Government of Nepal

Ministry of Physical Infrastructure and Transport

Department of Roads

Bridge Branch

Guideline for Quality Management for Concrete Bridges

2018

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Forward

Quality means excellence. It is thus a philosophy rather than a mere attribute. The difference between two objects is judged by their qualities. We set some standards which determine the level of acceptability. Nowadays, application of quality management is not only becoming popular but also mandatory in construction industry.

Just knowing some quality control methods or procedures will not do any good. We must have to adopt and implement the quality control methods and tools that are available to us. The concept and its practice must be tuned in harmoniously.

Quality assurance in construction activities guides the use of correct structural design, specifications and proper materials ensuring that the quality of workmanship by the contractor /sub-contractor is achieved and finally maintaining the structure after construction is complete through periodic assessments for maintenance and repairs. Quality control has to be imposed by the contractor whereas quality assurance is carried out by a separate third party agency engaged by the owner, or owner itslelf.

The contribution of Er. Prabhat Kumar Jha, Senior Divisional Engineer, Bridge Branch for preparation of the "Guideline for Quality Management for Concrete Bridges-2018"; is highly appreciated. The suggestions and experience shared by peer review team ,engineers and experts has been incorporated.

The guideline is compiled version of to Standard Specifications for Road and Bridge Works,2073 of DOR, IRC SP 047:1998 Guidelines on Quality Systems for Road Bridges, and all other relevant IRC and IS codes.

I hope the guideline will lead the Department of Roads to achieve higher level of quality for Concrete Bridge Construction.

Thank You

……………………………
Er. Rabindra Nath Shrestha
Director General
Department of Roads

Acknowledgement

The Quality Management Guideline for Concrete Bridges has been prepared with reference to Standard Specifications for Road and Bridge Works, 2073 of Department of Roads, IRC SP 047:1998 Guidelines on Quality Systems for Road Bridges, and all other relevant IRC and IS codes.

The Guideline has covered the Material Selection, Steel Placement, Concrete Production and Placing and Post-Tensioning Activities including Typical Proformae. It is believed that the Guideline will boost the quality management during the construction of bridges under Department of Roads.

The effort and dedication of Er.Prabhat Kumar Jha, Senior Divisional Engineer of the Bridge Branch; is highly appreciable. Bridge Branch is obliged to the SDE. Shiv Raj Adhakari, SDE. Binod Sapkota and Er. Krishna Bahadur Kuwar, who had done the peer review of the Guideline and had recommended for approval. The support of Mr. Bishnu Shrestha, World Bank Consultant, is also acknowledged by the Department.

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Er. Arjun Jung Thapa
Deputy Director General
Bridge Branch
Department of Roads

Table of Contents

Contents **Page No.**

Chapter 1 Material Selection

C1. Material Requirement

C1.1 Cement

<u>Type of Cement</u>

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	3	15	3	3	IS 2386 part I

	0.075mm IS Sieve					
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	<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	IS 2386 Part 4

SN	Physical Characteristic	Permissible Values	Method of Testing
	Aggregate Impact Value	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) <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

<u>For Bridge Components</u>

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).

<u>Acceptance Testing</u>

The Contractor shall deliver to the Engineer samples containing *<u>not less than 50 kg of any aggregate</u>* 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.

<u>Compliance Testing/Process Control Testing</u>

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

<u>Classification of Anti-Washout Concrete Admixtures</u>

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

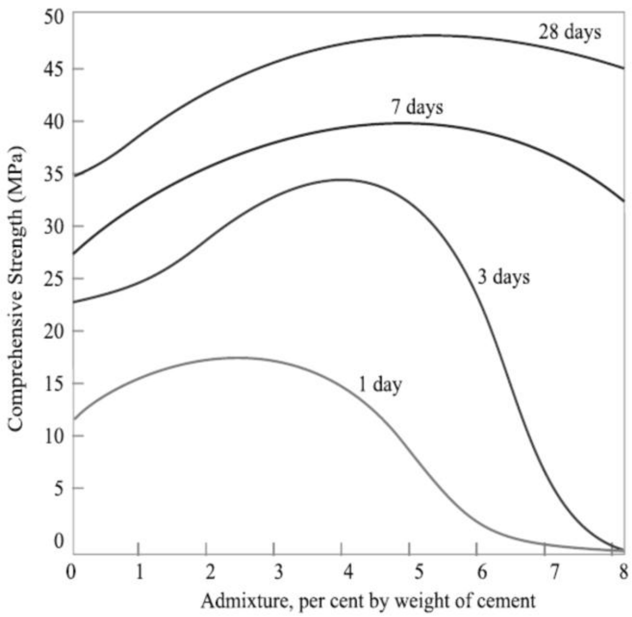


Figure 1.2 : Effect of Admixture Dose

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 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

SN	Nominal Dia.,mm	Cross-Section Area,mm2	Mass per meter
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.

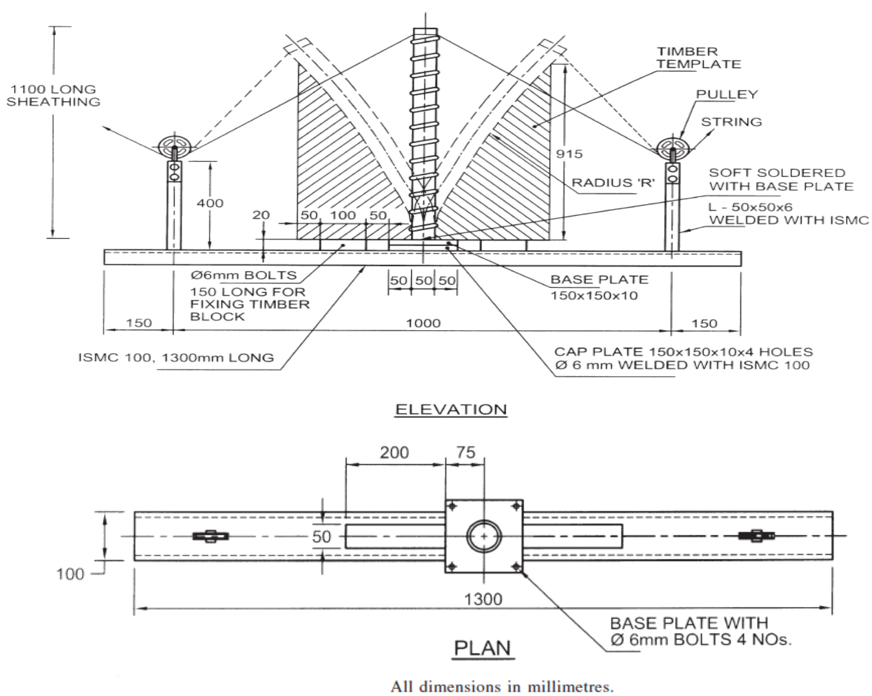


Figure 1.2 Workability Test

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:

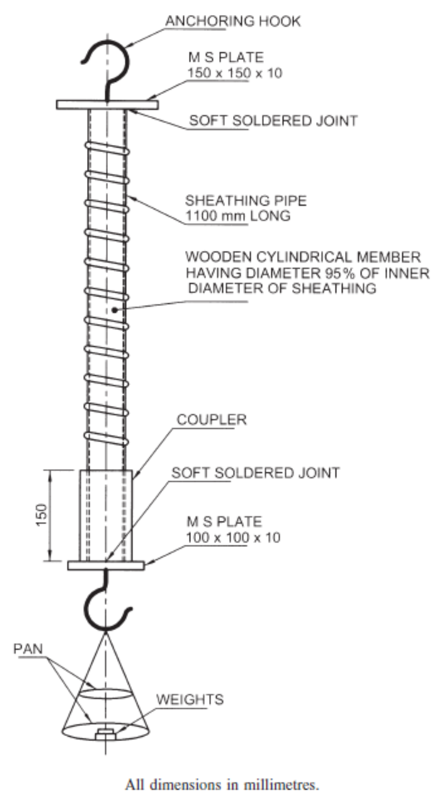


Figure 1.3 Tension Load Test

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

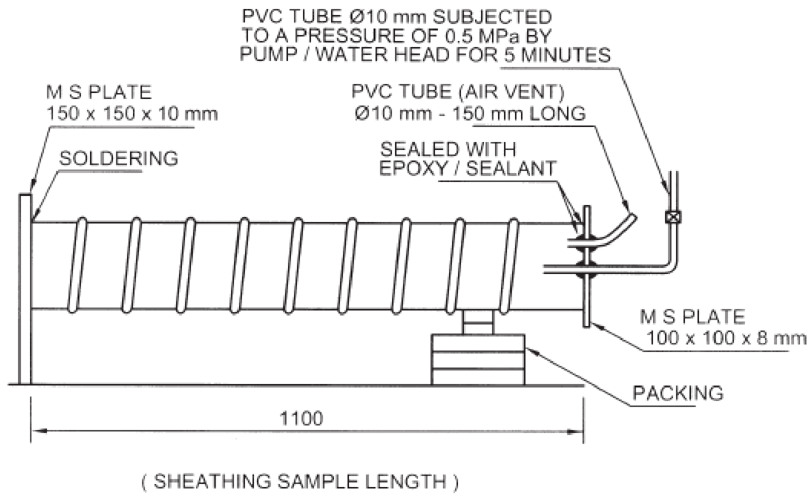


Figure 1.4 Test For Water Loss Study

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.

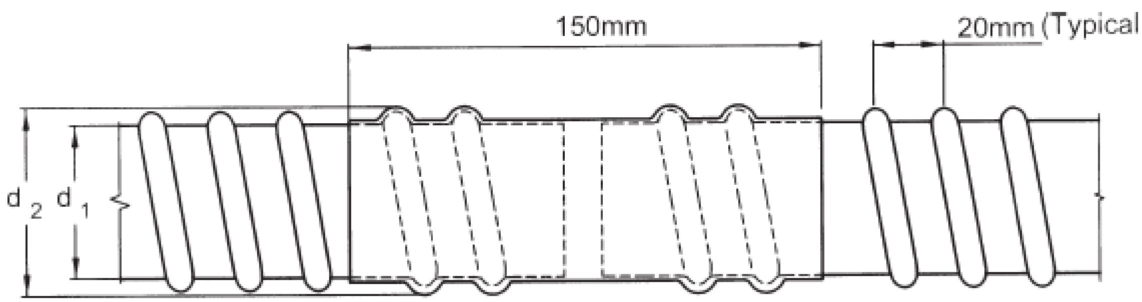


Figure 1.5 Typical details of a sleeve coupler

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.

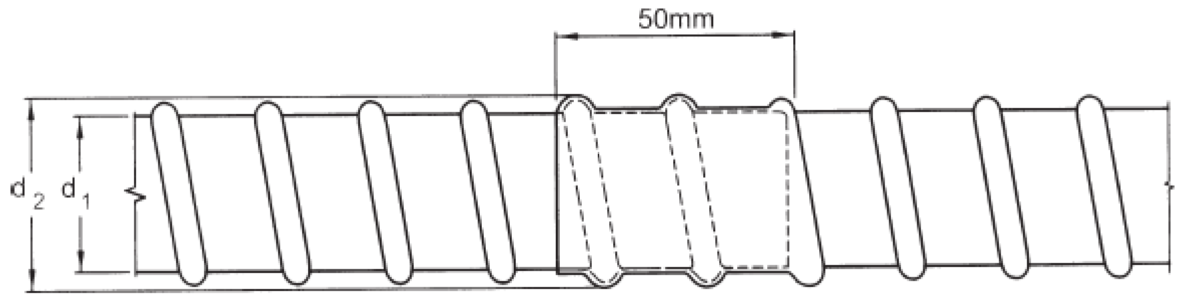


Figure 1.6 Typical details heat-shrink coupler

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.1.8 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.

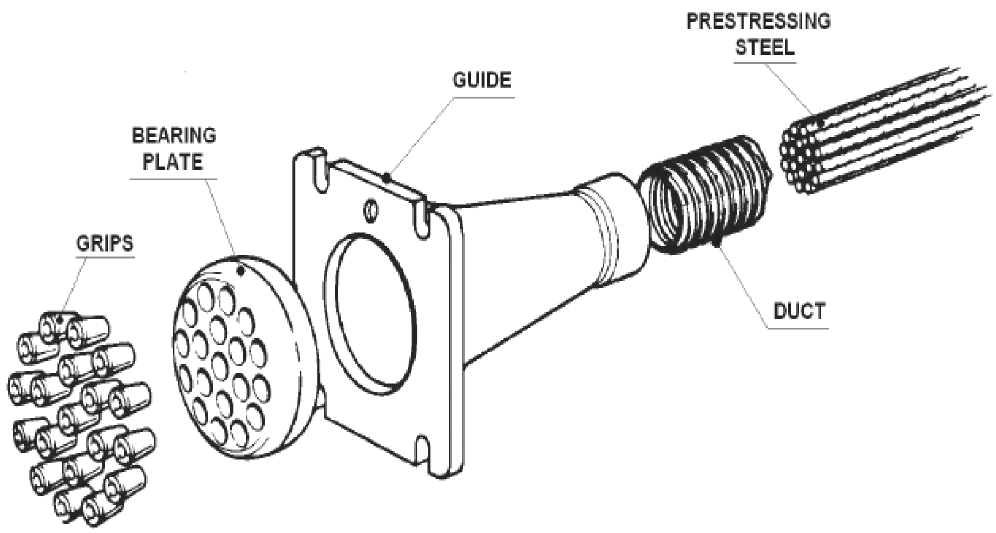
No damaged anchorages shall be used. Steel parts shall be protected from corrosion at all times.

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.

