PWD Handbook Chapter No. 40
PLACEMENT OF CONCRETE

1. Introduction and Scope:

1.1 Introduction :

The placement of concrete is a very important operation, which largely determines the success of a structure and its durability.

It is not only sufficient that a concrete mix is properly proportioned (designed), batched, mixed, and transported but also of utmost important that concrete must be placed in a systematic manner to yield optimum results.

There are number of phases to get good quality concrete. These include selection of good quality ingredients, proper proportioning of ingredients, mixing of ingredients, transportation of fresh concrete, pouring of fresh/plastic concrete into formwork or mould, compaction of wet concrete, removal of formwork and curing of concrete etc.

One of the important activities among this is transportation & pouring of concrete or placement of concrete. The placement of concrete is having large impact on success of a structure and its durability.

Concrete placing, curing and finishing etc. these operations are just as important in obtaining quality in the completed structure as the inspection of the material and the mixing operations. It is essential that the field engineer observes these operations to assure that they comply with good construction procedures.

Placing concrete is a challenging job and every concrete placement is different. Size, shape, colour, finish and depth etc. have to be considered when pouring concrete. Once these items are decided, the steps to place concrete are relatively always the same in regard to layout, preparation, and concrete placement.

The operation of placing and compacting are interdependent and are carried out simultaneously. They are most important for the purpose of ensuring the requirements of impermeability and durability of hardened concrete in the actual structure.

As long as placing is concerned, the purpose is to place the concrete as close as possible at the point of placement so that segregation is avoided and concrete can be fully compacted.

The aim of good concrete placement is to get the concrete into position without segregation and at a speed and in a condition that allow it to be compacted properly.

1.2 Scope :

This chapter covers guidelines / principles / procedures and factor affecting the placement of concrete including quality control & safety precautions during concrete placement. This chapter also covers main point to be attended during placing concrete by pump. This chapter does not cover special concretes like tremie, piles, maritime climate concreting, marine concreting, high strength concretes (above M50 grade), high performance concretes, self-compacting concrete, or any specialized concrete etc. [For tremie placing of concrete, refer IS 456-2000, para 14.2.4 a]

“Concrete production and delivery can be by a Ready Mixed Concrete (RMC) supplier. If concrete production and delivery to site for placement is also being done by the same agency responsible for the construction, the sub-organization of the agency responsible for the production of concrete should be treated as the RMC supplier for the purpose of interpreting this document.”

2. References :

The references referred for preparing this chapter is given in annexure A. These standards are subject to revision and the most recent editions of the standards indicated in annexure- A shall be referred to.

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3. General Guidelines about placement of concrete :

To achieve proper placing of concrete, following guidelines should be kept in mind.

a) The concrete should be placed in uniform layers. It should not be placed in large heaps or in general in sloping layers.
b) The rate of placing and compaction should be equal. If one proceeds slowly, mix could stiffen so that it is no longer sufficiently workable. [On no account should water ever be added to concrete that is setting] On the other hand, if it is too quickly, one might race ahead of the compacting gang which will make difficult for them to do their job properly.
c) Concrete should be compacted with method of vibration so that entrapped air can be removed.
d) Each layer should be fully compacted before placing the next layer and subsequent layer should be placed whilst the underlying layer is still plastic so that monolithic construction is achieved.
e) Impact of concrete on formwork or reinforcement should be minimized. In relation to the placement method, reinforcement cage should be stiff enough to avoid displacement of bars and movements of formwork during placement, compaction, and worker's movement.
f) For deep section, a long down chute or pipe ensures accuracy of location of concrete and minimum segregation.
g) It should be seen that the placing is proceeding in a pre-planned manner.
h) Concreting on sloping form should start from bottom to top to avoid segregation. Concrete should be stiff enough (i.e. low workability) to be retained on the sloping surface. If the slope is higher (say > 20°, back form are required to retain concrete on slope while vibrating it.
i) At a horizontal construction joint, placing of concrete involves free fall of concrete. While the fresh concrete falls on the hard surface, the larger particles of coarse aggregate rebound and go away from position of drop, collect near the surface of formwork, thus introducing segregation. Higher is the free fall of concrete, more will be the rebound and more segregation. Thus just above the joint, honey-comb is formed at the face of concrete (formed against the vertical shutter). After a small padding layer of concrete is deposited (on the previous hard concrete), the aggregate from the falling concrete gets embedded in the padding concrete and segregation is not seen at the formed surface of concrete. Hence at horizontal construction joint, hone-comb is seen only for few cm height. This height of likely honey-comb is proportional to the height of freefall of concrete. Solutions to this problem are as below.

(i) The height of free fall of the concrete should be limited to about 1.5 m. to avoid the danger of segregation and the rate of concreting must be as constant as possible[1]. However for placement on hard surfaces or at construction joints, the free fall of concrete should be restricted to about 0.3 to 0.5 m only to reduce the chances of segregation.

