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GUIDELINES FOR DESIGN AND CONSTRUCTION OF PRESTRESSED ROCK ANCHORS

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BUREAU OF INDIAN STANDARDS
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Indian Standard

GUIDELINES FOR DESIGN AND CONSTRUCTION OF PRESTRESSED ROCK ANCHORS

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Indian Standard

GUIDELINES FOR DESIGN AND CONSTRUCTION OF PRESTRESSED ROCK ANCHORS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 27 July 1982, after the draft finalized by the Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Ground anchors are used in civil engineering for the following applications:

a) To resist lateral thrust on retaining walls and *in-situ* diaphragm walls,
b) For stabilizing of slopes and land slides,
c) To resist uplift on basements and other foundations,
d) To strengthen masonry and concrete dams, and
e) For testing of large diameter piles.

0.2.1 This standard is being prepared as a guideline for design and construction of prestressed rock anchors. The other types of anchors, such as prestressed soil anchors or unstressed rock anchors are not covered in this standard.

0.3 This edition 1.2 incorporates Amendment No. 1 (March 1985) and Amendment No. 2 (December 1988). Side bar indicates modification of the text as the result of incorporation of the amendments.

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

1. SCOPE

1.1 This standard deals with design and construction of permanent and temporary prestressed rock anchors constructed by using high strength prestressing steel (wires and strands).

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

2. TERMINOLOGY

2.0 For the purpose of this standard the following definitions shall apply (*see* Fig. 1).

2.1 Permanent Anchors — Any anchor required and constructed for service life of the structure.

2.2 Temporary Anchors — Any anchor required and constructed for duration of construction period only.

2.3 Fixed Length — The length of the anchor which is grouted in, from which the pullout capacity of anchor is achieved.

2.4 Free Length — The part of the anchor which is not bonded to the surrounding area and is free to elongate.

2.5 Fixed Length Grout — Cement grout which is placed/injected in the fixed length of the anchor that provided anchorage.

2.6 Free Length Grout — The grout surrounding the free length of the anchor. This secondary injection is provided surrounding the sheathing in case of sheathed anchors. For unsheathed anchors, this grout is provided after the stressing is completed and anchor is locked. The main purpose of this grout is to provide corrosion protection.

2.7 Consolidation Grouting — Grouting executed in the area surrounding the hole prior to inserting cables either to waterproof the hole or to strengthen the rock.

2.8 Design Load — Assigned load on anchor after allowance for all losses.

2.9 Prestressing Steel — The element of the anchor which is allowed to elongate and is anchored at the bottom to develop necessary prestressing force. This steel can be high tensile plain wires or standard cables.