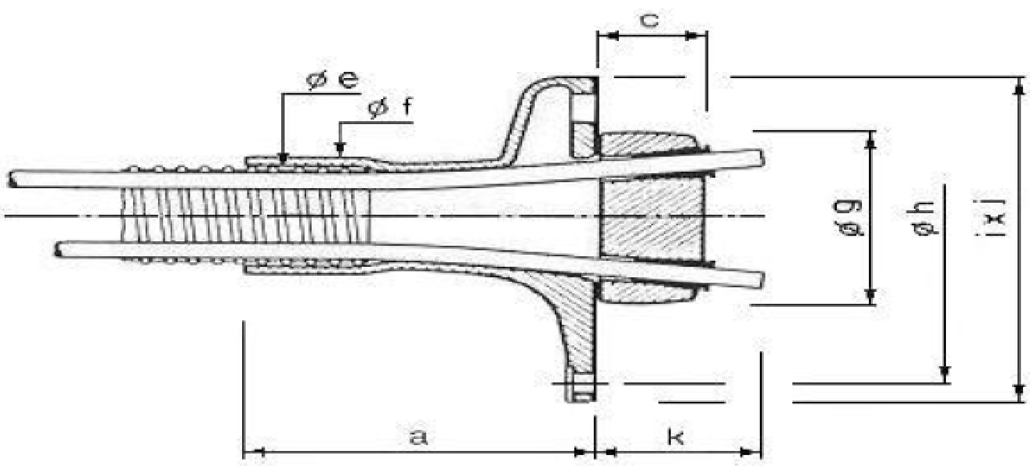
Swages of pre-stressing stand and button-heads of pre-stressing wire, whereprovided shall develop a strength of at least 95 per cent of the specified breaking load of the strand or wire as the case may be. Where swaging/button-heading is envisaged, the Contractor shall furnish details of his methodology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

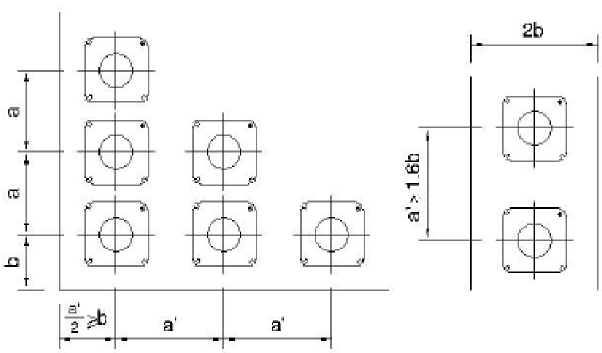


PRESTRESSING ANCHORAGES

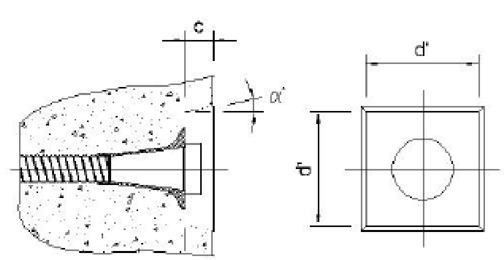


ANCHORAGE TYPE		a	c	e	f	Ø g	Ø h	i	j	k
4 K 13	-	104	45	45	56	85	158	147	147	75
7 K 13	4 K 15	103	50	62	72	120	184	160	160	85
12 K 13	7 K 15	180	55	84	100	140	254	220	235	90
19 K 13	12 K 15	190	60	95	105	160	190	244	244	95
27 K 13	19 K 15	270	70	127	136	200	234	275	293	105
37 K 13	27 K 15	395	78	171	190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

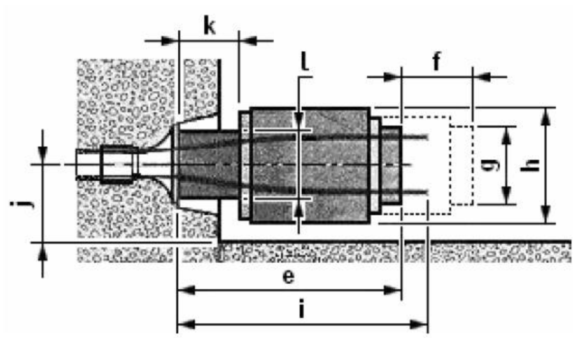


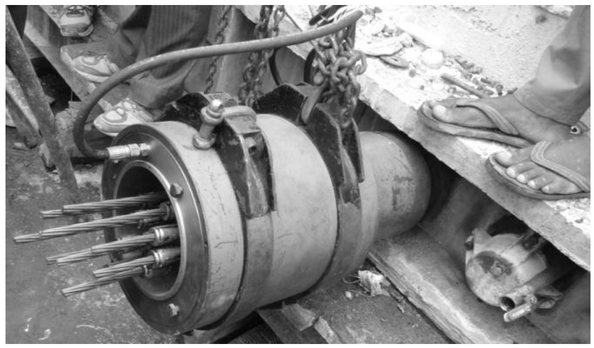
RECESS DIMENSIONS

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

C1.9 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.

C2.1 Non-Prestressing Steel Placement

All non-presressing steel shall confirm as per Table 1.7 and 1.8.The sampling and frequency of testing shall be as described in section C1.5 .All reinforcement not complying with the Specification shall be removed from site.

Unless otherwise shown on the Drawing, bending and cutting shall comply with IS: 2052.

C2.1.1 Bends and Hooks Forming End Anchorages

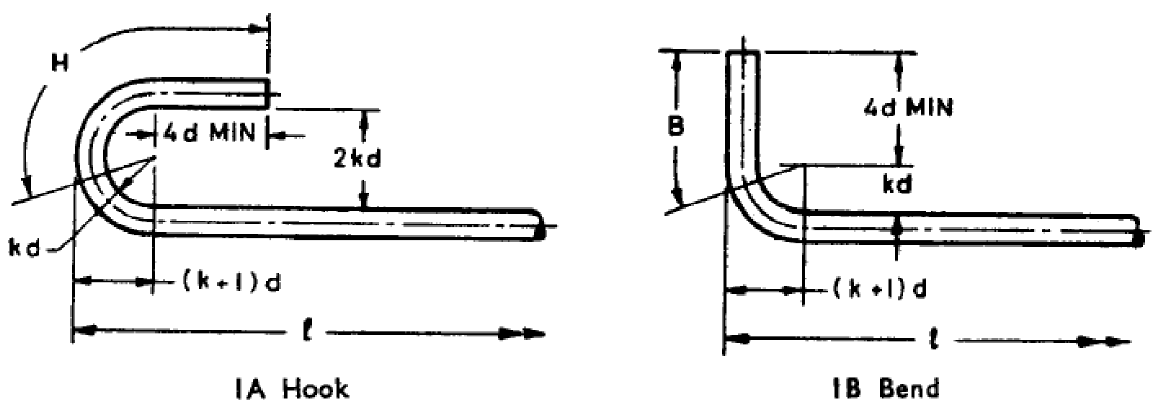


Figure 2.1 : Hook and Bend Details

Unless otherwise indicated in the schedule, a semicircular hook or a bend forming an anchorage to a bar shall be bent with an internal radius in accordance with Fig. 1A and Fig. 1B, respectively. The hook and allowances shall be in accordance with Table 2.1.

Table 2.1 Hook and Bend Allowances

Nominal Size of Bar,mm	Hook :Cold Worked Steel Bars,mm	Bend :Cold Worked Steel Bars,mm
10	130	75
12	155	75
16	210	95
20	260	120
22	285	130
25	325	150
28	365	170
32	415	190
36	470	215
40	520	240
45	585	270
50	650	300

Binders, Stirrups, Links and the Like - In the case of binders, stirrups, links, etc, the straight portion beyond end of the curve at the end shall be not less than eight times the nominal size of the bar.

C2.1.2 Curved Bars

Bars specified to be formed to radii exceeding those given in Table 2.2 need not be bent, but the required curvature may be obtained during placing.

C2.1.3 Bending and Cutting Tolerances

Bars shall be bent in accordance with the appropriate dimensions shown in the schedule. Where an overall or an internal dimension of the bent bar is specified, the tolerance, unless otherwise stated, shall be as in Table 2.3

Any excess in length of bar supplied over the total of the lengths of the various portions of the bar between bends, including the specified tolerances or not, shall be taken up in the end anchorages, or in the portion of the bar which shall be indicated on the schedule. The cutting lengths shall be specified to the next greater whole 25mm of the sum of the bending dimensions and allowance.

Table 2.2 Bars Bent to A Radius

Nomina Size of Bar, mm	Critical Radius,m
10	3.5
12	5
16	8
20	12
22	18
25	24
28	34
32	40

Table 2.3 Permissible Bending and Cutting Tolarances

Bar	Dimensions		Tolerance	
	Over, cm	Up to and Including, cm	Plus, mm	Minus, mm
For Bend Bars	-	75	3	5
	75	150	5	10
	150	250	6	15
	250	-	7	25
For Straight Bars	All lengths		25	25

The cutting tolerance for bars to be bent shall be the tolerance given for straight bars, To allow for this cutting tolerance when dimensioning bent bars, at least one dimension shall not be specified.

C2.1.4 Fixing Reinforcement

The economy of reinforced concrete design will be fully realized only when the reinforcements are maintained at their designed positions at all times. The important factors in fixing the reinforcement are precision and convenience.

Reinforcement shall be thoroughly cleaned. All dirt, scale, loose rust, oil and other contaminants shall be removed before placing it in position. If the reinforcement is contaminated with concrete form previous operation, it shall be cleaned before concreting in that section.

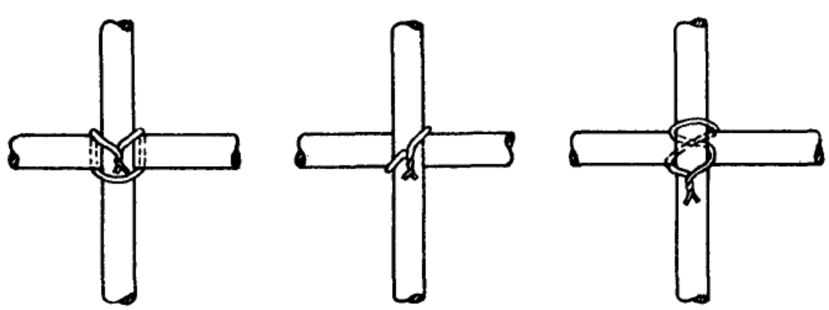
Reinforcement shall be placed in position as given on the detailed design drawing fixing of reinforcement and concreting, the position of the reinforcement shall be checked prior to concreting.

Minimum lap-length of reinforcement bars shall be 50-65d where d is the dia. of the smaller diameter bar to be lapped (unless otherwise specified). Not more than 50 percent of reinforcement crossing a section shall be lapped at that location. All laps in reinforcement shall be properly staggered and minimum distance between the laps shall be 1.33 times the lap length.

The precautions shall be taken to prevent displacement of reinforcement during shuttering and concreting.

Tying of Reinforcement Bars - Bars crossing each other, where required, shall be secured by binding wire (annealed) of size not less than 0.90mm and conforming to IS: 280-1962 Specification for Mild Steel Wire (Revised), in such a manner that they will not slip over each other at the time of fixing and concreting.

Every compression bar shall be tied at least in two perpendicular directions. Stirrups may be staggered, provided it is ensured that the corresponding stirrups form a uniform pattern in elevation.



a. **b.** **c.**

Figure 2.2 Three methods of trying reinforcement bars

Three methods of tying reinforcement bars are illustrated in Fig. 2.2 of the three methods, the method illustrated in Fig. 2.2 should be preferred to method given in Fig. 2.2b, and that given in Fig. 2.2.b to the one given in Fig. 2.2.c.

Cover Block

Cover blocks, which are generally of cement mortar, shall be used to ensure the required cover for reinforcement. Cover blocks are generally square of rectangular in plan with or without binding wire embedded in them which will be tied to the reinforcement at the time of placing. Rings with suitable hole at the centre may also be used.

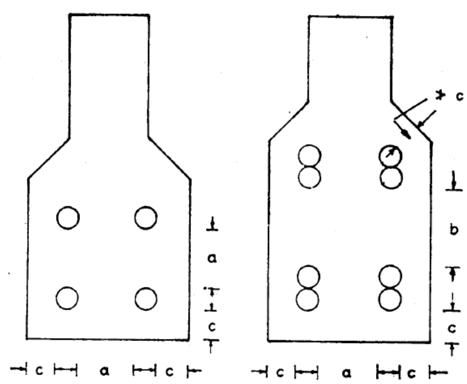
The mortar or concrete used for the cover blocks or rings shall not be leaner than the mortar or concrete in which they will be embedded.

To provide necessary cover for reinforcement at any section, only single cover blocks shall be used.

C2.2 Prestressing Steel Placement

C.2.2.1 Cover and Spacing of Prestressing Steel

Wherever prestressing cable is nearest to concrete surface, the minimum clear cover measured from outside of sheathing, shall be 75 mm.



a, b $\nless$ 50 mm or diameter of duct whichever is greater, C $\nless$ 75 mm

Figure 2.3 Cable Cover

A minimum clear distance of 50 mm or diameter of the duct, whichever is greater, shall be maintained between individual cables when grouping of cables is not involved.

Individual cables or ducts of grouped cables shall be deflected or draped in the end portions of members. The clear spacing between cables or ducts in the end one metre of the members as specified in figure 2.3 shall be maintained.

The placement of cables or ducts and the order of stressing and grouting shall be so arranged that the prestressing steel, when tensioned and grouted, does not adversely affect the adjoining ducts.

All cables shall be threaded by threading machine or any contrivance into preformed ducts.

Wherever two stage prestressing is contemplated, a dummy core shall be provided in the preformed ducts of the second stage cables, which shall be pulled out after the first stage prestressing and grouting is over. Thereafter, the cables for the second stage shall be threaded into the preformed ducts. Where prestressing in more than two stages is contemplated, the above procedure shall be followed for subsequent stage cables also.

Stressing of cable/part of cable to avoid shrinkage cracks shall not be treated as a stage.

C.2.2.2 Splay of Cables in Plan and Minimum Radius of Cables In Elevation

The splay of cables in plan, for bringing them from their position in the bottom flange at mid-span into the web towards the supports shall not be more than 1 in 6. The points of splay shall be suitably staggered on both sides of the longitudinal centre line of the web of the girder. The minimum radius of curvature, spacing and cover for curved cables shall be specified to ensure that bursting of the side cover both perpendicular to the plane of curvature and in the plane of curvature of the ducts does not take place.

C.2.2.3 Emergency Cables/Strands

Besides the design requirements, additional cables/strands shall be symmetrically placed in the structure so as to be capable of generating prestressing force of about 4 per cent of the total design prestressing force in the structure. Only those cables which are required to make up the deficiency shall be stressed and the remainder pulled out and the duct hole shall be grouted.

C.2.2.4 Others

- Cut lengths out of the long mono-strand, each length being equal to actual length of the concerned cable required between its stressing Jacks plus additional lengths beyond the Jacks to enable gripping the strands adequately by the Wedges of the Jacks.
- Bunch together designed monostrands into a 'multistrand' holding them together by binding wire tightened around the bunch at about 1.0 m intervals.
- Insert these cables in to their respective Sheathing Ducts which are already placed to the required profile in the already concreted deck.
- All Prestressing Cables shall be laid to smooth profiles using the specified profile ordinates given in the attached Prestressing Drawing. Short 12 mm dia. cross-bars shall be spot welded to the stirrup legs at approximately 2 m centers along the length of cables to give the necessary profile to the cables.
- At the time of installation of Cable-Sheathing (HDPE Ducts), the sheathing materials shall be examined for any possible punctures/cuts/etc. and the same shall be sealed with waterproof tape. The number of joints should be kept to the minimum, and each joint adequately sealed against the possibility of any ingress of any material and mortar. Joints in adjacent ducts

should be staggered by at least 300 mm. Adequate concrete shield should exist between the adjacent ducts to prevent any accidental flow of grout from one duct to the other and the ducts shall be strictly maintained in their correct alignment and profile during the placing of concrete.

- Prestressing tendons may be gripped by wedges, yokes, double cones or any other approved type of gripping devices. The prestressing wires may be gripped singly or in groups. Gripping devices shall be such that in a tensile test, the wire or wires fixed by them would break before failure of the grip itself.
- Prior to concreting the Deck, INSERT 80 mm ID Plain HDPE Ducts into the 90 mm ID Corrugated HDPE Ducts (which have already been placed to the required cable profiles), protruding them suitably beyond the cable–Anchorages.
- After concreting of the Deck is over, REMOVE these 80 mm ID Plain HDPE Ducts AND quickly blow oil-free compressed air through the emptied 90 mm ID Corrugated HDPE Ducts in order to flush them clean. Stand-by flushing equipment, capable of developing a pumping pressure of 20 Kg/cm2 (2 MPa) and a sufficient capacity to flush out any blockages due to any accidental partial grout leaks in ducts, shall be kept available at site.
- The 19-stranded multistrands may now be inserted in to their respective 90 mm ID corrugated HDPE Ducts already placed inside the Concreted Deck.
- Prestressing tendons shall never be heated or exposed to flame or to welding. Protruding Ends of tensioned strands of Grouted Cables, protruding beyond anchorages, shall only be saw-cut, not flame-cut. Recesses at anchorages (in the girder–ends) shall be filled and sealed with non shrink cement mortar after the protruding strand–ends of tensioned, anchored and grouted cables are cut to suit.

