C1. Material Requirement

C1.1 Cement

Type of Cement

1a. Ordinary Portland cement 33 Grade (Confirming to IS 269-2015)

1b. Ordinary Portland cement 43 Grade (Confirming to IS 269-2015)

1c. High Strength Ordinary Portland cement 53 Grade (Confirming to IS 269-2015)

2. Portland Pozzolana cement (Confirming to IS 1489-Part-I)

4. Low Heat Portland cement (Confirming to IS 12600)

5. Rapid hardening Portland cement (Confirming to IS 8041)

Note :(1) Use of Portland Pozzolana Cement may be permitted only in Plain Concrete members.

Cement shall be free flowing and free of lumps. It shall be supplied in the manufacturer's sealed unbroken bags or in bulk. Bagged cement shall be transported in vehicles provided with effective means of ensuring that it is protected from the weather.

Bulk cement shall be transported in vehicles or in containers built and equipped for the purpose.

Cement in bags shall be stored in a suitable weatherproof structure of which the interior shall be dry and well ventilated at all times. The floor shall be raised above the surrounding ground level not less than 30 cm and shall be so constructed that no moisture rises through it.

Each delivery of cement in bags shall be stacked together in one place. The bags shall be closely stacked so as to reduce air circulation with min gap of 500 mm from outside wall. If pallets are used, they shall be constructed so that bags are not damaged during handling and stacking. Stack of cement bags shall not exceed 8 bags in height. Different types of cement in bags shall be clearly distinguished by visible marking and shall be stored in separate stacks.

Cement form broken bags shall not be used in the works. Cement in bags shall be used in the order in which it is delivered.

Bulk cement shall be stored in weather proof silos which shall bear a clear indication of the type of cement contained in them. Different types of cement shall not be mixed in the same silo.

The Contractor shall provide sufficient storage capacity on site to ensure that his anticipated programme of work is not interrupted due to lack of cement.

Cement which has become hardened or lumpy or fails to comply with the Specification in any way shall be removed from the Site.

All cement for any one structure shall be from the same source as far as possible.

All cement used in the works shall be tested by the manufacturer. The manufacturer shall provide the results of tests as given in Table 1.1 for each supply and for the last six months of his production.

Each set of tests carried out by the manufacturer on samples taken from cement which is subsequently to site shall relate to no more than one day's output of each cement plant.

Cement which is stored on site for longer than one month shall be tested in such laboratory for every 200 tons or part thereof and at monthly intervals thereafter.

The Contractor shall keep full records of all data relevant to the manufacture, delivery, testing and the cement used in the works and shall provide the Engineer with two copies thereof.

Cement type selection and its content :

i. High strength Ordinary Portland Cement 53 Grade, conforming to IS: 12269 or 43 Grade conforming to IS: 8112, capable of achieving the required design concrete Strength and Durability, shall be used.

ii. Cement shall be obtained from approved Manufacturers only.

iii. Cement content in the Concrete Mix:

- for PRESTRESSED CONCRETE: not less than 400 kg/m^3 AND not more than 500 kg/m^3.
- for REINFORCED CONCRETE: not less than 350 kg/m^3 AND not more than 450 kg/m^3.

Table 1.1. Physical Requirement for OPC

SN	Characteristic	Requirement			Method of Testing
		OPC 33	OPC43	OPC53	
i.	Fineness, Sqm/Kg (Min.)	225	225	225	IS 4031-Part 2
ii.	Soundness (Le-Chatelier Method),mm, (Max.)	10	10	10	IS 4031-Part 3
iii.	Setting time: Initial,min,(Min.) Final,min,(Min.)	 30 600	 30 600	 30 600	IS 4031-Part 5
iv.	Compressive Strength,MPa a)72±1 hr,Min b)168±2 hr,Min c)672±4 hr,Min Max.	 16 22 33 48	 23 33 43 58	 27 37 53 -	IS 4031-Part 6

Note : 1. In the event of cement failing to comply the soundness specified in the above table, further tests in respect of each failure shall be made as described in IS 4031 – Part 3, from another portion of the same sample after aeration. The aeration shall be done by spreading out the sample to a depth of 75mm at a relative humadity of 50-80# for a total period of 7 days. The expansion of cement so aerated shall not more than 5mm.

2. If cement exhibits false set, the ratio of final penetration measured after 5 min. of completion of mixing period to the initial penetration measured exactly after 20 sec. of completion of the mixing period, expressed as %, shall be not less than 50. In the event of cement exhibiting false set, the initial and final setting time of cement when tested by the method described in IS 4031-Part 5 after breaking the false set, shall confirm to the value given in the above table.

3. The samples shall be taken within 3 weeks of the delivery and all the tests shall be commenced within 1 week of sample.

4. Cement may be rejected, if it dose not comply with any of the requirements of above table.

C1.2 Aggregate

Aggregates are inert granular materials such as sand, gravel or crushed stone. These are either naturally occurring or obtained by crushing rocks, boulder or stone. Depending on the dimensions of the granules, aggregates are classified as fine (sand) and course (gravel or crushed stone).

Coarse aggregates

Coarse aggregates are particles greater than 4.75mm, but generally range between 10mm to 40mm in diameter. These are either uncrushed natural gravel or crushed stone produced from crusher plant or combination of natural gravel and crushed stone.

Fine aggregates

Fine aggregate are basically sands from the land or the river source. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 4.75mm sieve.

Table 1.2 Limits of deleterious materials

SN	Deleterious Substance	Fine Aggregate % by Wt., max.		Fine Aggregate % by Wt., max.		Method of Test
		Uncrushed	Crushed	Uncrushed	Crushed	
i.	Coal and lignite	1	1	1	1	IS 2386 part II
ii.	Clay Lumps	1	1	1	1	IS 2386 part II
iii.	Material finer than 0.075mm IS Sieve	3	15	3	3	IS 2386 part I
iv.	Soft Fragments	-	-	3	-	IS 2386 part II
v.	Shale	1	-	-	-	IS 2386 part II
vi.	Total % of all Deleterious material (i. to v)	5	2	5	5	

Sampling : As per IS 2430

Table 1.3 Grading Requirement

S.N	IS sieve Designation	Percentage Passing for Single Sized Coarse Aggregate of nominal Size				Percentage Passing for Graded Coarse Aggregate of Nominal Size			Fine aggregate
		40 mm	20 mm	12.5mm	10 mm	40 mm	20 mm	12.5mm	4.75mm down
i)	80 mm					100			
ii)	63 mm	100							
iii)	40 mm	85-100	100			90-100	100		
iv)	20 mm	0-20	85-100			30-70	90-100	100	
v)	16 mm			100					
vi)	12.5 mm			85-100	100			90-100	
vii)	10 mm	0-5	0-20	0-45	85-100	10-35	25-35	40-85	100
viii)	4.75 mm		0-5	0-10		0-5	0-10	0-10	90-100
ix)	2.36 mm								75-100
x)	1.18 mm								55-90
xi)	0.60 mm								35-59
xii)	0.30 mm								8-30
xiii)	0.15 mm								0-10

Table 1.3 Physical Characteristic Requirement confirming IS: 383 (2016)