2.10 Sheathing — Enclosure to the prestressing steel provided for corrosion protection.

2.11 Anchorage — The means by which prestressing force is transmitted to rock or structural element.

2.12 Bearing Plate — A plate used at the top end of the prestressed anchor to distribute anchor force to the structure.

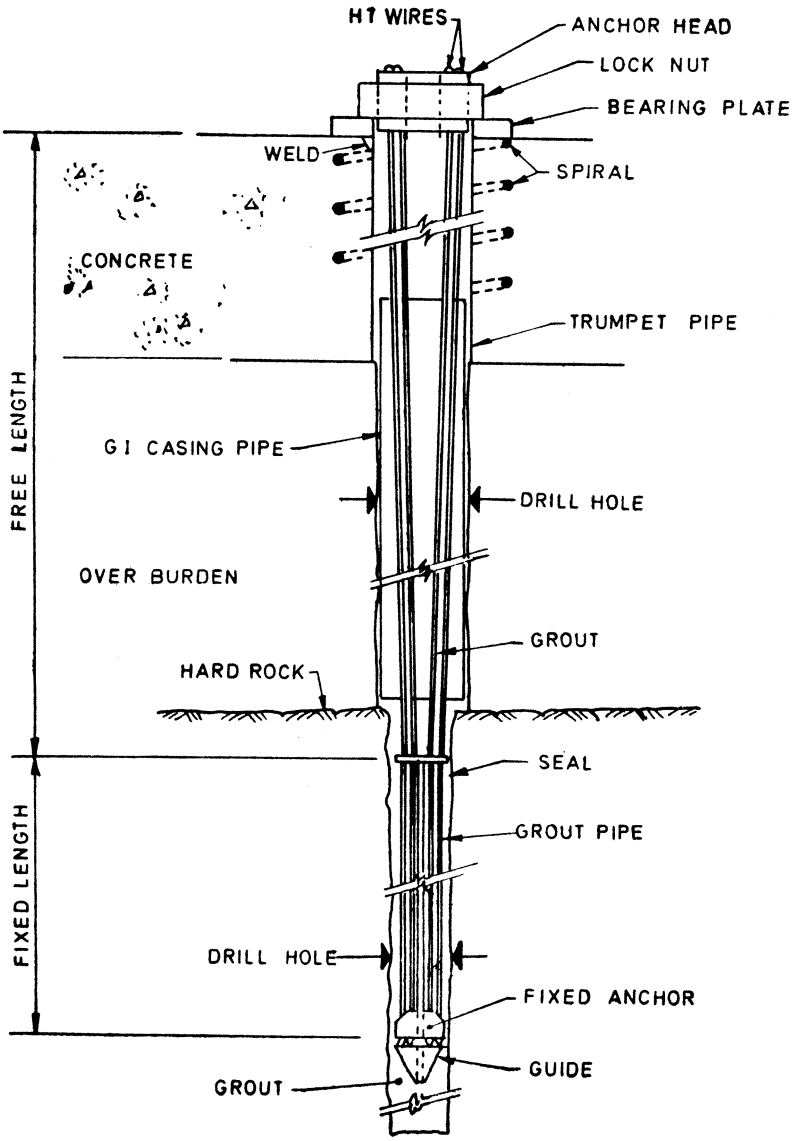


FIG. 1 TYPICAL DETAILS OF PRESTRESSED ROCK ANCHOR

2.13 Allowable Bond Stress of Rock — Bond stress between the rock and the grout used in the design. This normally assures a minimum safety factor of 3.

2.14 Lugeon — Lugeon is defined as flow of water in litres/minutes/metre length of the test section at a pressure of $1 MN/m^2$ ($10 kgf/cm^2$) during water test.

2.15 Prestressing Force — The load to which the anchors are initially stressed to cater for design load and allowance for the expected losses.

3. NECESSARY DATA

3.1 The following data are required for design and construction of anchors:

a) Service life of anchor (temporary or permanent);
b) Design load per anchor; and
c) Soil investigation for following factors:
   i) Complete borehole log indicating types of soil and rock encountered with respect to depth. The depth of penetration into rock with core drilling should be minimum 10 m (*see* IS : 1892-1979*).
   ii) Undrained shear strength and bulk density at different depths [*see* IS : 2720 (Part XI)-1971†].
   iii) Shear strength and unit weight of rock [*see* IS : 1121 (Part IV)-1974‡ and IS : 1122-1974§].
   iv) Sulphate and chloride contents in soil as well as ground water [*see* IS : 2720 (Part XXII)-1972 ||].
   v) Permeability of rock and fissures — pervious zones water table and artisian head if any recorded on boreholes [*see* IS : 5529 (Part II)-1985¶].

*Code of practice for subsurface investigation for foundations (*first revision*).

†Methods of test for soils: Part XI Determination of the shear strength parameters of a specimen tested in uncosolidated undrained triaxial compression without the measurement of pore water pressure.

‡Methods of test for determination of strength properties of natural building stones: Part IV Shear strength (*first revision*).

§Methods of test for determination of true specific gravity of natural building stones (*first revision*).

|| Method of test for soils: Part XXII Determination of organic matter (*first revision*).

¶Code of practice for *in situ* permeability tests: Part II Tests in bedrocks (*first revision*).

4. MATERIALS

4.1 The cement shall be either ordinary Portland cement conforming to IS : 269-1976* or sulphate resistant cement conforming to IS : 6909-1973†.