C3.1 Classes of Concrete

The classes of structural concrete to be used in the works shall be as shown on the Drawing. The mix designed properly for reference Table 3.1 may be used, in which the class designation includes two figures. The first figures indicate the characteristic strength f_{ck} at 28 days expressed in N/mm^2 and the second figure is the maximal nominal size of aggregate in the mix expressed in millimeters. Letter M in the class designation stands for Mix, letter SM stand for Special Mix.

Consistence of the mix, assessed through the Slump Test where the slump is measured in millimeters, is designate as follows:

- S: Stiff consistence, for slump ≤40
- P: Plastic consistence, for slump >40 and ≤90
- VP: Very Plastic consistence, for slump >90 and ≤150
- F: Flowing consistence for slump >150

Table 3.1 Concrete Classes and Strength (IRC 21:2000/DOR Specification)

Classes of Concrete	Consistence	Type of uses	Characteristic Strength f_{ck} (N/mm^2)	Maximum Nominal Size of Aggregate mm	Trial mixes Minimal Target Strength	Early works test cubes	
						Any one result (N/mm^2)	Average of 3 consecutive results (N/mm^2)
M 20/20	S	Ordinary	20	20	30	16	24
M 25/20	S	Ordinary	25	20	36	21	29
M 30/20	P	High Quality	30	20	42	26	34
M 35/20	P	High Quality	35	20	47	31	39
M 45/20	P	High Quality	45	20	58	41	49
M 50/20	P	High Quality	50	20	63	46	54
M 55/20	P	High Quality	50	20	69	51	59
SM 30/20	VP	Underwater	30	20	42	26	34
SM 30/20	F	Bored Piles	30	20	42	26	34
SM 45/20	P	Post-tensioned Girders	45	20	58	41	49

C3.2 Design of Proposed Mixes

Mix design shall be done under reference of IS 10262:2009, and the minimum property to be verified is as per Table 3.2.

Table 3.2 Concrete property to be verified

SN	Characteristic	Requirement	Method of Testing
1	Density	Min. 25 KN/m3	IS : 516 - 1959
2	Compressive Strength	As per Table 3.1	IS : 516 - 1959
3	Flexural strength	33% of Target f_{ck}	IS : 516 - 1959
4	Tensile splitting strength	70% of Target f_{ck}	IS : 5816-1999

Water-Cement Ratio, by weight, shall not exceed 0.40 for Reinforced Concrete, and 0.37 for Prestressed Concrete.

The contractor shall design all the concrete mixes called for in the Drawing using the ingredients which have been approved by the Engineer to achieve the strength called for in Table 3.1

Brief of IS-10262-2009-Concrete Mix Design – Indian Standard Method

The following points should be remembered before proportioning a concrete mix a per IS-10262-2009.

- This method of concrete mix proportioning is applicable only for ordinary and standard concrete grades.
- The air content in concrete is considered as nil.
- The proportioning is carried out to achieve specified characteristic compressive strength at specified age, workability of fresh concrete and durability requirements.

This method of concrete mix design consist of following 11 steps

1. Design specification
2. Testing of materials
3. Calculating target strength for mix proportioning
4. Selecting water/cement ratio
5. Calculating water content
6. Calculating cement content
7. Finding out volume proportions for Coarse aggregate & fine aggregate
8. Mix calculations
9. Trial mixing and
10. Workability measurement (using slump cone method)

11. Repeating step 9 & 10 until all requirements is fulfilled.

Let us discuss all of the above steps in detail

Step-1. Design Specifications

This is the step where we gather all the required information for designing a concrete mix from the client. The data required for mix proportioning is as follows.

- Grade designation (whether M25,M30,SM35 etc)
- Type of cement to be used
- Maximum nominal size of aggregates
- Minimum & maximum cement content
- Maximum water-cement ratio
- Workability
- Exposure conditions (As per IS-456-Table-4)
- Maximum temperature of concrete at the time of placing
- Method of transporting & placing
- Early age strength requirement (if any)
- Type of aggregate (angular, sub angular, rounded etc.)
- Type of admixture to be used (if any)

Step-2. Testing of Materials as per Chapter 1

Step-3. Target Strength Calculation as per Table 3.1

Step-4. Selection of Water-Cement Ratio not exceeding upper limit mentioned above

Step-5. Selection of Water Content

Selection of water content depends upon a number of factors such as

- Aggregate size, shape & texture
- Workability
- Water cement ratio
- Type of cement and its amount
- Type of admixture and environmental conditions.

Factors that can reduce water demand are as follows

- Using increased aggregate size
- Reducing water cement ratio

- Reducing the slump requirement
- Using rounded aggregate
- Using water reducing admixture

Factors that can increase water demand are as follows

- Increased temp. at site
- Increased cement content
- Increased slump
- Increased water cement ratio
- Increased aggregate angularity
- Decrease in proportion of the coarse aggregate to fine aggregate

Maximum water content per cubic meter of concrete for nominal maximum size of aggregate : 186 for 20mm Nominal Aggregate.

Do the following adjustments if the material used differs from the specified condition.

Type of material/condition	Adjustment required
For sub angular aggregate	Reduce the selected value by 10kg
For gravel with crushed stone	Reduce the selected value by 20kg
For rounded gravel	Reduce the selected value by 25kg
For every addition of 25mm slump	Increase the selected value by 3%
If using plasticizer	Decrease the selected value by 5-10%
If using super plasticizer	Decrease the selected value by 20-30%

Note: Aggregates should be used in saturated surface dry condition. While computing the requirement of mixing water, allowance shall be made for the free surface moisture contributed by the fine and coarse aggregates. On the other hand, if the aggregate are completely dry, the amount of mixing water should be increased by an amount equal to moisture likely to be absorbed by the aggregate

Step-6. Calculating Cementious Material Content

From the water cement ratio and the quantity of water per unit volume of cement, calculate the amount of cementious material. After calculating the quantity of cementious material, compare it with the values given in the table shown in Step-4. The greater of the two values is then adopted.

If any mineral admixture (such as fly ash) is to be used, then decide the percentage of mineral admixture to be used based on project requirement and quality of material.

Step-7. Finding out Volume Proportions for Coarse Aggregate & Fine Aggregate

Step-8. Mix Calculations

The mix calculations per unit volume of concrete shall be done as follows.

a	Volume of concrete=	$1m^3$
b	Volume of cement=	(Mass of cement/specific gravity of cement)*(1/1000)
c	Volume of water=	(Mass of water/specific gravity of water)*(1/1000)
d	Volume of admixture=	(Mass of admixture/specific gravity of admixture)*(1/1000)
e	Volume of total aggregate (C.A+F.A)=	[a-(b+c+d)]
f	Mass of coarse aggregate=	e*Volume of coarse aggregate*specific gravity of coarse aggregate*1000
g	Mass of fine aggregate=	e*Volume of fine aggregate*specific gravity of fine aggregate*1000

Step-9. Trial Mix

Conduct a trial mix as per the amount of material calculated above.

Step-10. Measurement of Workability (by slump cone method)

The workability of the trial mix no.1 shall be measured. The mix shall be carefully observed for freedom from segregation and bleeding and its finishing properties.

Step-11. Repeating Trial Mixes

If the measured workability of trial mix no.1 is different from stipulated value, the water and/or admixture content shall be adjusted suitably. With this adjustment, the mix proportion shall be recalculated keeping the free water-cement ratio at pre-selected value.

Trial-2 – increase water or admixture, keeping water-cement ratio constant

Trial-3 – Keep water content same as trial-2, but increase water-cement ratio by 10%.

Trial-4 – Keep water content same as trial-2, but decrease water-cement ratio by 10%

Trial mix no 2 to 4 normally provides sufficient information, including the relationship between compressive strength and water-cement ratio.

C3.3 Material Quantity for Small Volume of Concrete (<20 Cum)

Table 3.3 Quantity of Materials Required for Different Grade of Concrete

Class of Concrete	Characteristic Strength (N/mm^2)	Cement (Kg)	Total Aggregate (Kg)	Fine Agg./ Total Agg. (%)	Maximum Water (Ltr)	Workability
M20/20	20	350	1875	35 - 45	160 – 170	Stiff
M30/20	30	350	1825	35 - 45	175	Plastic
M35/20	35	350	1825	35 - 45	175	Plastic

C3.4 Concrete Production

C3.4.1 Proportioning

Concrete mixes shall be proportioned according to the Design mix. Cement and aggregate shall be batched either by weight or by volume, without compromising the requirements. Water may be measured by weight or volume. The quantity of cement, each size of aggregate and water as indicated by the mechanism employed shall be *within a tolerance of plus or minus three percent of the respective weight/ volume per batch agreed by the Engineer*.

The water to be added to the mix shall be reduced by the amount of free water contained in the coarse and fine aggregates. This amount shall be determined by the Contractor by a method agreed by the Engineer.

C3.4.2 Machine Mixing

Concrete for the works shall be batched and mixed in one or more plants or concrete mixer unless the Engineer agrees to some other arrangement. If concrete mixers are used, there shall be sufficient number of mixtures including stand by mixers.

Batching and mixing plants shall be complying with the requirements of IS: 1791 and capable of producing a uniform distribution of the ingredients throughout the mass. If the plant proposed by the Contractor does not fall within the scope of IS: 1791 it shall have been tested in accordance with IS: 4634 and shall have a mixing performance within the limits of IS: 1791.

Truck mixers shall comply with the requirements of IS: 4925 and shall only be used with the prior approval of the Engineer

All mixing operations shall be under the control of an experienced supervisor

The aggregate storage bins shall be provided with drainage facilities arranged so that the drainage water is not discharged to the weigh hoppers. Each bin shall be drawn at least once per week and any accumulations of mud or silt shall be removed.

If bulk cement is used, the scale and weight hopper for cement shall be distinct from the scale and weight hopper for aggregates.

Cement and aggregates shall be batched by weight. Water may be measured by weight or volume.

The weighing and water dispensing mechanisms shall be maintained in good order.

The nominal drum or pan capacity of the mixer shall not be exceeded. The turning speed and the mixing time shall be as recommended by the manufacturer, but in addition, when water is the last ingredient to be added, mixing shall continue for at least one minute after all the water has been added to the drum or the pan.

The blades of pan mixers shall be maintained within the tolerances specified by the manufacturer of the mixer and the blades shall be replaced when it is no longer possible to maintain the tolerances by adjustment.

Mixers which have been out of use for more than 30 minutes shall be thoroughly cleaned before any fresh concrete is mixed. Mixers shall be cleaned out before changing to another type of cement.

C4.2.2 Hand Mixing

Concrete for structural purposes should not be mixed by hand. However, for small volumes of works(<20 Cum for a project), hand mixing may be carried out subject to approved of the Engineer.

For making hand mixing concrete, cement, sand and aggregate shall be batched separately by volume or by weight as applicable. Then cement and sand shall be mixed dry to uniform colour. The aggregate shall be stacked in a proper shape upon which cement sand mix shall be spread and whole mix shall be mixed to uniform consistency.

For hand mixed concrete the specified quantities of cement shall be increased by 10 % and not more than 0.25 cubic meter shall be mixed at one time. During windy weather precautions shall be taken to prevent cement from being blown away in the process of gauging and mixing.

C3.5 Transportation of Concrete

The concrete shall be discharged from the mixer and transported to the works by means which shall prevent adulteration, segregation or loss of ingredients, and shall ensure that the concrete is of the required workability at the point and time of placing. The loss of slump between discharge from the mixer and placing shall not be more than 25 mm or one third of the value whichever is the less.

The capacity of the means of transport shall not be less than the full volume of a batch.

The time elapsing between mixing transporting placing and compacting altogether of a batch of concrete shall not be longer than the initial setting time of the concrete. If the placing of any batch of concrete is delayed beyond this period, the concrete shall not be placed in the works.

During hot or cold weather, concrete shall be transported in deep containers or other suitable methods to reduce the loss of water by evaporation in hot weather and heat loss in cold weather may also be adopted.

C3.6 Placing of Concrete

C3.6.1 Preparation of Surface to Receive Concrete

Excavated surfaces on which concrete is to be deposited shall be prepared as set out in Section 900 Earthwork of DoR Yellow Book.

Existing concrete surfaces shall be prepared as set out in section C3.9. Before deposition of further concrete, they shall be clean, hard and sound and shall be wet but without any free standing water.

Any flow of water into an excavation shall be diverted through proper side drains to a sump or be removed by other suitable which will prevent washing away the freshly deposited concrete or any of its constituents. Any under drain constructed for this purpose shall be completely grouted up when they are no longer required by a method agreed by the Engineer.

Unless otherwise instructed by the Engineer surfaces against which concrete is to be placed shall receive prior coating of cement slurry or mortar mixed in the proportions similar to those of the fines proportions similar to those of the fines portion in the concrete to be placed. The mortar shall be kept ahead of the concrete. The mortar shall be placed into all parts of the excavated surface and shall not be less than 5 mm thick.

If any fissures have been cleaned out they shall be filled with mortar or with concrete as instructed by the Engineer.

The amount of mortar placed at one time shall be limited so that it does not dry out or set before being covered with concrete.

C3.6.2 Placing Procedures

The Concrete shall be deposited as nearly as possible in its final position. It shall be placed so as to avoid segregation of the concrete and displacement of the reinforcement, other embedded items or form work. *It shall be brought up in layers approximately parallel to the construction joint* *planes and not exceeding 300 mm in compacted thickness unless otherwise permitted or directed by the Engineer, but the layers shall not be thinner than four times the maximum nominal size of aggregate.*

As a general guidance, the maximum permissible free fall of concrete may be taken as 1.5 m.

When placing on a nearly horizontal surface, placing shall start at the lower end of the surface to avoid decompaction of concrete.

Layers shall not be placed so that they form feather edges nor shall they be placed on a previous layer which has taken its initial set. In order to comply with this requirement, another layer may be started before initial set of the preceding layer.

All the concrete in a single bay or pour shall be placed as a continuous operation. It shall be carefully worked round all obstructions, irregularities in the foundations and the like so that all parts are completely full of compacted concrete with no segregation or honey combing. It shall also be carefully worked round and between water stops, reinforcement, embedded steelwork and similar items which protrude above the surface of the completed pour.

All work shall be completed on each batch of concrete before its initial set commences and thereafter the concrete shall not be disturbed before it has set hard. No concrete that has partially hardened during transit shall be used in the works and the transport of concrete from the mixer to the point of placing shall be such that this requirement can be complied with.

Concrete shall not be placed during rain which is sufficiently heavy or prolonged to wash mortar from coarse aggregate on the exposed faces of fresh concrete. Means shall be provided to remove any water accumulating on the surface of the placed concrete. Concrete shall not be deposited into such accumulations of water.

In dry weather, covers shall be provided for all fresh concrete surfaces which are not being worked on.Water shall not be added to concrete for any reason.

When concrete is discharged from the place above its final deposition, segregation shall be prevented by the use of chutes, down pipes, trunking, baffles or other appropriate devices.

Forms for walls shall be provided with openings or other devices that will permit the concrete to be placed in a manner that will prevent segregation and accumulations of hardened concrete on the formwork or reinforcement above the level of the placed concrete.