SN	Physical Characteristic	Permissible Values	Method of Testing
i.	Toughness/Strength : Aggregate Abrasion Value/LAA Aggregate Crushing Value Aggregate Impact Value	<30%(for wearing course) <35% for Concrete grade at/above M30 <45% for Concrete grade less than M30 <30% In case the aggregate crushing value exceeds 30 percent then the test for 'ten percent fines' should be conducted and the minimum load for the ten percent fines should be 50 kN <30% (for wearing course)	IS 2386 Part 4

SN	Physical Characteristic	Permissible Values	Method of Testing
		<35% for Concrete grade at/above M30 <45% for Concrete grade less than M30	
ii.	Durability: Soundness either: Sodium Sulphate or Magnesium Sulphate	10%(FA) 12%(CA) 15%(FA) 18%(CA)	IS 2386 Part 5
iii.	Flakiness Index	<15% for Concrete grade at/above M30 <25% for Concrete grade less than M30	IS 2386 Part 1
iv.	Water Absorption	<2%	IS 2386 Part 3

For Bridge Components

i. Maximum size of Coarse Aggregate used shall be 20mm.

ii. In zones of congestion in the structural sections like End Block of PSC Girder, if absolutely necessary, 12 mm. down sized Coarse Aggregates may be used (but the Mix shall then be re-designed to suit).

Acceptance Testing

The Contractor shall deliver to the Engineer samples containing *not less than 50 kg of any aggregate* which he/she proposed to use in the works and shall supply such further samples as the Engineer may require. All the materials shall be accepted if the results of not less than three consecutive sets of test.

Compliance Testing/Process Control Testing

The Contractor shall carry out routine testing of aggregate for compliance with the quality requirement during the period that concrete is being produced for the works. Frequency test shall be as follows:

Table 1.4 Frequency of Aggregate Test

Aggregate Type	Frequency
Fine aggregate	1 set (3 nos) test for each 10 to 50 cum and additional test for each 50 cum of concrete
Coarse Aggregate	1 set (3 nos) test for each 25 to 125 cum and additional test for each 125 cum

If the aggregate from any source is variable, the frequency of testing shall be increased as instructed by the Engineer.

Delivery and Storage of Aggregate

Aggregate shall be delivered to site in clean and suitable vehicles. Different type or sizes of aggregate shall not be delivered in one vehicle.

Each type or size of aggregate shall be stored in a separate bin or compartment having a base such that the contamination of aggregate is prevented. Dividing walls between bins shall be substantial and continuous so that no mixing of types or sizes occurs.

The storage of aggregate shall be arranged in such a way that drying out in hot weather is prevented in order to avoid fluctuations in water content. Storage of fine aggregates shall be arranged in such way that they can drain sufficiently before use in order to prevent fluctuations in water content of the concrete.

C1.3 Water

Water for concrete and for its curing shall be of potable quality and presence of any salts, sugars and pollutants like chlorides, sulphates, algae, etc., shall be well within the limits specified in table 1.5.

The average 28 days compressive strength of at least three 150mm concrete cubes prepared with water proposed to be used shall not be less than 90% of the average stenght of 3 similar concrete cubes prepared with distilled water.

Table 1.5 Water Quality Requirement

SN	Impurities	Permissible limits, Max.	Method of Testing
i.	Organic	200 mg/l	IS 3025 Part 18
ii.	Inorganic	3000 mg/l	IS 3025 Part 18
iii.	Sulphate (SO_3)	400 mg/l	IS 3025 Part 24
iv.	Chloride (Cl)	500 mg/l	IS 3025 Part 32
v.	Suspended Matter	2000 mg/l	IS 3025 Part 17
vi.	PH Value	Not < 6 <5ml of 0.02 N NaOH required to neutralize 100ml water sample (Phenolphthalein as indicator)	IS 3025 Part 22

C1.4 Additives

To suitably improve workability and increase initial setting time of concrete and cement grout, Admixtures conforming to IS: 9103, and ASTM C–494 Type F water-reducing, high range admixtures, shall be permitted in appropriate dosages, subject to their satisfactory proven use.

Contractor shall submit to the Engineer full details of the admixture he proposes to use and the manner in which he/she proposes to add it in the mix. The information provided shall include:

(i) The typical dosage, the method of dosing, and the detrimental effects of an excess or deficiency in the dosage.

(ii) The chemical names of the main active ingredients in the admixture.

(iii) Whether or not the admixture contains chlorides, and if so the chloride ion content expressed as a percentage by weight of admixture.

(iv) Whether the admixture leads to the entrainment of air when used at the manufacturer's recommended dosage, and if so the extent to which it does so.

(v) Details of previous uses of the admixture in Nepal.

The workability, compressive strength and the slump loss of concrete with and without the use of admixtures shall be established during the trial mixes before use of admixtures.

Types of Admixtures:

a) Accelerating Admixture

b) Retarding Admixture

c) Water Reducing Admixture

d) Air-entraining Admixture

e) Super-plasticizing Admixture

f) Anti-washout Admixture

Compatibility of the admixtures with the cement and any other pozzolan or hydraulic addition shall be ensured by for avoiding the following problems.

(i) Requirement of large dosage of superplasticizer for achieving the desired workability.

(ii) Excessive retardation of setting

(iii) Excessive entrainment of large bubbles

(iv) Unusually rapid stiffening of concrete

(v) Rapid loss of slump

(vi) Excessive segregation and bleeding

Table 1.6 Physical Requirement for Additives

S.N.	Requirements	Accele-rating Admixture	Retarding Admixture	Water Reducing Admixture	Air-Entraining Admixture	Superplasticizing Admixture (for Water-Reduced Concrete Mix)	
1	2	3	4	5	6	7	8
i)	Water content, percent of control sample, Max	_	_	95		80	80
ii)	Slump	_	_	_	_	Not more than 15mm below that of the control mix concrete	
iii)	Time of setting, allowable deviation from control sample hours:						
	Initial						
	Max	-3	+3	± 1	_	_	+4
	Min	-1	+1	_	_	+1.5	+1
	Final						
	Max	-2	+3	± 1	_	+1.5	± 3
	Min	-1	+1	_	_	_	_
iv)	Compressive strenght, percent of control sample, Min						
	1 day	_	_	_	_	140	_
	3 days	125	90	110	90	125	125
	7 days	100	90	110	90	125	125
	28 days	100	90	100	90	100	100
	6 months	90	90	100	90	100	100
	1 year	90	90	100	90	100	100
v)	Flexural Strength percent of control sample, Min						
	3 days	110	90	100	90	110	110
	7 days	100	90	100	90	100	100
	28 days	90	90	100	90	100	100
vi)	Length change, perent of increase over control sample, Max						
	28 days	0.010	0.010	0.010	0.010	0.010	0.010
	6 months	0.010	0.010	0.010	0.010	0.010	0.010
	1 year	0.010	0.010	0.010	0.010	0.010	0.010
vii	Bleeding, percent increase over control sample, Max	5	5	5	5	5	5
viii	Loss of workability	_	_	_	_	At 45 min the slump shall be not less than that of control mix concrete at 15 min	At 2 h, the slump shall be not less than that of control mix concrete at 15 min
ix	Air content (%) Max, over control	–	–	–	–	1.5	1.5

Anti-washout admixture

Anti-washout admixture (also, viscosity improving admixture) of concrete for underwater concreting is produced as a viscosity modifying admixture to enhance the rheological properties of cement paste. It mainly composed of microbial polysaccharides for example gum or polysaccharide derivatives for instance hydroxyethyl cellulose and hydroxypropyl methyl cellulose.