(ii) The concrete placing should be done by chute / pipe without any appreciable freefall for initial placement of concrete. This requires sufficient space between the reinforcement mesh for insertion of chute or pipe.

[1] As per technical specification: Reinforced concrete.

For smaller members having insufficient place (for pipe insertion), the alternate method could be as follows.

For the first pour of concrete to be placed over hard surface, maximum size of aggregate should be restricted depending upon the freefall of concrete. If the height of freefall is about a meter, the maximum size of aggregate in the concrete can be about 4 to 5 mm size, and for 300 mm fall it can be 10 mm. This will need a concrete mix designed for the smaller aggregate size and it should be highly cohesive and should be batched and produced. However if the quantity of the padding concrete needed is very small, one can remove larger size aggregate fraction from the normal concrete supply and this modified concrete can be used. Bigger size aggregate can be removed by sieving or hand picking.

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4. Steps of Preparation before Concrete Placement:-

4.1 Site Preparation

Before concrete can be placed, the site needs to be prepared. The area needs to be cleared and/or cleaned. Most often earth moving equipment is used to clear the area to speed the process. In case of road pavements, all grass, rocks, trees, shrubs, and old concrete needs to be removed, exposing raw earth. Proper sub grade preparation is important to allow the concrete to cure properly as well as reduce the chances of heaving from expansive soils.

4.2 Formwork

Once the sub base is prepared, forms can be set. Concrete forms are made from wood, metal or plastic, and can range in height from 20 cm to many metre. Plan of construction joint be ready at the time of erection and checking of formwork.

Photograph 4.2: Form Work

The formwork should be sufficiently rigid not to be deformed under the pressure of the fresh concrete and sufficiently watertight so slurry does not leak out. Before each time it is used, it must be cleaned and treated with a suitable bond breaker. The reinforcement must be correctly positioned and rigidly held in place as a cage with cover. Reinforcement shall be tied adequately and shall be inspected and approved before placing concrete.

[2]Hardened concrete, debris and foreign materials shall be removed from the interior of forms and from inner surfaces of mixing and conveying equipment. Runways shall be provided for wheeled concrete handling equipment. Such equipment shall not be wheeled over reinforcement nor shall runways be supported on reinforcement. Simultaneously, for walking of the workers, platforms shall be provided independent of the reinforcement cage, such that reinforcement shall not move (of the order of mm). Movement of bars in plastic concrete can form an annular layer of porous concrete around bars, weakening the bond with concrete and enhance the corrosion of steel thus affect the durability.

[2] As per Technical Specifications : Reinforced concrete

4.3 Placement Plan Review

Preparation for the delivery of concrete begins with a review of the placement plans. The grade of concrete with nominal maximum size of aggregate (MSA) and workability are required to be checked.

The plan shall also provide important information about concrete pour such as concrete pour sequence, location, dimensions of the construction joints, concealed pipe, fitting or holes etc.

The contractor must intimate the competent authority at least 48 hours prior to commencement of concrete operations. No concrete shall be placed until all formwork, reinforcing steel, embedded items and surfaces against which concrete is to be placed, have been checked and approved by the competent authority and pouring permission is given.

It shall be ensured that for concretes below M20 grade having volumes of more than 150 m^3, approved mix proportioning (design) is available. For concretes of grade M 20 and above, mix proportioning (design) is mandatory for any volume of concrete, thus the nominal mixes are not permitted.

All the erected formwork shall be checked for line, level, finish, treatment with bond breaker, safety of formwork, etc. It shall be ensured that all the arrangements are provided for construction joints, keyways, concealed pipes, half round pipe fittings and holes etc.. Before actual pouring of concrete begins, it shall be ensured that all the fixtures like bituminous pads, PVC/Copper water stoppers, porous rails/plugs/pipes etc. are placed in perfect alignment as per approved design and drawing.

4.4 Weather Condition

The field engineer is required to know the weather forecast for the concrete placement operation. Weather condition may influence everything from the timing of concrete delivery and placement to postponing the operation altogether. Generally concrete is placed in temperatures between 5^0C to 40^0C or as specified. Specific precautions are required when temperature of concrete is <10°C or >30°C. (Refer IS 7861 part I & part II).

4.4.1. Effects of Hot Weather on Concrete

(either concrete or air temperature is more than 30°C)

Effects of hot weather on concrete, in the absence of special precautions, may be briefly described as follows:

A) **Accelerated Setting -** High temperature increases the rate of setting of the concrete. The time during which the concrete can be handled is reduced.

B) **Reduction in Strength -** High temperature may result in the increase in mixing water demand to maintain the workability with consequent reduction in strength. Even if water cement ratio does not change due to curing at higher temperature, the potential long term strength gets reduced. So also the permeability of concrete cured at higher temperature is higher.

C) **Increased Tendency to Crack –** Plastic shrinkage cracking occurs at the surface of the freshly placed concrete while it is still plastic. Plastic shrinkage cracks may form in the young concrete due to rapid evaporation of water.

