Fig. 3

i) The stability of the slopes, particularly in the case of cuts, is very adversely affected by rain water finding its way into the tension cracks and exerting hydrostatic force on the slipping mass of the soil Covering the surface of the slopes by CNS materials and proper surface drainage will reduce the chances of rain water finding its way into the cracks.

k) It is necessary to stack the excavated soil away from the cuts to prevent it inducing slips by surcharge.

25.3.1.5.2 Canal in Embankment

The construction should be carried out, in the following steps:

a) Proper moisture should be added to CNS material and expansive soil.

b) Expansive soils CNS Material above ground level should be composed simultaneously inlayers with appropriate equipments to ensure proper density,

c) The CNS material in embankment should be laid and compacted in layers simultaneously with the body of the banks" so as to obtain good compaction and to avoid any slippage plane being developed between the two materials. The compaction of CNS materials should also be to the standard proctor density with optimum moisture content. It may be done either with sheep foot rollers or 8 to 10 ton ordinary rollers.

d) Provision of surface drain and internal drainage filter should be made to minimize external/ internal erosion. A rock toe with inverted filter may be provided at either end of canal bank.

e) Special care in required to be taken to provide internal drainage for the banks, having bed filling of 2 meters or more. A sand blanket is spread on the base of the bank and rockfills with regular inverted filters are also necessary at the outer toes.

f) For both the cuts and banks, paved surface drains should be provided at the berms, to avoid erosion of the finished surface. As far as possible, water from these drains, should be drained away from the canal

g) The drainage properties of the CNS material itself need to be given due consideration as water locked up in this saturated layer is likely to cause pore pressures on the lining during canal draw-down conditions.

h) Murum (gravelly soil) material on outer slopes of canal embankment should be trimmed to the required thickness.

i) To protect outer slopes from erosion, proper turfing should be used.

25.3.1.5.3 Similar procedure should be followed for canal in partial cutting and embankment.

25.3.1.5.4 Pride

25.3.15.4.1 The problem of effectively compacting the subgrade for side lining on slopes is .very important in case of black cotton expansive soil zone in cutting or embankments, where backfill of CNS material is required to Replaced for the sides and bed, in addition to design thickness. Twenty cm or so (Perpendicular to side slope) of extra pride may be provided and compacted in horizontal layers to the required density. This pride should be removed only just prior to the placement of lining, thus making a fresh and well compacted surface available for bedding.

25.3.1.5.4.2 For cutting in soft material where the CNS backfilling is not required the best method is to leave the cutting 20 cm or so undercut (Perpendicular to the canal slope) and remove this undercut only just prior to the placement of concrete lining. Similar procedure may be' adopted in case of cutting in hard strata.

25.3.1.5.4.3 ***Use of Polyethylene Sheets Below Concrete Lining***

The use of polyethylene sheet below concrete lining could be either for achieving better ultimate imperviousness of the lining as a whole or it may be used only for limited purpose as an assistance, during construction, for avoiding the cement slurry from concrete escaping in the subgrade below, Use of LDPE sheets 200 gauge (50 microns) is to achieve only the latter limited purpose. If overall imperviousness is proposed to be achieved, it would be necessary to use HDPE-HM sheet of sufficient thickness, strength, toughness and durability.

25.3.1.5.4.4 ***Under Drainage Arrangements and Joints in Lining.***

The drainage properties of CNS material itself need to be given due consideration as water locked up in this saturated layer is likely to cause pore pressure on the lining during canal draw down conditions. To release the 'same if holes are provided for drainage in concrete lining, care will have

to be taken to provide inverted filters at the back of the holes so as to avoid the CNS material being washed away by fluctuating water levels in the canal. Such drainage holes are, however; not advocated for general adoption.

25.3.1.5.4.5 It is recommended to provide regular drainage arrangements using porous concrete sleepers, 7.7 cm x20 cm with 50 mm perforated G.I. Pipes at 3 m centre to centre coming out through the sides of the lining. Two porous concrete sleepers on either side of the- bed, below, the side may be provided. A50 to 75 mm thick sand mat below the bed and side cast in-situ lining (below the polyethylene sheet) should be provided. Where the sand mat is not economically feasible additional porous concrete sleepers may instead be provided at right angles to the longitudinal rails (along the cross section of the canal) at 3 m centre to centre. The porous concrete sleepers have to be encased in filter materials:

An illustratory arrangement is shown in Fig. 4

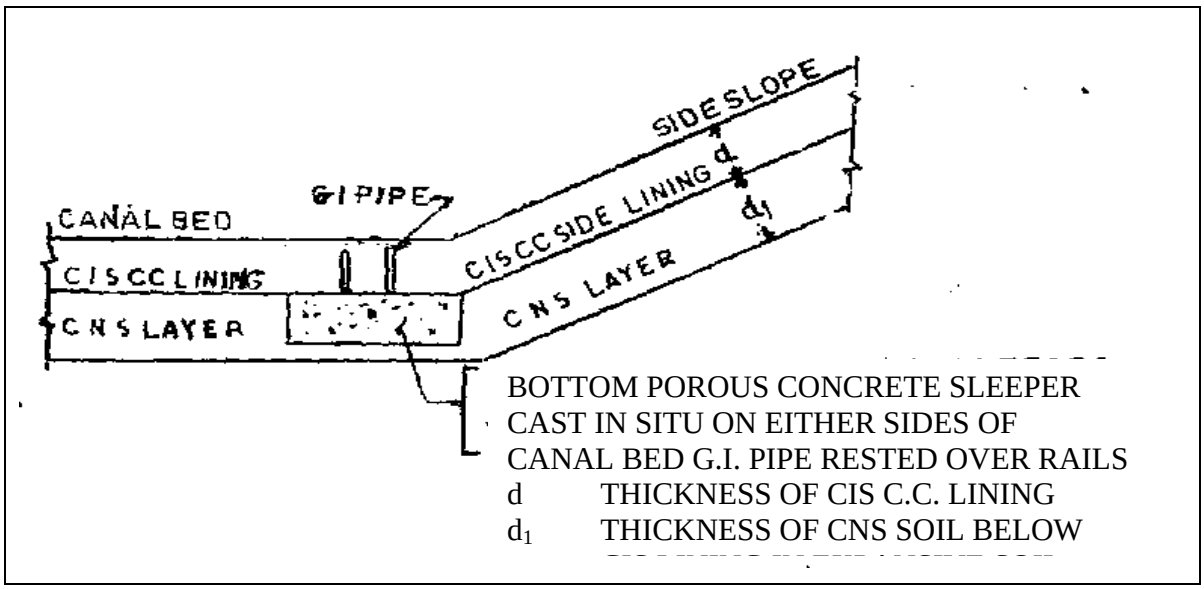


Fig.4- ILLUSTRATORY DETAIL OF BOTTOM RAILS

25.3.1.6 ***Laying of CNS Soil.***

25.3.1.6.1 The CNS layers should be firmly bonded at the interface of CNS and expansive soil through provision of serration in expansive soil base and thorough compaction of interface layers.

25.3.1.6.2 Before placement of CNS material the surface of excavation of embankment to receive CNS shall be roughened & thoroughly wetted about 15 cm so as to ensure firm bond between the original surface & CNS layer.

25.3.1.6.3 C.N.S. soil should be compacted in suitable layers so as to. Obtain the density not less than 90% of M.D.D. at its optimum moisture content or slightly on the drier side of optimum but not lower than 1 percent.

25.3.2 ***Preparation Of Subgrade Consisting of Soil***

The subgrade should be prepared, dressed and rolled true to level and according to the required cross-section of the canal to form a firm compacted subgrade for the lining.

25.3.2.1 In other than predominantly sandy reaches where the dry bulk density of the natural soil

is not less than 1.8 g/cm3 initial excavation should be done up to about 30 cm above the final section and the cutting to final shape should be done immediately before lining.

25.3.2.2 For checking the uniformity of side slopes, sample profiles at an interval of about 20 m. in straight reaches and 10m in curved, reaches should be made. Concrete templates of suitable size should be laid on the sample profiles. To begin with the top and bottom of the side templates should be fixed with reference to the established centre line of the canal and the corresponding design levels. For verifying the slope of the templates representing the sample profiles the diagonals of the cross-section of canal, between the two opposite side templates are checked. After laying the templates to the correct profile a cord should be stretched over the two templates (representing the same profiles) and run along the slope till the surface between the two profiles is I properly leveled and dressed from top to bottom.

25.3.2.3 If at any point material of prepared sub grade has been excavated, beyond the neat lines required to receive lining, the excess excavation should be filled with graded filter material compatible with subgrade material and thoroughly compacted in accordance with 25.3.2.5 and 25.3.2.6.

25.3.2.3.1 When partial filling of an existing canal is necessary to adequately reduce the cross-sectional area to that required for lined canal, the fill should be placed and suitably compacted to avoid its settlement and rupture of the lining

25.3.2.4 To cover up any lapses in the compaction of the inner core of the banks near the edges and to allow sufficient width for a labourer to work conveniently a lip cutting width of not less than 50 cm horizontally should be provided.

25.3.2.5.1 Compaction of Subgrade Predominantly Sandy Reaches

25.3.2.5.1 Bed

The compaction of the bed should be done by over saturating the bed by flooding it with water before lining is laid.

25.3.2.5.2 *Sides*

The compaction of sides should be done by over cutting the subgrade by 15 cm and refilling it with lean mortar with adequate quantities of lime or cement or by vibro-compactors.

25.3.2.6 Compaction of Subgrade in Other than Predominantly Sandy Reaches.

All compaction should be done at optimum moisture content in layers not more than 15 cm thick to obtain a dry bulk density of not less than 95 percent of the density at optimum moisture content obtained in accordance with IS 2720 (Part 7) 1992.

25.3.2.6.1 Where the dry bulk density of the natural soil is equal to or more than 1.8 g/cm3 the procedure described in 25.3.2.1 should be followed.

25.3.2.6.2 ***Bed***

Where the dry bulk density of the natural soil is less than 1.8 g/cm3 and the subsoil water is near the Subgrade, the consolidation should be done by under cutting the bed by 7.5 cm and then ploughing up to 15 cm below the sub grade level, the loosened soil should then be recompacted with sheep foot rollers or other suitable devices. Where the subsoil water is low, requiring no dewatering and the dry bulk density of the natural soil is less than 1.8 g/cm3 the consolidation should be done by digging the canal up to subgrade level and after loosening the earth below subgrade up to 15 cm by disc harrows, or ploughing and compacting the same to a depth of 11 cm. After there, the second layer of 15 cm of earth should be laid over 'the compacted layer by taking earth from lip cutting and compacting this to a depth of II cm. The compacted layer of 7 cm above the subgrade level, should be removed and the subgrade brought to design before laying the lining

25.3.2.6.3 ***Sides***

Consolidation on sides should be done, by manual labour or suitable compactors to a depth of 30 cm to obtain a minimum dry bulk density of not less than 90 percent of the density at optimum

moisture content

25.3.3 ***Anti - Salt Treatment***

Soil in all reaches should be tested for salt content before the lining is started. Where the salt content is over 1.00 percent or sodium sulphate is over 0.36 percent, the subgrade should first be covered with about 2mm thick layer of bitumen obtained by evenly spraying bitumen at a rate of about 2.35 kg/m^2. To get a good bond bitumen, bitumen and soil, crude oil at a rate of 60.5 lit/m^2 should be sprayed over it in advance of spraying bitumen. In case such a situation is encountered only in small packets the replacement of subgrade up to suitable depth by suitable earth from adjoining reaches should be considered, if economical. Before spraying crude oil, subgrade should be perfectly dry, clean and free from dirt, and crude oil should be allowed to penetrate the subgrade surface. Bitumen should be heated to a temperature of 175°C and applied to the subgrade by a suitable sprayer, immediately following the application of bitumen, dry sand should be uniformly spread. Lining should be started 6-12 hours after spraying.

25.3.4 ***Reaches Consisting Of Rock***

25.3.4.1 The subgrade in rock shall be excavated to the required cross section. Over excavation in rock is generally unavoidable and should be minimized by using wedging and barring methods, for final dressing.

25.3.4.2 Over-excavation in hard strata having side slopes flatter than 1:1 beyond the profile line may be backfilled with gravel and aggregate, large aggregate forming the bulk of backfill with smaller aggregate filling the voids and a layer of pea gravel as binding material. The bed may then be compacted with road roller and sides with hammers to form a firm backing for the lining.

For over excavation in hard strata having side slope steeper than 1:1 beyond the profile, the backfilling may be Suitably done with chip masonry or lean concrete. However, for bed the backfilling may be done with properly compacted mururn. Over excavation upto 5 cm may be back filled. If over excavation is up to 10cm, lean concrete may be used. Beyond 10 cm backfilling with chip masonry is preferable.

25.3.4.3 For slip-form paving, over excavation up to 10 to 15 cm may be required. Such over excavation may be backfilled with selected material and compacted at optimum moisture. The material selected, should be machine trimable and be gravel/stone-free earth.

25.3.4.4 Tar paper shall be used for placing concrete.

25.3.4.5 Tolerance in Excavation

Excavated profile provides the final base for the lining and the tolerance should be comparable to those required for paving.

Departure from established alignment:

± 20mm on straight section

± 50 mm on tangents, and

± 100 mm on curves.

Departure from established grade:

± 20mm

25.4 UNDER DRAINAGE OF LINED CANALS

25.4.1 **General**- Where a lined canal crosses areas subject to seasonal high ground water or where the soil is sufficiently watertight to prevent the free draining of the seepage or leakage from the

canal, suitable under drainage; shall be provided to protect the lining. Where the sub-grade is free draining but the area is subject to high ground water, excessive hydrostatic pressure sufficient to damage the lining may develop at its back when the canal is empty or the water level in the canal is relatively low and the ground water level is high. A similar situation may occur in areas where the canal is lined for reasons other than to prevent seepage and soil is sufficiently watertight to prevent free drainage of the leakage from the canal, the accumulation of water in the soil surrounding he canal may result in local high ground water table, which during a period of rapid draw down of water level in canal may produce damaging hydrostatic back pressure.

25.4.2 Methods Of Under Drainage.

25.4.2.1 The under drainage of canal lining for the following types of sub-grades may be accomplished by the methods specified in 25.4.2.2

(a). **Free draining sandy soil- Soil** comprising of gravel and clear sand or clear sand. This may have a permeability greater than 10^{-4} cm/sec but less than 10^{-3} cm/sec.

(b). **Poor draining-** Soil comprising of very fine sand admixture of sand, silt and clay or clay. Soil with permeability less than 10^{-4} cm/sec and greater then 10^{-6} cm/sec; and

(c). **Practically impervious** - Soil comprising of homogeneous clays below zone of weathering. Soil with a permeability less than 10^{-6} cm/sec.

25.4.2.2 Selection of Drainage Arrangement:-

The drainage arrangements provided to reduce or eliminate hydrostatic pressure behind lining usually comprise of longitudinal drains, cross-drains, pressure release valves and continuous filters. These are provided singly or in combination depending upon classification of sub-grade and position of GWT The type of drainage arrangement to be adopted depending upon discharge of canal classification of sub-grade and position of GWT is given; Annexure-1. Where extensive lining works are involved, the adequacy of various drainage arrangements could be determined on three dimensional Electrical Analogy Model at the discretion of Chief Engineer.

Various components of drainage arrangements are described in following paras.