4.2 The prestressing steel shall conform to IS : 2090-1983‡.

5. DESIGN CONSIDERATIONS

5.1 Prestressing Steel — The number of wires or strands are so provided that initial prestressing force is at a level of 70 percent of guaranteed ultimate tensile strength of the steel.

5.2 Fixed and Free Length of Anchors

5.2.1 The fixed length of the anchor is decided based on allowable bond stress between: (a) steel and grout, (b) the grout and the rock, and (c) shear strength of rock. The fixed length (bond length) should be provided considering the following aspects:

a) Co-relation between unconfined compressive strength of the rock and bond value (*see* Fig. 2),

b) From the data available on typical rocks (Table 1), and

c) Experience with similar type of rocks in adjacent areas.

NOTE — Considerable experience is required for assigning the bond value in design of anchors. Several different aspects, such as, smoothness and roughness of the rock, shear strength of the rock, weathering, etc, are to be considered. To form the basis to make a reasonable estimate of bond value, the above 3 aspects should be considered,

5.2.2 Fixed length of the anchor is decided based on the pullout criteria. In Fig. 3, method of checking the pullout capacity of anchors is given. The minimum safety factor of 1.5 for permanent anchors and 1.25 for temporary anchors is required against pullout. Minimum fixed length of 5 m is considered desirable and if the pullout criterion indicates additional fixed length should be provided.

6. METHOD OF CONSTRUCTION

6.1 Drilling Through Overburden — Drilling through overburden is normally carried out by suitable equipment. For keeping the side stable,

*Specification for ordinary and low heat Portland cement (*third revision*).
†Specification for supersulphated cement.
‡Specification for high tensile steel bars used in prestressed concrete (*first revision*).

either temporary casing is provided or bentonite mud circulation is used. The size of the hole depends upon the capacity of the anchor. In case of inclined bores use of casing tube shall be obligatory.

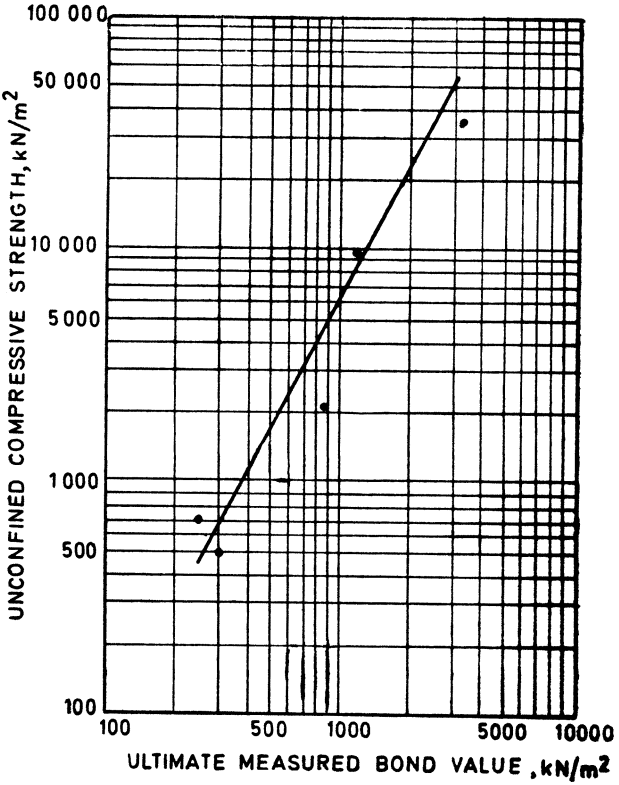


FIG. 2 TENTATIVE RELATION BETWEEN BOND AND UNCONFINED COMPRESSION STRENGTH

6.2 Drilling Through Rock — Drilling through rock is carried out by using either rotary method with water flush or using pneumatic percussion method with air and/or water flush.

6.3 Water Proofing of the Hole — After drilling through rock a water test is carried out and if water loss is found to be excessive the hole is grouted (*see* IS : 6066-1984*). The grout is then redrilled and water test repeated and the whole procedure is repeated till

*Recommendations for pressure grouting of rock foundations in river valley projects (*first revision*).

satisfactory lugeon value is obtained. In case of temporary anchors repetative grouting and redrilling may not be done.