Photograph 4.4.1 C: Plastic Shrinkage crack

D) **Rapid Evaporation of Water During Curing Period –** By appropriate early curing effort, it is necessary to retain moisture for hydration and maintain reasonably uniform temperature conditions during the curing period. The heat of hydration causes the temperature of concrete to rise, which should be kept under check by allowing dissipation of heat and by cooling effect of wet curing.

E) **Difficulty in Control of Air Content in Air-Entrained Concrete** - It is necessary to control air content in air-entrained concrete. This also affects workability. For a given amount of air-entraining agent, hot concrete will entrain less air than concrete at normal temperatures.

4.4.2. Effect of Cold weather on concreting
(either concrete or air temperature is 5°C)

In absence of special precautions (Refer IS 7861 part II), cold weather may have following effects on concrete.

A) Delayed Setting - When the temperature is below 5°C, the development of concrete strength is significantly retarded compared with the strength development at normal temperatures. The hardening period necessary before the removal of forms, as well as the maturity period of concrete are thus increased.

B) Freezing of Concrete at Early Ages - When concrete is exposed to freezing temperatures, there is the risk of concrete suffering irreparable loss of strength, durability, and increase of permeability etc.

C) Repeated Freezing and Thawing of Concrete - If concrete is exposed to repeated freezing and thawing after final set and during the hardening period, lot of cracks are produced in the concrete, thus the performance of concrete will be significantly poor.

D) **Stresses Due to Temperature Differential -** It is a general experience that large temperature differentials within the concrete member may promote cracking and have a harmful effect on the durability. Such differentials are likely to occur in cold weather at the time of removal of form insulations. Similar effect takes place also when cold water is sprayed on warm concrete. Temperature shocks (sudden change of surface temperature) on concrete should be avoided.

4.4.3. General Measures to Mitigate Bad Effects of Weather on Concrete

The basic approach to keep concrete temperature regulated is by controlling the temperature of its ingredients. The contribution of each ingredient to the temperature of concrete is a function of the temperature, specific heat, and content of that ingredient. The aggregates and mixing water exert the most pronounced effect on temperature of concrete. Thus, in hot weather, all means shall be employed for maintaining the materials at low temperatures as practicable. Similarly in cold weather, the materials should be suitably heated.

The contractor may chill / heat the water and or aggregates used in the concrete mix to achieve this range of temperatures; however, the heating is required to be done in accordance with the specifications for hot / cold-weather concrete (IS 7861). The field engineer should use a digital thermometer to check the concrete temperature.

4.4.4. Minimizing Plastic Shrinkage Cracking.

To minimize plastic shrinkage cracking in flat concrete surface, adopt the following measures according to their suitability.

i) Dampen the sub-grade and forms.
ii) Prevent excessive surface moisture evaporation by providing fog sprays and erecting wind breaks. This is required immediately after laying concrete.
iii) Carryout all operation in shade to avoid heat transfer from sun.
iv) Cover concrete with wet burlap or polyethylene sheets between finishing operations, to avoid evaporation loss.
v) Use cooler (25 to 30°C) concrete in hot weather.
vi) Cure continuously as soon as finishing has been completed.
vii) Curing of flat surfaces (concrete pavement or flooring) to be done in three phases. In hot season (air temperature > 30°C), soon after placing concrete (& while finishing), the surface should be sprayed with fog / mist / fine water spray. Soon after finishing, the surface should be covered by plastic sheet or wet hessian or wet gunny bags /cloth or spray of curing compound, all this to avoid loss of water from concrete. This second phase will continue till the arrangements for the final phase is done. The final phase is a long term arrangement (10 to 14 days) for wet curing by ponding of water.

a) Hot weather Condition: [When concrete or air temperature is > 40^0C]

The temperature of concrete during the period of mixing while in transport and / or during placing shall not be permitted to rise above 40^0C or lower if specified. For pavement works, IRC specifies a temperature limit of 30^0C. Any batch of concrete which had reached a temperature greater than specified at any time in the aforesaid period shall not be placed but shall be rejected and shall not thereafter be used in any part of the permanent works. The field engineer shall record at frequent intervals the concrete and air temperature and general weather condition. The record shall include frequent checks on temperature of concrete as delivered (each transit mixer) and after placing in the forms.

All such data shall be gathered when the work is progress so that conditions surrounding the construction of any part of the structure can be determined if necessary at a later date.

Temperature of concrete can be controlled by

- Shading the area of operation and handling of concrete.
- Misting / fog spraying with water.
- Spraying cold water on the drum of agitator / transit mixer.
- Spraying of outer side of forms.
- Covering the concrete.

b) Wet Weather / Rainy weather:-

- Placing of concrete should not be started while it is raining or rainfall is anticipated unless adequate protection is available on site.
- Rain water should not be allowed to mix in concrete and also to wash or damage the surface of concrete.
- Cap the hopper of the truck mixer.