25.4.3 Pressure Release Valve (PRV) :-

Pressure release valve (PRV) is a valve provided in a canal lining which opens into the canal to relieve excess hydrostatic pressure behind the lining. The PRV shall be such that it will operate a differential pressure less than which will be damaging to the lining with factor of safety of two. This should be operative generally with a differential head of 100 mm and above. PRV should generally be of such material which will be abrasive resistant and which will not be affected due to its presence in the water. PRVs made of plastic, fibre glass, P. V. C etc. which are strong but have no resale value should be used. This would discourage pilferage which is common with metallic valves 50 mm,75mm, 100mm and 150 mm diameter valves are generally used for release of pressure-behind lining. Typical pressure release valve and PRV housed in pocket filter is shown in (Fig.5)

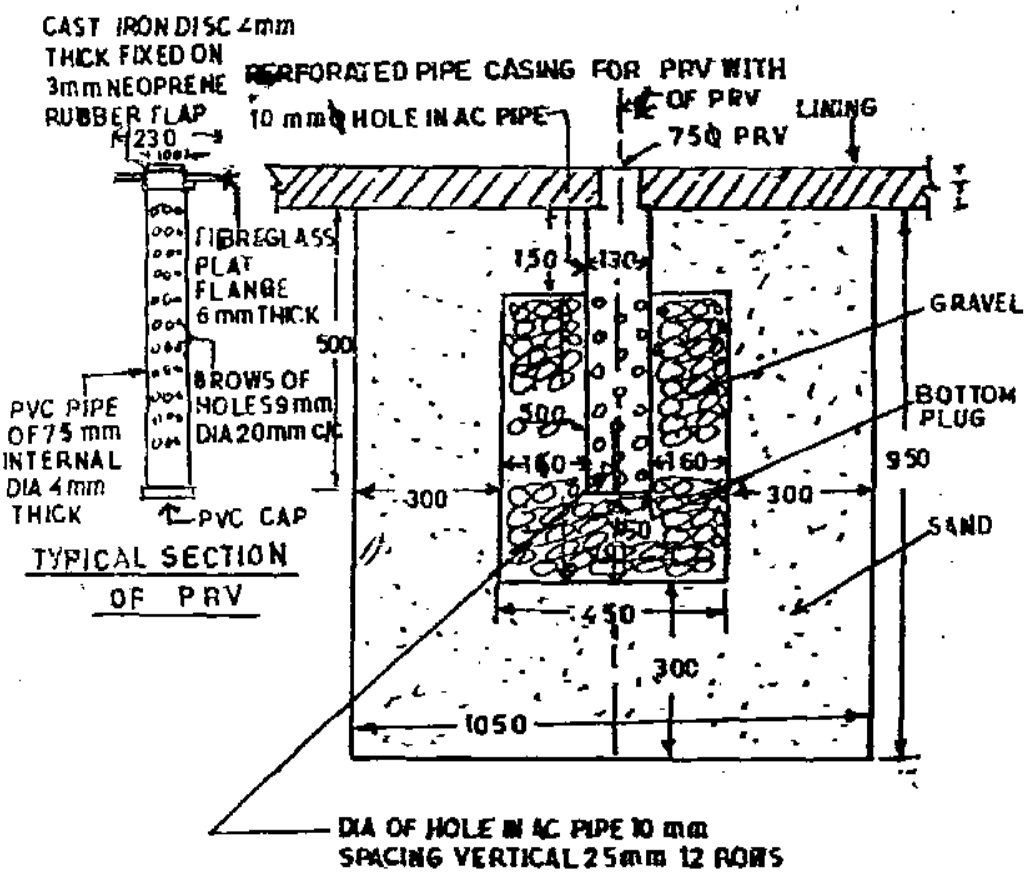


Fig. 5 TYPICAL CROSS SECTION OF POCKET FILTER WITH PRV IN BED

The size of PRVs for different conditions of water table/discharge of channel shall be provided as indicated in Table-2.

TABLE-2

Discharge upto 15 cumecs		Discharge above 15 cumecs	
Bed	Slope	Bed	Slope
----------Diameter of PRV in mm------			
i. GWT below CBL			
50	50	100	50
ii. GWT. Above CBL			

75	50	150	50

25.4.3.1 Pocket Filter :-

The pressure release valves are provided in pockets filled with graded filter or concrete/masonry outlets with graded metal underneath the lining. The dimensions of out-let/pocket filter w.r.t to dimensions of PRV shall be as indicated in Table - 3.

Table – 3

Size of Pressure release valve		Size of outlet/pocket filter		
Diameter	Length of Strainer pipe	Length	Width	Depth
		----------mm----------		
		OUTLET		
150	500+ T	450	450	600
100	500+ T	450	450	600
		POCKET FILTER		
75	500+ T	1050	1050	950
50	450+ T	600	600	600

Note :- “T” in col-2 of table-2 represents thickness of lining in mm.

25.4.3.2 Rows:-

Pressure release valves in pocket filter shall be provided in rows in the bed and slope of canal. The number of rows depend on bed width, depth, drainage media, size of valve and sub-grade.

However, for general guidance number of rows on the bed of canal may be such that for every 10m bed width one row shall be provided Minimum number of rows for width 10 m and above shall be two and for less than 10 m shall be one. The number of rows shall be so arranged as to be symmetrical in plan with reference to centre line of canal. On the sides in general, one row at every 4m should be provided. The first row should be about 50 cm above curve line and top row at 50 cm to 100 cm below” full supply level. If the water depth is less than 1.5 m one row should be adequate. Valves in .adjacent rows should be staggered.

25.4.3.3 Spacing

For general guidance, one pressure relief valve for every 100 m^2 should be provided in the canal bed, while on the sides, one pressure relief for every 40 m^2 should be provided. However the spacing should be decided on this general consideration, keeping in view the site conditions.

25.4.3.4 Construction - Pockets shall be excavated (fig.6) with their sides as nearly vertical as possible. Pockets on slopes shall be excavated with their sides at right angles to the slopes.

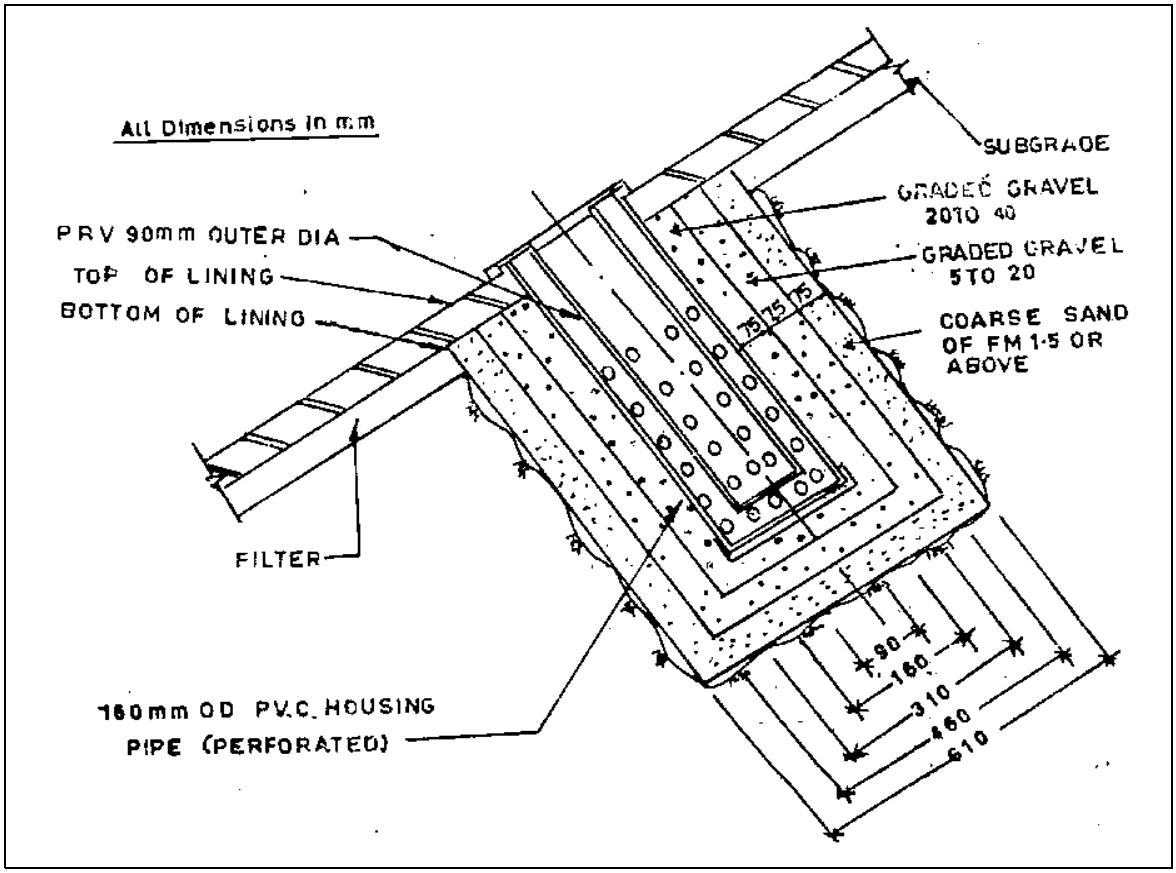


Fig. 6 PRV POCKET ON SLOPE

Any material out side the lines or required excavation which is disturbed shall be removed.

Note: - The graded filter shall be designated in such a way that there is no loss of soil particles. The gradation curve of bed material should be obtained from the sieve analysis. The 15 percent size (D15) of the layer (A) should be at least four times as large as 15 percent size of the soil and less than 4 times 85 percent size D85 of the soil. Design of the other layer should be designed in a similar way till the requirement of the filter opening is met.

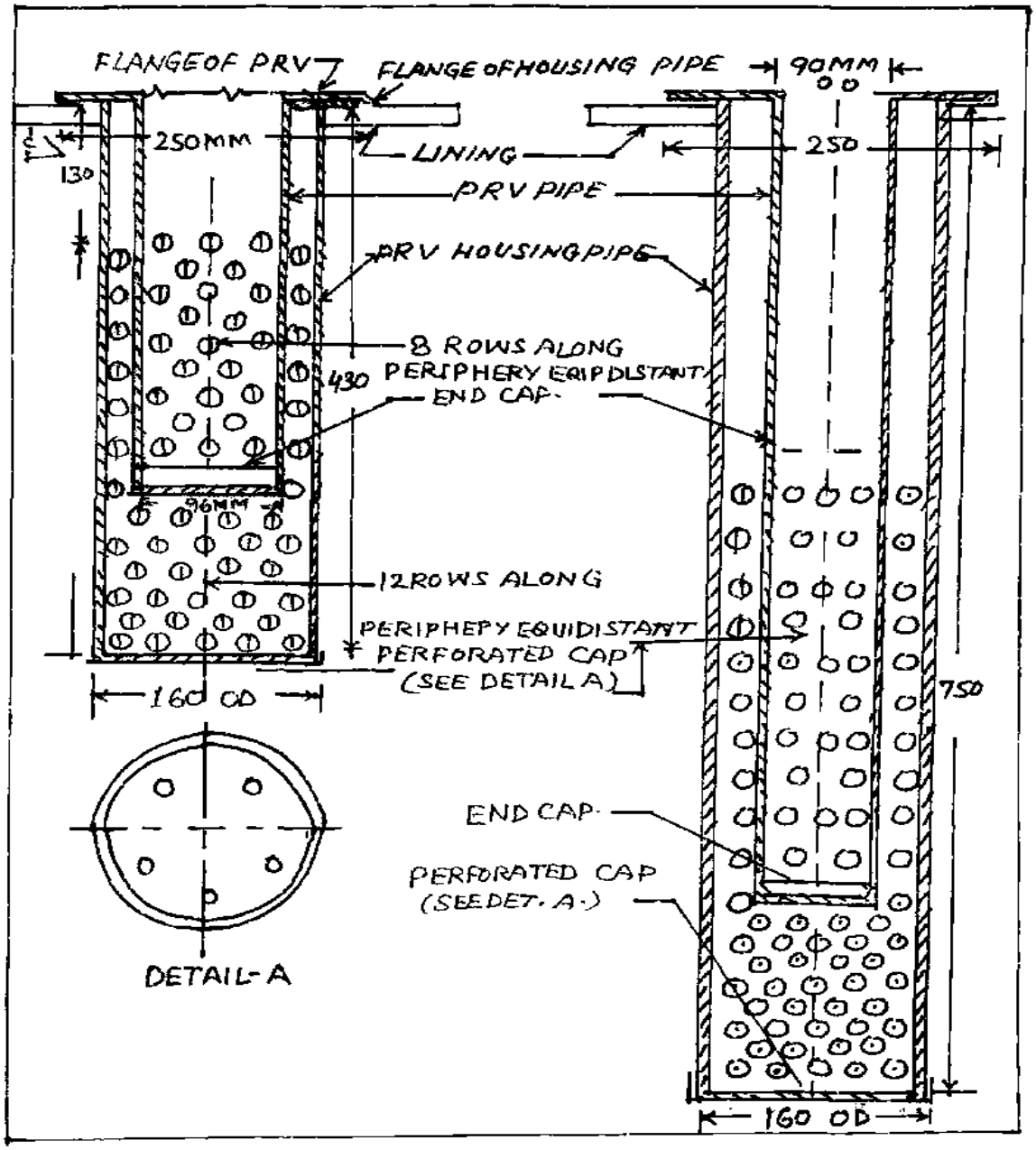


Fig. 7 DETAIL OF PERFORATION IN DRY HOUSING PIPE (DETAIL OF PRV NOT SHOWN)

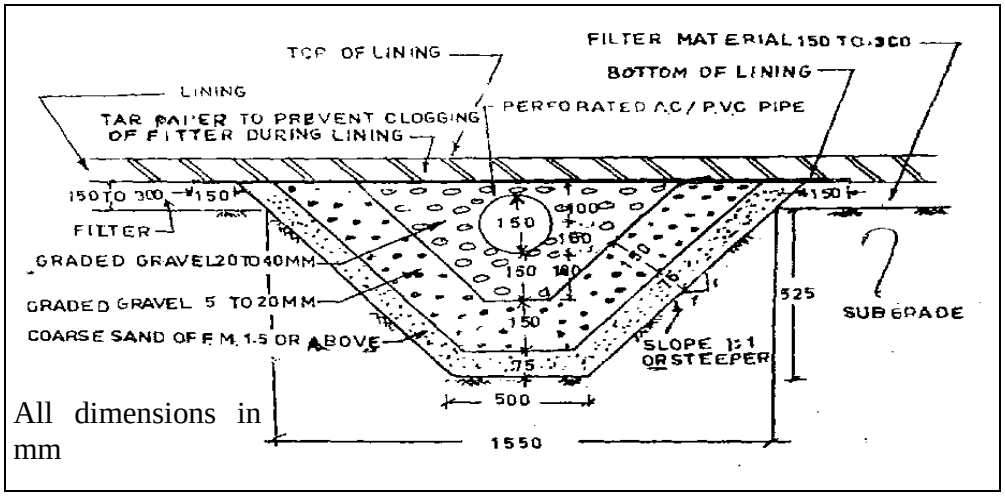
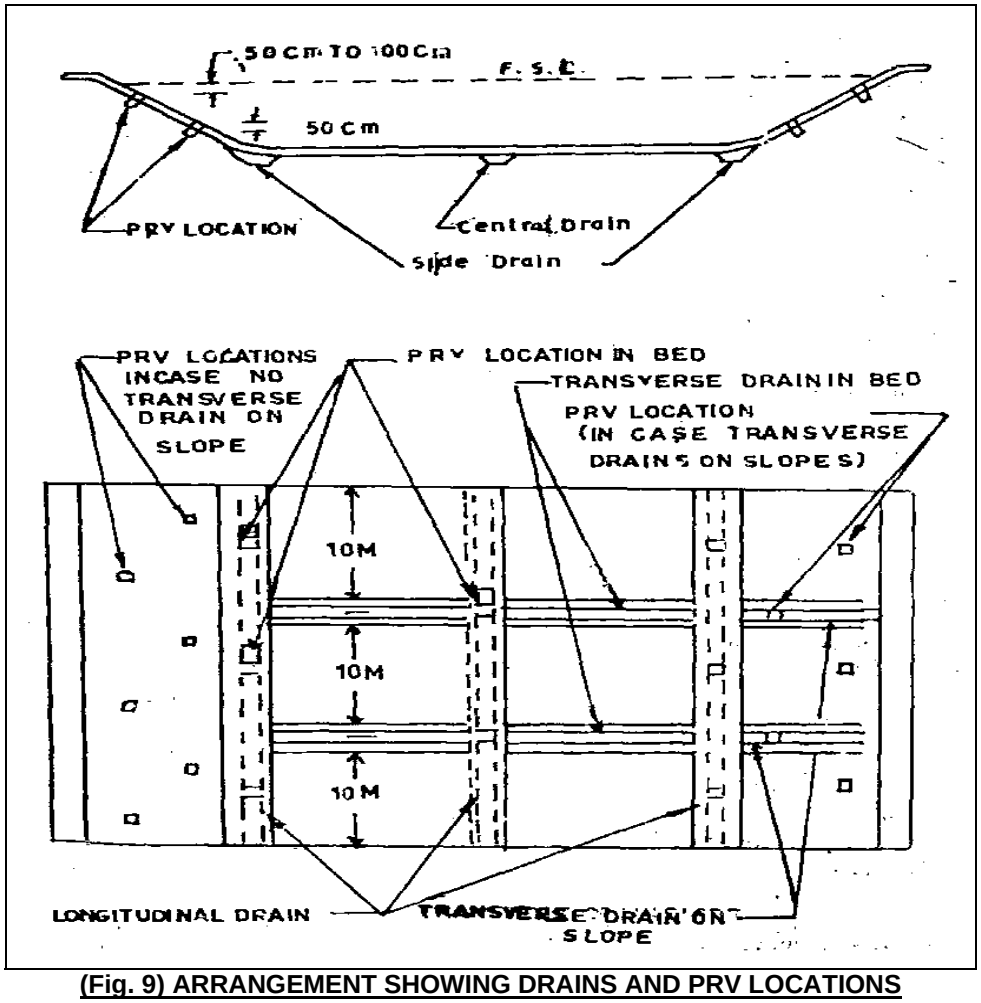


Fig. 8 : SECTION OF LONGITUDINAL/TRANSVERSE DRAINS
(pressure relief value not shown)



(Fig. 9) ARRANGEMENT SHOWING DRAINS AND PRV LOCATIONS

25.4.3.4.1 Graded filter meeting the requirements as shown in the above figure shall be carefully placed and compacted to form an even bedding upto the elevation of the bottom of canal lining. The gravel shall be clean and well graded.