TABLE 1 ALLOWABLE ROCK GROUT BOND VALUES

(*Clause* 5.2.1)

SL NO.	TYPE OF ROCK	ALLOWABLE BOND STRESS
(1)	(2)	(3)
i)	Basalt	0.5N/mm^2 to .7N/mm^2 (5kgf / cm^2 to 7kgf/cm^2)
ii)	Khaondolite/Charnokite	0.3N/mm^2 to .5N/m^2 (3kgf/cm^2 to 5kgf/cm^2)
iii)	Granite	0.5N/mm^2 (5kgf/cm^2)
iv)	Shale	(0.3N/mm^2) (3kgf/cm^2)
v)	Weathered sandstone/ Quartzite	0.25N/mm^2 (2.5kgf/cm^2)
vi)	Jointed quartzitic	(0.35N/mm^2) (3.5kgf/cm^2)
vii)	Grey chioritic schist	(0.35N/mm^2) (3.50kgf/cm^2)
viii)	Sandstone/Quartzite	0.3N/mm^2 (3kgf/cm^2)

6.4 Fabrication of Anchors — Anchors can be shop fabricated or fabricated on site depending upon the construction requirements.

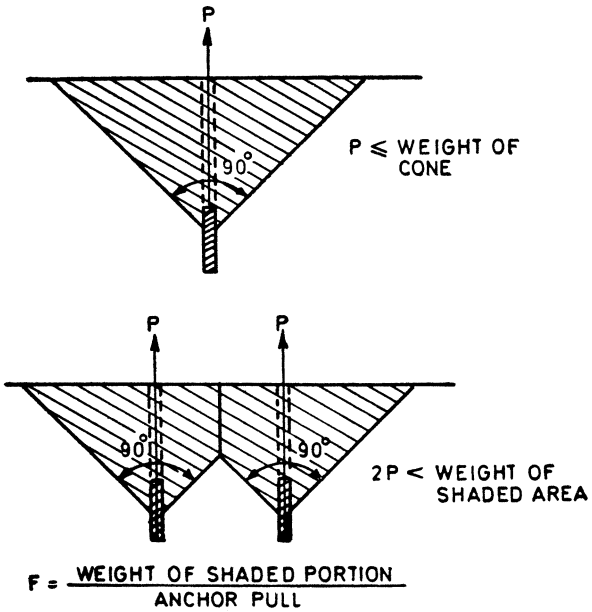
6.4.1 Anchors shall be free of dirt, detrimental dust or any other deleterious substance. Anchors shall be handled and protected prior to installation to avoid corrosion or physical damage.

6.5 Lowering Anchors — Anchors are placed in accordance with type of anchors. Suitable guide system and temporary fixing of the anchor is required to avoid movement of anchor during grouting. Grout tubes are checked to ensure that they are free. Suitable spacers are also provided when required to ensure that anchor assembly does not get entangled.

6.6 Fixed Length Grouting — After the anchor is lowered, the fixed length of the anchor is grouted. Grouting is carried out under pressure by fixing a packer at the top of the fixed length or as necessary in accordance with the type of anchor. Normally thickest possible grouting (0.5 water cement ratio) is adopted for primary grouting

(*see* IS : 6066-1984*). Adequate care is required so that the free length of the anchor remains free to elongate.

Alternatively a predetermined quantity of the grout is placed at the bottom of the hole immediately prior to the lowering of anchor.



P = Load Transferred by bond (tonnes)
F = Factor of Safety against failure.

FIG. 3 CALCULATION OF FACTOR OF SAFETY FOR PULL

6.7 Stressing — Stressing is carried out after 21 days of grouting when, it attains the required strength. Depending on the different types of anchors used, details of the stressing jack vary. The anchor is stressed for about 10 percent of the load and elongation measurements taken beyond this range. This takes care of any seating errors. Anchor is subsequently stressed to 10 percent excess load over the design and elongation noted. After noting the elongation, the anchor is locked either to design load or part of the design load depending on the requirements.