It is demonstrated that, the Anti-washout admixture is substantially influential in enhancing the cohesiveness of concrete that is poured underwater and in danger of washout or segregation due to surrounding water.

The amount of Antiwashout admixture which is required to be added to concrete mixture is specified based on required flowability, depth of the underwater placement, horizontal flow distance, water to cementitious materials ratio and the quantity of cementitious materials to be utilized.

Figure 1.1 Without or With(right) Anti-washout Admixture

Classification of Anti-Washout Concrete Admixtures

It can be divided into the following classes:

Class-A Anti-Washout Admixtures

Water soluble synthetic and natural organic admixture which improve the viscosity of the mixing water. The ranges of this class applied are between 0.2 to 0.5% solid by mass of cement.

Anti-washout admixtures containing cellulose ether, pregelatinized starches, carageenans, polyacrylamides, polyethylene oxides, alignates, carboxyvinyl polymers, and polyvinyl alcohol are examples of the Class A.

Class-B Anti-Washout Concrete Admixtures

It is organic flocculants which can dissolve in water and absorbed by cement particles, and consequently it enhances viscosity by increasing attractions between cement particles.

The dosage is between 0.01 and 0.10% solid by mass of cement. Examples of Class B are Styrene copolymers with carboxyl groups, synthetic polyelectrolytes, and natural gums.

Class-C Anti-Washout Concrete Admixtures

It is emulsions of different organic material that not only improve attractions between particles but also provide extremely fine particles in the cement paste. The amount of Class C anti-washout admixture that is usually added it ranges from 0.10 to 1.50% solid by mass of cement.

Paraffin-wax emulsions that are unstable in the aqueous cement phase, acrylic emulsions, and aqueous clay dispersions are examples of Class C anti-washout admixture.

Class-D Anti-Washout Concrete Admixtures

These are large surface area inorganic materials which rise mixture capacity to retain water. The dosage range employed is 1-25% solid by mass of cement. Examples include bentonites, pyrogenic silicas, silica fume, milled asbestos, and other fibrous materials.

Class-E Anti-Washout Concrete Admixtures

It is inorganic materials which provide extra fine particles to the mortar pastes. The mount of the Class E that is added is between 1 to 25% solid by mass of cement.

Fly ash, hydrated lime, kaolin, diatomaceous earth, other raw or calcined pozzolanic materials, and various rock dusts are examples of Class E Antiwashout admixture.

Compliance

For compliance with this specification, test concrete in which admixture is used for conformance with the in Table 1.7.

Table 1.7. Physical Requirements[A]

Requirement	Limits
Slump Loss, % of control at 30 minutes	50
Strength, min % of Control	
3 days	90
7 days	90
28 days	90

[A]The values in the table include allowance for normal variation in test results. The object of the 90% strength requirementis to require a level of performance comparable to that of the reference concrete. The effects of antiwashout admixture on time of setting is not a requirement, but the user should be aware that some brands of admixtures retard this property. If this is critical to the work that this be controlled, then this needs to be controlled by creating a job-specific requirement.

Note : Effect of Superplasticizers on the Properties of Hardened Concrete

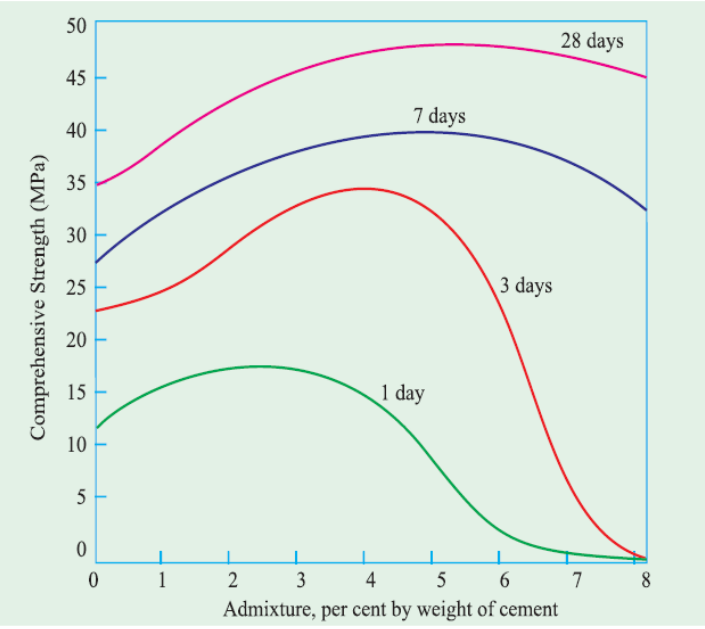


Figure 1.2 : Effect of Admixture Dose

Plasticizers or superplasticizers do not participate in any chemical reactions with cement or blending material used in concrete. Their actions are only physical in fluidizing the mix, made even with low water content. Their fludifying action lasts only as long as the mix is in plastic condition. Once the effect of adsorbed layer is lost, the hydration process continues normally. *It can be categorically said that the use of right quality of plasticizers or superplasticizers when used in usual small dose (say up to 3% by weight of cement) there is no bad effect on the properties of hardened concrete*. Only in case

of bad quality lignosulphonate based plasticizer is used, it may result in air-entrainment, which reduces the strength of concrete. Since plasticizers and superplasticizers improve the workability, compactability and facilitate reduction in w/c ratio, and thereby increase the strength of concrete, it contributes to the alround improvement in the properties of hardened concrete.

As a matter of fact, it is the use of superplasticizers, which is a pragmatic step to improve alround properties of hardened concrete. The use of superplasticizer has become an unavoidable material in the modern High Performance Concrete (HPC).

It has been mentioned earlier that all plasticizers and superplasticizers exhibit certain retarding properties. These retarding properties do not make significant difference when the dosage is normal (say upto 3%). The strength parameter is not reduced beyond one day. Bu when plasticizers are used in higher dose, the strength development will be greatly affected in respect of one day and even three days strength. However, seven day strength and beyond, there will not be any reduction in strength. The typical strength development of lignosulphonate type water reducing admixture is shown in Fig. figure 1.2

At the same w/c ratio, naphthalene based or melamine based superplasticizers do not considerably modify the drying shrinkage of concrete. At the same consistency, they sometime reduce drying shrinkage appreciably.

The total creep is higher when concrete contains naphthalene sulphonates, at high w/c ratio (0.64). On the contrary, when w/c ratio is low, the difference in creep between samples with and without plasticizers are insignificant.

Impermeability plays a primary role on the durability of concrete and since this depends on w/c ratio, superplasticizers should exert a favourable effect. Superplasticizers, owing to the reduction in w/c ratio, reduce the penetration of chlorides and sulphate into the concrete and, therefore, improve their resistance to the de-icing effect of salt or sea water. For the same reason, the resistance to sulphate attack is also improved.