25.4.3.4.2 Any suitable material such as tar paper shall be placed over the entire surface of the broken .rock or gravel fill to prevent water from concrete entering the fill:

Pressure relief valves should be provided on the longitudinal/transverse drains (see fig.9) and on slopes, if there are no transverse drains. The PRV may be provided in pockets filled graded filter underneath the lining. Pockets may be square with sides 800 mm or cylindrical with diameter 600 mm.

Pockets on slopes should be excavated with their sides at right angles to the slope. The PVC perforated housing pipe for the PRV should be 750 mm long for sides and 430mm long for bed and should conform to class-2 of IS 4985-1988. It should be placed in the centre of the pocket. Graded filter as shown in fig.6 should then be carefully placed in the pocket and compacted to form an even bedding for canal lining. Perforations in the housing pipe should be as shown in fig. 7.

25.4.4 ***Longitudinal And Transverse Drains***

25.4.4.1 ***(a) Longitudinal drains***

The section of the drain should be trapezoidal with bottom width 500 mm, depth 525mm and with suitable side slopes. The drain should be carefully filled up to the bottom of the lining with graded filter as shown in fig.8 and properly compacted so as to form an even bedding for lining. The pipe may be asbestos cement pipe or PVC pipe. It should be perforated. Usually 150mm dia pipes are used. The perforations/holes should be 12mm in diameter and should be done by drilling. On an average there should be a minimum of 100 perforations/hole per meter length of pipe and the perforations/hole in adjacent rows should be staggered. The pipe should be properly surrounded with suitable filter. Care should be taken that the filter does not get clogged during lining.

25.4.4.1.1 ***(b) Transverse drains***

Transverse drains, Where necessary, should be provided in the bed and on the side slopes upto ; free board level. Section of transverse drains should be same as of longitudinal drains shown in fig. 8. The drain should be carefully filled up to the bottom of the lining with graded filter as shown in fig. 8 and properly compacted so as to form an even bedding for lining. The pipe may be asbestos cement pipe or PVC pipe. It should be perforated. Usually 150mm dia pipes are used. The perforations/holes should be 12mm diameter and should be done by drilling. On an average there should be a minimum of 100 perforations/hole per meter length of pipe and the perforations/holes in adjacent rows should be staggered. The pipe should be properly surrounded with suitable filter. The arrangement showing drains and PRV locations is given in fig.9.

25.4.4.1.2 ***Spacing of Drains***

Spacing of longitudinal drains shall be as indicated in Table - 4.

Table – 4

Canal bed width	No. of drains
Less than 10 m	One central drain
10m and upto 20m	Two toe drains
Above 20 m and upto 30m	One central and two toe drains
30 m and above	One for every 10 m width arranged symmetrically with the centre line of canal.

25.4.4.1.3 The spacing of transverse drains shall be at every 10-15 meters depending on sub-grade.

25.4.4.2 **Rows** - Criteria for fixing the number of rows shall be same as given in 25.4.3.2

25.4.4.3 ***Outlets*** - Outlets shall be provided through suitable concrete boxes collecting water from drains with pressure relief valves on the top of the boxes shown in Fig. 10. These boxes shall be of

precast cement concrete, open at the top and with a circular cross section. The inner diameter and depth of boxes shall be about 450 mm and 600 mm respectively. These boxes shall be filled with graded filter material.

25.4.4.3.1 Spacing Of Outlets - On each drain exit, a pressure relief valve shall be provided at a spacing of 100m or as specified. Outlets on adjacent drains shall be staggered.

25.4.4.4 *Construction Of under Drains With Open Joints*

Trenches for under drains shall be excavated to not less than the dimensions specified in para 25.4.4.1 with the sides of the trenches as nearly vertical as practicable. Any material outside the lines of required excavation for trenches which is disturbed shall be removed.

Broken rock or gravel shall be carefully placed and compacted to form an even bedding, up to the invert level of pipe or drain and so as not to disturb the pipe after being laid and to held it securely in position. The pipe or drain shall be laid nearly in the centre of trenches with partially open uncemented joints. The entire trench outside the pipe shall be filled with broken rock or gravel graded filter up to the elevation of the bottom of the concrete canal lining. Broken rock or gravel used in back filling trenches for under-drains shall be clean and well graded with sizes from 4.5 mm to 12.5 mm.

DETAILS OF OPEN JOINTED PIPE DRAIN

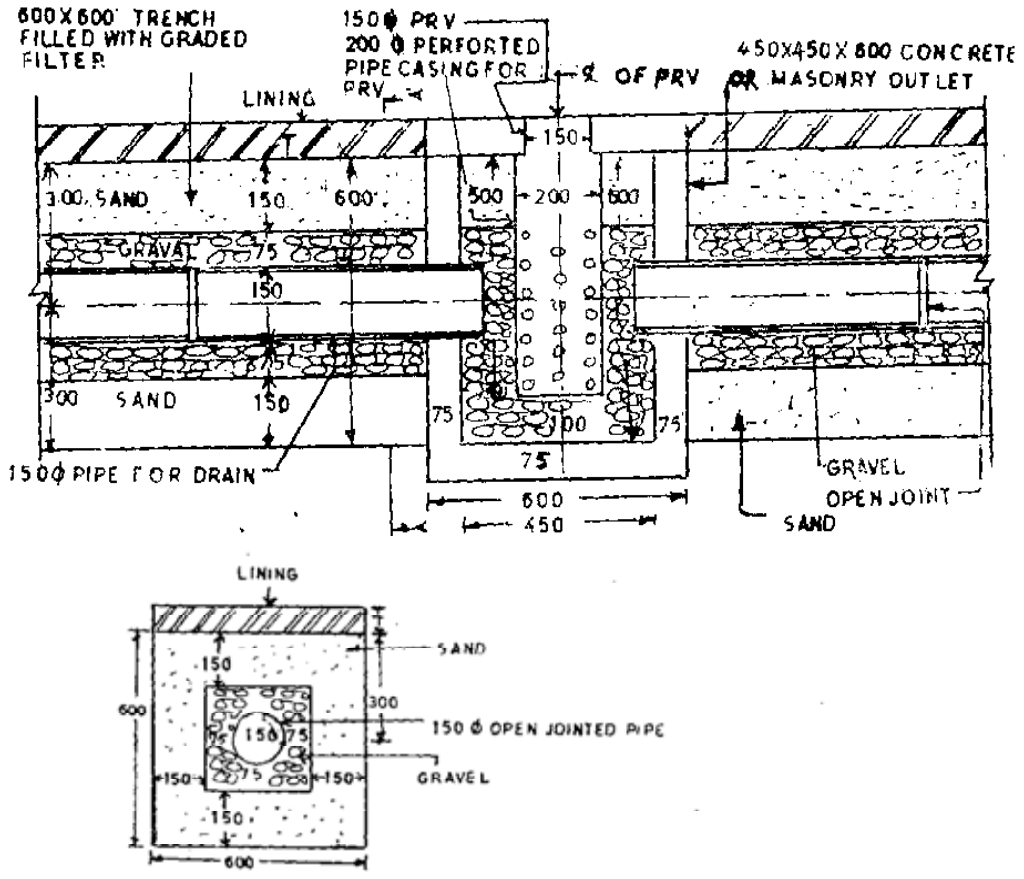


Fig. 10 DETAILS OF OPEN JOINTED PIPE DRAIN

Any suitable material, such as tar paper shall be placed over the entire surface of the broken rock; and gravel fill to prevent water from 'concrete entering the fill in case of cast in-situ concrete lining.

25.4.5 *Under Drains For Clayey Sub-Grade -* For clayey soil a 7.5 cm or as specified thick layer of sand or suitable filter material shall be provided underneath the lining. Rows of pipes with open

joints in gravel filled trenches with outlets as specified at 25.4.4.3 shall be provided. Other details of drains, outlets and construction shall be according to paras 25.4.4.1, 25.4.4.3 and 25.4.4.4.

25.4.6 ***Under drainage For CNS Material :-***

Where ever cohesive non Swelling (CNS) layer is provided, the permeability of CNS layer will decide drainage provisions considering CNS layer as sub-grade. Provisions of CNS layer be made in accordance with para25.3.1.4

25.5 USE OF POLYETHYLENE FILM UNDER RIGID SURFACE LINING OF SOIL COVER

25.5.1 ***General:***

"A plastic membrane of low density polyethylene film of suitable thickness may be used below the concrete lining in sides and in beds where the subgrade of the lining is of pervious materials like murum etc., so as to prevent absorption of water in subgrade from green concrete, during placement on the subgrade. However, the Superintending Engineer shall decide whether the polyethylene film shall be used or not in the case of every individual work"

25.5.2 ***Film***

25.5.2.1 The low density polyethylene film should conform to IS 2505-1984 and be of nominal thickness not less than 150 microns (thickness to be designed based on type or sub grade and water depth) and should be black in colour.

The film shall be uniform in colour texture and finish. The material shall be substantially free from pin holes and undispersed raw materials, streaks and particles of foreign matter, There shall be no other visible defects, such as holes, tears or blisters. The edges shall be free from nicks and cuts visible to unaided eye.

The film shall be furnished in the form' of flat, sheet or rolls or in the form of flat tubing or in any other specified form as agreed to the suppliers & the purchaser. The film shall be free from any objectionable colour.

25.5.2.2 ***Grades*** - The film shall be classified according to the optical properties, impact strength and slip, ' Each grade shall be designated by a set of 3 numerals.

The first one will indicate optical property. The second impact strength and the third slip property. Wherever numeral 'zero' is used, it shall mean the material has not been tested for that particular property.

For typical properties the numeral 1 shall mean low clarity, numeral 2 normal clarity and numeral 3 high clarity. For impact strength numeral 1 shall indicate low impact strength, numeral 2 normal impact strength and numeral 3 high impact strength. For slip property numeral 1 shall denote low slip, numeral 2 medium slip, numeral 3 high slip and numeral 4 shall mean extra high slip.

Example: -

Grade 001 - This shall mean that the film has not been tested for optical properties and impact; strength and it is of low slip.

Grade 210 - This shall mean that the film is of normal clarity, low impact strength and slip has not been tested.

Grade 314 - This shall indicate that the film of high clarity, low impact Strength and extra high slip.

25.5.3 Preparation of Sub-Grade

25.5.3.1 The sub-grade preparation shall be as per provisions under para 25.3. Additional requirement for this shall be as detailed hereunder.

25.5.3.1.1 Kankar or any sharp angular material shall be removed to provide reasonable smooth sub-grade. Any weeds roots and vegetation that may damage the film shall be removed.

25.5.3.1.2 If the reaches are weed infected suitable anti-weed treatment of the sub-grade May be

done to discourage weed growth under the film The weedicides should be selected with utmost care specially where the canal water is used for drinking/bathing purpose and should not be harmful

After completion of the spraying of weedicides and before taking up the next activity a period of 24 hours should be allowed for penetration of chemicals into the soil.

25.5.3.1.3 A layer of fine sand of thickness 12mm to 25mm should be provided over the subgrade (in bed only) to facilitate working conditions over the film As there is no bond between concrete & LDPE film, the canal profile should not be smoothened (with a layer of sand etc) as the undulations will form keys& prevent sliding tendency of concrete.

25.5.4 ***Laying Technique***

25:5.4.1 The film shall be laid over the sub-grade prepared below the designed bed level to the extent of cover thickness in strips perpendicular to water flow depending upon the width of the film, width of the bed & perimeter of the section Longitudinal joints should be avoided.

25.5.4.2 The film shall be spread loosely over the sub-grade so that it shall attain the contours of sub-grade and compensate for thermal variation during the day. It recommended that an extra length of 3.5 percent, over the length of the film required for spreading over bed and side slopes should be provided to take care of thermal variations during the day.

As polyethylene film is likely to be affected by very high temperature about 45°C obtaining in summer days it would be advisable to avoid laying of the film under such high temperature. In case it is necessary to continue the work on hot days as well working should be restricted to morning hours only.

25.5.4.3 Adjacent layers of film sheet should be laid in such a manner that the width of an overlap should be adequate and the overlap should point downstream.

The film sheets should be jointed using of the method described in 25.5.4.3.2 to 25.5.4.5.3.

25.5.4.3.1 ***Jointing of film sheet***

There are various methods of jointing adjacent lengths of film sheet to avoid leakage along the joints. The suitability of a particular method depends on prevailing site conditions.

25.5.4.3.2 ***Simple over lapping***

The method of over lapping is shown in Fig. 11 (i). The simple over lap should not be less than 30cms for earth cover and 15cms for hard cover. Since the simple over lap is prone to leakage it is least preferred, yet it can be adopted for small channels.

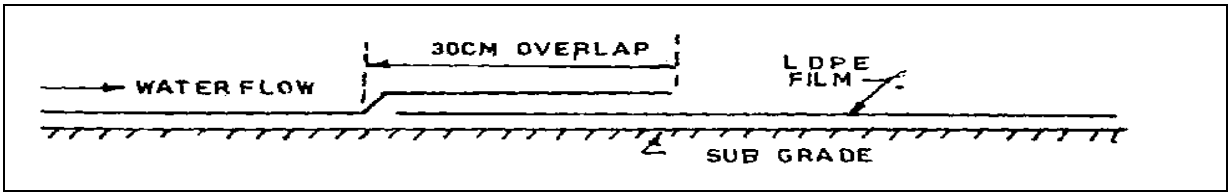


FIGURE 11 (i) Simple Overlap

25.5.4.3.3 ***Folded overlapping***

The methods of folded over laps are generally used in practice. The first type is the simple folded over lap as showing in Fig. 11 (ii). In this the fold should not be less than 7.5 cms. In the second type folded over laps are embedded in a trench having a minimum width of 30 cms and depth of 15 cms as shown in Fig. 11 (iii). After the over lapping the trench should be filled with excavated material or cement concrete and coping provided over it.

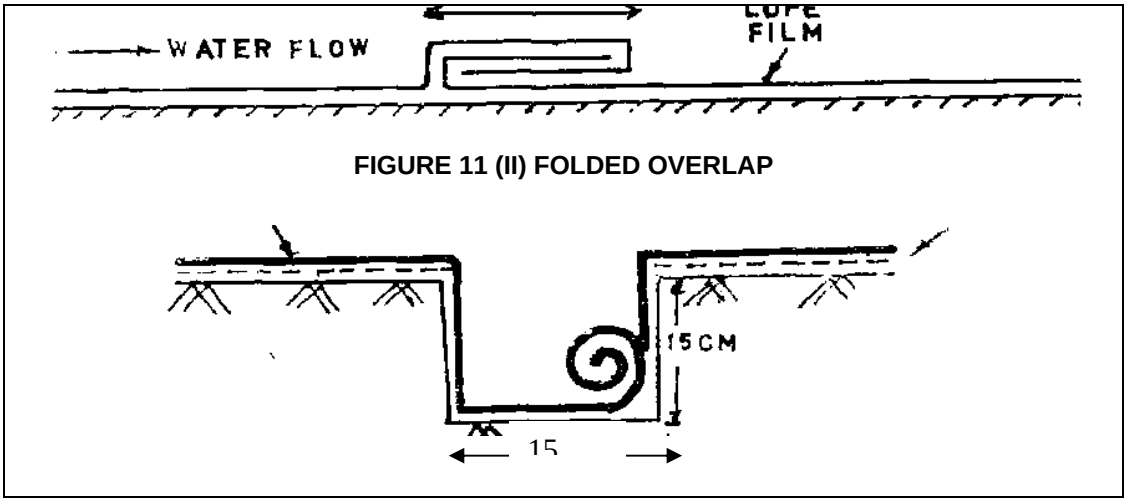


FIGURE 11 (II) FOLDED OVERLAP

FIGURE 11(iii) FOLDED JOINTS EMBEDDED IN A TRENCH TO FACILITATE LINING

25:5.4.3.4 ***Jointing by hot bitumen***

The film sheet can also be jointed by a coat of bitumen. Bitumen the grade 85/25 and 80/100 in the ratio of 2:1 should be heated at a temperature around 100^0C. Heated bitumen can be tested on a small piece of film sheet so that overheated bitumen may not damage the film. After ascertaining the appropriateness of the temperature, apply a thick coat of tested bitumen on a 10 cm area along the width of both the sheets and fold them as shown in Fig. 11 (iv) and cover the same with brick masonry profiles (Dhamalies) at a suitable interval depending upon the width of the film which should come directly over this joint at a regular intervals, in order to ensure a better joint of the film sheet. Using, damaged fill sheet is not recommended. However, this method has been found convenient for repairing punctures in the film at site itself. In case of big holes, pieces of sheet should be pasted from both sides.