NOTE — Normally, so observed elongations are somewhat different due to various reasons, such as, variation in 'E' value of wires, measuring errors, variable stress

*Recommendations for pressure grouting of rock foundations in river valley projects (*first revision*).

distribution within the fixed length of the anchor, etc. Up to 16 percent variation is allowed compared to theoretical elongation. In any case, as far as loading on the anchor is concerned, the directly measured value as indicated by calibrated dynamometer and pressure guages is to be taken as correct. The factors such as relaxation of wires and creep will be considered before the anchor is finally locked and grouted. For this, once the anchor is locked at the design load, it will be kept undisturbed for minimum seven days or till one day after the last anchor has been stressed in a particular unit, whichever is later and then checked for the losses due to relaxation, creep, etc, for the individual anchor. The anchor is then restressed to the design load and free length of anchor is finally grouted. Certain type of anchor designs are possible in which free length is enclosed in plastic sheathing, it is however ensured that no grout should come in contact with the steel in the fixed length portion of the anchor. Due to prestressing force the settlement/movement of the structure itself can be measured by placing 3 dial gauges around the anchor head.

7. CORROSION PROTECTION

7.0 The various methods of corrosion protection for minimizing corrosion of prestressed anchors are as under.

7.1 Corrosion Protection of Free Length of Anchor

a) To avoid ingress of water in the free length of anchor, a galvanized iron pipe of suitable diameter conforming medium grade of IS : 1239 (Part I)-1979* is provided;

b) *Tendom* comprising of several 7 mm diameter high tensile steel wires enclosed in a 2 mm thick suitable diameter PVC pipes is provided. The diameter of the PVC pipe should be greater than enclosed wires;

c) The annular space between the PVC pipe and the hole or galvanized iron pipe is filled with neat cement grout; and

d) The wires should be painted with epoxy based paint as under;

   i) High tensile steel wires are first cleaned with sand papers:

   ii) Immediately afterwards, a coat of suitable primer is uniformly applied by brush.

   iii) When the coat of primer is sufficiently dry, a coat of epoxy based paint is given uniformly.

NOTE — The base paint and thinner are so proportioned that smooth brushing is possible.

7.2 Corrosion Protection of Fixed Length of Anchors — This is done by one or more of the following:

a) The fixed length of the anchor is grouted using neat cement repeatedly under pressure to obtain the permeability of under 3 lugeons for the surrounding strata. This reduces the ingress of water and prevents corrosion.

*Specification for mild steel tubes tubulars and other wrought steel fittings: Part I (*fourth revision*).

b) The fixed length is treated with epoxy formulation (*see* IS : 8230-1976†) as under:

i) *Pretreatment* — The high tensile steel wires are first pretreated by sand blasting or grit blasting process. Thereafter, the wires are cleaned thoroughly by using thinner.

ii) The first coat of epoxy formulation is applied uniformly on the prestressed wires and it is allowed to dry for a period of 2 to 3 hours. The second coat is applied thereafter and the same is allowed to dry for 24 hours. This is then roughened by sand paper and the third coat is then applied uniformly. While the third coat is still tacky, quartz sand is sprinkled over it to increase the bond.

c) Additional high tensile wires can be provided to account for long term corrosion. The number of extra wires, however, that can be provided depends on the diameter of anchor hole. By provision of extra wires, in effect, the stresses in each wire are reduced which prevents to a large extent stress corrosion as well.

8. TESTING OF ANCHORS

8.1 Water-Proofing — The anchorage length (fixed length) for all permanent anchors has to be tested for water-proofing to avoid corrosion. Water tests are normally carried out by fixing a packer at the top of the fixed length or top of holes and conducting the test under pressure. Normally if the water loss is less than 3 lugeons, the hole is considered to be satisfactory and where salinity in the grout is high, minimum acceptable permeability value is taken as 1 lugeon.

8.2 Strength — During the stressing operation 100 percent anchors are stressed to 10 percent over design load to check their suitability.

†Specification for steel-filled epoxy resin based adhesives.

(*Continued from page* 2)

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Amendments Issued Since Publication

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