Suffice it to say that the use of plasticizer or superplasticizer, could lead to the reduction in w/c ratio, without affecting the workability and thereby concrete becomes stronger. Therefore, it will contribute to the alround improvement of hardened properties of concrete.

C1.5 Reinforcement

Fe 415, Fe 500 and above deformed bar with characteristic strength f_y 415 MPa,500 MPa and above respectively, where characteristic strength f_y shall be taken as the minimum value of 0.2% proof stress or yield stress.

Any reinforcement which is likely to remain in storage for a long period shall be protected from the weather so as to avoid corrosion and pitting. The reinforcement bar bent and fixed in position shall be free from rust orscales, chloride contamination and other corrosion products. Where cleaning of corroded, effective method of cleaning such as sand blasting shall be adopted.

All reinforcement shall be delivered to site either in straight lengths or cut and bent. No reinforcement shall be accepted in long lengths which have been transported bent over double.

Reinforcement shall be stored at least 150 mm above the ground on clean area free of mud and dirt and sorted out according to category, quality and diameter.

Table 1.8 Chemical Composition (IS 1786:2008)

Constituent	*Percent, Maximum*								
	Fe 415	Fe 415D	Fe 415S	Fe 500	Fe 500D	Fe 500S	Fe 550	Fe 550D	Fe 600
Carbon	0.30	0.25	0.25	0.30	0.25	0.25	0.30	0.25	0.30
Sulphur	0.060	0.045	0.045	0.055	0.040	0.040	0.055	0.040	0.040
Phosphorus	0.060	0.045	0.045	0.055	0.040	0.040	0.050	0.040	0.040
Sulphur and phosphorus	0.110	0.085	0.085	0.105	0.075	0.075	0.100	0.075	0.075

For guaranteed weldability, the Carbon Equivalent should be less than 0.42.

Table 1.9 Mechanical Properties of High Strength Deformed Bars (IS 1786:2008)

S.N.	Property	Fe 415	Fe 415D	Fe 415S	Fe 500	Fe 500D	Fe 500S	Fe 550	Fe 550D	Fe 600
1	2	3	4	5	6	7	8	9	10	11
i)	0.2 percent proof stress/ yield stress, Min, N/mm^2	415	415	415	500.0	500.0	500.0	550.0	550.0	600.0
ii)	0.2 percent proof stress/ yield stress, Max, N/mm^2	–	–	540.0	–	–	625.0	–	–	–
iii)	TS/YS ratio[1)], N/mm2	≥ 1.10, but TS not less than 485.0 N/mm^2	≥ 1.12, but TS not less than 500.0 N/mm^2	1.25	≥ 1.08, but TS not less than 548.0 N/mm^2	≥ 1.10, but TS not less than 565.0 N/mm^2	1.25	≥ 1.06, but TS not less than 585.0 N/mm^2	≥ 1.08, but TS not less than 600.0 N/mm^2	≥ 1.06, but TS not less than 660N/mm^2
iv)	Elongation, percent, min. on gauge length 5.65√A, where A is the cross-sectional area of the test piece	14.5	18.0	20.0	12.0	16.0	18.0	10.0	14.5	10.0
v)	Total elongation at maximum force, percent, Min, on gauge length 5.65√A, where A is the cross-sectional area of the test piece [2)]	–	5	10	–	5	8	–	5	–

1) TS/YS ratio refers to ratio of tensile strnght to the 0.2 percent proof stress or yield stress of the test piece

2) Test, wherever specified by the purchaser.

Table 1.10 Nominal Cross-section Area and Mass (IS 1786:2008)

SN	Nominal Dia.,mm	Cross-Section Area,mm2	Mass per meter
i)	*4*	12.6	0.099
ii)	5	19.6	0.154
iii)	6	28.3	0.222
iv)	8	50.3	0.395
v)	10	78.6	0.617
vi)	12	113.1	0.888
vii)	16	201.2	1.58
viii)	20	314.3	2.47
ix)	25	491.1	3.85
x)	28	615.8	4.83
xi)	32	804.6	6.31
xii)	36	1018.3	7.99
xiii)	40	1257.2	9.86
xiv)	45	1591.1	12.49
xv)	50	1964.4	15.42
Tolerance			
SN	**Nominal Size,mm**	**Tolerance on Nominal Mass, %**	
i.	Upto 10mm	-8	
ii.	10mm to 16mm	-6	
iii.	Over 16mm	-4	

Testing frequency :

- For 1-25 bundles lot 3 rod (one from each bundle) from randomly selected 3 bundles.
- For 26-65 bundles lot 4 rod (one from each bundle) from randomly selected 4 bundles
- For 66-180 bundles lot 5 rod (one from each bundle) from randomly selected 5 bundles
- For 181- 300 bundles lot 7 rod (one from each bundle) from randomly selected 7 bundles
- For > 300 bundles lot 10 rod (one from each bundle) from randomly selected 10 bundles

C1.6 Prestresssing Steel

The prestressing steel shall be IS:14268:1995" Uncoated stress relieved low relaxation seven ply strand for prestressed concrete" as per Table1.11.

Table 1.11 Physical Properties of Prestressing Strands

Class	Nominal Dia. of Strand, mm	Nominal Area of Strand,mm^2	Nominal Mass of Strand, Kg/m	Min. Breaking Strength of Strand,KN	0.2% Proof Load(90% of Breaking Strength),KN
I	9.5	51.6 ± 0.40	0.405	89.0	80.1
	11.1	69.7 ± 0.40	0.548	120.1	108.1
	12.7	92.9 ± 0.40	0.730	160.1	144.1
	15.2	139.4 ± 0.40	1.094	240.2	216.2
II	9.5	54.8 + 0.66 / -0.15	0.432	102.3	92.1
	11.1	74.2 + 0.66 / -0.15	0.582	137.9	124.1
	12.7	98.7 + 0.66 / -0.15	0.775	183.7	165.3
	15.2	140.0 + 0.66 / -0.15	1.102	260.7	234.6
Minimum % elongation = 3.5% of minimum gauge length of 600mm					
Relaxation loss % = 2.5 % max., at 70% of specified MBS after 1000hr or, 1.8 % max., at 70% of specified MBS after 100hr.					

CLASS : The strand shall be either Class I or Class II depending on the breaking strength of the strand given in Table 1.11.

Strand : The seven wires strand shall have a centre wire at least 1.5 % greater in diameter than the surrounding wires enclosed tightly by six helically placed outer wires with a uniform length of lay of at least 12 times but not more than 16 times of the nominal diameter of the strand. The wire in the strand shall be so formed that they shall not fly out of position when the strand is cut without seizing.

Data in respect of modulus of elasticity, relaxation loss at 1000 hrs., minimum ultimate tensile strength, stress-strain curve etc. shal1 necessarily be obtained from manufacturers.