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5. Concrete Delivery:-

The smooth delivery of concrete to the job site is important. Delay in the delivery of the concrete or during the placement may cause problems that are time consuming and costly to resolve.

Prior to the beginning of concrete delivery, the field engineer should contact the plant technician to check the following items:

a) Grade with MSA of concrete to be used
b) Quantity of concrete needed for “start” pour and “end” pour
c) Workability (slump) requirements
d) Proposed starting time of delivery
e) The desired rate of delivery
f) The time gap from mixing to delivery should be within the specified period as considered of the order and considered in design of mix proportioning.

Temperature of aggregate, water and cement shall be maintained at the optimum level so that the temperature of the concrete is between 5^0 C to 40^0 C (or as specified) from the time of mixing to placement. Mixing time shall ensure adequate quality and uniformity. The effect of mixer surface exposed to the hot sun should be minimized by painting and keeping the mixer drum yellow or white and spraying it with cool water. Cement hydration, temperature, loss of workability and loss of entrapped air increases with passage of time after mixing. Thus the period between mixing and delivery shall be minimized. Sufficient personnel shall be employed to handle and place concrete immediately on delivery. Attention shall be given to coordinate the delivery of concrete with the rate of placement to avoid delays from delivery to placing.

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6. Placement Equipments:-

General: Plant, equipment, machines, and tools used in the work shall be planned and be subject to approval. These shall be maintained in a satisfactory working condition at all times.

i. Provide equipment with capability of producing the required product meeting grade controls, thickness control, and finishing requirements as specified.
ii. Use of equipment shall be discontinued if it produces unsatisfactory results.
iii. There shall have access at all times to the plant and equipment to ensure proper operation and compliance with specifications.

Following equipments are used for effective placement of concrete as per the requirement.

a) Transit Mixer
b) Bucket
c) Chutes and belts
d) Buggies
e) Spreaders or belt placer
f) Crane
g) Boom Pump
h) Telescopic placer
i) Tremie for concrete
j) Paver
k) Concrete pump

a) Bucket :

Concrete buckets help to deliver concrete on specific location of the site which is generally very high or very low and usually not accessible by chute etc. The buckets are operated with the help of crane, tower crane or forklift. They have opening at the bottom to allow the concrete to flow out of the bucket, when in place.

Clean and check the concrete buckets for accumulation of dry and hardened concrete and see that such material is removed prior to use. Control segregation by minimizing the fall of concrete when discharging in and from the concrete bucket. Move the bucket during discharge into the forms to prevent the formation of concrete heaps. See photograph 6.(a) for an example of placing concrete with a bucket.

Photograph 6 (a): Placing Concrete with a bucket

b) Chutes and Belts :-

Chute is a long smooth metal trough with rounded bottom and open ends used for conveying concrete to a lower elevation by gravity flow.

Direct and control the fall of concrete discharged from the ends of chutes and belts by a baffle. Unrestricted fall permits the coarse portion of the concrete to separate and carry ahead to the front end of the discharge while the mortar portion of the batch flows under and to the back of the main discharge position, thereby causing segregation.

When the concrete is discharged from a ready mix concrete truck, move the chute side ways to avoid heap forming to spread concrete and to reduce segregation. Never permit the concrete to build up in piles. Spread by moving the chute in as large an arc as possible within the pour area. Once the concrete is slightly above the form elevation, move the truck to a new location and repeat the process. Move the concrete from high to low area by shoveling. Never move concrete with a vibrator. See photograph 6 (b) for an example of placing concrete from the end of a chute.

Photograph 6 (b): Placing concrete from the end of a chute

c) Buggies:-

Buggy is a cart which carries small amount of concrete usually upto 0.17 m^3 from mixer or hopper to the point of placement.

Concrete placement should start at the far end of the section whenever concrete buggies are used on flat slab construction. Always place concrete from buggies toward the top edge of the previously deposited concrete. Shovel out concrete that appears segregated and spread over the bottom of the pour. Fill any depressions left by the removal of the segregated material by placing fresh concrete in the cavity and not by vibrating the concrete from the edges of the cavity.

d) Boom Pump:-

[3]Key considerations in placing concrete by a boom pump are:

- Schedule the concrete delivery ½ hr. (or within time as planned and ordered for setting time of concrete) after the scheduled arrival of the pump to allow for set up time. Schedule second concrete truck to be released on call, once the pour is successfully under way and all subsequent trucks to typically arrive at ½ hr. interval.

[3] PS 3000 : Installation manual

- The hose of the pump delivering the concrete into the forms should be not more than 6 to 7.5 cm. dia.
- The speed of the concrete dropping from the height of the boom must be reduced and controlled.
- Before actual pumping starts, pumps are generally primed with a lubricating film of mortar that should not be placed in the forms. This initial slurry should be disposed off safely away from the work area or mixed back in the next batch of concrete if permitted.

Discharge of the concrete from the end of the pump and pipe/ hose is controlled similar to that for chutes or buggies since concrete has the tendency to segregate, when discharged from the hose.