C3.6.2.1 "CONCRETING" IN "ADVERSE WEATHER" CONDITIONS

a) 'Concreting' in "Cold" Weather

- Concrete that freezes soon after placing, gains rather low strength and some permanent damage is certain to occur. Therefore, such concrete shall be removed and replaced immediately.

- ‘Planning for Protection of fresh concrete’ during placement, and until it has attained the minimum properties required for the environment and the loading to which it will be exposed, shall be done well in advance of concreting and approved by the Engineer.
- Appropriate equipment shall be made available in time for heating the concrete materials, for constructing enclosures and for maintaining favourable temperatures even after the concrete is placed.
- Concrete shall never be placed on cold Forms and cold steel.
- When the temperature of these items is below 5ºC, the Contractor shall use means to raise their temperatures to above 10ºC.
- When faced with prolonged cold temperatures, all aggregates, or mixing water, or both, shall be heated to about 25ºC to 32ºC.
- At temperature at least 10ºC above freezing, it is seldom necessary to heat the Aggregates.
- At temperatures below or at freezing, often only the Fine Aggregate is heated to produce concrete of the required temperature, provided the Coarse Aggregate is free of frozen lumps and the Temperature of Water for the Mix is at least 10ºC.
- If aggregate temperatures are above freezing, the desired concrete temperature usually can be obtained by heating only the mixing water.
- Appreciable fluctuation in the mixing water temperature from batch to batch shall not be allowed.

b) Concreting’ in "Hot" Weather:

- No concrete shall be placed when the ambient air temperature at job site in shade is expected to exceed about 35ºC during placement operations.
- When the temperature of the 'concrete mixture' is expected to exceed about 25ºC, a retarding admixture shall be included in the approved mix design since setting time tends to reduce at higher temperatures.
- The temperature of the concrete mixture immediately before placement shall not exceed 32ºC.
- When the ambient air temperature is above 32ºC, all Forms, reinforcing steel, and other contact surfaces shall be cooled to below 32ºC until concrete is placed.
- When such high ambient temperature conditions exist, the most appropriate solution is to resort to evening–night–&–morning–time concreting.
- However, if the above stated precautions are taken to help lower the temperature of contact surfaces and the concrete mix–ingredients are also cooled (explained ahead), concreting can be carried out even during day hours provided the ambient air temperature in shade does not exceed 40ºC.
- Mixers, chutes, belts, hoppers, pump lines, and other production and placement

equipment can be shaded, painted white, covered with (wet) burlap, or otherwise cooled to reduce the effect of the sun's heat.

- Forms and reinforcing steel can be sprinkled with cold water and covered with wet burlap until controlled concreting commences.
- Sprinkling the area with water spray, gainfully cools the contact surfaces and surrounding air and desirably increases its relative humidity.
- This not only reduces the ‘temperature rise’ of the concrete but also minimizes evaporation of water from the concrete during placement and after casting.
- For slabs on ground, it is a good practice to dampen the sub-grade the evening before concreting.
- There should be no standing water or puddles on the sub-grade or inside the Forms when the concrete is placed.
- The mix water may be cooled by using shaved or crushed ice but only as much ice should be used as will be melted entirely before this water is added to the mix.
- All water used for making ice and for cooling or sprinkling, and curing, must meet the same quality requirements as those for water used for Mixing of Concrete.
- Of particular concern are the polluting sulphates and chlorides (salts) in the mix, which can adversely affect the cement and corrode the reinforcing steel, respectively. These must be kept below their specified limits.
- Aggregates should be cooled by shading and sprinkling water (fog spray).
- Transporting and placing concrete shall be done as quickly as practical during hot weather.
- Delays contribute to loss of slump, a damaging increase in concrete temperature and loss of workability.
- Enough workmen and equipment shall always be available to handle and place concrete immediately upon delivery.
- Prolonged mixing, even at agitating speed of the Drum, shall be avoided since it might heat-up the mix and reduce workability.
- If delays occur, the heat generated by continued mixing/agitating can be minimized by stopping the mixer and then agitating intermittently, but the delays shall be kept short.
- Since concrete hardens more rapidly in hot weather, extra care in placing techniques is required to avoid Cold Joints.
- For placement of Concrete in Walls, Shafts, Columns, etc., shallower layers may be required to assure proper consolidation and monolithicity with each previous lift, effective dissipation of heat of hydration and to prevent segregation of the mix.
- Temporary sunshades and windbreakers help to minimize adverse effects of hot weather, winds, and surface evaporation.

C3.6.3 Interruptions to Placing

If the concrete placing is interrupted for any reason and the duration of the interruption cannot be forecast or is likely to be prolonged, the Contractor shall immediately take the necessary action to form a construction joint so as to eliminate as far as possible feather edges and sloping top surfaces and shall thoroughly compact the concrete in accordance with section C3.7. All work on the concrete shall be completed before elapse of initial setting time and it shall not thereafter be disturbed until it is hard enough to resist damage. Plant and materials to comply with this requirement shall be readily available at all time during concrete placing.

Before concreting is resumed after such an interruption the Contractor shall cut out and remedy all damaged or uncompacted concrete, feather edges or any undesirable features and shall leave a clean sound surface against which the fresh concrete may be placed.

If it becomes possible to resume concrete placing without contravening the Specification and the Engineer consents to a resumption, the new concrete shall be thoroughly worked in and compacted against the existing concrete so as to eliminate any cold joints.

In case of long interruption concrete shall be resumed as directed by Engineer.

C3.6.4 Dimension of Pours

Unless otherwise agreed by the Engineer, pours shall not be more than1.5m high and shall as far as possible have a uniform thickness over the plan area of the pour. Concrete shall be placed to the full planned height of all pours except in the circumstances described in section C3.6.3.

The Contractor shall plan the dimensions and sequence of pours in such a way that cracking of the concrete does not take place due to thermal or shrinkage stresses.

C3.6.5 Placing Sequence

The Contractor shall arrange that the intervals between successive lifts of concrete in one section of the works are of equal duration. This duration shall not be less than three days or not more than seven days under temperate weather conditions unless otherwise agreed by the Engineer.

Where required by the Engineer to limit the opening of construction joints due to shrinkage, concrete shall not be placed against adjacent concrete which is less than 21 days old.

Contraction gaps in concrete shall be of the widths and in the locations as shown on the Drawing and they shall not be filled until the full time interval shown on the Drawing has elapsed.

C3.7 Compaction of Concrete

Concrete shall be fully compacted throughout the full extent of the placed layer. It shall thoroughly worked against the formwork and around any reinforcement and other embedded item, without displacing them. Care shall be taken at arises or other confined spaces. Successive layers of the same pour shall be thoroughly worked together.

Compact before the initial setting but not later than 30 minutes of its discharge from the mixer.

Compact concrete using internal (needle/poker) vibrators of suitable size or form vibrators, during placing and worked around the reinforcements, to produce dense, homogeneous and void free mass.

Whenever vibration has to be applied externally, the design of formwork and the disposition of vibrators should receive special consideration to ensure efficient compaction and to avoid surface blemishes.

Immersion and surface vibrators shall operate at a frequency of between 70 and 200 hertz.

A sufficient number of vibrators shall be operated to enable the entire quantity of concrete being placed to be vibrated for the necessary period and, in addition, stand-by vibrators shall be available for instant use at each place where concrete is being placed.

Vibration shall be continued at each until the concrete ceases to contract, air bubbles have ceased to appear, and a thin layer of mortar has appeared on the surface. Vibrators shall not be used to move concrete laterally and shall be withdrawn slowly to prevent the formation of voids.

The vibrators shall be inserted vertically into the concrete to penetrate the layer underneath at regular spacing which shall not exceed the distance from the vibrator over which vibration is visibly effective and some extent of vibration is overlapped.

Vibration shall not be applied by way of reinforcement nor shall the vibrator be allowed to touch reinforcement, sheathing ducts or other embedded items.

C3.8 Curing and Protection of Young Concrete

All structural concrete shall be cured for a period of time required to obtain the specified strength, <u>but for not less than fourteen consecutive days (and nights) beginning immediately after ‘initial setting’ of concrete (which is when it loses its surface sheen</u>).

Period : Regular (not less than 7 days after casting) inspection

<u>Curing (Membrane–curing or Water–curing) of laid concrete shall be carried out as generally explained below</u>:

<u>Membrane–Curing the Concrete:</u>

- Except for at Construction Joints and surfaces sealed by Forms, liquid membrane curing compound can be used (for curing the concrete) as follows:
- On bridge deck top surface and other exposed surfaces, liquid membrane curing compound shall be applied soon after Initial Setting and as the Surface Sheen has disappeared and the concrete is still slightly damp (not wet).

- On shuttered i.e. formed vertical surfaces, Forms shall be stripped as soon as practical (generally after 24 hours of casting) and liquid membrane curing compound applied immediately except in the areas that require rubbing or finishing during the curing period.
- These areas shall be kept water-wet until their finishing is completed, whereafter the liquid curing membrane shall be uniformly applied on them also when their surface is damp.
- White–pigmented liquid membrane curing compound shall be used for all surfaces where the structure temperature during curing period is likely to reach about 35ºC or more.
- For bridge decks which are to receive an asphaltic overlay, residual curing membrane (after curing) shall be removed prior to the overlaying.
- Removal methods and results should be approved by the Engineer.
- The membrane curing compound used shall be of longer lasting duration and in accordance with the requirements specified for curing membrane material, AASHTO M 148 or the equivalent IS Specification.
- The curing membrane shall be applied in two applications one immediately following the other.
- The rate of each application of curing compound shall be as prescribed by the manufacturer, with a spreading rate per application of at least one litre of liquid per five square metres of concrete surface.
- If the concrete has dried up or has become dry, it shall be thoroughly wetted with water and the curing compound applied just as the surface film of water disappears and the surface is damp.
- During curing operations any unsprayed surfaces shall be kept cured with watered Hessian cloth, and sprayed with the curing compound when Surface is damp (not wet).
- Any curing membrane material on Construction Joints and/or on reinforcing steel shall be completely removed before the following concrete pour.
- Hand operated spraying equipment shall be capable of applying constant and uniform pressure to provide uniform and even distribution of the curing membrane at the rates required.
- The curing compound shall be kept thoroughly mixed at all times during usage/application.
- No traffic of any kind shall be permitted on the curing membrane until the curing period is completed, design permitting.

Water–Curing the Concrete:

- All concrete surfaces, unless still sealed by unreleased Forms (which shall be kept from heating–up under ambient temperature) or submerged, shall be water-cured unless liquid membrane cured.
- Water curing shall begin just after initial setting of concrete (which generally occurs by about 60 minutes of placement of un-admixtured concrete and by about 120 to 180 minutes of placement of admixtured concrete) and just after the surface water sheen has disappeared.
- Surfaces water–cured shall be covered with wet sand, cotton mats, or double–thickness burlap (Jute/Hessian) sheets.
- This Hessian material shall be placed tightly around and behind any projecting reinforcing steel in order to completely cover the fresh concrete surface.
- The Hessian material shall be completely saturated with water and kept continuously saturated throughout the curing period.
- After the initial saturation, unless water is kept running, all surfaces shall be covered with thick polythene sheeting or other approved impervious material in order to protect/prevent drying-up of concrete surface being cured continuously.
- The sheeting shall be weighted down or secured well to prevent moisture–loss but the surfaces of the concrete shall be readily available for inspection of the Engineer (or his Representative).
- The sheeting material shall be in good repair.
- Sheeting that contains holes or is otherwise damaged shall be repaired or replaced immediately.
- The Contractor shall be responsible for thoroughly inspecting and monitoring the concrete surfaces throughout the curing period to ensure continuous wet curing.
- Additional water shall be poured on any areas where saturation is reduced.
- Inspection of curing by the Contractor shall be conducted at least TEN times per day and night for the duration of the curing period – and even more often if ordered so by the Engineer.
- The Engineer shall be advised of the curing inspection schedule and he (or his Representative) may accompany the workmen to verify the acceptability of curing.

C3.8.1 'COLD–WEATHER' CURING:

- When concrete is placed and the air temperature is expected to drop below 5ºC during the curing period, the Contractor shall provide suitable measures such as straw, additional burlap or other suitable blanketing materials and/or housing and artificial hot–air–curing to maintain the concrete temperature between 10ºC and 32ºC as measured on the surface of the concrete.

- The surface of the concrete shall be kept moist and warm by the use of an approved warm moisture barrier such as warm wet Burlap/Hessian.
- The moisture barrier should be maintained in intimate surface contact with the concrete during the entire curing period.
- After the completion of the curing during the entire required curing period, the Contractor shall stop the curing and remove the protection in such a manner that rapid cooling of the concrete will be prevented.
- When concrete is placed in 'cofferdams' and subsequently flooded with ground water, the above curing conditions may be waived, provided the surface of the water is not permitted to freeze/dry.

C3.9 Construction Joint

Whenever concrete is to be bonded to other concrete which has hardened, the surface of contact between the sections shall be deemed a construction joint.

Where construction joints are shown in the Drawing, the Contractor shall form such joints in such positions. The locations of joints, which the Contractor requires to make for the purpose of construction, shall be subject to the approval of the Engineer. Construction joints shall be in vertical or horizontal planes except in sloping slabs where they shall be normal to the exposed surface or elsewhere where the Drawing require a different arrangement.

Construction joints shall be arranged as to reduce to a minimum the effects of shrinkage in the concrete after placing, and shall be placed in the most advantageous positions with regard to stresses in the structures and the desirability of staggering joints.

Feather edges of concrete at joints shall be avoided. Any feather edges which may have formed where reinforcing bars project through a joint shall be cut back until sound concrete has been reached.

The intersections of horizontal and near horizontal joints and exposed faces of concrete shall appear as straight lines produced by use of a guide strip fixed to the formwork at the top of the concrete lift, or by other means acceptable to the Engineer.

Construction joints formed as free surfaces shall not exceed a slope of 20 per cent from the horizontal.

The surface of the fresh concrete in horizontal or near horizontal joints shall be thoroughly cleaned and roughened by means of high pressure water, and air jets or wire brush, when the concrete is hard enough to withstand the treatment without the leaching of cement. The surface of vertical or near vertical joints shall be similarly treated if circumstances permit the removal of formwork at a suitable time.

A Construction Joint should not be located near the centroid level of the section as here transverse SHEAR stress is highest. The Joint should be nearly perpendicular to the principal lines of tensile stress and in general be located at points of minimum Shear and minimum Moment – as far as possible.

Where dowels, reinforcing bars, or other adequate ties are not shown at Construction Joints in the Drawings, 'keys' should be formed at reasonable spacing by embedding water-soaked beveled timbers while the concrete is still soft.

These keys should be sized as may be shown in the details, or as directed by the Engineer, and these key-forming timbers shall be removed when the concrete has initially set.

The concrete surface shall then be thoroughly soaked with clean water (just before further concreting) and the free water, etc. air-blown away, and the cleaned concrete surface painted with a thin layer of cement slurry, and only then further concrete poured.

'Wire-mesh' and other similar items do not provide a proper construction joint, and they shall not be used.

In resuming concreting work, the surface of the concrete previously placed shall first be thoroughly cleaned of dirt, scum, laitance, loosely projecting aggregates and any other soft material, using stiff wire brushes, and – if deemed necessary by the Engineer – by sand blasting.