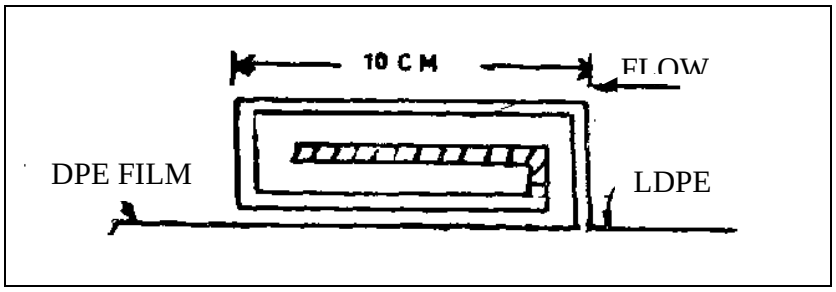


Fig 11 (iv) Jointing by hot Bitumen

25.5.4.3.5 ***Sealing by adhesive tapes***

Adjacent lengths of film sheet can also be jointed with suitable adhesive tapes as shown in Fig. 11 (v) Hydrostatic pressure and the over-layer is sufficient to make the over lap practically water tight. However in the areas where high temperature exists (40° - 50°C) during summers and with passage of time under submerged conditions, the joints may open up. Soil particles creeping into the joint while laying may also lead to leakage.

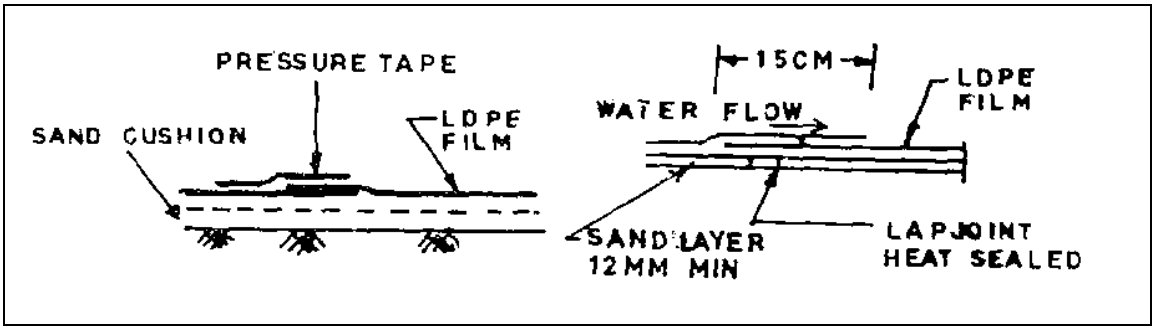


FIG. 11 (v) OVERLAP JOINT WITH PRESSURE TAPE

FIG 11 (vi) HEAT STEALING OF JOINTS

25.5.4.3. ***Heat sealing:***

As shown in Fig. 11 (vi) the overlap joints can be heat sealed with a hot iron. The temperature of the iron should be adjusted and maintained at 150°C and pressed on the film sheet joint overlap for 4 seconds for a 150 micron film thickness sheet. For every 50 micron increase in the film sheet thickness the time would be increased by one second. To avoid the risk of film/sheet sticking to iron a poly-tetra-fluoroethylene (PTFE) impregnated glass cloth or Teflon sheet or Cellophane sheet should be placed between the film and the iron.

Note- Heat Sealing is the most effective of all the methods.

25.5.4.3.7 In all type of joints the overlap should be kept normal to the flow and should point downstream of the canal.

25.5.4.4 Film sheet should be spread on well prepared subgrade and should be held in position at two extremities of the bed by placing excavated earth on it, while two ends of film sheet are being loosely held over the embankment.

25.5.4.5 Extra length of film sheet should be placed in trench at embankment top and covered with earth. The embankments may be then raised to designed level.

25.5.4.5.1 Excavated earth should be placed over the film sheet to build up the canal section. The earth layer should be compacted by using light rollers and manual templates. It may be so arranged that earth from over- excavation of an adjacent section be used for covering tile film sheet in the earlier section. Thus, by the time earth cover is provided in one section, the adjacent section is ready to receive film sheet lining.

25.5.4.5.2 The film/sheet on the bed should be covered first. To avoid any damage to the film/sheet a layer of earth, free from gravel or granular material should be laid and compacted over the film.

25.5.4.5.3 The remainder of the earth cover should be spread in 15 cm layers, watered and compacted using light rollers or manual templates.

25.5.4.6 ***Connection To Structures*** - In case of structures in lined channels film should be embedded in the solid structure, i.e. R.C.C/masonry by about 15 cm to provide impermeable layer. This film should be protected by a layer of 50 mm to 100 mm thick cement concrete.

25.5.5 Top Cover

The top cover may be an earth layer of suitable thickness (25.5.5) or of pre-cast Concrete Tiles, in-situ Cement Concrete, Stone Slab (see 3873:1993), or burnt clay tile (see 1 S:3872-1992)

Earth Cover

(a). For canals with velocities less than or equal to 0.6 m/s, minimum thickness of cover over the film sheet should not be less than 30 cm in bed and 60 cm on the sides.

(b). For canals with velocities more than 0.6 m/s, the film/sheet on the bed should have a rigid cover against possible bed erosion. For sides the cover should be of any rigid type.

(c). Side slopes should be designed in accordance with the stability requirements with lining in position. Side slopes not steeper than 1.5: 1 are recommended.

(d). If the cover material contains Kanker or sharp angular material, a cushion layer 7.5cm thick of sieved earth (free from Kankar, etc.) may be provided over the film sheet:

(e). To prevent effect at the water line, Kankar or gravel of stone aggregates of size 4 to 5 cm may be spread over the cover prior to compacting, using light roller or manual ramming.

25.5.5.1 In case of cement concrete lining the concrete should be so placed that the aggregates do not puncture the film sheet.

25.5.5.2 For a better bond between the smooth surface of film sheet and rigid cover lining, cement slurry may be sprayed over the film sheet before placing the rigid lining.

25.5.5.3 ***Do's and Don'ts for Geomembrane For Canal Lining.***

(1) Keep the rolls in original packing prior to actual use of laying and see at the time of delivery that the rolls are packed properly.

(2) Apply uniform pressure while thermal welding (heat sealing) the film sheet.

(3) Don't leave unpacked rolls exposed to over prolonged periods or preferably store them indoors.

(4) Don't rough-handle or drag rolls, as the film sheet may get damaged in the process.

(5) Don't let workers walk on the film sheet while the lining operation is in progress to avoid puncturing of the film sheet, in case this is unavoidable, they should walk barefoot.

(6) Don't slide cover material like bricks etc. on film/sheet to avoid damage and displacement.

(7) Don't use hooks for lifting the rolls.

25.6 CAST IN SITU CEMENT CONCRETE LINING

25.6.1 ***Cement Concrete***

Cement concrete of specified mix shall be provided at places as shown in the drawings. The specifications for cement concrete shall be in accordance with the one laid down in relevant specifications for Chapter 7 and 16.

25.6.2 ***Preparation or Sub-Grade***

The sub-grade preparation shall be as per provisions under para 25.3 as applicable.

25.6.3 ***Laying of Concrete Lining***

25.6.3.1 **Slump** - For hand-placing and for placing with the light machines where concrete is screeded from bottom to the top of the slope, the consistency shall be such that the concrete will barely stay on the slope. A stump of 60 to 70mm shall be generally allowed. For heavier longitudinally operating slip-form machines, a slump of 50 mm at the laying point shall be permitted. To have a close control of consistency and workability of the concrete the slumps of concrete shall not vary by more than 20 mm

which would otherwise interfere with the progress and quality of the work.

25.6.3.2 Thickness

The thickness of lining should be fixed depending upon the nature of the canal requirement, namely hydel channel or irrigation channel, full supply depth and channel capacity. Hydel channel should have a greater thickness than channels meant for irrigation because of draw down effects and where closure for repairs may not be useful. Deeper channels should have a greater thickness than shallow depth channels. Minimum thickness of canal lining based on canal capacities are given in Table 5.

Table 5. Thickness of In-situ Concrete Lining

Capacity of canal (1) (cumes)	Depth of water (2) (m)	Thickness of lining (3) (mm)
0 - 5	0 – 1	50 - 60
5 - 50	1 - 2.5	60 - 75
50 - 200	2.5 - 4.5	75 - 100
200 - 300	4.5 - 6.5	100 - 120
300 - 700	6.5 - 9.0	120 - 150

NOTE - If surface deterioration in freezing climate is expected, these thicknesses may be increased. The lining will not be subjected to external hydrostatic earth pressures or uplift caused by expansive clays on frost heave.

25.6.3.3 Tolerance in Concrete Thickness, Alignment and Grade

a)	Departure from Established alignment	$\pm$ 20 mm on straight reaches, 50 mm on partial curves or tangents
b)	Departure from established grade	$\pm$ 20mm on small canals
c)	Variation on concrete lining thickness	$\pm$ 10 mm provided average thickness is not less than specified thickness.

25.6.3.4 *Mixing*

Concrete should normally be mixed in a mechanical mixer.

25.6.3.5 *Transporting :* The specification given under para 7.4.4 of Chapter 7 & 16 shall apply

25.6.3.6 *Placing*

Placing of concrete should not be started until all form work, installation of parts to be embedded and preparation of surfaces upon which concrete is to be laid have been completed. All absorptive surfaces against which concrete is to be laid should be moistened thoroughly so that moisture will not be withdrawn from freshly placed concrete. The surfaces however, should be free from standing water and mud and 1:3 cement slurry shall be spread over the moist subgrade before placing concrete to prevent absorption of water from concrete making it spongy. A plastic membrane of low density polythene film of suitable thickness may be used below the concrete lining in sides and in beds where the subgrade of the lining is of pervious materials like murum etc, so as to prevent absorption of water in subgrade from

green concrete, during placement on the subgrade. The approved film is to be laid on the neatly well dressed subgrade, and fixed in the subgrade so as to prevent displacement during the placement of the concrete. The use of polythene sheets is for achieving better ultimate imperviousness of the lining as a whole. The following properties of L.D.P.E. film are given as guidelines with deviation to the extent of (plus or minus) 10 percent.

1) Tensile strength 17.5 N/mm^2

2) Tear resistance 9.5 N/mm^2

NOTE - Till better materials are developed, use of LDPE film of appropriate strength and resistance against slippage of tunnel may be adopted as a second line of defence against embankment failure and as a seepage barrier particularly in high capacity channels of relatively bigger depth.

In case filter material is to be provided over subgrade to take care of different hydrostatic pressure and draw-down in canals, designs of coarse filter material blanket immediately in contact with lining would be necessary. To make such filter blanket effective and to prevent ingress of concrete into it, before placement of concrete, polythene sheet should be placed over the filter blanket. All concrete should be placed directly in its final position within 20 minutes of mixing. Concrete should not be dropped from excessive height and free fall should, be kept to a minimum to avoid segregation. Construction should be continued until satisfactory construction joint is made. Concrete should not be placed faster than the placing crew can compact properly.

25.6.3.6.1 ***Hand Placing***

Hand placing of concrete should normally be adopted where cheap labour is available.

25.6.3.6.1.1 Depending upon the construction method and arrangement of concreting, the sequence of placing concrete either on the sides or the bed should be decided. It is preferable to place concrete on the sides first if the concreting equipment and the construction materials like aggregate, sand etc. are kept on the canal bed. This will prevent the bed from getting spoiled by the subsequent concreting operations for the sides. Other things being equal placement for bed first should be preferred.

25.6.3.6.1.2 The concreting of the sides and bed should be done in alternate panels. The panel width should vary from 2 to 3 m. In no case should the panel width exceed more than 3 m. as wider bays require unwieldy vibrators for compaction. The construction joints should be either parallel or perpendicular to the direction of flow. In case the full supply depth is high, construction joints along the direction of flow to divide the length of the panel should be provided. For this purpose wooden rafters should be used. The succeeding panels should be laid at an interval of one day). If the sloping-length is less than 2.5 to 3 metres, concrete should be placed in one operation over the entire length. In case of deeper canals where the sloping length is more it should be suitably divided (say for a length of about 2 metres) in each alternate panel so as to prevent appreciable downward flow of concrete.

The bays/panels should be formed by proper form work of M.S. channels laid all around the bay. The channels should be firmly spiked to the subgrade so that no movement takes place at the time of concreting and vibration. The depth of the M.S. channels should correspond to the required thickness of concrete lining. The concrete should be dumped in the bay from bottom to top and then spread all over the bay uniformly and to the required thickness guided by the channels. The spread concrete should then be compacted properly and thoroughly by means of mechanical or screed vibrators. An improvised plate vibrator operated by high horse power engine and a winch for moving the vibrator up the inclined slope should be made use of for proper compaction. When width of panel is less i.e. upto2 m manual operation of vibrators is possible and may be permitted. In no case the concrete should be compacted by tamping. The compacted surface should be true to the required side slope. Before re-Using the channel forms, they should be thoroughly cleaned and well oiled. Care should be taken while placing and vibrating the concrete that, the sub-grade in the adjacent bays does not get spoiled. **25.6.3.6.1.3** For bed lining the procedure for laying the concrete on the canal beds should be same as that for side lining except the operations specifically required on sloping surfaces. The compaction should be done by means of a heavy screed vibrator moving on the side channels.

25.6.3.6.1.4 In order to test the effectiveness of vibration, permeability and strength of concrete cores at suitable places from the side as well as from the bed concrete should be taken.

25.6.3.6.1.5 In-situ sleepers in case of bed, and precast in case of sides, should be provided under the joints. The sleepers should be 20 cm wide and 15 cm deep. The sleepers should be placed centrally below the joint. Concrete used for sleepers should be of the same grade, as for lining. Alternatively brick sleepers 225 x 150 mm with 1:4 mortar may be used. Concreting near the joints should be done with utmost care so as to avoid segregation and collection of loose pieces of aggregate along the form work which may later result in honey combing.

25.6.3.6.1.6 Concreting near the junction of the side concrete and bed concreting should be done such that both should rest firmly against each other to resist any back-kick from external hydrostatic forces (see Fig. 12 and 13) The sketches indicate the procedure for formation of junction of the sides with bed depending upon the sequence laying concrete i.e. sides first and vice-versa.

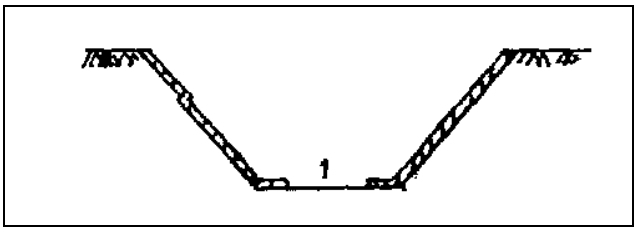


Fig. 12 Sides Cast First

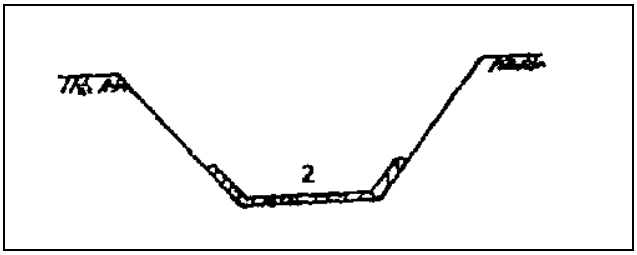


Fig. 13 Bed Cast First

25.6.3.6.2 ***Mechanical Placing of Concrete***

Concrete for slip-form should be air entrained to provide a more workable and slipabe mix. Percentage of air should as follows:

Maximum Aggregate Size mm	Air Percent by Volume
10	8.0
12.5	7.0
20	6.0
25	5.0

Air entraining agents will always be used in concrete by means of slip- form paving machine for entraining air.

a) Sub grade guided slip-form

This should be used for lining small to moderate size canals. The slip-form should be supported directly on the subgrade and operated longitudinally along it, concrete should be screeded on the bed along the canal and on the sides from bottom to top.