Test samples of sufficient length to permit the tests for breaking load, 0.2 percent proof load and elongation shall be cut from one end of a coil selected at random from a group of every 5 numbers of coils. The test piece shall not be detached from the coil or length of strand, except in' the presence of purchaser or his authored representative. Should 10 percent or more of the selected coils fail to fulfil the requirement of this standard, the parcel from which they were taken shall be deemed not to comply with this standard.

Prestressing steel shall be subjected to acceptance tests prior to actual use on the works (guidance may be taken from BS:4447). The modulus of elasticity value, as per acceptance tests, shall conform to the design value which shall be within a range not more than 5 per cent between the maximum and minimum.

C1.7 Sheathing Ducts

The sheathing ducts shall be either in mild steel or in HDPE. They shall be in as long lengths as practical from handling and transportation considerations without getting damaged.

C1.7.1 MS sheathing ducts

Unless otherwise specified, the material shah be Cold Rolled Cold Annealed (CRCA) Mild Steel intended for mechanical treatment and surface refining but not for quench hardening or tempering. The material shall be clean and free from rust and normally of bright metal finish.

The thickness of metal sheathing shall not be less than 0.3 mm, 0.4 mm and 0.5 mm for sheathing ducts having internal diameter upto 50 mm, 75 mm and 90 mm respectively. For bigger diameter of ducts, thickness of sheathing shall be based on recommendations of prestressing system supplier.

Table1.12 Details of Ducts

No. of Strands/Dia. in mm	Diameter of Duct in mm		Thickness of MS Sheathing in mm	Thickness of HDPE duct in mm
	Metallic	HDPE		
6/13	50	50	0.3	2.0
122/13	75	75	0.4	2.5
19/13	85	85	0.4	2.5
27/13	100	100	0.5	3.0
12/15	85	85	0.4	2.5
19/15	100	100	0.5	3.0
27/15	125	130	0.5	4.0

The sheathing shall conform to the requirements specified *below* and a test certificate shall be furnished by the manufacturer.

TESTS ON SHEATHING DUCTS (Ref. IRC 18:2000)

All tests specified below shall be carried out on the same sample in the order given below. At least 3 samples for one lot of supply (not exceeding 7000 metre length) shall be tested.

Workability Test : A test sample 1100 mm long is soldered to a fixed base plate with a soft solder (Figure1.2). The sample is then bent to a radius of 1800 mm alternately on either side to complete 3 cycles. Thereafter, the sealing joints will be visually inspected to verify that no failure or opening has taken place.