Where concrete has become too hard for the above treatment to be successful, the surface whether formed or free shall be thoroughly scabbled by mechanical means, manually or wet sand blasted and then washed with clean water. The indentations produced by scabbling shall not be less than 10 mm deep and shall be away from the finished face by 40 mm.

If instructed by the Engineer the surface of the concrete shall be thoroughly brushed with a thin layer of mortar composed of one part of cement to two parts of sand by weight immediately prior to the deposition of fresh concrete. The mortar shall be kept just ahead of the fresh concrete being placed and the fresh layer of concrete shall be thoroughly and systematically vibrated to full depth to ensure complete bond with the adjacent layer.

No mortar or concrete shall be placed until the joint has been inspected and approved by the Engineer.

COLD JOINTS:

When a planned 'continuous' placement of concrete in any structural member is interrupted or delayed, for any reason, for a period long enough for the previously partially placed concrete to take its initial set, the Engineer may declare such a joint as a Cold Joint and the Contractor shall immediately remove the previously partially placed concrete from the Forms.

However, where feasible, the previously partially placed concrete may instead be suitably and carefully hacked and its hacked end brought into 'low shear low moment' zone as far as possible, and given shear key depressions after bringing it nearly perpendicular to the principal lines of tensile stress (for example: brought to vertical or nearly vertical in a beam with principal bending reinforcement horizontal) and thereafter same treatment shall be given to it as to a Construction Joint and only then the concreting resumed (making sure all reinforcements are as per the approved Drawings and the Shuttering has been brought to line and plumb tightly).

C3.10 Records of Concrete Placing

Records of the details of every pour of concrete placed in the works shall be kept by the Contractor in a form agreed by the Engineer. These records shall include class of concrete, location of pour, date and duration of pour, ambient temperature and concrete temperature at time of placing and all relevant meteorological information such as rain, wind etc., moisture contents of the aggregates, details of mixes batch numbers, cement batch number, results of all tests undertaken, part of the structure and place where test cube samples are taken from.

The Contractor shall supply to the Engineer four copies of these records each week covering work carried out the preceding week. In addition, he shall supply to the Engineer monthly histograms of all 28 day cubes strength results together with cumulative and monthly standard deviations, Coefficient of Variation, and any other information which the Engineer may require concerning the concrete placed in the works.

C.11 Underwater Concreting

Concrete is often required to be placed *underwater or in a trench filled with the bentonite slurry*. In such cases, use of bottom dump bucket or tremie pipe is made use of. In the bottom dump bucket concrete is taken through the water in a water-tight box or bucket and on reaching the final place of deposition the bottom is made to open by some mechanism and the whole concrete is dumped slowly. This method will not give a satisfactory result as certain amount of washing away of cement is bound to occur. In case of Well bottom plugging, the same water level inside and outside the well shall be maintained till minimum 24hr of concreting.

C.11.1 Tremie Method

Underwater concreting using tremie method is convenient for pouring large amount of high flowable concrete. Tremie method is the most acceptable method of concreting under water.The concrete is moved to the hopper by either pumping, belt conveyer or skips.

Figure 3.1 Tremie Concreting Method

In this method ,a tremie pipe shall be inserted in the water up to the point where concrete is going to be placed. Generally the diameter of a tremie pipe varies from 20 cm to 30 cm. Depending upon the depth of concreting under water we can add more tremie pipe by coupling it with one another.

Before inserting the tremie pipe into the water, the bottom end of the tremie pipe must be closed with a plug or thick polythene sheet or other suitable material.

After tremie pipe reaches at the desired depth, a funnel is fitted to the top end of the tremie pipe, to facilitate pouring of concrete.

Then concrete having a very high slump of about 150 mm to 200 mm is poured into the funnel, until the whole length of tremie pipe is filled up with concrete.

Then the tremie pipe is lifted up and given a slight jerk by a winch & pulley arrangement. Due to application of jerk and weight of the concrete inside the pipe, the bottom plug fall and the concrete gets discharged.

At this stage, **make sure that the end of the tremie pipe remains inside the concrete, because this will prevent entering of water into the pipe from the bottom.**

When all of the concrete inside the pipe gets discharged, the tremie pipe is again completely filled with concrete and the process is repeated. This process of filling and discharging of concreting is repeated, without any interruption, until the concrete level comes above the water table.

Notes

- Pumping of water should not be allowed while concreting, because it may suck cement particles from the concrete.
- No compaction is required for under water concreting, as concrete gets compacted by the hydrostatic pressure of water.

Tremie pipe, which upper end connected to a hopper and lower end continuously submerged in fresh concrete, shall be used to place concrete at the exact location from a hopper at the surface. The reason to immerse the tremie pipe lower end is to prevent intermixing of both concrete and water. Tremie pipe typical arrangement is shown in Figure 3.2a.

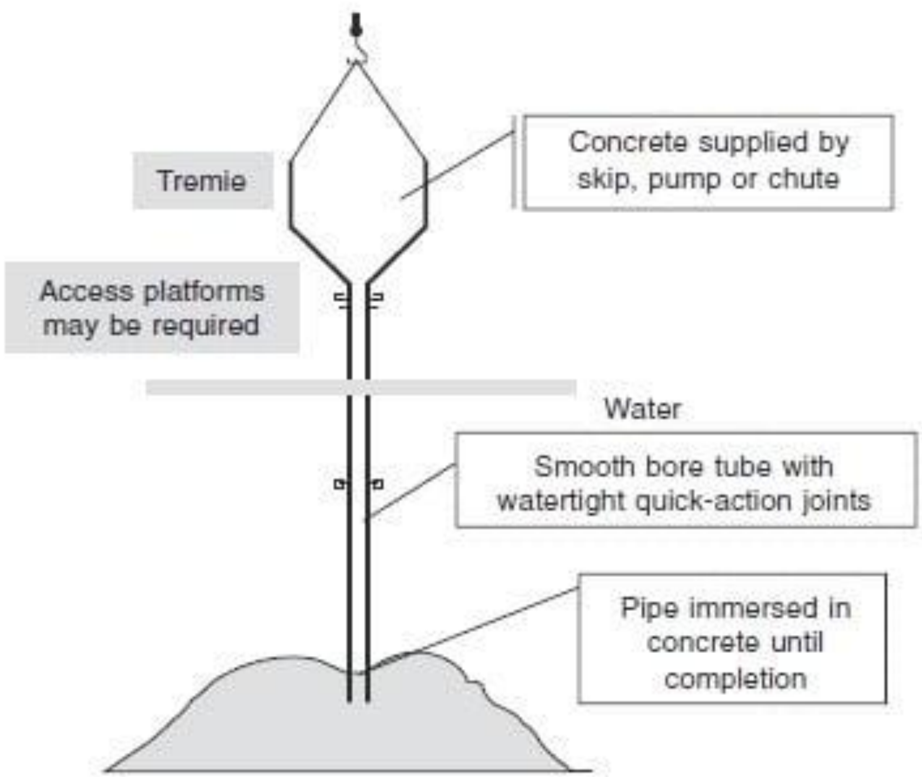


Figure 3.2a Typical Arrangement of Tremie Method of Underwater Concreting

There number of factors that should be considered during Tremie pipe technique of underwater concreting:

Tremie Equipment

The tremie pipe might be configured in three different ways such as constant length that is raised during concreting, pipe with different sections which dismantled during concreting and telescope pipe.

An aluminum alloy pipe can adversely affect the concrete due to chemical reactions between them therefore it should be avoided. The pipe should have an adequate diameter to prevent blockage because of aggregate size.

The usual diameter is between 200- 300 mm and occasionally 150 mm and 450 mm could be used but aggregate size should be considered for example 19 mm and 40 mm aggregate size is lower limit for 150 mm 200 mm pipe diameter respectively.

Tremie seal

To avoid intermixing water and concrete in the pipe, a wooden plug of plat is used to seal the end of the pipe. This prevents entering water in to the pipe and keeps it dry.

After the pipe reach the intended position the concrete is poured and break the seal. Then concrete flow out of the pipe and creating a seal by accumulating around the lower end of the pipe

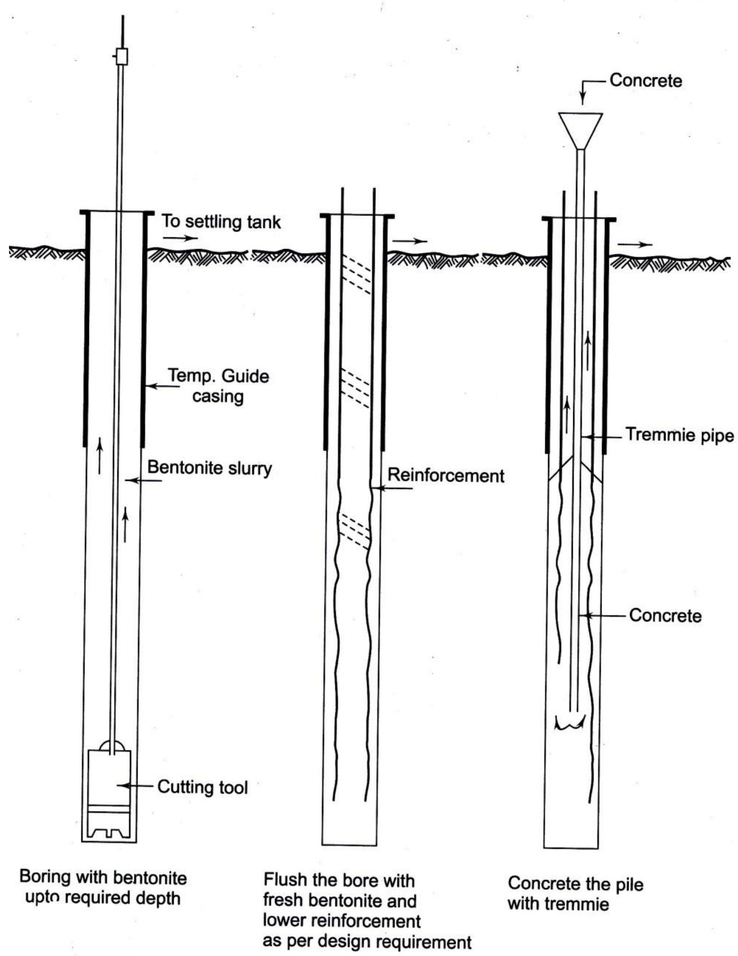


Figure 3.b Schematic drawing of concreting in Bored Pile

Placing the concrete

As soon as concreting began the pipe mouth should be submerged up to 1- 1.5 m into fresh concrete to prevent water entering the pipe. The concrete flow rate is controlled by lowering and raising the pipe and either decrease or increase in concrete discharge indicates the loss of the seal, therefore flow of concrete should be continuous and carefully monitored.

Flow pattern

Two types of flow pattern are recognized namely, layered and bulging. The bulging flow is desired because it displaced the concrete uniformly which leads to lesser laitance deformation and flatter slopes.

C.11.2 Pumping Technique

Underwater concreting using pumping technique is a developed version of Tremie pipe and it is quicker method for concreting in areas that is difficult to access such as under piers.

Pumping provide several advantages that Tremie pipe is lacking for example, pouring concrete from mixer to formworks directly, solve blockages in the pipe because concreting is through pumping instead of using gravitational force, and risk of segregation is decreased. Figure 3.3 show typical pipeline configuration.

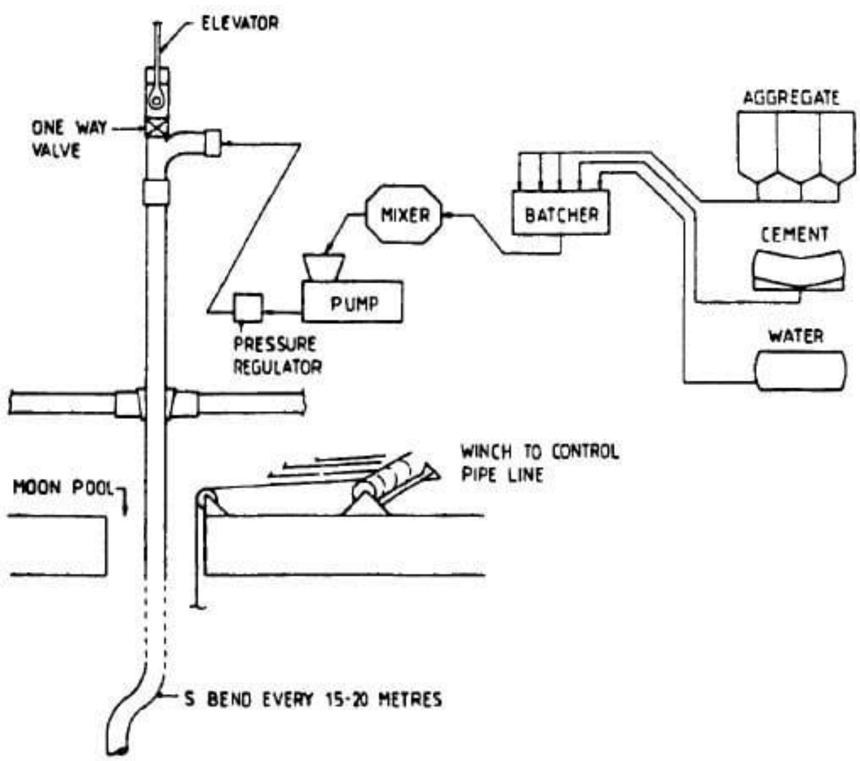


Figure 3.3 Typical Configuration of Underwater Concreting Pump Line

C3.11.3 Skips Method

The equipment that is used for conveying concrete is a bucket with double door opening at the bottom and overlapping canvas flaps which is fitted at the top to prevent concrete washing. The skip is lowered down through water slowly as soon as it filled with concrete and when it reaches the location the doors are opened either automatically or manually.

The Skip technique of underwater concreting is suitable for cases where a large mass of concrete is required for stabilizing foundations and small amount of concrete is needed for different locations. Shows opened and closed skips.