(b) Rail guided slip-form

They are adopted for larger canals of considering length. Slip-forms supported on rails placed along both berms of the canals should be operated .longitudinally. Concrete should be spread uniformly on the bed longitudinally and on the sides from bottom to top.

25.6.3.6.3 ***Procedure for laying concrete in Panels***

The concrete of lining in panels shall be placed in the manner prescribed in para 25.6.4.3.1 or 25.6.4.3.2 as specified.

25.6.3.7 ***Finishing***

The surface of concrete finished against forms should be smooth and should be free from projections, honeycombing and other objectionable defects. Immediately on the removal of forms, all unsightly ridges or lips should be removed and undesirable local bulging on exposed surfaces should be remedied by tooling and rubbing. Repairs to concrete surfaces and additions, where required, should be made by cutting regular openings into the concrete and placing fresh concrete to the required lines. The chipped openings should be sharp and should not be less than 70 mm in depth. The fresh concrete should be reinforced with wire mesh extending to the full depth of the slab and chipped and trowelled to the surface of the openings. The mortar should be placed in layers not more than 20 mm in thickness after being compacted and each layer should be compacted thoroughly. All exposed concrete surface should be cleaned of impurities, lumps of mortar or grout and unsightly stains.

25.6.3.7.1 The concrete should be finished to an even and smooth surface free from pockets, voids or exposed aggregates. This should be obtained by careful use of a long- handled steel trowel. Any remaining roughness or rough spots shall be rendered smooth, without any time interval after laying the concrete, with cement mortar of 1:3 proportion.

25.6.3.8 ***Curing***

Subsequent to laying of concrete lining and after a period of 12 hours or as earlier as warranted by site conditions, the lining should be cured for at least 28 days.

25.6.3.8. ***Bed lining***

Twelve hours after laying of concrete, small bunds longitudinal and cross-wise consisting of earth materials or lean mortar (1:15) should be laid for a height of 8 cm for the purpose of curing. Water will be kept always ponded in these bunds for 28 days continuously.

25.6.3.8.2 ***Side Lining***

The panel in which concreting is done on the previous day should be covered with burlap or empty cement gunny bags,

For the purpose of curing, water tank of 5000 liters capacity should be placed on a platform at the edge of service road at the rate of one for 500 m length of lining, which should be kept filled with water with arrangement of outlet and flexible hose of at least 300 m length. Water should be continuously sprinkled on the gunny bags or hessian cloth keeping them wet for 28 days. Sprinkling shall be done during night time also. The curing of side slopes may be done by constructing masonry drains

with weep holes or perforated pipes on the coping at the top of lining or by sprinklers.

25.6.3.8.3 ***Surface Drainage***

The top of the side lining concrete should be keyed into the Subgrade both in cutting as well as banking by taking it horizontally for a width of about 300 mm This key would prevent direct entry of surface rain water behind the lining. The top surface of the key should be finished with downward slope of 1 in 10 or so towards the canal. A day after completion of concreting of all panels between two templates, concreting of key slab should be done. Concurrently with the curing operation, surface drainage arrangement of the bank such as construction of keys, bank surface slope away from the lining and construction of longitudinal drain on the outer edge shall be completed. This is necessary to prevent surface and subgrade erosion and' consequent damage to lining.

25.6.4 ***Joints***

25.6.4.1 ***Expansion Joints***

These should not be provided except where a structure intersects in the canal. The details are given in relevant Indian Standards covering such structures.

25.6.4.2 ***Construction Joints***

Construction joints form a work link in the lining and deterioration is generally noticed at such joints. Besides joints are potential seepage points for the canal water. As such number of joints should be kept to the minimum and great care should be taken to obtain well compacted and smooth concrete surface at joints. To ensure a good surface the shuttering should be smooth, cleaned, well oiled and rigidly fixed at site. Besides different mechanisms for compaction of concrete in lining, tamping with iron bar near the joint surface gives better results.

To cater for initial shrinkage and cracks, concreting should be done in alternate panels or bays. The panel size for the bed and slope of the canal should be adopted as given in 25.6.3.6. A 25 cm vide L.D.P.E. film of 150 micron thickness should be placed on the top of sleepers, provided to support construction joints. The top of film and side of panel should be applied with primer conforming to IS:3384-1985. This sheet acts as an intercepts for seepage through the joint. In case lining is laid by mechanical paver, PVC water stops are placed at joints along with the concreting. The water stops in such' a case should be provided at a spacing not more than 4 meters centre to centre.

25.6.4.3 ***Laying of Precast Concrete Tiles.***

25.6.4.3.1 The tile should conform to IS: 10646: 1991.

25.6.4.3.2 The lining should be started only when at least 35 m length of canals subgrade is properly dressed to receive lining. The arrangement foil mortar and availability of sufficient number of tiles should be ensured before starting the work Arrangement for proper soaking of the files shall be made.

25.6.4.3.3 The subgrade should then be uniformly soaked with water without 1 making it slushy to ensure that water penetrates to a depth of about 300mm in sandy soil and about 150 mm in other soils. Wetting of subgrade should continue in advance of laying of tiles so that soil does not absorb moisture from the mortar laid on the subgrade on laying the layer of tiles,

25.6.4.3.4 Single tile profile of lining parallel to central line of the canal should be prepared at suitable intervals. Mortar (1:3) should uniformly be spread over subgrade for a minimum thickness of 12 mm and the tiles should be properly laid in position quickly. It should be ensured that vertical joints are completely filed with mortar. The tiles should be laid in bed with their lengths at right angles to the central line of the canal while on the other side slopes they should be laid parallel to the central line.

Tiles should be firmly embedded in mortar However, if any, should be rectified by relaying defective portion with fresh mortar. The tiles should be laid over a minimum of 12 mm thick cement mortar

and having aggregate less than 6 mm to bring overall fineness modulus less than 2. Hollow joints should be raked and pointed with the same mortar. The thickness of joint should be not exceed 12 mm.

25.6.4.3.5 Slab should be firmly embedded in mortar. Hollows if any should be rectified by relaying the defective portions with fresh mortar.

25.6.4.3.6 On completion of laying lining should be kept wet by sprinkling water over it to keep the mortar wet On the next day, the surface should be kept wet and joints should be carefully wetted. Hollow joints should be raked to a depth of 12 mm, loose mortar removed from sides and top of tiles and the joints properly refilled. Loose tiles should be removed and relaid. Curing of Mortar joints after laying shall be ensured for 14 days. Satisfactory curing can be achieved by covering the joints with soaked gunny bags (burlap) & keeping the same wet for 14 days.

25.6.4.3.7 The complete lining should be checked for level with wooden templates and spirit level.

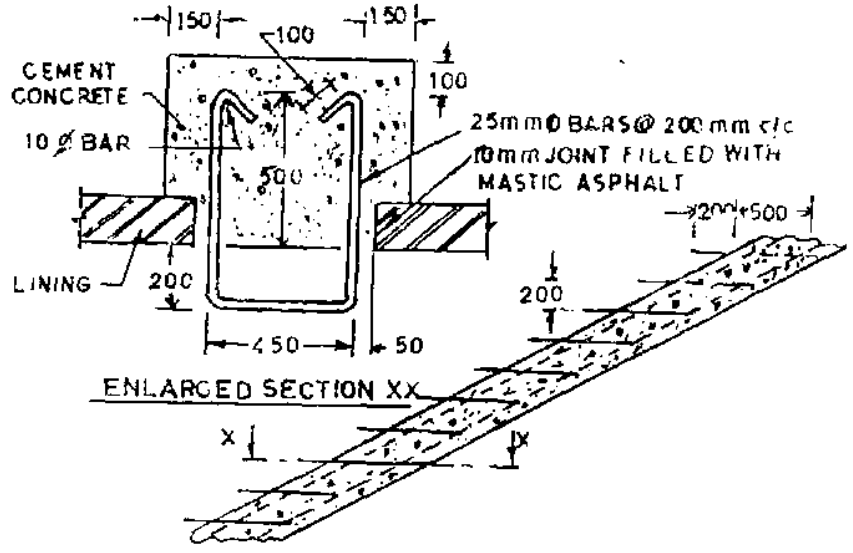
25.6.5 Safety Ladders

25.6.5.1 Safety ladders should be constructed in canal lining as directed by the Engineer-in-Charge.

25.6.5.1.1 Safety ladders consisting of ladder rungs should be constructed in canal lining about 30 m. upstream of the point where the canal enters some underground structure. In other reaches safety ladder may be provided at a spacing of about 300 m. the ladders being provided alternatively on either side.

25.6.5.1.2 Ladder rungs should be smooth, round mild steel bars, galvanised or coated with coal tar after installation.

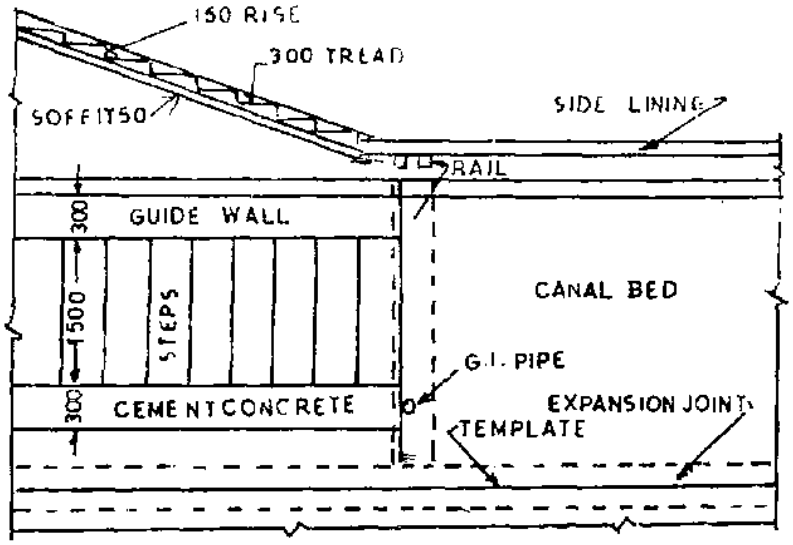
25.6.5.2 Typical details of safety ladder are illustrated in Fig. 14



ALL Dimensions in mm

Fig. 14 Details of Safety Ladders

25.6.5.3 As all alternative to safety ladders tops of rise 150 mm, tread 300 mm and 1500 mm wide may be provided in plain cement concrete of grade M-10 at a spacing of 300 m centre to centre (staggered) on either side of canal. Details of the steps are illustrated in Fig.15.



All Dimensions in mm

Fig. 15 Details of Steps

25.7 PRECAST CEMENT CONCRETE LINING

25.7.1 Manufacture: The precast cement concrete tile will be compressed Mechanically at the time of manufacture so as to achieve higher strength stipulated in this standard. The cement used in the manufacture of tiles shall conform to IS: 269:1989, IS:455:1989 or IS:1489-1991. Fine aggregates and coarse aggregates shall conform to IS:383-1990. The size of the coarse aggregate shall be not more than 20mm. Pozzolana conforming to IS:1344-1990 or IS:3812-1992 may also be used as aggregate. The potable water shall be used for mixing concrete and curing.

25.7.2 Dimensions

25.7.2.1 The nominal dimension shall be as below:

500 mm x 500 mm x 250 mm, 400 x 400 mm, 300mm x 300mm and 250 mm x 250 mm.

25.7.2.1.1 Each these shall be manufactured in the thickness 60, 50 and 40 mm.

NOTE- However other size than these given in 25.7.2.1 may also be manufactured if specifically required by the user.

25.7.3 Tolerance

In length and breadth shall be 3 mm and thickness shall not be less than the specified value.

25.7.4 Shape

the tile shall have its all sides at right angles to the faces.

25.7.5 Flexural Strength of Manufactured Tiles.

When tested according to the method given at Annex. II minimum breaking load per cm length of tile shall not be less than 41 kg for 60 mm, 29 kg for 50 mm and 18 kg for 40 mm tiles thickness.

25.7.5.1 Marking

25.7.5.1.1 Each tile shall be suitably marked as under:

a) Source of manufacture, and

b) Size with thickness.

25.7.5.1.2 The tiles may also be marked with the Standard Mark.

25.8 FLAG STONE LINING

25.8.1 Shaping & Size - Each flag stone shall be rectangular or square in shape and of uniform thickness. The stone slab should conform to IS-128-1988 or IS-3622- 1993 of length 0.45 M to 0.9 M width 0.45 M and thickness 35 to 50 MM

NOTE- The size (length and width) of stone slab may vary. But at least one dimension shall be as specified above, so that the longitudinal joints run continuous and parallel.

25.8.2 Physical Characteristics

Flag stone slabs shall be sound, clean, hard and tough. It shall be free from sand holes, weathered portions, adhering, flaws, cracks, soft seams and other inherent defects due to subsequent weather effects. The slabs shall be quarried fresh from the quarry in all cases and only the slabs conforming to requirements of theses specifications shall be brought to work site for use.

The physical properties of the flag of the stone shall be as below :-

S.No.	Characteristics	Requirements	Method of testing (Ref.to IS)
1.	Moisture absorption after 24 hrs. immersion in cold water.	Not more than 2.5 percent by weight	IS: 1124-1990
2.	Transverse strength	Not less than 7N/MM	IS:1121-1993
3.	Resistance to wear	Not greater than 2mm, on the average and 2.5mm on any individual specimen.	IS: 1704-1960
4.	Durability	Shall not develop signs of spalling disintegration or crack.	IS:1126-1990

25.8.3 Dressing Of Slabs

The sides shall be chisel dressed vertically roughly to a depth of 10 mm. Beyond this depth the sides shall be dressed slightly splayed so as to from an inverted shaped joint with the adjoining flag stone.

25.8.4 Preparation Of Sub-Grade

The subgrade shall be prepared as per provisions laid down under para 25.3 as applicable.

25.8.5 Profiles

Flag stone profiles of lining at right angle to the center fine of the canal shall be prepared at suitable intervals. Mortar shall be uniformly spread over the subgrade (15 ± 5 mm, to accommodate tolerance in slab thickness) and the stone shall be properly laid in bed at right angle to the centre fine of the canal while on the side slopes they shall be laid parallel to the centre line. Enough number of profiles both in bed and slopes shall be laid each day so mat when the work is started next day me marks shall be already in position.

25.8.6 Laying

25.8.6.1 Flag stones shall be cut, dressed and finished to the size and shape mentioned in para 25.8.1 and 25.8.3 or any other size found convenient in handling or as per site conditions and as directed by Engineer-in-Charge. Half size flag stone mentioned in para 25.8.1 shall also be made available for breaking joints at me time of placing them m position.

25.8.6.2 Stones and other construction materials shall be carted and stacked at convenient intervals along the canals to avoid excessive lead and handling of materials.

25.8.6.3 For lowering the flag stone in canal bed, wooden or iron chute of width suitable for flag stones and sides 7.5 cm high shall be used. Flag stone shall not be lowered by sliding m the surface of previously completed fined section of the canal. At the bottom of the chute one or two earth filled bags should be kept to prevent the stones from breaking by hitting hard canal bed.

25.8.6.4 The laying of flag stones shall be started only when atleast 35 m length of canal with subgrade is properly dressed to receive fining. Necessary arrangements for proper soaking of flag stone slabs, mortar mixing arrangements and sufficient number of flag stones shall be made available before starting me work.

25.8.6.5 Where Ground Water is high, the water table shall be lowered to atleast 30 cm below the sab-grade by dewatering.

25.8.6.6 The subgrade shall men be uniformly soaked with water without making it slushy to ensure hot water penetrates generally to a depth to about 300 mm m sandy soil and about 150 mm in other soils. Wetting of subgrade shall continue in advance of laying of tiles so that the soil does not absorb moisture of cement mortar (1:5 mix) laid on me subgrade for laying the flag stone.