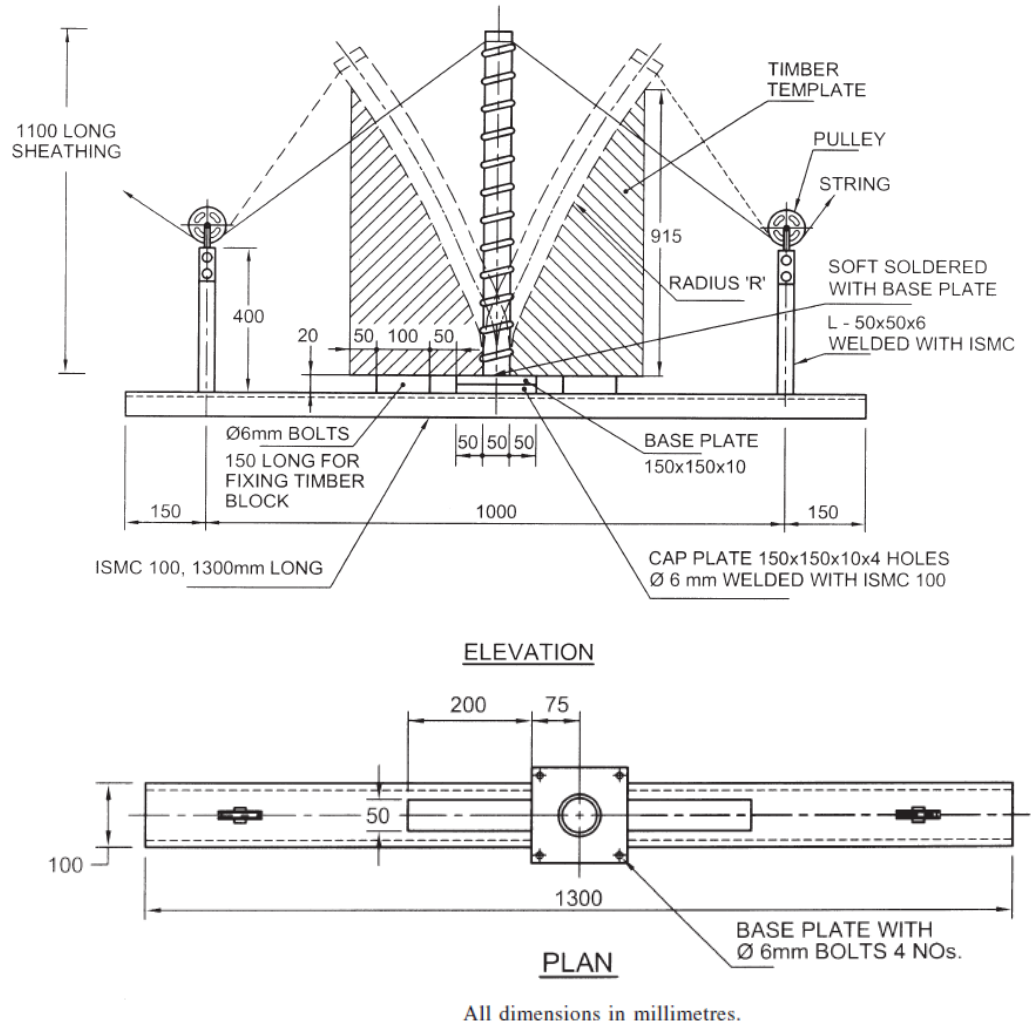


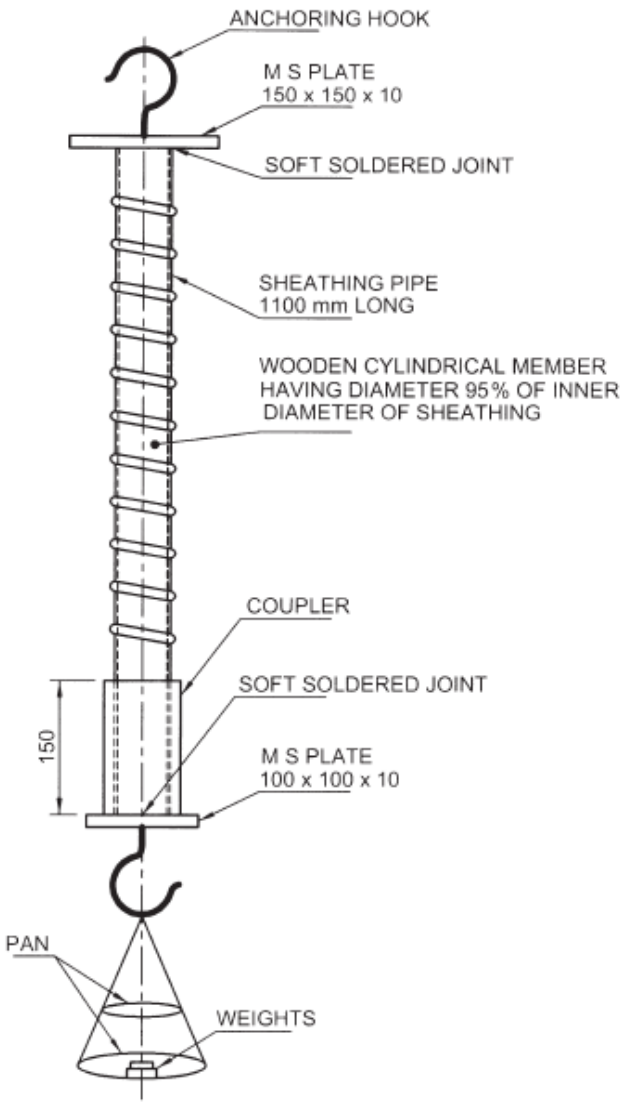
Figure 1.2 Workability Test

Transverse Load Rating Test : The test ensures that stiffness of the sheathing is sufficient to prevent permanent distortion during site handling. The sample is considered acceptable if the permanent deformation is less than 5 per cent.

Tension Load Test : The test specimen is subjected to a tensile load. The hollow core is filled with a wooden circular piece having a diameter of 95 per cent of the inner dia of the sample to ensure circular profile during test loading, Figure 1.3

Diameter of Sheath mm	*Load* N
25 to 35	250
More than 35 up to 45	400
More than 45 up to 55	500
More than 55 up to 65	600
More than 65 up to 75	700
More than 75 up to 85	800
More than 85 up to 90	1 000

A coupler is screwed on and the sample loaded in increments, till specified load. If no deformation of the joints nor slippage of couplers is noticed, the test shall be considered satisfactory:



All dimensions in millimetres.

Figure 1.3 Tension Load Test

Water Loss Test : The sample is acceptable if the water loss does not exceed 1.5 per cent of the volume.

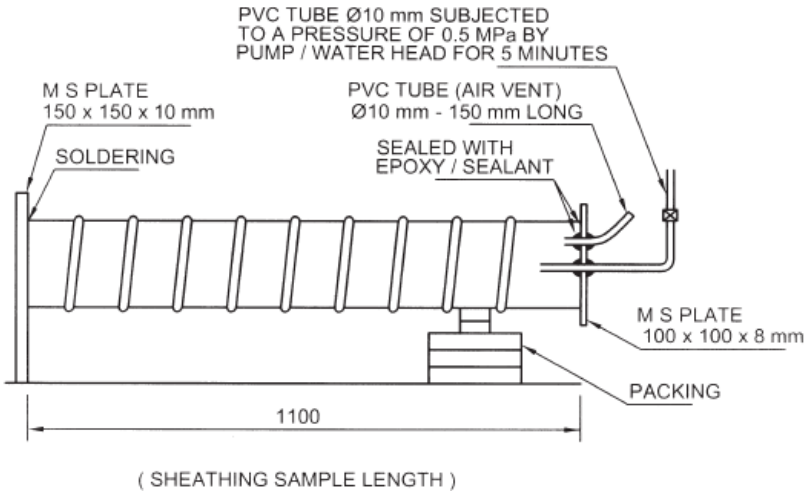


Figure 1.4 Test For Water Loss Study

C1.7.2 Corrugated HDPE sheathing ducts

Unless otherwise specified, the material for the ducts shall be high-density polyethylene with more than 2 per cent carbon black to provide resistance to ultraviolet degradation and shall have the following properties :

Specific Density	:	0.954 g/cm3 at 23°C
Yield Stress	:	18.0 N/mm^2
Tensile Strength	:	21.0 N/mm^2
Shore Hardness D-3 sec. value	:	60
-15 sec. value	:	58
Notch impact strength at 23°C	:	10 kJ/m^2
-40°C	:	4 kJ/m^2
Coefficient of Thermal Expansion for 20°C - 80°C	:	l.50 x 10^{-4} kJ/m^2

The thickness of the wall shall be 2.3 ± 0.3 mm as manufactured and 1.5 mm after loss in the compression test, for duct size upto 160 mm OD.

The sheathing ducts shall be of the spiral corrugated type. The ducts shall be corrugated on both sides. With such an arrangement, long lengths of sheathing ducts may be used with consequent reduction in the number of joints and couplers.

Where sheathing duct joints are unavoidable, such joints shall be made cement slurry tight by the use of corrugated threaded sleeve couplers which can be tightly screwed on to the outer side of the sheathing ducts. A heat-shrink coupler could also be used if suitable.

Typical details of a sleeve coupler is shown in **Figure 1.5.** The length of the coupler should not be less than 150 mm but should be increased upto 200 mm wherever practicable. The joints between the ends of the coupler and the duct shall be sealed with adhesive sealing tape to prevent penetration of cement slurry during concreting. The couplers of adjacent ducts should be staggered wherever practicable. As far as possible, couplers should not be located in curved zones. The corrugated sleeve couplers are being conveniently manufactured using **the** sheath making machine with the next higher size of die set.

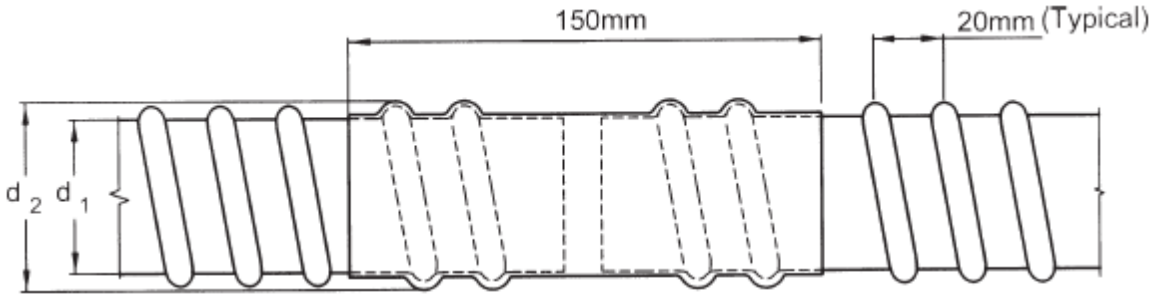


Figure 1.5 Typical details of a sleeve coupler

The heat-shrink coupler **Figure 1.6** is supplied in the form of bandage rolls which can be used for all diameters of sheathing ducts. The bandage is coated on the underside with a heat sensitive adhesive so that after heating the bandage material shrinks on to the sheathing duct and ensures formation of a leak proof joint, without the need for extra taping or support in the form of corrugated sleeve couplers. The heating is effected by means of a soft gas flame.

These ducts shall be joined by adopting any one or more of the following methods, as convenient to suit the individual requirements of the location, subject to the satisfactory pressure tests, before adoption.

- Screwed together with male and female threads.
- Joining with thick walled HDPE shrink couplers with glue. This can also be used for connection with trumpet, etc.
- Welding with electrofusion couplers.

The joints shall be able to withstand an internal pressure of 0.5 bar for 5 minutes.