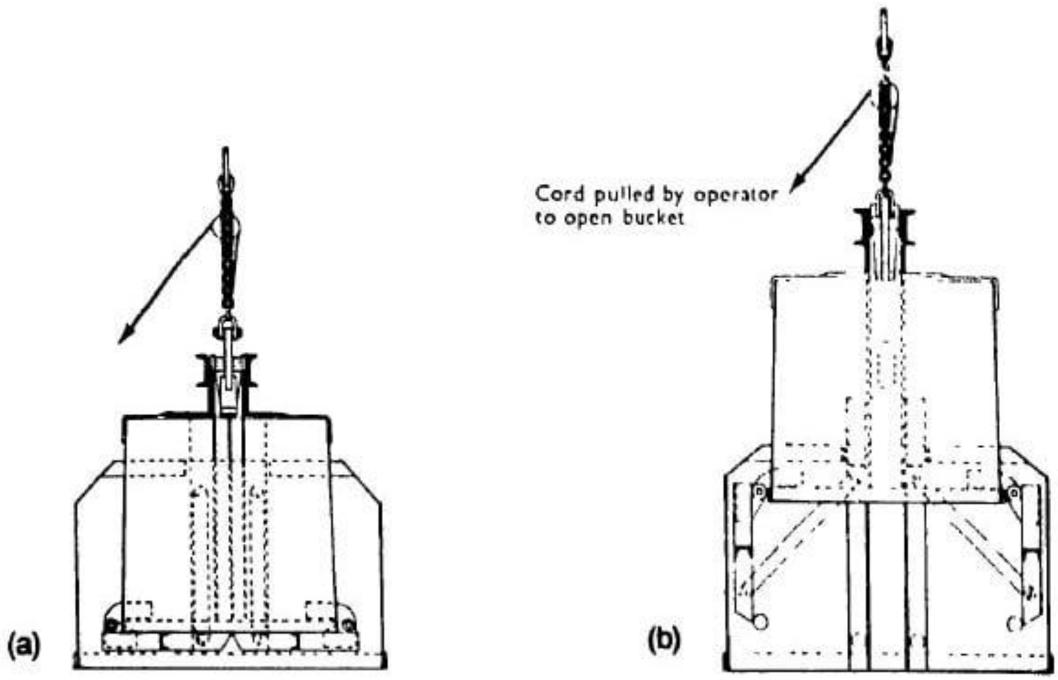


Figure 3.4 Skips for Underwater Concreting (a) Closed and (b) Opened

<u>Underwater Concreting using Preplaced Aggregate Concrete & Bagged Concrete Method should be avoided.</u>

C3.12. Concrete Quality Control

Random sampling and lot by lot of acceptance inspection shall be made for the 28 days' cube strength of concrete. Concrete under acceptance shall be notionally divided into lots for the purpose of sampling, before commencement of work. The basis of delimitation of lots shall be as follows;

i. No individual lot shall more than 30 cu.m. in volume
ii. Different grades of mixes of concrete shall be divided into separate lots
iii. Concrete of a lot shall be used in the same identifiable component of the Bridge/ structure

C3.12.1 Sampling and testing

Concrete for making 3 test cubes shall be taken from a batch of concrete at point of delivery into construction, according to procedure laid down in IS: 1199.

A random sampling procedure to ensure that each of the concrete batches forming the lot under acceptance inspection has equal chance of being chosen for taking cubes 150 mm cubes shall be made, cured and tested at the age of 28 days for compressive strength in Table 3.1. The 28-day test strength result for each cube shall form an item of the sample. Test at other age also shall also be performed, if specified.

Where automated batching plant/ Ready Mixed Concrete Plant is located away from the place of use and the time gap between production and placement is more than initial setting time or where any ingredients are added subsequent to mixing, separate set of samples shall be collected and tested at batching plant and at location of placement. The results shall be compared and used to make suitable adjustment at batching plants so that properties of concrete at placement are as per the requirements.

C3.12.2 Test specimen and sample strength:

Three test specimens shall be made from each sample for testing at 28 days. Additional cubes maybe required for various purposes such as to determine the strength of concrete at 7 days or for any other purpose.

The minimum frequency of sampling of concrete of each grade shall be in accordance with Table 3.4.

Table 3.4 Frequency of Sampling

Quantity of concrete in work (m^3)	No. of samples
1-5	1
6.1-15	2
15.1-30	3
31.1-50	4
51- and more quantity of work	4 plus one additional for each 50 m^3 or part of it.

C3.12.3 Acceptance criteria

The concrete shall be taken as having the specified compressive strength as per Table 3.1

“In case of a dispute about the strength of concrete in a particular area of the cast concrete, three

50 mm dia. and 100 mm. long Standard concrete cores shall be drilled out from such an individual area and tested for their crushing compressive strength. These values shall then be rectified for concrete age and how the cores were cut, and the corresponding equivalent "cube" strengths worked out for each core. If their average exceeds 85% of required 28 days works cube strength and none falls below 75% of the required 28 days works cube strength, then concrete in such disputed area may be accepted – but of course subject to contractual conditions for poor work.

Where minimum density of hardened concrete is specified (Generally 24KN/m^3), the mean of any four consecutive non – overlapping samples shall not be less than the specified value and any individual sample result shall not be less than 97.5 per cent of the specified value.

C3.13. Other

CAUTION AGAINST "PLASTIC-SHRINKAGE" CRACKING of Concrete AND USING EXCESSIVE DOSAGES OF ADDITIVES like 'RETARDER' and 'SUPER-PLASTICISER'

a) Plastic Shrinkage cracks develop prior to initial setting of concrete and can appear more prominently in slabs. If the rate of surface evaporation from the freshly laid concrete is faster than the rate of upward bleeding through it, the concrete surface tends to dry up, hence shrink, causing cracks in plastic concrete due to tension from this shrinking under such condition. These cracks travel downwards from the surface and their propagation is locked only upon 'initial setting' of concrete.

b) The longer the initial setting time, deeper will these cracks penetrate. Should they travel down to a significant depth of slab, then the slab can become a bunch of isolated concrete blocks separated by these cracks, and hence not be structurally monolithic with the rest of the Deck-section. Such deep-penetrating crack distress, in all probability, generally is not repairable by Epoxy filling of these cracks. The result may be a major Damage, requiring major rehabilitation.

c) Hence minimum doses of Retarders and Super-Plasticizers shall be used so as to keep the initial setting time to just the required minimum to allow the required 'workability' of concrete.

d) These cracks can be of random pattern (alligator-skin pattern) and/or may be somewhat parallel to each other and nearly perpendicular to the direction of wind that prevailed at the time of casting. Hence the field staff must look for these cracks before the concrete has initially set and , should these cracks occur, the plastic concrete should be quickly lightly 're-trowelled' on its surface (not re-vibrated) to close these cracks in time.

e) Reducing the ambient Temperature and increasing the ambient Relative Humidity (by Fog-spraying), lowering the Temperature of Concrete to less than 32ºC (by cooling the Aggregates and the mix-water), and reducing the Dosage of Retarder and Super-Plasticizer, will help in controlling the endemically dangerous Plastic Shrinkage Cracking.

f) Concrete slabs which are correctly re-trowelled should not exhibit Plastic Shrinkage cracks because the action of floating and trowelling is a form of recompaction that tends to close them as fast as they form. (This trowelling can, however, aggravate sedimentation of solids in the mix and cause Plastic Settlement cracks – see ahead.)

g) Although the Plastic Shrinkage cracks can be wide at their start (even up to 2 mm), the width rapidly diminishes with depth. Nevertheless, in severe cases they may pass through the full depth of a slab, in contrast with most types of Plastic Settlement cracks.
If not noticed in the soffit of not-easily-accessible-slab-soffits, thorough wetting at the top of the slab may show them in case of full depth penetration. Taking cores can reveal them precisely.

h) Plastic Shrinkage cracks rarely reach the free ends of the slab (e.g. the edges of a slab) because these edges are free to move under plastic shrinkage. This is a very important way of differentiating them from long-term drying shrinkage cracks if the time of formation is unknown. However, Plastic Shrinkage cracks will form up to the ends of a slab which has been cast against a previous pour, especially if there is continuity of steel, because this acts as restraint.

i) The factors that determine rate of surface evaporation are: the temperature of the concrete, the air temperature, relative humidity, and wind velocity of the air adjacent to the concrete. The evaporation increases as the humidity decreases, as the wind velocity increases, as the air temperature decreases, and as the concrete temperature increases. Of particular interest is the fact that rapid evaporation is at least as big a problem in cold weather as in hot weather! Even when the relative humidity be 100 per cent in cold weather, there will be a large amount of evaporation if the concrete is warm! Of all the factors listed above, only the concrete temperature is easily controllable. There is a definite advantage to cool the concrete! It shall be placed as cool as practical in warm weather and should not be overheated in cold weather. If the concrete temperature is reduced to about 27ºC to 15ºC, much of the evaporation can be eliminated!

j) In hot weather, sometimes concreting during 4 p.m. on the previous day up to 12 noon on the next day may be resorted to for preventing formation of Plastic cracks and obtaining better quality concrete. But this will be effective only if it gives significantly lower concrete temperatures and lower wind velocity. The reduction of air temperature BUT not that of concrete (even with the increase in relative humidity) will not significantly reduce the Plastic Shrinkage cracking.

k) If it is not possible to eliminate the risk of Plastic Shrinkage cracks even by improved timely curing, then changes to the concrete mix must be considered. First, check that the concrete does not contain an admixture with high retarding effects. If it does, try to reduce it or replace it with the one that does not retard so much (rather than counter it by adding a compensating accelerator!). Second, consider the use of air entrainment. Air-entrained concrete exhibits less Plastic Shrinkage cracks than plain concrete. At first sight this might seem illogical because as air entrainment reduces the rate of bleeding it should increase the risk of Plastic Shrinkage cracks occurring at a given rate of evaporation. However, most commercially available air-entraining agents are ‘detergents’ and therefore reduce the surface tension caused by drying, and consequently reduce the shrinkage cracking.

l) The prevention and timely repair of Plastic Shrinkage cracks in slabs is particularly critical. This is because the cracks are wide at the top and can rapidly take in pollutants which may cause subsequent spalling and prevent the subsequent satisfactory application of sealing materials. Clearly wide cracks in slabs are not likely to be self-healing at the top and are likely to spall and allow ingress of pollutants.

CAUTION AGAINST POSSIBLE DAMAGE DUE TO "PLASTIC SETTLEMENT" CRACKING OF CONCRETE

a) Plastic Settlement cracks occur in not-yet-initially-set concrete when there is a relatively high amount of bleeding through it and some form of obstruction to the downward sedimentation of its solids (e.g. the reinforcement bars). These obstructions ‘break the back of the settling concrete’ over them as its solids fall downwards around them, fomenting formation of hollows under their ‘belly’. Thus Cracks show directly over formwork-tie-bolts and over reinforcement near the top of the plastic concrete, reflecting their pattern. Such Cracks can also appear in narrow columns and walls where the said sedimentation is prevented by the resulting arching of the concrete due to downward passage for sedimentation and there may be further aggravation by the presence of horizontal bars.

b) Plastic Settlement Cracks can be prevented by reducing the bleeding and hence the sedimentation, and by reducing the obstructions to sedimentation.

c) Admixtures such as plasticizers reduce water demand and thus are the most effective way of reducing bleeding and sedimentation and hence the plastic settlement cracks. These can also be eliminated by light re-vibration (not re-trowelling) of the not-yet-initially-set concrete if they have formed, thus also filling back the under–belly hollows.

d) This light re-vibration shall not be applied too soon otherwise a second phase of bleeding can still cause Plastic Settlement cracks. The correct time can easily be determined by simple site trials: it will be the last time that a vibrating poker can be inserted into the concrete and removed without leaving a significant trace. Re-vibration is often the only way to eliminate plastic settlement cracks, particularly in deep sections. Trowelling the surface can actually aggravate these cracks as the pressure may only cause further settlement of solids!

ii. BEWARE OF CRACKS DUE TO "PLASTIC–SHRINKAGE" and "PLASTIC SETTLEMENT" IN CONCRETE WHILE IT IS STILL PLASTIC AND HAS NOT YET ATTAINED "INITIAL SET"

a) Plastic cracks by their very nature pass through the cement matrix and around aggregate particles; therefore they are very rugged and capable of transferring shear, providing there is sufficient reinforcement to maintain aggregate interlock. Consequently full structural repairs (using epoxy formulation) may not be necessary, though preferable….BUT only if the crack penetration is minor BECAUSE otherwise if deep penetration damage is done, EPOXYING WILL NOT restore full monolythicity (…..in which case the Deck-slab may have to be demolished, requiring major and very costly rehabilitational exercise). HENCE BEWARE OF PLASTIC CRACKING!!

b) If cracks follow the pattern of the top reinforcement it may be difficult at first to determine whether they are due to Plastic Shrinkage or Plastic Settlement. If it can be shown that the cracks 'pass through the slab' and follow the pattern of the steel, then they are almost certainly Plastic Shrinkage cracks that have been orientated by the steel!

c) Plastic cracks often form in the top face of sections e.g., Plastic Shrinkage cracks in slabs, and/or Plastic Settlement cracks on top of deep beams and walls. Thus they can be accessible, and this coupled with the fact that they form so early in the life of concrete, means that they may widen as thermal contraction and drying shrinkage take place. Consequently it may not be wise to fill plastic cracks with 'rigid' epoxy materials until it is certain that the long-term effects have subsided.

d) Plastic Settlement cracks over steel must be immediately and efficiently 'sealed' if the concrete is in an exposed state (to eliminate the risk of corrosion of the steel). Reduced bond strengths due to under-belly voids thus formed under steel bars are dangerous.

C4.1 Post- Tensioning

Prestressing steel may be tensioned by means of hydraulic or mechanical jacks. Devices attached to the tensioning apparatus for measuring the applied force shall be such that they do not introduce errors exceeding 5 percent. *Jacking Force normally should not exceed 76.5% of the Breaking Load.*

Before commencement of prestressing, it should be ensured that all the Cables/Ducts are free of any clogs and that the structure–members are free to accommodate the horizontal and vertical movements due to application of prestress, and that there is enough space for the movement of the jack piston.

Prestressing cables shall be protected against any unacceptable rusting, damage due to 'pitting', and any greasing. The strands must be thoroughly cleaned with petrol at locations where Stressing Jacks and Wedges have to grip them.

Each Cable shall be stressed from both its ends simultaneously, equally and gradually, and the extensions recorded at each suitable increment of Jacking Force. Any slack in the prestressing tendon shall first be taken up by applying a small initial tension. The initial tension required to remove slackness shall be taken as the starting point for measuring elongation. Further increase of tension shall be carried out in suitable steps and corresponding elongations noted. The ‘force-elongation’ relationship shall be recorded in tabular and/or graphical form. The magnitude of initial effective elongation corresponding to initial tension applied to remove slackness shall be obtained from the recorded and linearized portion of measured tension elongation relationship and added to the measured elongation to give the total elongation.

Alternatively, the same correction can be carried out graphically as shown in Fig. 4.1.

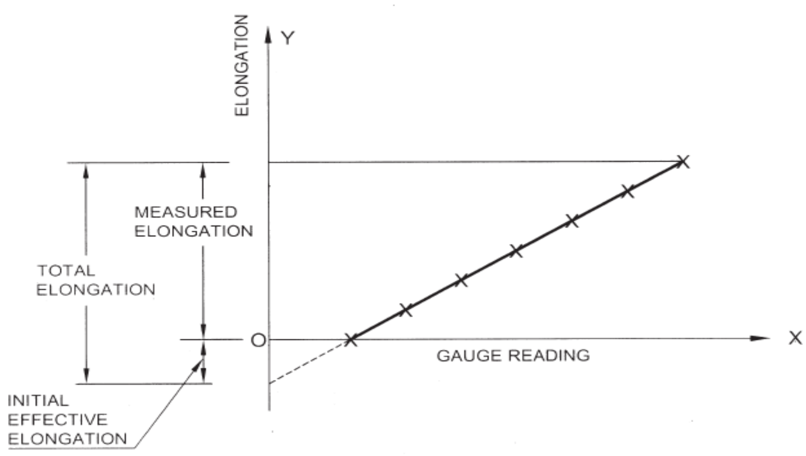


Figure 4.1 Determination of Actual Elongation

In practice, the force and elongation of tendon may not exactly match with the expected values given in stressing schedule. In such cases either the force (or the elongation) will be achieved first and the other value lag behind. In such cases the force (or elongation) shall be further increased, but not exceeding 5 percent of the design value till the elongation (or force), which had lagged behind reaches the design value*. If, even after reaching 5 percent extra value of the force (or elongation), the other lagged quantity does not reach the design value, reference should be made to the designer for review and corrective action.*

When two or more prestressing wires or strands are to be tensioned simultaneously by the same tensioning apparatus, care shall be taken to ensure that all such tendons are of the same length from grip to grip.