Concrete has a tendency to become stiffer or loose more slump and entrained air from pumping than with other placement methods. So it becomes necessary to increase the slump and entrained air content of the concrete from the specified range to assure that it meets specification at the point of placement. A restrictor is provided near the outlet of the pipe to minimize uneven discharge. See photograph 6 (d) below of concrete placement by boom pump.

Photograph 6 (d): Concrete placement by a boom pump

e) Spreaders or belt placer:-

Concrete spreaders are use on large paving projects, large slab works and bridge decks. The purpose of the spreader is to move large quantities of concrete within short distances with minimum segregation and deposit the concrete within the forms as near as possible to its final position.

Spreader / placer will even out the irregularities by moving the concrete from high areas to low area and when sufficient concrete is placed.

The placer/spreader generally involves any combination of the following: unloading belts, augers, plow systems, or strike offs. Sensors may control steering, grade or both. Photograph 6(e1) & 6(e2) shows a spreader and belt placer respectively.

Photograph 6 (e1): Spreader

Photograph. 6 (e2): Belt placer

f) Transit Mixer (TM)

A transit mixer is a mobile concrete mixing machinery that not only mixes concrete but also transports the mixture to the site.

Transit Mixer’s basic purpose is not mixing of concrete, but keep it agitated. As a mixer, transit Mixer is not efficient enough. It's use as a mixer is the last alternate.

In a transit mixer usually, the concrete mixer or mixing unit is mounted on a truck or trailer from which it can be attached to vehicle like tractor for concrete transport.

Photograph 6(f): Transit Mixer

Types of transit mixer are as followed.

i. Truck mounted transit mixer

ii. Trailer concrete mixer

i. **Truck mounted transit mixer:-**

This is special concrete transport trucks and is made to transport and mix concrete up to the construction site. These are mobile concrete mixers in which the concrete mixing drums are mounted on the truck chassis. These drums are made up of steel or fiber glass. During mixing, drums rotate in a particular direction that pushes the concrete inside the drum but when rotation happens in other direction, concrete is forced out of the drum on to the chutes to guide the concrete to the job site.

For mixing, the drum should be set to rotate at high speed (14 rpm), and during transit (as a agitator) it can be set to rotate at low speed (4 rpm).

Based on the discharge of concrete from the trucks, the truck mounted transit mixer are of two kind.

a) Rear discharge truck mounted mixer:-

These are the common traditional transit mixer units in which the truck and chute need to be guided for appropriate concrete placement on the site.

b) Front discharge truck mounted mixer:-

These are the advanced forms of transit mixer units that are facilitated with special controls inside the cab of a truck with which the chute can be moved in a various directions for concrete placement without requiring any guiding personnel for the purpose as in case of rear discharge trucks.

ii. **Trailer Concrete Mixer:-**

This is a mini version of a truck transit mixer and is often used to supply short load of concrete. It is the cart away style trailer mixer that is usually pulled behind a pickup truck and batched from smaller batching systems.

g) Crane:-

This is used primarily for high rise structure. It provides efficient movement of equipment. However a crane also represents a high risk of personal injury and operators of crane should be properly trained on the correct use of this equipments. Operators must use good judgment and common sense when using an overhead crane to carry a full concrete bucket to the formwork.

The essential parts of the crane are crane-bridge, trolley and hoist hook assembly.

The crane bridge is supported by an end truss and travels the length of the bay on rails. The trolley travels from side in the bay and carries the hoist hook assembly. Tower cranes have a tower fixed at a location and the boom rotates. Rail mounted cranes have a basic frame moving on rails.

Photograph 6 (g): Crane

h) Paver:-

A concrete paver is used for concrete slab on grade (layers supported on ground) such as pavement of runways, taxing areas in airport, road, parking areas, bridges decks & wearing coats, canal linings, and industrial floors.

Mechanized cement concrete lining of bed and side slopes of canal section shall be done by concrete paver. When bed width is less than 3 m, specialized pavers are required or work can be done by manual method if permitted.

Slip-form paver is an automated equipment for laying concrete pavements and it does not require side forms. Fixed-form pavers require side forms to retain concrete and the paver moves on the side forms.

Concrete transported by transit mixer or other equipments shall be delivered in front of the concrete paver.

Pavers and the support equipments shall be capable of placing canal lining at an average advanced rate of not less than about 8 m per hr., so that cutting of contraction joints or placement of strip in contraction joints is achieved smoothly and efficiently while the concrete has not set.

Precautions while using pavers:-

- The wear & tear of the drum used should be attended at regular interval, otherwise it may cause deformations in surface and thickness of the pavement or lining.
- If there is any kind of eccentricity developed in the axis of drum, it shall be attended at once to avoid any surface irregularities, improper compaction and safety hazards.
- The canal paver is unable to reach key portion and many times the bed portion (in case of small bed widths). This leaves this portion prone to lack of compaction. The concrete at these portions shall be compacted by other means like surface vibrators etc. (For more details refer to IRC 15, IRC 43 and IRC SP 46.)