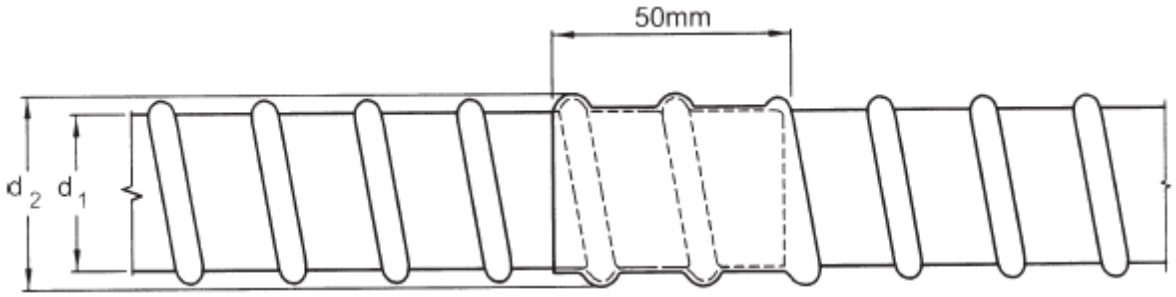


Figure 1.6 Typical details heat-shrink coupler

The ducts shall transmit full tendon strength from the tendon to the surrounding concrete over a length not greater than 40 duct diameters.

TESTS ON CORRUGATED HDPE SHEATHING DUCTS (Ref. IRC 18:2000)

The additional acceptance tests (besides the above mentioned tests for MS Duct) for the prestressing systems employing corrugated HDPE ducts shall cover the following two tests:

Bond Test : To establish satisfactory bond characteristics between the tendon and concrete, in the ultimate condition. The failure capacity of the bond shall be at least equal to the anchorage efficiency or 0.95 of failure capacity of the tendon. At least 3 nos. of tests shall be carried out to ascertain the adequacy of the duct.

Compression Test for The Loss of Wall Thickness : To establish the wear and tear of the sheathing material and the rigidity of the duct surface against indentation and abrasion under concentrated line loading from the tendon constitutents. The residual thickness of the duct shall not be less than 1.5 mm.

C.1.7 Anchorage and Jack

Anchorage of cables in the top deck surface shall not be permitted. All anchorages shall be properly sealed after prestressing and grouting operations. All wires/strands in one cable should be stressed simultaneously by using multi-stressing jack.

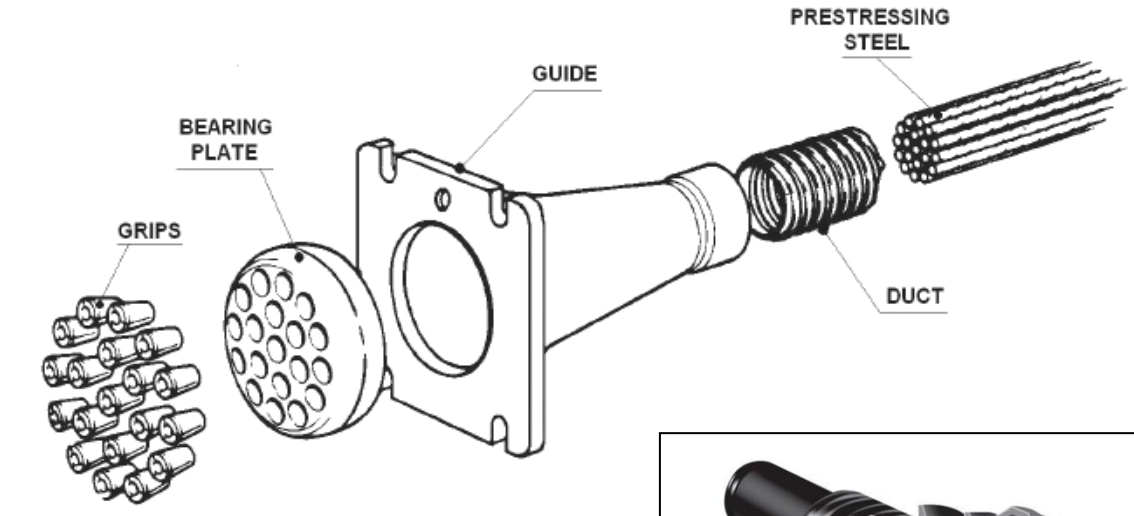
Pre-stressing accessories like jacks, anchorages, wedges, block plates, etc. shall be procured from authorised manufacturers only. Anchorages shall conform to "Recommendations for acceptance and application of pre-stressing systems" published by FIB. The pre-stressing accessories shall be subjected to an acceptance test prior to their actual use on the work. Test certificates from a laboratory fully equipped to carry out the tests shall be furnished to the Engineer. Such test certificates shall not be more than 12 months old at the time of making the proposal for adoption of a particular system for the project.

No damaged anchorages shall be used. Steel parts shall be protected from corrosion at all times. Threaded parts shall be protected by greased wrappings and tapped holes shall be protected by suitable plugs until used. The anchorage components shall be kept free from mortar and loose rust and any other deleterious coating.

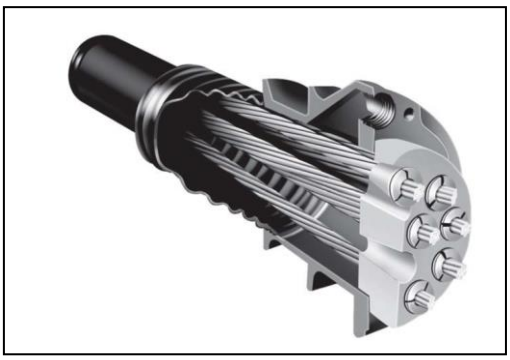
Swages of pre-stressing stand and button-heads of pre-stressing wire, whereprovided shall develop a strength of at least 95 per cent of the specified breaking load of the strand or wire as the case may be. Where swaging/button-heading is envisaged, the Contractor shall furnish details of his methodology and obtain approval of the Engineer, prior to his taking up the work.

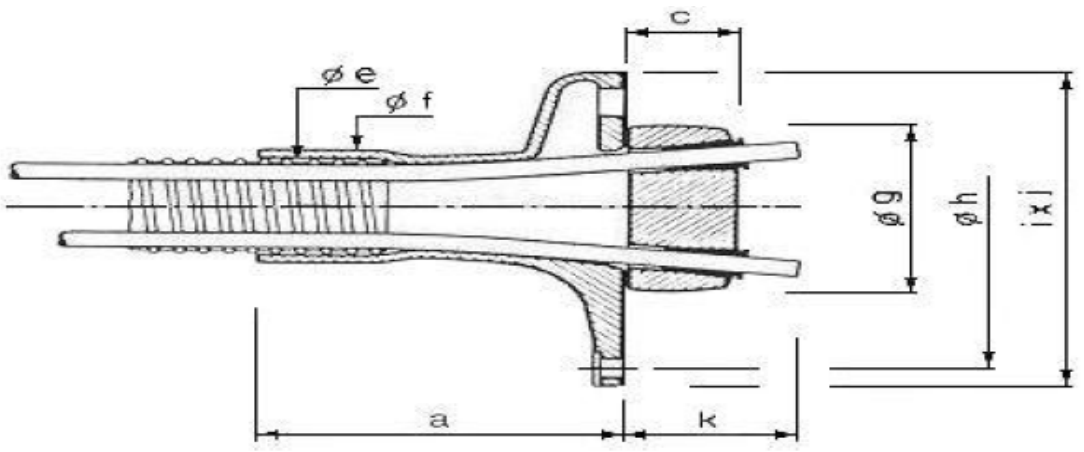
Un- tensioned Steel reinforcements, around anchorages shall conform to the details of pre-stressing system and as shown on the drawing.