The placement of tendons and the order of stressing and grouting shall be so arranged that the prestressing steel, when tensioned and grouted, does not adversely affect the adjoining ducts.

The Cable Elongations at their Jacking-Points, mentioned in the drawing, are based on the assumption that the Modulus of Elasticity of Cable-steel, Es_d, (generally 1.95 × 105 MPa (i.e. 1.988 × 106 kg/cm2)). However, if Es_d of the actually supplied Cable-steel at site is slightly different, then the required Elongations at each end shall be re-worked out at site by multiplying the specified values by the ratio of (assumed Es_d / actual Es), and these shall then be the 'correct' specified extentions.

Tensioning of Prestressing Cables:

Normally, the specified required extensions shall be achieved at the specified Jacking Forces at stressing ends.

Check the correct functioning of the jack, pump and leads.

The difference between calculated and observed tension and elongated during pre-stressing operations shall be regulated as follows:

a) If the calculated elongation is reached before the specified gauge pressure is obtained, continue tensioning till attaining the specified gauge pressure, provided the elongation does not exceed 1.05 times the calculated elongation. If 1.05 times the calculated elongation is reached before the specified gauge pressure is attained, stop stressing and inform the Engineer.

b) If the calculated elongation has not been reached at the specified gauge pressure, continue tensioning by intervals of 5 kg/sq. cm. until the calculated elongation is reached provided the gauge pressure does not exceed 1.05 times the specified gauge pressure.

c) If the elongation at 1.05 times the specified gauge pressure is less than 0.95 times the calculated elongation, the following measures must be taken, in succession, to determine the cause of this lack of discrepancy:

(i) De- tension the cable. Slide it in its duct to check that it is not blocked by mortar which has through holes in the sheath. Re- tension the cable if free.

(ii) Re-establish the modulus of elasticity of steel for the particular lot from an approved laboratory.

If the required elongation is still not obtained, further finishing operations such as cutting or sealing, should not be undertaken without the approval of the Engineer.

When stressing from one end only, the slip at the end remote from the jack shall be accurately measured and an appropriate allowance made in the measured extension at jacking end. Extensions should also be checked 24 hours after anchoring the cables to guard against the possibility of 'slow slipping', if any. If the average observed 'slow slip' at anchorages of a cable exceeds 3mm, the matter should be reported to the Designer for any further instructions.

All cables which satisfy the above provisions shall be grouted, taking care that the cables not yet stressed do not get accidentally blocked due any internal grout leak.

The number of stages of pre-stressing and grouting shall be reduced to a minimum, 2 in the case of simply supported girders.

The Sequence of Stressing of Cables shall be as indicated in the attached relevant Prestressing Drawing and the prestressing shall be accomplished accordingly.

After completion of stressing and anchoring a cable, the Jack Force shall be released in such a way so as to avoid shock to the anchorage and the cable.

A complete record of pre-stressing operations along with elongation and jack pressure data shall be maintained in the approved format.

An appropriately experienced Technical representative of the Supplier of Prestressing system shall carry out and supervise all Prestressing and Grouting Operations at site and ensure, monitor and certify their correctness.

C4.2 Grouting the Ducts of Successfully Tensioned Cables

The purpose of grouting is to provide permanent protection to the post-tensioned steel against corrosion and to develop bond between the prestressing steel and the surrounding structural concrete. The grout ensures encasement of steel in an alkaline environment for corrosion protection and by filling the duct space, it prevents water collection and freezing.

Prestressing steel shall be bonded by the Grout to the concrete by filling the void space between the duct and the tendon with cement grout.

In cold and frosty weather, injection should be postponed unless special precautions are taken. If frost is likely to occur within 48 hours after injection, heat must be applied to the member and maintained for at least 48 hours after injection so that the temperature of the grout does not fall below 5°C. Prior to commencement of grout, care must be taken to ensure that the duct is completely free of frost/ice by flushing with warm water, but not with steam.

When the ambient temperature during the day is likely to exceed 40°C, grouting should be done in the early morning or late evening hours.

When the cables are threaded after concreting, the duct must be temporarily protected during concreting by inserting a stiff rod or a rigid PVC pipe or any other suitable method.

During concreting, care shall be taken to ensure that the sheathing is not damaged. Needle vibrators shall be used with extreme care by well experienced staff only, to ensure the above requirements.

It is a good practice to move the cables in both directions during the concreting operations. This can easily be done by light hammering the ends of the wires/strands during concreting. It is also advisable that 3 to 4 hours after concreting the cable should be moved both ways through a distance of about 20 cms. With such movement, any leakage of mortar which has taken place in spite of all precautions, loses bond with the cables, thus reducing the chance of blockages. This operation can also be done by fixing prestressing jacks at one end pulling the entire cable and then repeating the operation by fixing the jack at the other end.

The cables to be grouted should be separated by as much distance as possible.

In case of stage prestressing, cables tensioned in the first stage should not remain ungrouted till all cables are stressed. It is a good practice, while grouting any duct in stage prestressing, to keep all the remaining ducts filled up with water containing 1% lime or by running water through such ducts till the grout has set. After grouting the particular cable, the water in the other cables should be drained and removed with compressed air to prevent corrosion.

End faces where anchorages are located are vulnerable points of entry of water. They have to be necessarily protected with an effective barrier. Recesses should be packed with mortar concrete and should preferably be painted with water proof paint.

<u>For this purpose each cable shall normally be Grouted within 5 days of completion of its successful tensioning unless specific requirements require delaying it till certain other cables are first successfully stressed. Grouting shall be carried out as early as possible but not later than 2 weeks of stressing a tendon.</u>

The Grout shall consist of Ordinary Portland Cement, Water, and an Expansive Admixture(approved by the Engineer. All grout shall pass through a screen with 2 mm maximum clear openings prior to being introduced into the grout–pump. No admixtures containing chlorides and nitrates shall be used.

The Grout shall be mixed in mechanical mixing equipment of a type that will produce uniform and thoroughly mixed colloidal grout. The water content shall not be more than 24 litres per 50 kg sack of cement. Retempering of grout shall not be permitted. Grout shall be continuously kept agitated until it is pumped in.

Grouting Equipment shall be furnished with a pressure gauge having a full-scale reading of upto 20 Kg/cm^2 (2 MPa) and it shall be capable of grouting at a pressure of at least 10 Kg/cm^2 (1 MPa).

If the expansive Admixture (other than Aluminium compound) is used to expand the Grout, it shall be added strictly as per Manufacturer's instructions. The ducts shall be completely filled, from the low end, with grout, under NOT MORE THAN 7 kg/cm^2 pressure. Grout shall be pumped through the duct and continuously wasted at the outlet until no visible slugs of water or air are seen. All vents shall then be closed, and the grouting pressure at the injection–end raised to 10 kg/cm^2 and held for a minimum of 10 seconds before closing the hole in the cable–anchorage at the injection–end.

If some delays in Grouting are unavoidable (e.g. due to sequence of construction planned), temporary protection against corrosion shall be provided by ventilating the Ducts with dry/hot air, since any humid conditions contribute considerably to acceleration of corrosion of cable–steel.

Annex:

Reference to IRC SP 047: Guidelines on Quality Systems for Road Bridges

TYPICAL PROFORMAE

Note:

Typical proformae which have been adopted on some of the work sites are attached to give an idea of the structure of these proformae. These are indicative and may be modified, augmented or supplemented according to the needs of a particular work. The proformae are divided into categories :

Category A: Planning Proformae

Category B: Inspection Proformae

Category C: Surveillance Proformae

Category D: Proformae for Registers and Records

Category E: Proformae for Procedural Guidelines of QA System

Proforma "A4"

TEST FREQUENCY SCHEDULE

Specified Material: **Specification:** **IS (Relevant)**

Consignment Identification Number	Specified Test	Performance standard	Performing agency	QA Agency	Frequency of Performance	Frequency of Assurance	Frequency of Audit
	a) Chemical Properties b) Physical Properties c) Special Requirement (As Specified)						

Proforma 'B1'

DATA SHEET FOR SIEVE ANALYSIS - AGGREGATE

SAMPLE NO.	DATE OF SAMPLING
QUANTITY OF AGGREGATE :	METHOD OF TEST
SOURCE :	DATE OF TESTING
TO BE USED IN STRUCTURE :	SAMPLING & TESTING BY
	WEIGHT OF SAMPLE

IS SIEVE NO.	MASS RETAINED	CUMULATIVE MASS RETAINED	% CUMULATIVE RETAINED	ACCEPTABLE LIMIT

REMARKS

Note :

Plot a Grain Size Distribution Curve

Signed
Date

For Contractor
Name

Signed
Date

For Department
Name

Proforma 'B-2'

FORMWORK INSPECTION CHECK LIST

LOCATION DATED:

CONTRACTORS' INSPECTION REQUEST NO YES NO N.A.

CONTRACTORS' DRG OR SKETCH NO.

1. Formwork design/drawing/sketch approved including de-shuttering arrangements
2. Trial panel approved (if required)
3. Formwork alignment correct
4. Formwork levels correct, including screeds
5. Formwork dimensions correct
6. Formwork member spacing correct
7. Formwork member material quality acceptable
8. Falsework member sizes correct
9. Falsework member spacing correct
10. Falsework member material quality acceptable
11. Gaps between primary & secondary members closed/wedged.
12. Face boarding/Plywood/Metal thickness correct
13. Joints between panels closed (no gaps)
14. Joints between panels flush (no steps/lips)
15. Panel flatness acceptable
16. Gaps between secondary members and face panels closed
17. Tie rod material and sizes correct
18. Tie road spacing correct
19. Tie rods tight, face cones flush
20. Spacers between shutter surface tightly fitting
21. Box outs, cast-in items, ducts

fixed correct, securely. Contd..

22. Prestressing sheathing & vents, alignments & spacing of supports acceptable
23. Empty sheathing secured against floatation
24. Prestressing anchorage positions & fixing acceptable
25. Chamfers/fillets sizes, straightness, fixing acceptable
26. Formwork clean
27. Formwork release oil material approved.
28. Formwork release oil applied correctly.
29. Construction joint preparation satisfactory
30. Contraction/expansion joint preparation satisfactory
31. Safe access constructed
32. Adequate work space provided for labour, equipment
33. Shutter vibrators (if required) location & fixing arrangements approved

Inspected by: (for Contractor)	Name	Signed	Date
Approved by: (for Department)	Name	Signed	Date

Proforma 'B-3'

REINFORCEMENT INSPECTION CHECKLIST

LOCATION DATED:

YES NO N.A.

CONTRACTORS INSPECTION REQUEST NO.

REF DRG NO.

1. Working drawing checked and approved
2. Latest revision being used
3. Bar schedules approved
4. Reinforcing steel material approved
5. Bar bending & cutting satisfactory
6. Corrosion treatment of bars, if required, satisfactory
7. Bar sizes correct
8. Bar spacing correct
9. Bar lap lengths correct
10. Bar laps at correct locations
11. Bar tied as specified
12. Bar assembly rigid and adequately supported (including spacers/chair supports).
13. Cover to bottom bars correct
14. Cover to side bars correct
15. Cover to top bars correct
16. Cover blocks approved including fixing

Inspected by: (for Contractor)	Name	Signed	Date
Approved by: (for Department)	Name	Signed	Date

Proforma 'B-4'

INSPECTION CHECK LIST BEFORE APPROVAL TO CONCRETE

LOCATION:	DATED:
CONTRACTORS' INSPECTION REQUEST NO.	YES/NO Check N.A INITIAL

1. Method statement approved
2. Batching plant mixers in working order (separate dispenser for admixture, if required, available)
3. Standby batcher in working order
4. Water, sand, coarse aggregate, cement, admixture approved.
5. Water, sand, coarse aggregate, admixture, cement stock sufficient.
6. Concrete conveying arrangement (including transit mixers) available in working condition and of sufficient capacity
7. Formwork approved
8. Reinforcement approved
9. Prestressing sheathing approved
10. Concreting equipment in working order
11. Standby crane, vibrators present
12. Tremie in working order (for under water work)
13. Concrete gang present, including carpenter, steel fixer, mechanics and electricians
14. Access provided
15. Safety arrangements adequate
16. Lighting provided
17. Communications between various points provided
18. Arrangements for arranging suspension/ stoppage of concrete provided
19. Curing arrangements made
20. Laboratory notified

Inspected by: (for Contractor)	Name	Signed	Date
Approved by: (for Department)	Name	Signed	Date

Proforma 'B-5'

PROFORMA FOR CONCRETE DELIVERY AND POUR RECORD

1. CONCRETE BATCHING DELIVERY TICKET NO.

Location of Pour :	Date	
Concrete Grade :	Mix. Temp.	
W/C Ratio	Slump	
Cement Contents	No. of Cubes Taken	
Max. Aggregate size		
Admixutre (Type & Dosage)		
Batching Started, Hrs. :	Batching Finished, Hrs.	
Quantity Batched, Cu. m. :		
TRUCK ARRIVED ON SITE	Truck No.	
Slump Test Result (S)	Hrs.	
Discharge Started	Mm at	Hrs
Placement Completed :	Hrs	
No. of Sitecubes Taken :	Hrs	
Place Where Cubes Taken	Hrs	
Placement Temperature of Concrete :		
Ambient Temp.		
Weather Condition :		

Inspected by: (for Contractor)	Name	Signed	Date
Approved by: (for Department)	Name	Signed	Date

Proforma 'B-6'

POST CONCRETING INSPECTION

Note: Post concreting inspection shall be carried at various stages such as after stripping of side shuttering, each stage of prestressing, decentering and/or as per designers stipulation.

Location :
Date of pour :

Stage of Inspection :
Date of Inspection :

Specified Class :

S or NS

	Observation	Type of Remark S orNS*	
1	Position/Dimensions of the member	Alignment Levels Dimensions	S or NS S or NS S or NS
2.	Surface Defects (honey combing/ sand streaks/air bubbles/cold joints)	No defects Minor defects Major defects	(Note type and extent of defect)
3.	Class of Finish	S or NS	
4.	Cracks	No cracks Cracks Nature of cracks	Date first observed
5.	Any other Defect		
6.	Non conformance report no.	Report No./ Not Applicable	

Remarks :

In case of NS report in item (1) to (5), it should be examined by competent authority before approval or non approval. If required, a separate non-conformance report (including sketches, photographs etc.) shall be prepared for further action.