Photograph 6 (h): Canal Lining Using Paver

i) Telescopic Placer (Tele-Belt)

Photograph 6 (i): Telescopic Placer

Use of telescopic placer (tele-belt) in concrete placement saves time, labor and can work in tight controlled situation.

j) Tremie[4]

This method is used for placing concrete under water or at sizable depths, in columns or piles etc. The concrete is placed through vertical pipe, the lower end of which is always kept inserted into the concrete top surface which is already placed. Due to pressure of concrete column in the pipe, the concrete in the member (say pile) moves upwards displacing water as more concrete is poured at top of the pipe in to the funnel. The rate of concrete movement is controlled by adjusting the length of submergence of pipe into the concrete. As the placement proceeds, the pipe is lifted slowly and also the concrete surface in the member rises slowly. Only the top surface of concrete in the member comes in contact with water and rest of the concrete below is not subjected to washing action. After filling the pile little more than the required level, the top loose and washed concrete is removed before it can set.

When concrete placing is not under water, tremie is used to reduce free fall of concrete and its bottom end may remain slightly above the concrete surface.

k) Concrete pump :

For concreting by pump, refer details in section 11.

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[4] IS 456-2000 : code of practice for plain and reinforced concrete, clause 14.2.4 (a).

7. Concrete placement procedure:-

7.1 Line Diagram of Steps in placement of concrete

Site preparation
↓
Form Work
↓
Concrete Delivery planning
↓
Placing equipment
↓
Placement of concrete
↓

Transportation	Pouring/ Placing	Early finishing (Spreading / leveling)	Compaction / vibration	Curing	Removal of form work	Final finish	Safety precautions

7.2 Precaution to be taken before and during concrete placement

7.2.1 Before Placement:-

a) Examination:-

I. Verify site conditions

II. Verify requirements for concrete cover over reinforcement.

III. Verify that anchor bolts, embedded plates, reinforcement, sleeves and other items to be casted into concrete are accurately placed and positioned securely, and will not cause hardship in placing concrete.

[5]b) Form setting:-

Design, erect, support, brace and maintain formwork to support vertical and lateral loads that might be applied until such loads can be supported by concrete structure. The formwork shall take loads and pressure of concrete during placing and consolidation as well as the loads of workers, equipment etc. and thereby induced vibrations without displacements / movements. Movement of concrete during setting and hardening may induce cracks in young concrete and loss of bond to reinforcement, thus permanently weaken the concrete.

Fabricate and erect formwork such that concrete members and structures are of correct size, shape, alignment, elevation and position, with tolerances within permissible limits. Refer IS 456-2000 chapter 11 & IS 14687.

[5] Construction standard specification, sec. 03351 Jan 15 2003

Design and fabricate formwork shall be rigid enough such that during placing, compaction, finishing and setting of concrete, it does not move or vibrate by movements of workers and the use of equipment. It should be able to withstand impacts and shocks without cracking of or damage to concrete cast. It should be readily removable without impact, shock or damage to cast in place concrete.

Verify lines, levels and measurements before proceeding with formwork.

All the formwork should consist of good quality and sufficiently strong material. Adequate restraint should be provided against tilting, overturning etc. The formwork should be especially checked for the permissible deviations (tolerances) in dimensions specially so for eccentricity. The arrangement should be such that it shall facilitate movement of men and machinery like vibrators etc.

Common deficiencies in design of formwork:-

Following common design deficiencies causing failure of formwork should be avoided.

a) Lack of allowance in design for loading due to wind, power equipments and temporary material storage etc.
b) Insufficient anchorage against uplift due to battered form faces.
c) Insufficient allowance for eccentric loading due to placement sequence.
d) Failure to assess bearing stresses in members in contact with shores and strut.
e) Failure to provide proper lateral bracing or lacing of shoring.
f) Failure to investigate the slenderness ratio of compression members.
g) Inadequate arrangements to tie corners of intersecting cantilevered form together.
h) Failure in considering loads imposed on anchorages during gap closure in aligning formwork.

Before and during release of formwork, following points should be carefully checked.

(i) Worker must have proper knowledge of the sequence of releasing formwork and props to be left in position.
(ii) All formwork material should maintained in good condition. Any member of the formwork should not be allowed to drop from a height but should be carefully brought down.
(iii) Forms should be released such that it should not damage both concrete and forms.
(iv) The sequence of dismantling is strictly adhered to in view of safety of workman and also structure.

Period of Releasing formwork.

Formwork of various structural members should be released after the period shown below.

i	Vertical formwork to columns, walls, beam	16-24 hrs.
ii	Soffit formwork to slab (Props to be re-fixed immediately after removal of formwork)	3 days
iii	Soffit formwork to beams (Props to be re-fixed immediately after removal of formwork)	7 days
iv	Props to slabs - Spanning up to 4.50 m.	7 days
v	Props to slabs - Spanning over 4.50 m.	14 days
vi	Props to beam and arches - Spanning up to 6 m.	14 days
vii	Props to beam and arches - Spanning over 6 m.	21 days

Refer IS 14687-1999 and IRC 87 for formwork practice.