25.8.6.7 Before placing a flag stone at least 15 ± 5 mm, thick fairly stiff cement mortar of 1:5 mixes shall be laid on the subgrade prepared as above/polyethylene sheet by covering the area to be occupied by each flag stone. Mortar shall not be spread in advance. It shall be ensured that each flag stone obtains an area of contact with the mortar of not less than 90%. The bottom of the flag stone shall be cleaned with a wire brush and surface made wet just before placing it in position. The joints between adjacent flag stone shall have a width not exceeding 20 mm at exposed face. Mortar in the joint shall also be placed at the time of laying each flag stone as a simultaneous operation and well grouted into it. Cement mortar for joints should be fairly stiff on 1:5 mix.

25.8.6.8 **Curing** - On completion of laying and from the next day, the lining shall be kept wet by sprinkling water over it keep the mortar well wetted.

On the next day the surface shall be kept wet and joints of the stone slab shall be carefully tested. Hollow joints shall be raked to a depth of 12 mm. loose mortar removed from sides and top of stone slabs and the joints properly refilled. Any loose stone slab shall be removed and relaid. Curing of mortar joints after laying should be ensured for 14 days. Satisfactory curing can be achieved by covering the joints with soaked gunny bags and keeping the same wet for 14 days.

25.8.6.9 The completed lining shall be checked for level with wooden templates and spirit levels.

25.8.6.10 The horizontal embedment of lining into the embankment at the top of lining in the case of flag stone lining shall be done with cast-in-situ 6 cm thick cement concrete 1:3:6. The embedment shall extend atleast 20 cm into the earthen embankment.

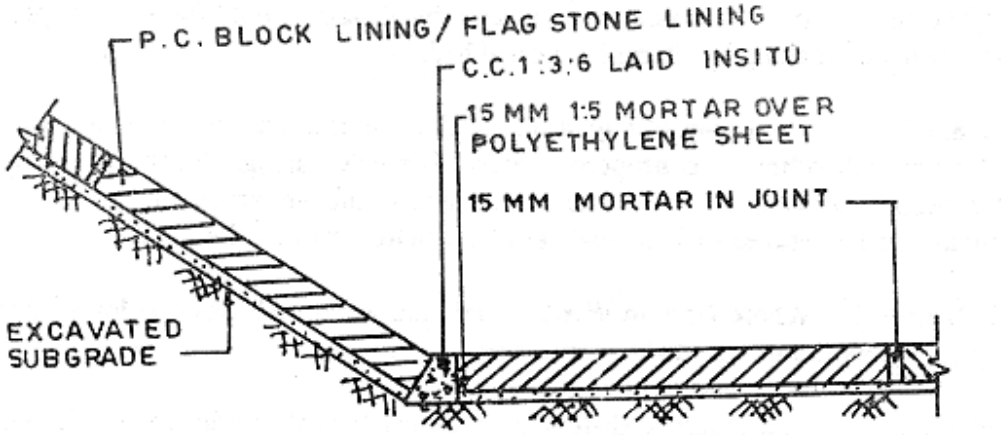


Fig. 16 P.C. Block Lining Detail Of Bed With Side

25.8.6.11 The trapezoidal junction of blocks in the bed and the side slope shall be facilitated by placing a small quantity of concrete in wedged shape as shown in fig. 16.

25.9 BURNT CLAY TILE LINING

25.9.1 Layers of Tiles for Bed and Side Slopes - The lining shall consist of single tile lining or double tile lining as specified by the Engineer-in-Charge (see Fig. 17). The tiles used for lining of canals shall conform to IS:3367-l993 and shall be of class 105, class 75 as specified. The average compressive strength shall not be less than 105 kg/cm2 for class 105 and 75 kg/cm2 for class 75.

25.9.1.1 Bed

25.9.1.1.1 Single Tile Lining - This shall consists of single layer of burnt clay tiles laid on about 10 mm thick 1:5 cement mortar on the well dressed sub-grade (see Fig. 17 A). Joints shall be well filled with mortar of the same consistency. Joint shall than be raked to 12 mm depth and after that not less than 20 mm thick cement plaster 1:3 shall be laid on it, which shall be given smooth finish. The mortar shall be laid on 6 m lengths, the lengths being laid alternatively. The total thickness of lining shall be not less than 80 mm. The thickness of joints shall not exceed 10 mm.

25.9.1.1.2 Double Tile Lining - This shall consist of double, layer of tiles, with a sandwiched layer of cement mortar, laid in accordance with para 25.9.1,2

Note :- However, the first layer of tiles in the canal bed may be allowed to be replaced by 75 mm thick 1:3:6 brick-bat cement concrete with necessary modifications in the rates of tile items. This change shall be allowed only to the extent required for utilising the broken tiles accumulated on the site due to normal breakages during the course of the work.

25.9.1.2 Side Slopes, Double Tile Lining - The sides shall consist of double layer of tiles with not less than 15 mm thick sandwiched layer of cement mortar of 1:3 mix. The first layer of tiles shall be laid on about 10 mm thick 1:5 cement mortar spread on compacted sub-grade dressed to specified slope. The joints shall be filled with mortar of the same consistency. The first layer of tiles shall be covered with 1:3 cement plaster not less than 15 mm thick on the top of which second layer of tiles shall be laid in about 5 mm. thick 1:3 cement mortar except for the bottom one metre length before its junction with single tile lining in the bed. The last metre in such-case shall be joined to the single tile lining m the bed by laying 1:2:4 cement concrete in half metre width and by laying 1:3 cement mortar in the rest half. Total thickness of lining masonry shall be not less than 130 mm (see Fig. 17 A and 17 B).

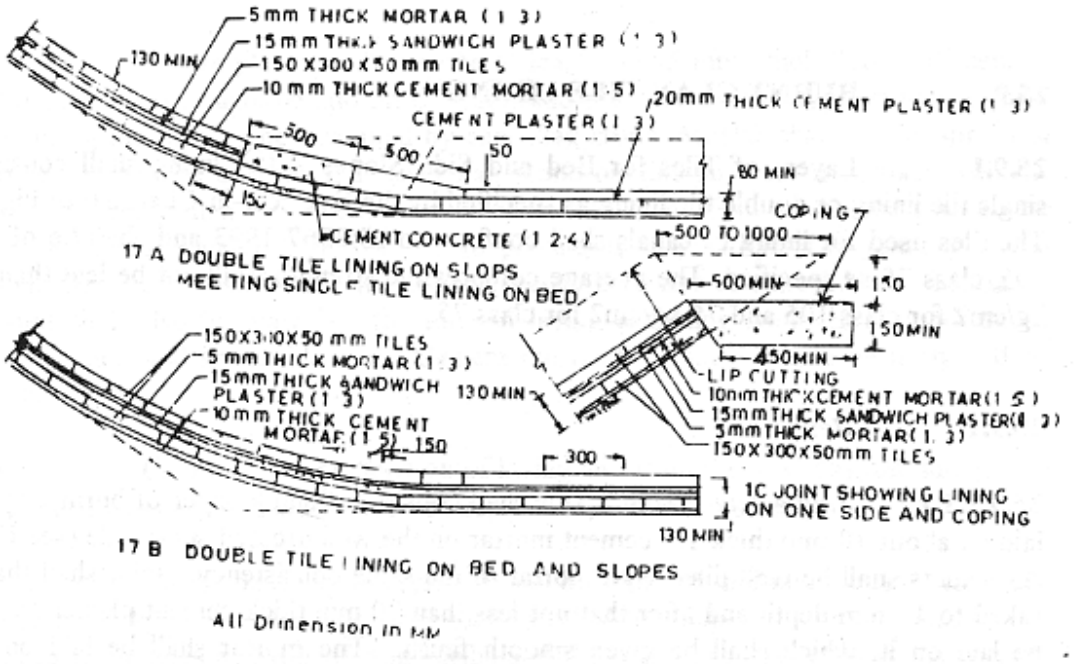


Fig. 17 Typical Sketch Of Canal Lining With Burnt Clay Tiles

25.9.2 Thickness

25.9.2.1 The thickness of joints shall not exceed 10 mm.

25.9.3 Mix For Cement Mortar

The following proportion for cement mortar shall be used for lining works. However, the mortar shall conform to IS:2250-1981.

(a)	For 10 mm thick cement mortar sub-grade	1:5 By Volume
(b)	Mortar for masonry of first layer of tiles	1:5 By Volume
(c)	For 15 mm thick sandwich cement and sand plaster	1:3 By Volume
(d)	For 5 mm thick cement and sand mortar and for tile masonry for, top layer	1:3 By Volume
(e)	For20 mm thick cement and sand plaster over the layer of tiles for single tile lining in bed.	1:3 By Volume

The use of pozzolana and other admixture including water-proofing compounds may be permitted, if approved by the Engineer-in-Charge. The pozzolana shall conform to the relevant Indian Standard.

25.9.4 Top Coping

To check the leakage of rain water behind the lining in sides, not less than 150mm, thick cement concrete coping of Grade M-100 conforming to specifications given under chapter 7 & 16 or of a double layer of tiles with a mortar mix specified for slopes (see para 25.9.3) shall be provided horizontally on the top of the fining (see Fig.17). The width of the coping at the top shall not be less than 350 mm.

25.9.5 Preliminary Work

25.9.5.1 Preparation of subgrade - The sub-grade shall be prepared as per provisions laid down under para 25.3 as applicable.

25.9.5.2 Hump- Humps of concrete of masonry about 150 nun high shall be provided where necessary in the bed of the canal at every 300 m intervals, to ensure that during short closures the bed of the canal does not dry and thus does not expose the plaster to direct rays of sun which may otherwise result in formulation of cracks.

25.9.5.3Soaking Of Tiles

Arrangements shall be made by those engaged in the work and be regulated mat tiles properly soaked in water for at least two hours are available for carrying out the work during each day.

25.9.6 Laying Of First Layer Of Tiles-First And Second Day Programme

25.9.6.1 The fining shall be started only when at least 35 m length of canal with subgrade is properly dressed to receive lining. Necessary arrangements and sufficient number of tiles be made available before starting the work.

25.9.6.1.1 Where spring level is high the water table shall be lowered to at least 30 cm below the subgrade by de-watering.

25.9.6.1.2 The sabgrade shall then be uniformly soaked with water without making it slushy to ensure that water penetrates to a depth of about 300 mm in sandy soil and about 150 mm in other soils. Wetting of subgrade shall continue m advance of laying of tiles so that the soil does not absorb moisture from 10 mm thick mortar laid on the subgrade for laying the layer of tiles.

25.9.6.1.3 Single tile profiles of lining parallel to centre line of the canal shall be prepared at suitable intervals. Mortar shall be uniformly spread over the subgrade and the tiles shall be properly laid in position quickly after that. Care shall be taken to see that the vertical joints are completely filled with mortar. The tiles shall be laid m bed at right angles to the centre line of the canal while on me side slopes they shall be laid parallel to the center line.

25.9.6.1.4 Enough number of profiles both in the bed and slopes shall be laid each day so that when the work is started next day the marks shall already be in position. Construction points or panels at suitable width each bed and sides shall be perfectly rolled, levelled and laid with profiles every day to receive lining of the first layers of tiles on the next day.

25.9.6.1.5 Tiles shall be firmly embedded in mortar. Hollows, if any, shall be rectified by relaying the defective portions with fresh mortar.

25.9.6.2 Curing And Correction - Thud And Fourth Day Programme -

On the third day the layer of tile shall be kept wet by sprinkling water over it, to keep the mortar well wetted on the fourth day, the surface shall be kept wet and joints of the tile masonry shall be carefully tested. Hollow joints shall be raked to a depth of 12 mm, loose mortar removed from sides and top of tiles and joints properly refilled. Any loose tile shall be removed and relaid.

25.9.6.3 Laying Cement Mortar Layer-Fifth Day Programme

25.9.6.3.1 Cement plaster of 1:3 mix shall be laid on the completed portion of the bed. To ensure proper thickness of mortar being laid and to achieve perfect -level in spreading of cement mortar L-shaped wooden frame of 1m x 1.5 m made of 20 mm, thick wooden plankings, shall be used. The plaster shall be well pressed while laying so that any excess of water or air locked into pores is driven out, thereby exercising uniform plaster over the layer of tiles. The surface of the plaster shall be finished even and smoothness after lightly sprinkling it with pure cement. This ensures a smooth hard surface thus checking the erosion of the surface of the plaster by water action.

25.9.6.3.2 For Double Tile Lining - When double tile lining is to be laid either on bed or side slopes, not less than 15 mm thick sandwiched layer of 1:3 cement sand mortar shall be laid by using L-shaped wooden frames of 1m x 1.5 m made of 15 mm, thick wooden plankings. This shall be done to ensure that correct thickness of 50 mm, is obtained over the whole surface. The plaster shall be well pressed while laying so that any excess of water or air locked into pores is driven out, thereby providing uniform plaster over the first layer of tiles. The upper side of the plaster shall be made rough for proper bond with the upper layer of tiles by means of fibre brushes or brooms. Wire brushes and nails shall not be used for the purpose.

25.9.6.3.3 The cement sand plaster shall be kept well wetted on the sixth day.

25.9.6.4 Laying Top Layer Of Tiles-Seventy Day Programme

25.9.6.4.1 The top layer of tiles in case of double tile lining shall be laid in 1:3 cement mortar about 5 mm thick. This layer of tiles shall be laid firmly and properly to proper levels in beds and correct slopes on the sides with joints not more than 10 mm thick.

25.9.6.4.2 Tiles used on the top layer shall be the best and laid with great precaution. Vertical joints shall be laid flush with cement mortar and no cement pointing shall be done on top of the tiles. The completed lining shall be checked for level with wooden templates and spirit levels.

25.9.7 Inspection

Daily inspection of the work shall be carried out at the site and joints found empty shall be localised and thereafter filled properly and relaid, if necessary. The results of inspection may be kept in proper log book.

25.9.8 Curing

Work done on each day shall be kept thoroughly wet for curing. In case of single tile lining, subsequent to laying of cement plaster layer and after 24 to 36 hours; and in case of double tile lining after laying the second layer of tiles, the lining shall be cured for at least 28 days. For bed, this may be done by constructing 150 mm deep earthen bunds across the bed so that a small depth of water shall stand on the upstream of the bunds and curing assured.

The curing of side slopes shall be done by constructing masonry drains with deep holes or perforated pipes on the coping at the top of the lining or by using sprinklers.

25.9.9 Maintenance During Laying

During the progressive construction of lining the labours shall walk on foot-paths of planks provided for the purpose. Walking on layer of tiles, finished plastered surface or the lined portion of the canal unless properly set and cured for a period of 15 days, shall not be permitted. Such irregularities may cause dislodgement of tiles resulting in pervious lining.

25.9.10 Safety Ladders

Safety ladders shall be constructed in canal lining where shown on the drawings or as directed by the Engineer-in-Charge.

25.10 BOULDER LINING FOR CANALS

25.10.1 Specification For Stones For Lining

25.10.1.1 Stones used for lining should be rounded or subangular river cobbles or blasted rock pieces with sufficient base area to be stable.

25.10.1.2 An the stones should have reasonably uniform size with dimensions as given in Table 6. depending upon the canal capacity.

25.10.13 Individual stone should he sound, hard and durable and should be such that they will be able to sustain weathering and water action. They should be free from laminations, soft spots, cracks, seams and other defects.

NOTE - The help of tests and requirements given in Table-7 for stone may be taken in making a judgment of the suitability of stones for canal lining.

Table - 6 Dimensions of Stones and Thickness of lining

(Para 25.10.1.2)

Thickness of Lining mm	**Average Dimension Along the Longest Axis in mm**
150	150
225	225
300	300

NOTES-

1**,** A maximum tolerance of 10 percent is permissible in the thickness of lining and the dimensions of stones.

2. Lining's safe velocity may be adopted as 1.5 m/sec.

Table 7 Requirements for Stones

(Para 25.10.1.3) (Note)

Test	Requirements
Specific (apparent) gravity when tested according to the method given in IS: 1126:1974	Greater than 2.5
Soundness (Sodium sulphate method)when tested according to IS: 1126:1974	Less than 10 percent loss of weight after 5 cycles

25.10.2 Preparation Of Sub-Grade

The sub-grade should be prepared according to Para 25 - 3.