*S - Satisfactory, NS = Not satisfactory

Inspected by: (for Contractor) Name Signed Date

Inspected by: (for Department) Name Signed Date

Approval/ Non Approval by: (for Department) Name Signed Date

Proforma 'C-1'

MATERIAL QUALITY SURVEILLANCE FORM

CONTRACTOR			CONTRACT NO.	
MANUFACTURER	SUPPLIER	SOURCE	PURCHASE ORDER	INSPECTING AGENCY
INSPECTED AT	INSPECTION CERTIFICATE	DELIVERY CHALLAN	DISTIN-GUISHING MARK	DATE OF MFR./ SUPPLY
SHIPPING, STORAGE & OTHER REMARKS		(Satisfactory/ No Satisfactory)		DATE OF MFR./ SUPPLY

TEST RECORD

S.No.	Test	Method of Test	Acceptance Limits & Units	Obtained Value	Remarks
			(Appropriate Tests)		

Remarks :

Inspected by: Name Signed Date
(for QA Team)

In Presence of: Name Signed Date
(for Contractor)

Proforma 'C-2'

PRODUCTS QUALITY SURVEILLANCE FORM

NAME OF PRODUCT :

Contractor | Contract to

Manufacturer/Supplier/Source Inspecting Agency | Purchase Order

Inspection Certificate | Delivery Challan | Distinguishing Mark | Date of Manufacture/Supply

Drawing Nos. | Tender Specification Clause

Shipping, Storage & Other Remarks

S. No.	Test	Method of Test	Acceptance Range	Obtained Value	Remarks

Inspected by: (for QA Team) | Name | Signed | Date

In Presence of: (for Contractor) | Name | Signed | Date

Proforma 'C-3'

SURVEILLANCE FORM FOR PRE-CONCRETING OPERATIONS

CONTRACTOR		CONTRACT NO.
ELEMENTS OF STRUCTURE	IDENTIFICATION NO	LOCATION

SURVEILLANCE OBSERVATIONS

WORK DESCRIPTION	
1. Line, Level and Dimension as per Drg.	
2. Availability of adequate approved material	
3. Placing of Reinforcement (Including supports/spacers etc.)	
4. Form works and Scaffolding as per Drawing	
5. Box outs/embedded parts, if any	
6. Cleaning of forms	
7. Arrangements of Plant and Equipment	
8. Walkway for Pouring and Inspections	
9. Safety Arrangements	
10. Curing Arrangement	

Inspected by: (for QA Team) Name Signed Date

In Presence of: (for Contractor) Name Signed Date

Proforma 'C-4*

QUALITY SURVEILLANCE FORM WORKMANSHIP OF CONCRETE

CONTRACTOR		CONTRACT NO.
ELEMENTS OF STRUCTURE	IDENTIFICATION NO.	LOCATION

SURVEILLANCE OBSERVATIONS

The following items should be observed during concrete pour by the OA Surveillance Team.

1. **Mixing of Concrete**

— Check the concrete class and the respective mix design already approved.
— Check the condition of the aggregates to be used.
— Check the weighing and water dispensing methods adopted during the mixing.
— Check that the mixer machine has been cleaned properly.
— Check that the required mixing time is allowed.

2. **Transportation/Conveyance (as Specified, but generally to cover following):**

— Check if the equipment is in proper working order.
— Check if the specified methods are being followed.
— Check if the stipulated time limits are observed.
— Check if the non-conforming wet concrete is being rejected and disposed off.

3. **Placing of Concrete**

Check that :

— The concrete is not segregated during pour. The height of dropping is controlled.
— The concrete is poured in layers.
— The vibrators are being applied systematically to compact uniformly and adequately, avoiding over vibration.
— The concrete is not being pulled or pushed. Pouring is being done close to the final position.
— The cold joints are not allowed to be developed.
— The under water concrete is being poured only by tremies or pipeline.

— The forms are not getting displaced or deformed during the concrete pour and vibrating.
— No cement slurry is getting lost. Suitable number of carpenters are present to watch and repair formwork during the pour, if required.
— The concrete is poured within the allowable time limits from the time of batching.
— The concrete cubes are taken as required.
— The curing arrangements are satisfactory.
— The equipment is in working condition.
— ' The equipment is cleaned properly.
— The quality of wet concrete is as per specifications, (slump, homogenous mix etc.
— Continuous supply of concrete is assured.

Inspected by: (for QA Team)	Name	Signed	Date

In Presence of: (for Contractor)	Name	Signed	Date

Proforma 'D-1'

PARTICULARS OF WORK

Name of Work ____

Name of Conctractor ____

Address of Contractor ____

Contract agreement No. ____

Contract Amount ____

Applicable Schedule of Rates ____

Period of Completion ____

Date of Work Order ____

Stipulated Date of Completion ____

Actual Date of Starting of Work ____

Extensions ____

(1) ____

(2) ____

INCUMBANCY

Sr. No.	Designation*	Name	Period	
			From	To

* Departmental officers' designations covering all officers having execution responsibilities for the project.

Proforma 'D-3'

REGISTER OF DRAWINGS

Name of work :
Name of Contractor :

1.Receipt of Drawings

Sr. No.	Drawing No./ Date	Revision No	Brief Title	Issued By/ Source	Date of Receipt	No of Copies	Status of Drgs	Further Action	Signature and Date

2.Issue of Drawings

Sr. No.	Drawing No./ Date	Revision No	Brief Title	Sr. No of Receipt Register	Issued To	No of Copies	Status of Drgs	Drawing Supersedes Drg. No (If any)	Signature

Proforma 'D-3'

CEMENT REGISTER

1 . Weekly Receipt Issue (For week from………………. to……………….)

Name of Work :-

Name of Contractor

Closing Balance at the Site of Work from

previous week……………………………… bags.

Date	Quantity Received		Qnty. Used Bags/MT	Purpose	Closing balance at the end of day (bags/MT)
	Bags / MT	Source			
Total					

For Contractor

Name :

Signed:

Date:

For Engineer

Name :

Signed:

Date :

CONSUMPTION OF CEMENT ON DIFFERENT ITEMS OF WORKS, (THEROTICAL AND ACTUAL)

Name of Work :
Name of Contractor:

(A) Weekly records of items of Works

Sr. No.	Item of Work	Quantity of work done during the week

(B) Abstract for the Week Ending ……………. (Indicate Cement Consumption)

Sr. No.	Item of Work	Quantity of work done		Rate of Cement per Unit (bags/MT)	Cement required to be consumed theoretically (bags/MT)	Actual Cement consumed (bags/MT)
		Quantity	Unit			

For Contractor

Name :

Signed:

Date:

For Engineer

Name :

Signed:

Date :

Proforma 'D-5'

RECORDS OF CALIBRATION OF EQUIPMENT

Name of Work :

Name of Contractor :

ITEM	DATE CALIBRATED & PERSON CERTIFYING (FOR VENDOR OR CONTRACTOR)	*DATE OF NEXT CALIBRATION	DATE OF INSPECTION & PERSON APPROVING (FOR DEPARTMENT)	RESULT OF INSPECTIONS

* Frequency of caliberation for different equipment to be specified in advance.

Proforma 'D-6'

DAILY PROGRESS REPORT

Name of Work :

Name of Contractor :

Date	Activity Location	Item of Work	Weather Condition	Special Problems/ Difficulties	Remarks	Signature with date	
						Recorded	Checked

For Contractor

Name :

Signed:

Date:

For Engineer

Name :

Signed:

Date :

Proforma 'D-7'

REGISTER OF INSPECTION NOTES

Name of Work :

Name of Contractor :

Name of inspection Note	No and date under which recceived	Reviewed by	Signature	No & Date of Compliance submitted	Reviewed by	Signature	Remarks

Proforma 'D-8'

REGISTER OF OBSERVATION MEMOS ISSUED FROM THE QUALITY CONTROL CELL

Name of Work :

Name of Contractor :

Year	Observation Memo No	No and Date under which it is received	Reviewed By	Signature	No and date of compliance submitted	Reviewed By	Signature	Remarks

Proforma 'D-9'

RECORD OF PRESTRESSING WORKS

1 Name of Work :
2 Name of Contractor :
3 Span Length
4 Span No
5 Name and no of component

6 Date of Casting
(Indicate average cube strength
at 7 days and 28 days as per design)

7 Gauge Pressure not to exceed …………………………

Date of Pre stressing	No of Cable/ Wire or pairs of wires	Side…………………………………………………………………………………………..				
		Gauge Reading	Initial Extension in mm	Locking Pressure	Slip Observed in mm	Final Extension in mm
1	2	3(i)	3(ii)	3(iii)	3(iv)	3(v)

Gauge Reading	Side………………………………………………………………………………				Total Final Extension in mm	Calculated extension in mm for an initial pull per cable/wire/pair of wire
	Initial Extension in mm	Locking Pressure	Slip Observed in mm	Final Extension in mm		
4 (i)	4 (ii)	4 (iii)	4 (iv)	4 (v)	5	6

Theoretical Extension required in mm	Loss or gain in extension in mm	Progressive loss or gain of extension in mm	Slip observed in any , after 10 days	Remarks	Signature		
					AE	EE	Contractor
7	8	9	10	11	12(i)	12 (ii)	12 (iii)

For Contractor
Name :
Signed:
Date:

For Engineer
Name :
Signed:
Date :

Proforma 'D-10'

GROUTING RECORDS

Name of the Work

Cable* No. '
Date of Grouting

Name of Contractor :
Span No. :
Date of Cable installation :
Type of Cement: OPC/IISOPC
Week & Year of Manufacture
of OPC/IISOPC :
W/C Ratio :

Name & Amount of admixture
used, if any :

Temp:	Mixing Water ------------------	Grout ------------------	
Time:	Start ----------------	Finish ------------------	
Equipment:	Grout mixer ------------	Grout Pump ------------------	
Cable Duct:	Diameter --------------	Length ------------------	
Volume of grout in litres	----------------	Regrouting ------------------	
Grouting pressure			
Cement consumption: Theoretical	------------------	Actual	

Pre-Grouting Checks :				
Free of blockage:	inlet:	Yes/No	Outlet	Yes/No
	Vents:	Yes/No	Cable Duct :	Yes/No
Leakage observed:		Yes/No	Sealed :	Yes/No

If cable duct blocked: Remedial Measures --

Grouting Observations:

Passage of grout through vents	Yes/No
Passage of grout through outlet	Yes/No
Any equipment failure	
Post grouting checks	…………………………………………………….
Probbing by stiffwire	……………………………………………
Remarks	………………………………………………………..
Signatures of officers present during grouting:	

For Contractor
Name :
Signed:
Date:

For Engineer
Name :
Signed:
Date :

Proforma 'D-11'

PERFORMA FOR RESULT ANALYSIS (CEMENT)

Name of Work :
Name of Contractor :

Type of Cement: Grade of Cement

Sr. No	Consignment No./ Date	Sample Ref. No./ Date	Result of Chemical Test C3A, etc	Result of Physical Test (Fitness, Strength etc)	Result of Special Test , If Any
			Provide Separate Column for each test		
No of Samples					
Mean					
Standard Deviation					
Range					
Remarks :					

For Contractor
Name :
Signed:
Date:

For Engineer
Name :
Signed:
Date :

Proforma 'D-11'

PROFORMA FOR RESULT ANALYSIS (CONCRETE)

Concrete Grade : Slump Test:

Name of Contractor : 28 Days Strength:

Notes:For every Grade of concrete, separate analysis proforma should be used, Separate analysis proforma should be used with every change in mix-design.

Sr . No .	Sample Ref. No.	Structural element	Wet concrete properties		Hardened concrete Properties Strength at Age in days		
			Temp	Slump	3 Days	7 Days	28 Days
				Provide separate	column for each test		
No.of samples Mean Standard Deviation Range Comments							

For contractor
Name
Signed Date

For Engineer
Name
Signed Date

Proforma 'E-1'

GUIDELINES FOR NON-CONFORMING WORKS

1. GENERAL

In broad terms, for the Quality Assurance of the finished work it is necessary for the materials and workmanship to conform with the Contract requirements. Ideally, non-conforming work shall be rejected.

The Statement above is true in general terms but special difficulties arise in the case of concrete, where the non-conformance may only be known after 28 days cube results become available, in which period work has progressed further. In some of the situations, acceptance after repair/review for adequacy is feasible. Therefore, separate procedures are laid out for some of the non-conforming situations. In case the item does not meet the requirements after such repair/review, the non-conforming item should be rejected.

2. CONCRETE WORKS

The primary means by which Quality Assurance shall be achieved is by the procedures described in relevant material qualification and workmanship method statements. The non-conforming concrete items

shall be further reviewed, as given below :

2.1 Non-conformance Other than Strength or Finish

In the event that any requirement other than strength and standard of finish is not met then the following procedure shall be followed:

1 . The Contractor shall be notified without delay verbally and in writing by the following means:

a) Return of the Request for Inspection Form signed "not approved" with the reasons for rejection stated

b) Issue of a Site Instruction or Site Works Order or letter stating the facts and confirming that the works are not approved.

2. Approval to carry out concreting of a similar nature shall be withheld.

3. The Contractor shall be asked for his proposals to rectify the non-compliance which may involve re-submission of materials, new trial mixes, revised method statement.

4. The acceptance or reiection of any unapproved concrete work shall be referred to the Engineer.

5. When satisfied with the measures taken to ensure future compliance the Engineer shall confirm approval to continue concrete for permanent works.

2.2. Non-Conformance with Strength Requirements

1 . The Specification for concrete recognises the statistical possibility of cube failures and thus limits of means, standard deviation, minimum values of strength are specified. The rejection criteria is set out in the agreement.

2. In the event of cube failures outside the provision of the Contract then the non-compliance procedures described in the specification shall be followed :

a) Approval of concreting of similar works shall be withheld.

b) All aspects of concreting shall be reviewed.

c) The cause of failure shall be identified and measures taken to remedy the problem.

3. Various repair/rectification procedures for commonly arising/non-conformance, are specified in contract. The contractor shall furnish his exact proposals for rectification under consideration.

4. The fact of non-conformance and the proposed rectification procedure is conveyed to the engineer/design organisation of owner (or design consultant) for review and opinion about :

i) Acceptability of measure proposed by the contractor, if any.

ii) Further non-destructive testing, if any,

iii) Acceptability in case strength is achieved at a later age (e.g. 90 days)

iv) Acceptability at the level of strength achieved for the stress levels in concerned members

v) Acceptance of repair/rectification/strengthening measures with modifications, if required, or rejection.

5. Rejection in case the item does not pass modified acceptance limits after repairs.

Non-Conformance with Finish Requirements

1. Where the required finish is non attained then the non-conformance procedure for repair/rectification, as described in the Specification shall be followed.

2. In addition the following procedures shall be followed:

a) Approval of similar form work shall be withheld.

b) All aspects of formwork shall be reviewed.

c) The cause of poor finish shall be identified.

3. Revised specifications/instructions to avoid further recurrence of non-conformance shall be issued.

RECORDS

1. It is mandatory that all instances of work outside the Specification are recorded in writing, and conveyed to the Contractor. This ensures that :

a) The Contractor is irrefutably informed.

b) A record of non-compliance is built up to give a general guide to the Contractor's performance.

2. The records of repair/rectification, retesting, inspection and acceptance shall be kept as part of 'as-built' documentation.

3. Record of all references to designers for concessions/rectification and approval given by them shall be kept.

4. Record of compliance to the modifications in procedures, testing, etc., if any shall be kept.

References :

1. IRC SP 047:1998 Guidelines on Quality Systems for Road Bridges
2. IRC 18:2000 Design Criteria for Prestressed Concrete Road Bridges(Post Tensioned Concrete)
3. IS 1343 (1980): Code of Practice for Prestressed Concrete
4. IRC 21:2000 Standard Specifications and Code of Practice for Road Bridges
5. IS 1786 (2008): High strength deformed steel bars and wires for concrete reinforcement
6. IS 383 (1970): Specification for Coarse and Fine Aggregates From Natural Sources For Concrete
7. IS 9103 (1999): Specification for Concrete Admixtures
8. IS 14268 (1995): Uncoated stress relieved low relaxation seven-ply strand for prestressed concrete
9. Standard Specifications for Road and Bridge Works 2073
10. Notes of DOR PSC Superstructure Standard Drawing

Government of Nepal

Ministry of Physical Infrastructure and Transport

Department of Roads

Bridge Branch