[6]c) Placing reinforcement:-

- Place, support and secure reinforcement and embedded items against displacement by formwork construction or concrete placement operations. Locate and support reinforcement by metal spacers etc.
- Clean reinforcement of loose rust and mill scale, earth oil, concrete from previous pour and other materials which reduce or destroy bond with concrete and which is porous.
- Variation of cover to reinforcement affects the performance and durability of concrete member. Hence specified clear cover should be achieved within a close tolerance of ±3mm or as specified. Cover blocks should be fixed such that these do not move during placing and compaction of concrete.

d) Preparation for placing concrete:-

- Remove water from excavation or surfaces over which concrete is to be placed.
- Before placement, remove wood chips, hardened pieces of concrete, loose concrete, loose aggregates, etc. from forms.
- Clean all equipment.
- Before placing fresh concrete, the existing surface (may be old concrete) should nearly be saturated in advance (but surface dry) so that the mortar below (or old concrete) does not absorb water from the fresh concrete, changing its workability and affecting its compaction. Before placement, the surfaces and form work should be cooled by water spay, to the limiting temperature (30 to 40°C or as specified).
- Forms, reinforcement and sub-grade shall be sprinkled with water just prior to placement of concrete. The area around the work shall be kept wet to the extent possible to cool the surrounding air so as to reduce temperature and evaporation from the concrete.

[6] As per master specifications : Cast in place concrete sec. 033000 (Revised 10.6.2011)

7.2.2 During placement:-

The aim of good concrete placing is quite simple. It is to get the concrete into position quickly and in a condition that allows it to be compacted and finished correctly and with ease.

a) Whenever possible, discharge concrete directly from the truck mixer. If concrete needs to be discharged at elevated locations, this can be done with the help of a concrete pump or crane and bucket conveyor.
b) Ensure adequate access for the pour. Carefully place the concrete in a series of layers of equal depth normally not more than 300 mm deep.
c) Next layer should be placed within about 30 minutes (or the setting time of concrete), such that the concrete in the earlier layer is yet not set while fresh concrete is being placed on it. This way a cold joint can be avoided. If this is not done, the joint should be treated as a construction (or cold) joint, which needs permission to be introduced and requires many more precautions.
d) Do not allow the concrete to pile up in large heaps or sloping layers.
e) Deep sections such as walls and columns need extra care. [7]Concrete should not be allowed to have a free fall preferably not more than 1.5 m, and 0.5 m at construction joint. Where necessary, use tremie pipe or concrete hose to place concrete in forms. Use of a truck mixer fitted with conveyor is also advantageous in some applications.
f) All forms must be rigid, level and ensure that inside portion is cleaned up and applied with a de-moulding treatment (form release agent etc.) before concrete is placed.
g) Always make sure that there is adequate safe access to the discharge point for personnel and equipment.
h) Prepare old concrete by roughening of the surface if specified, and cleaning with steel brush or water blasting. Apply bonding agents in accordance with the instructions, wherever specified.
i) In location, where new concrete is required to be doweled to existing work, drill holes in existing concrete, insert steel dowels and pack the remaining space with non shrink grout or epoxy grout.
j) Foundation surfaces against which concrete is to be placed, must be free from standing water, mud and debris. Surfaces shall be clean and free from oil, objectionable coatings, and loose material.
k) Locate construction joints wherever indicated on drawings or permitted by Engineer-in-charge. Construction joint shall be given the proper treatment as specified in section Annexure C.
l) Entrapped air during placement of concrete should be removed by vibration.
m) It is necessary to compact the concrete thoroughly working solidly around all embedded reinforcement and filling all form angles and corners. Over-vibration is equally harmful causing segregation, and should be avoided.
n) When placing fresh concrete against or upon hardened concrete, make sure that a good bond develops. For improving bond for monolithic action, roughening of the surface of old concrete is required at the construction joint. Roughening may not be required where the two layers do not require monolithic action. If specified, a chemical bonding agent should be used.

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[7] IS 456-2000 : Para 13.2

7.3 Factors Affecting the placement rate :-

Following factor may affect the rate of placement of concrete

- Mixing and truck loading
- Delivery distance to the site
- Quality control checks
- Placement set up
- Pumping

To control the above factors following steps should be implemented.

a) Calculate the placement rate.

b) Provide number of trucks etc. accordingly.

c) Provide Number of pumps.

d) Arrange stand by machinery and spare parts.

e) Check sufficiency of fuel, power supply, water, material and labour etc.

f) Calculate total working hrs to place concrete .

[8]7.3.1 Time Interval Between Mixing and Placing:-

Concrete should be placed in the forms within initial setting time of concrete being used or as modified by the use of chemical admixture from the time ingredients are loaded into the mixing drum.