Example of Freyssinet post tensioning Anchorage and Jack :K-Type



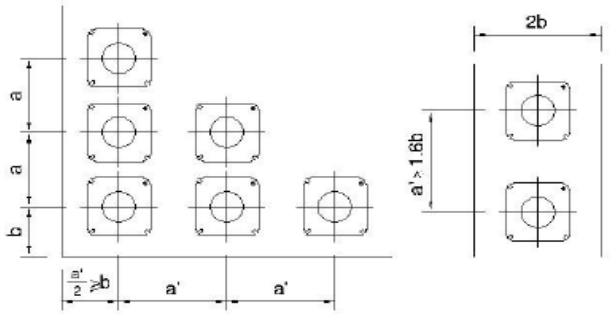
PRESTRESSING ANCHORAGES



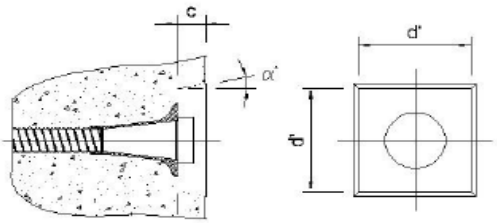


ANCHORAGE TYPE		a	c	e	f	Ø g	Ø h	i	j	k
4 K 13	-	104	45	45	56	85	158	147	147	75
7 K 13	4 K 15	103	50	62	72	120	184	160	160	85
12 K 13	7 K 15	180	55	84	100	140	254	220	235	90
19 K 13	12 K 15	190	60	95	105	160	190	244	244	95
27 K 13	19 K 15	270	70	127	136	200	234	275	293	105
37 K 13	27 K 15	395	78	171	190	252	425	365	365	115
-	37 K 15	467	85	178	206	270	495	425	425	125

ANCHORAGE SPACING & EDGE DISTANCE



ANCHORAGE CENTERS & EDGE CLEARANCES

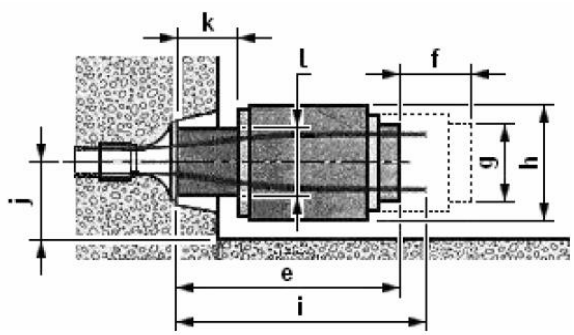


RECESS DIMENSIONS

CONC. CUBE STRENGTH in N/mm.²

ANCHORAGE TYPE	TENDON FORCE kN	BASE SQUARE OF GUIDE mm. X mm.	M30		M35		M40		M45		M50		M55		M60		RECESS DIMENSIONS			
			a	b	a	b	a	b	a	b	a	b	a	b	a	b	c	d'	Jack	α°
4K13	734.8	147 X 147	200	150	185	135	170	120	170	120	170	120	170	120	170	120	100	205	K100	10
4K15	1042.8	160 X 160	220	170	200	150	180	130	180	130	180	130	180	130	180	130	110	220	K100	10
7K13	1285.9		220	170	200	150	180	130	180	130	180	130	180	130	180	130	110	270	K200	10
7K15	1824.9	220 X 220	280	220	260	200	240	180	240	180	240	180	240	180	240	180	120	270	K200	10
12K13	2204.4		280	220	260	200	240	180	240	180	240	180	240	180	240	180	120	300	K350	10
12K15	3128.4	244 X 244	325	250	300	230	290	210	270	185	270	185	270	185	270	185	125	300	K350	10
19K13	3490.3		325	250	300	230	290	210	270	185	270	185	270	185	270	185	125	350	K500	10
19K15	4953.3	275 X 292.5	430	320	400	280	360	250	320	220	320	220	320	220	320	220	125	350	K500	10
27K13	4959.9		430	320	400	280	360	250	320	220	320	220	320	220	320	220	125	500	K700	10
37K13	6796.9	365 X 365	520	400	490	360	460	330	430	300	400	270	400	270	400	270	145	500	K700	30
27K15	7038.9		520	400	490	360	460	330	430	300	400	270	400	270	400	270	145	500	K700	30
37K15	9645.9	425 X 425	580	440	560	400	540	380	500	350	460	320	460	320	460	320	160	600	K1000	30

Jack:



JACK TYPE	ANCHORAGE TYPE		e	f	g	h	i	j	k	l
K 100	4 K 13	-	635	200	185	275	785	190	126	192
	7 K 13	4 K 15	635	200	185	275	785	190	126	192
K 200	7 K 13	4 K 15	720	200	220	350	875	230	228	274
	12 K 13	7 K 15	726	200	220	350	875	230	231	274
K 350	12 K 13	7 K 15	820	250	267	440	970	270	235	324
	19 K 13	12 K 15	820	250	267	440	970	270	230	324
K 500	19 K 13	12 K 15	940	250	267	515	1090	310	230	410
	27 K 13	19 K 15	933	250	267	515	1090	310	222	410
K 700	27 K 13	19 K 15	881	260	350	610	1030	360	142	478
	37 K 13	27 K 15	973	260	350	610	1125	360	104	478
K 1000	37 K 13	27 K 15	1062	220	400	710	1220	410	268	535
	55 K 13	37 K 15	1171	220	400	710	1320	410	279	535

C1.8 Recommended Practice for Storages and Handling of Prestressjng Material

1. All prestressing steel, sheathing, anchorages and sleeves or couplings shall be protected during transportation, handling and storage. For wires upto 5 mm dia, coils of about 1.5 m dia, and for wires above 5 mm dia, coils of about 2 m dia without breaks and joints shall be obtained from the manufacturer.

2. Materials shall be stored in accordance with the provisions contained in relevant specifications. All efforts shall be made to store the materials in proper places so as to prevent their deterioration or intrusion by foreign matter and to ensure their satisfactory quality and fitness for the work. The storage space shall also permit easy inspection, removal and re-storage of the materials.

3. The prestressing steel, sheathing and other accessories shall be stored under cover and protected from rain or damp ground. These shall also be protected from the ambient atmosphere if it is likely to be aggressive. All prestressing steel shall be provided with temporary protection during storage such as coating of soluble oils, silica gel or vapour phase inhibiting materials of proven specifications.

4. Storage at site shall be kept to the absolute minimum. All materials even though stored in approved go downs shall be subjected to acceptance test prior to their immediate use.