25.10.3. Laying

25.10.3.1 Sub-grade (both bed and slope) for the canal should be divided into compartments by stone masonry or concrete ribs. The Compartments should have dimensions of not more than 15m along the centre line of me canal The spacing of ribs across the centre line should be so chosen as to divide the canal bed and dope symmetrically about the centre line and in such a manner that ribs are provided at the junction of the slope and bed and of the upper extremity of the slope. The ribs along the slope of the bank should be continuous (see Fig. 18)

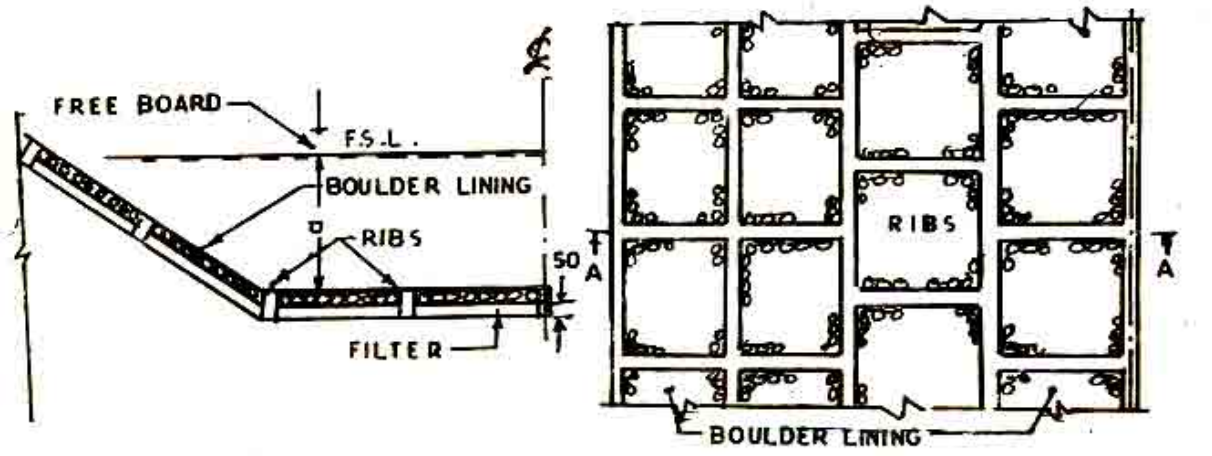


Fig. 18 Illustratory Layout Of Pitched Lining For Canal

25.10.3.1.1 If stone masonry ribs are used, the stones should meet the requirements specification 25.10.1.3.

25.10.3.1.2 If concrete ribs are used they should be made of Grade M 10 concrete in accordance with IS:456:1991.

25.10.3.1.3 Ribs should be rectangular in cross-section with width equal to the dimension of stone along its longer axis as specified in 25.10.1.2 and depth equal to the depth of lining plus thickness of filter.

25.10.3.2 A 15 cm thick layer of filter material, where required, should be laid in compartments formed by ribs. Filter material should be in accordance with the requirements specified in 25.10.4.

25.10.3.3 Stone, should be carefully hand packed in the compartments. The placing method should be such as to ensure a reasonably smooth surface and uniform thickness.

25.10.3.3.1 Spaces between the stones should be minimised. Such spaces should be wedged with spalls of suitable size to avoid filter material being washed out Such filling should immediately follow the placing of stones.

25.10.4 Filter

25.10.4.1 Filter material where required, should be free from flakes, soft particles, shale, organic matter of other deleterious substances.

25.10.4.2 Filter should satisfy the criteria

i) $\frac{\text{D15 (Filter)}}{\text{D15 (Base)}} > 4 \text{ and } < 20$

ii) $\frac{\text{D15 (Filter)}}{\text{D85(Base)}} < 5$

25.10.4.2.1 Where a large difference exists between the grading of the free draining material and of the soil to be retained, it may be necessary to use more than one layer of filter material, each progressively larger in grain size but satisfying the filter criteria given in 25.10.4.2. with respect to the adjacent lower layer.

25.10.4.3 Construction of Filter

25.10.4.3.1 The sub-grade, before placing the filter, should be firm and compacted suitably, wherever necessary according to IS:3873-1993.

25.10.4.3.2 Clean filter material should have sufficient water content (3 to 10 percent) during placement and placement should be such that segregation is prevented.

25.11 STONE MASONRY LINING FOR CANALS

25.11.1 Preparation Of Subgrade

25.11.1.1 Preparation of the subgrade should be done in accordance with para 25.3.

25.11.2 Laying

25.11.2.1 The stones should be of dimensions mentioned in Table 8 and should have specific gravity not less than 2.5 when tested according to IS:1122-1993 and soundness not less than 10% loss of weight after 5 cycles when tested according to IS: 1126-1990.

soundness not less than 10% loss of weight after 5 cycles when tested according to IS:1126-1990.

Table 8 : Dimensions of Stones and Thickness of Lining

(Para 25.11.2.1)

S.No.	Canal Capacity cumecs	Thickness of lining mm	Average Dimension along the longest axis mm	Minimum Dimension at any section mm
i)	0 to less than 10	150	150	75
ii)	10 to less than 100	225	225	110
iii)	100 and above	300	300	150

Note : Tolerance upto 10 percent is permissible in the thickness of lining and the dimensions of stones.

25.11.2.2 The stone should be laid on lime mortar (1:2) or cement mortar 1:3 over a bed of minimum 12 mm thick lime/cement mortar. The joints shall be pointed with similar mortar.

25.11.2.3 The lining should be started after at least 35m length of canal sub-grade is properly dressed to receive lining. The sub-grade should be uniformly soaked with water, without making it slushy, to ensure that water penetrates to a depth of about 300 mm in sandy soil and about 15° mm in other soils. Wetting of subgrade should continue in advance of laying of stone slabs so that the soil does not absorb moisture from the mortar placed on the subgrade for laying of the stone masonry layer.

25.11.2.4 If the water table is high it should be lowered to at least 300 mm below the subgrade.

25.11.2.5 The subgrade should be divided into compartments by stone masonry or concrete ribs of size not less than 300 mm x 150 mm. The compartments should have dimensions of not more than 15°m along the centre line of the canal. The spacing of ribs across the centre line should be selected in such a manner so as to divide the canal bed and slope symmetrically about the centre line, so that ribs are provided at the junction of the slope and bed and at the upper extremity of the slopes. If stone masonry ribs are used, the stone should meet the requirements given in 25.11.2.1

25.11.2.6 Pressure relief arrangements should be done according to para 25.4.

25.11.2.7 Single stone profiles of lining, parallel to centre line of the canal, should

with their length at right angles to the cater line of the canal, while on the side slopes they should be laid parallel to the center line.

25.11.2.8 Stone should be firmly embedded in mortar. Hollows, if any, should be rectified by relaying the defective porticos with fresh mortar.

25.11.2.9 On completion of laying and from the next day, the lining should be kept wet by sprinkling water over it to keep the morter well wetted, on the next day, the surface should be kept wet and joints of the stone masonry should be carefully tested. Hollow joints should be raked to a depth of 12 mm, loose mortar removed from sides and top of stone and the joints property refilled. Any loose stone should be removed and relaid.

25.11.2.10 The completed fining should be checked for level with wooden templates and spirit levels.

25.12 WATER COURSES AND FIELD CHANNELS LINING

25.12.1 General

25.12.1.1 The shape of the lined water-course may generally be rectangular, trapezoidal or semicircular. Following are the types of lining:

a) Brick/tile lining

b) Composite cement concrete and brick masonry lining

c) Cement concrete in-situ/precast lining

d) Stone slab/stone masonry fining, and

e) LDPE film with rigid cover.

25.12.1.1.1 Earthwork in Non-compaction Zone - it shall be free from shrubs, clods and shall be laid in 150 mm thick layers. Measurements shall be made as in the case of filling and 10 percent deductions may be allowed from actual measured cubical contents. The outer side slope shall depend upon the type of soil and height of the fin.

25.12.1.2 Compaction of Earthwork Under Bed :- Earth-work shall be laid under the bed in 75mm thick layers and compacted with steel tampers or by other mechanical means at optimum moisture content.

Note:- This type of earthwork shall be applicable for fin at the back of vertical wall only. For other sections, the earthwork shall be m accordance with IS:4701-1982.

25.12.1.3 **Soil Survey** - It is to know the type of soil moisture content and dry density attainable along the entire length of water-course or earthen channel

25.12.1.4 **Up Cutting** - After the compaction, the water course/field channels are cut to the final section by removing the extra soil from the bed and from the inner slopes of the banks.

25.12.1.5 **Alignment and Layout** - Construction bench marks shall be provided at an interval of 100 m with double levelling. The centre line of the water course/ field channel to be marked on pegs at an interval of 6 to 10 m apart longitudinally and shall be so fixed that their tops indicate the correct bottom level of the bed fining.

25.12.1.6 **Slope** - The bed slope of the lined section of the water-course to be adopted is fixed with regard to the designed full supply level at the head of the watercourse, the critical level of the field to be irrigated from the water-courses or the branch under consideration subject to the minimum limit of slope of 1.5 cm/100 m length, as far as possible. The permissible tolerance for finished bed level of water-course shall not be more than 1 cm as compared to the designed level

25.12.1.7 In case of problematic soils, suitable engineering measures shall be taken.

25.12.1.8 Free Board - 7.5cm of free board shall be provided above the calculated full supply level

25.12.1.9 Sub-grade - The surface over which lining is to rest is called sub-grade. It is to be perfectly true in profile in accordance with the cross-section of the watercourse so as to form a firm compacted bed for the lining.

25.12.2 **Procedure For Lining**

24.12.2.1 **Earthwork**

25.12.2.1.1 **Excavation** - The centre line shall first be pegged out and marked with DAG BEL or dimension lines as per designed L-section of channel All curves shall be properly laid down and the line indicating the top of the cutting or the toe of the embankments shall then be set out. These lines shall be ascertained from the X-section of the existing ground work and finished work. Reference pegs shall also. be driven into the ground.

25.12.2.1.1.1 Before commencing construction work, complete profiles of the compacted portion of the bed and embankments indicating finished section shall be set up at 150 metres apart or at such intervals as required due to the physical condition. These profiles shall be 3 metres in length along the alignment. Ends of the profile banks shall be stepped so that proper bond shall be achieved with earth fill laid afterwards. When the side slope in existing surface is more than 1:4, the ground shall be trenched or stepped to have Solid embankments. Manual excavation in cutting for channels shall be carried out in 0.6m to 1.5m lifts. Special precautions shall be taken to ensure that

excavation may be drained properly to prevent accumulation of water or formation of rain cuts. No excavated material shall be placed within 0.9 m from the edge of any trench. All gangways, paths and steps shall be kept within the section so that their removal in the end leaves the section true to design. In case of deep excavations, proper shuttering shall be done to avoid collapsing of trench.

25.12.2.1.1.2 Borrow pits shall be used for obtaining soils for earthfills only where absolutely unavoidable. No borrow pits shall be dug within 5 metres of the final section of the embankments, after making due allowance for future development. All borrow pits shall be dug to maximum depth of 0.3 m only.

25.12.2.1.1.3 All mud, slush and decay or other vegetation shall be excluded from the filling and clods of broken earth. The filling shall be placed in continuous horizontal layers of 75 mm thickness for hand compaction. Water shall be sprinkled on each layer and thoroughly rammed before the next one is laid. Filling shall be started from the outer edges working towards the centre in slightly concave layers and dressed to the desired cross-section of the channel. Earthfills shall be free from lenses, pockets, streaks or layers of material differing in texture. No filling shall be commenced without the permission of the Engineer-in-Charge.

25.12.2.2 Brick Lining - Bricks required for brick work shall be according to the specifications laid in IS 1077-1992 and shall be soaked m clear water immediately before use -for one hour or till the complete cessation of air bubbles, whichever is later. They shall be kept free from sand and silt. The bricks shall be laid in English bond with frogs upward. Half or cut bricks should be used only where required near the end of the walls (see Fig. 19)

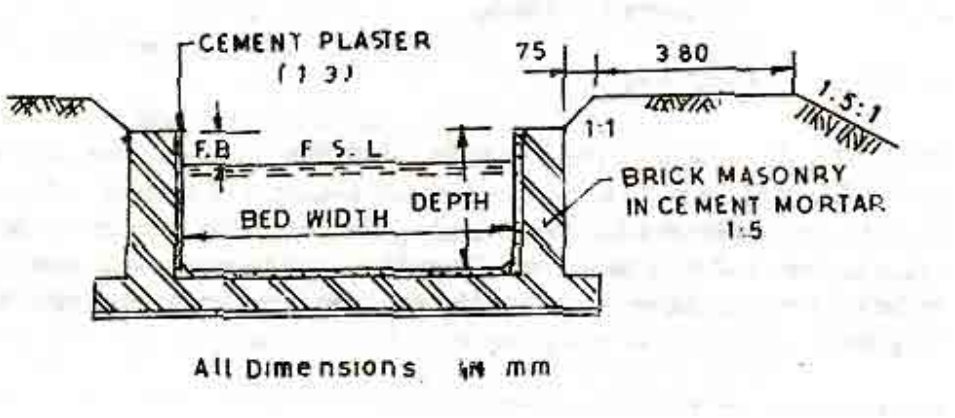


Fig. 19 Typical Brick Masonry Section

25.12.2.2.1 Section of the Side Walls - The width of the side walls shall be 115 mm for height upto 450 mm (6 courses). For height of the side walls of 525 mm (7 courses), the first course shall be of one full brick, that is, 225 mm width and 75 mm height. The width of the remaining six courses of the side

wall shall be 115 mm. For the height of side wall of 600 mm (8 courses), the first two courses shall be of full bricks, that is, the width will be 225 mm and the height will be 150 mm. The width of the remaining 6 courses win be 115 mm (see Fig.20)

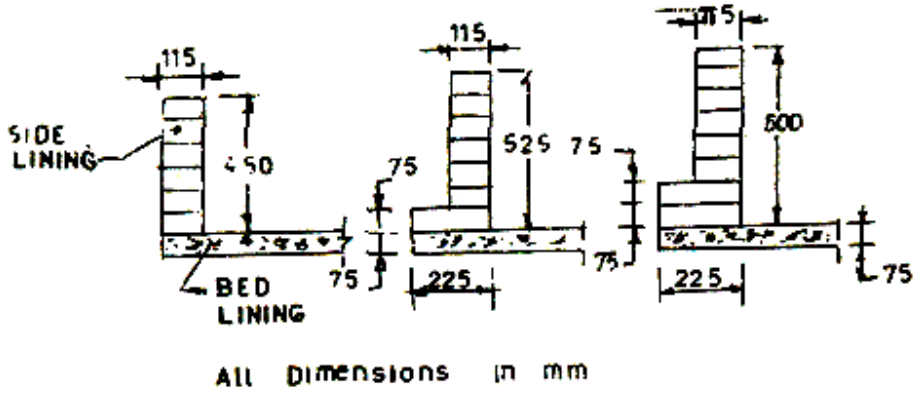


Fig. 20 Typical Section Of Side Walls

25.12.2.3 Composite Cement Concrete and Brick Masonry Lining - Following are the two methods for carrying out the lining work:

a) A bed of 50 mm thick 1:3:6 cement concrete is laid over 100 microns LDPE film conforming to IS:9698-1990. Side walls are constructed in brick masonry in 1:4 cement sand mortar (without plaster). The inside and top of these vertical walls should be finished with 10 mm thick 1:3 cement sand plaster (see Fig. 21).

b) Brick masonry in 1:5 cement sand mortar (with plaster) or 1:4 cement sand mortar (without plaster) on the sides and 5 cm thick 1:3:6 cement concrete in the bed should be laid over 1.5 to 2.0 cm thick subgrade of slate pieces/100 microns LDPE film.

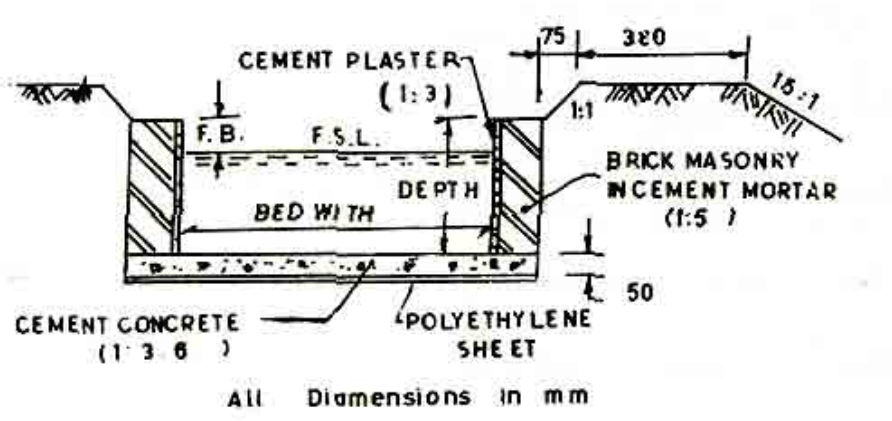


Fig. 21 Typical Cement Concrete And Brick Masonry Section

25.12.2.4 Cement Concrete Lining- 50 mm thick 1:3:6 cement concrete should be laid m the bed over a 100 micron LDPE film. The vertical side walls should be constructed with 75 mm thick 1:3:6 cement concrete. In case LDPE film is not being used, 75 mm thick 1:3:6 cement concrete shall be laid (see Fig.22).

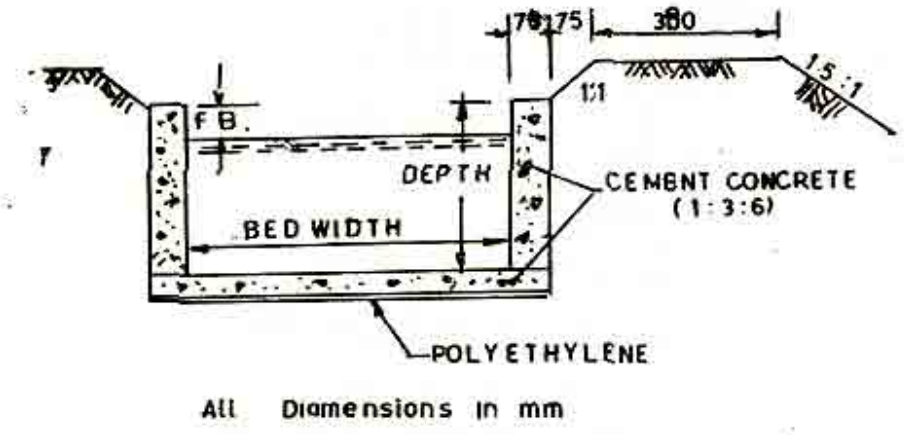


Fig. 22 Typical Cement Concrete Section

25.12.2.5 Stone Slab/Stone Masonry Lining

25.12.2.5.1 Stone Masonry Lining - Stone shall be free from laminations, soft spots, etc. Stone masonry should be laid in 1:2:8 mortar (1 cement: 2 lime : 8 stone dust) 1:5 (1 Cement :5 sand mortar). The joints should be raked and pointed with 1:3 cement mortar (see Fig.23)

25.12.2.5.2 Stone Masonry Lining - stone slab used for the bed shall have thickness of 25 mm. Stone dab should be laid in 1:2:8 mortar (1 cement: 2 lime : 8 stone dust) or 1:5 (1 cement : 5 sand mortar). All the joints shall be raked and pointed. Masonry on the sides shall be laid m 1:2:8 cement Bme/l:4 cement sand mortar. The remaining courses of side walls may be laid m 1:4 cement sand mortar,

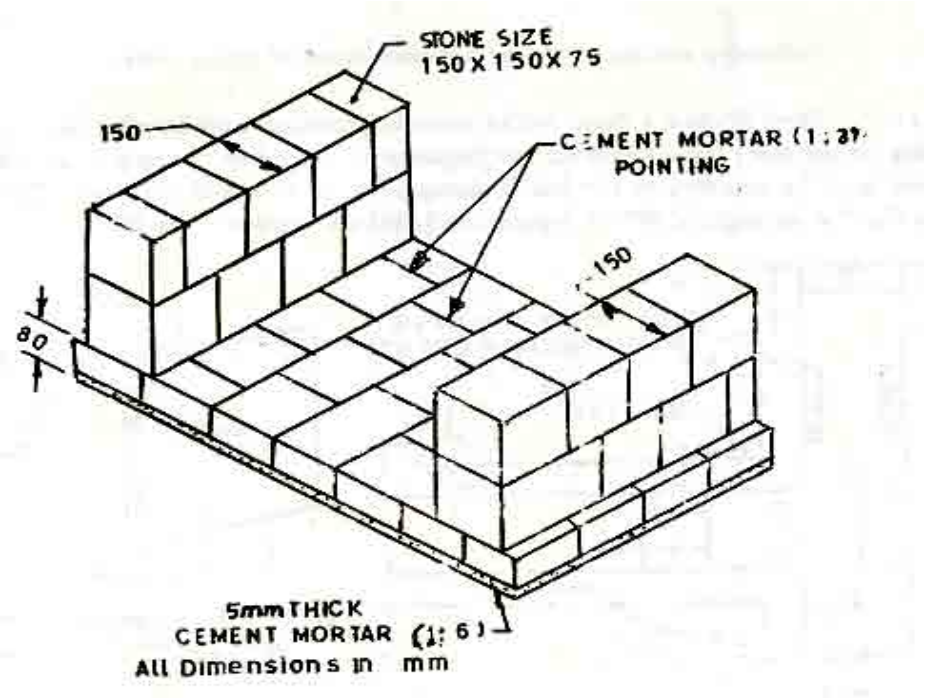


Fig. 23 Stone Masonry Lining

25.12.2.6 **Pre-Cast Cement Concrete Lining** - It shall be in accordance with para 25-7

25.12.2.7 **Strength Development** - Strength development is an important requirement before masonry/concrete is loaded to the full extent. The rate of construction shall synchronize with the development of strength, particularly in weak mixes. Extreme care shall be taken by putting the earth work behind the lining. Initially about 50 percent of the quantity of earthwork or upto 75 percent of the height shall be done. After a couple of runs of water in the lined water-course, the remaining earthwork may be completed and dressed.

25.12.3 **Testing**

25.12.3.1 The lining work constructed as explained in 25.12.2 shall be tested for leakage by filling the lined portion with available water. The points where some leakage is indicated shall be marked. These shall then be treated by raking and filling the joints on both sides of the side fining properly, wherever possible.

25.12.4 **Turnout For Nakka**

25.12.4.1 It is a structure capable of diverting the entire stream of water from the water-course to the chaks or from the field channels. These channels shall be strong because the farmers have tendency to dig and use earth around this structure to control leakage at gate point and thus unknowingly weaken the structure.

25.12.4.2 Following .are the two most common types of nakka plates:

a) **Steel Nakka** - Steel nakka plate is provided with handles (one or two depending on the size) and a chain with angle piece at the end having split sicks which is embedded into the masonry of the nakka structure so as to avoid pilferage. The steel nakka is fixed at an angle of 60°. A typical steel nakka is shown in Fig.24.

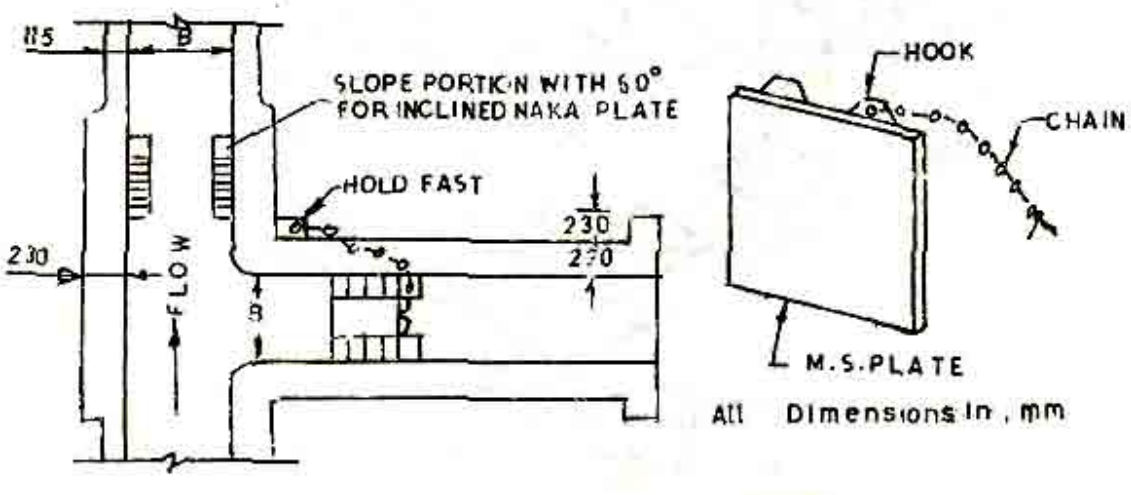


Fig. 24 Typical Design Of M.S. Plate Nakka Structure

b) **Circular Nakka** - It consists of a panel and a lid. The panel is fixed into the masonry of nakka structure at an angle of 60°. The lid is fixed into the panel after a couple of rotary motions. This is a water tight arrangement and practically no earth is required to control the seepage. A typical circular nakka is shown in Fig.25.

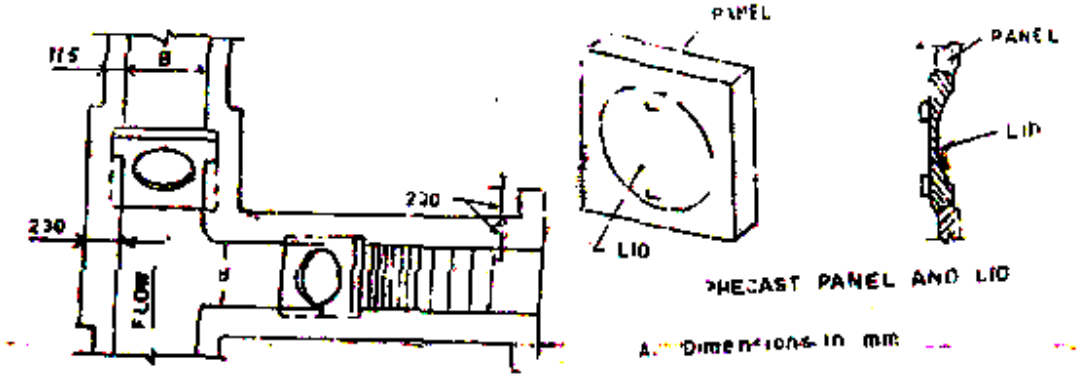


Fig. 25 Typical Design Of CIRCULAR Nakka Structure

NECESSITY AND TYPE OF DRAINAGE ARRANGEMENT

SUB-	GWT ELOW ANAL BED LEVEL CUTTING	REACHES	FILLING	REACHES	GWT ABOVE CANAL CUTTING	REACHES
1	2		3		4	
	I. Discharge above 15 cumec :					
(i)	Freedraning	---------- no drainage arrangement is necessary ----------			----------	
(ii)	Poorly	---------- no drainage arrangement is necessary ----------			------	
(iii)	draining	---------- no drainage arrangement is necessary ----------			----------	
	II. Discharge between 0.3 cumec to 3.0 cumec :					
(i)	Freedraning	---------- no drainage arrangement is necessary ----------			Bed : Longitudinal drain (LD) with pressure release valve (PRV) in pocket filter (PF) at15 m interval. Slope: PRV in PF at 15 m interval	
(ii)	Poorly draining	---------- no drainage arrangement is necessary ----------			Bed : LD with PRV in PF at 10.0m interval.	
(iii)	Impervious/rocky	---------- no drainage arrangement is necessary ----------			Bed : Sand filter and LD with PRV in PF at 10m interval. Slope: Sand filter from FSL extended upto	
	III. Discharge between 0.3 cumec to 15 cumec :					
(i)	Freedraning	---------- no drainage arrangement is necessary ----------			Bed: LD with PRV in PF at 10 m Interval Slope: PRV in PF at 10 m Interval.	
(ii)	Poorly draining	Bed : LD with PRV in PF at 15m interval. Slope : TD from FSL connecting to LD in bed at 15 m interval.	Bed : 15m Slope : from	Sand filter with PRV in PF at interval. (i) Cutting portions-sand filter FSL extending upto bed. (ii)Filling portion (a) draning – No arrangement	Bed: LD with PRV in PF at 10 m Interval Slope : TD from FSL connecting to LD at 10m Interval	
(iii)	Impervious/rocky	Bed : in Sand filter and LD with PRV PF at 15m interval.			Bed : Sand filter and LD with PRV in PF at 10m interval	
		Slope : Sand filter from FSL extending up to bed	Same arrangement as indicated in III (ii) column-3		Slope : Sand filter from FSL extending up to Bed	

(Continued……..)

	1	2	3	4
iv	**Discharge above 15 cumecs :**			
(i)	Freedraning	---------- no drainage arrangement is necessary ----------		Bed : Longitudinal pipe drain (LPD) with PRV in outlet at 10.0m interval. Slope : Transverse drain (TD) from FSL connected to LPD at 10.0 m
(ii)	Poorly draining	Bed : LPD with PRV in outlet at 15m interval. Slope : TD from FSL connected to LPD at 15.0 m interval.	Bed : LPD with PRV in outlet at 15m interval. Slope : TD from FSL connected to LPD at 15.0 m interval.	Bed : LPD with PRV in outlet at 10.0m interval. Slope : (TD) from FSL connected to LPD at 10.0 m interval.
(iii)	Impervious/rocky	Bed : Sand filter and LPD with PRV in outlet at 15m interval. Slope : Sand filter from FSL extending up to bed	Same arrangement as indicated in IV (ii) column 3	Bed : Sand filter and LPD with PRV in outlet at 10m interval. Slope : Sand filter from FSL extending up

Notes:

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(i) In case canal is passing through bunded paddy field the operative rainy season water level may cause hydrostatic pressure to build up against the lining in canal slopes. Therefore, if the hydraulic gradient line with an assumed 6:1 slope from the field adjoining the canal cuts the canal side slop more than 30 cms above the canal bed, drainange arrangement applicable for WT above CBL shall be provided even

(ii)Highest ground water table (GWT) available in a year shall be considered for providing drainage behind lining.

(iii)In case of GWT below CBL but perched ground water table above CBL, drainage arrangement as indicated in deep cutting for impervious /rocky subgrade shall be provided

(iv)PRV in slope shall be staggered with reference to bed.

(v) Explanation of abbreviations :-

(i)	GWT	-	Ground Water Table	(v)	LD	-	Longitudinal drain
(ii)	CBL	-	Canal bed level	(vi)	TD	-	Transverse drain
(iii)	PRV	-	Pressurerelease valve	(vii)	LPD	-	Longitudinal pipe drain
(iv)	PF	-	Pocket filter	(vii)	FSL	-	Full supply level

ANNEXURE - II

TEST FOR FLEXURAL STRENGTH OF MANUFACTURED TILE

(Para 25.7.5)

A-l SAMPLE

A-1.1 For ascertaining {he conformity to the requirements for flexural strength test, one tile from each lot of 500 shall be selected at random and tested.

A-2.1 Lot shall be considered conforming to the requirements of the flexural strength test if the sample passes the requirements of the test. In case it fails to satisfy the requirements of the test, two more tiles shall be selected at random from the same lot and tested for the requirements of flexural strength If any of these two tested fails to satisfy the strength requirements the lot shall be rejected.

A-2 TEST

A-2.1 The specimen shall be immersed m potable water for 24 hours and then taken out and wiped dry.

A-2.2 The specimen shall be placed horizontally on roller bearers 150 mm apart with their length parallel to bearers. The load shall be applied at mid-stand by means of steel bar parallel to the bearers. The length of the bearers and that of the loading bar shall be longer than the length of the specimen and their contact shall be rounded to a diameter of 25 mm. A plywood packing 3 mm thick and 25 mm wide shall be placed between the specimen and the loading bar. The loading bar and the bearers shall be self-aligning (see Rg.26)

A-2.3 Starting from zero, the load shall be increased steadily and uniformly at the rate not exceeding 2 kg/cm length (measured along with the bearers) per minute up to the load specified in 25.7.5. which shall be maintained for at least 1 minute. There shall not be any visual crack in the tile.

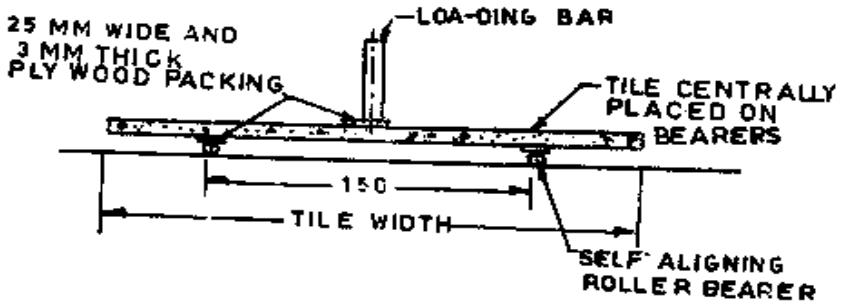

Fig. 26 Method Of Test For Flexural Strength Of Tile

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