[Here setting time of concrete is relevant, and tested as per IS 8142]

[9]7.3.2 Requirement as per weather condition:-

For weather condition and precautions, details are given in section 4.4

7.3.3 Bonding:-

Before depositing new concrete on or against concrete that has set, the surface of the set concrete shall be thoroughly cleaned so as to expose the coarse aggregate and be free of laitance, coating and loose particles. The cleaned surface shall be moistened by small quantity of water such that no free water remains on it when concrete is placed.

[In Euro codes & IS 456, condition of poor bond is specified. The bond is poor for a reinforcement, where bar is horizontal (or bar at about $< 45°$ to horizontal) and near the top face of a plastic concrete lift which is 30 cm thick or more. Where the plastic concrete thickness is 30 cm or more, after vibration, plastic settlement takes place in concrete, which is enough to form a gap or water film below bar and thus the bond strength around the bars is reduced in the matured concrete.

[8] Technical specifications : Reinforced concrete

[9] Technical specifications : Reinforced concrete

7.4 Construction Joints :- (Also called as Cold Joint)

The purpose of a construction joint is to join a section of fresh concrete to a previously poured section that has already set. Construction joints are required when a structural unit is too large to pour in one continuous operation or when rain, equipment problems or other conditions interrupt the pour.

The surface can be roughened between the reinforcement. Notching / grooving should not be preferred except for mass concrete. Roughening and notching / grooving should be preferably done before initial setting of concrete. Immediately before placing fresh concrete, forms are tightened against the concrete in place. To improve the bond between the sections, a bonding epoxy to the exposed surface before resuming the pour can be applied. On the epoxy covered surface, the first pour of new concrete should have some epoxy mixed in it.

Construction joint may not be allowed where the reinforcing steel has been spliced. It is more important that reinforcing bars are not in the plane of construction joint.

Concrete pour should be done with due care not to disturb the steel reinforcement, which has already been erected. If reinforcement is displaced, it needs to be retied immediately in the proper position. Concrete that is splashed on these bars is required to be cleaned off before the next section is poured to ensure a good bond. If the steel is exposed to the weather for long time after the pour, the steel may require coating to prevent rusting.

All construction joints except shown on approved drawing of monoliths, lining etc. shall be subjected to approval of the Engineer. Concrete shall be placed continuously so that the unit will be monolithic in construction. When concreting is done in layers, it shall be ensured that next layer shall be placed before the earlier layer has not initially set, to ensure monolithic construction. This needs careful sequencing of operations and providing more access points on the site.

Details specification about construction joint are attached separately in Annexure – C

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8. <u>Water proofing of concrete</u>.

Concrete if not waterproofed, absorbs water, water borne contaminants and chemicals that can cause deterioration. To protect the concrete and for ensuring its long serviceability, waterproofing is essential.

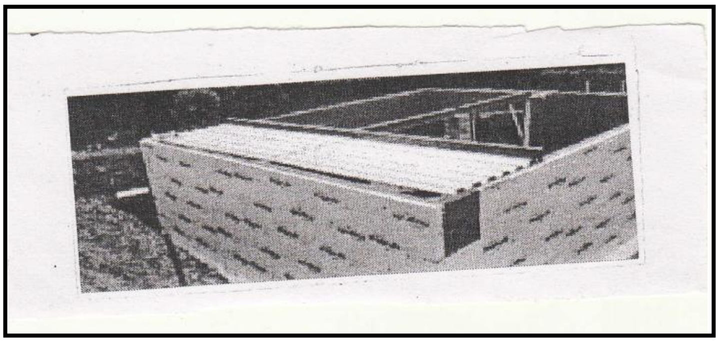
Making concrete waterproof means preventing water passage and resisting hydrostatic pressure.

Well graded and well compacted concrete does not require water proofing treatment however following methods are generally adopted for water proofing of concrete.

(i) Sheet membrane system (Exterior side)

Cold applied polymer-modified bitumen is a sheet membrane composed of polymer materials compounded with asphalt and attached to a polymer sheet. The polymer is integrated with the asphalt to create a more viscous and less temperature-sensitive elastic material compared to asphalt on its own. These sheets are self adhering and eliminate the harmful toxins typically associated with asphalt adhesion. They also increase tensile strength and resistance to acidic soils.

Disadvantage of sheet membrane system is that, this system involve accuracy, as membranes require sealing, lapping and finishing of beams at the corner, edges and between sheets.



Photograph 8: Sheet Membrane System

(ii) <u>Liquid-applied membrane</u>

Liquid applied membranes can be applied with a brush, spray, roller, trowel etc. and usually contain urethane or polymetric asphalt (hot or cold applied) in a solvent base.

These membranes are usually applied on the exterior side of the cured concrete.

Successful water proofing with liquid-applied membrane depends on proper thickness and uniform application.

(iii)<u>Admixtures</u>

Concrete absorbs water because surface tension in capillary pores in the hydrated cement paste "Pulls in" water by capillary action. Waterproofing admixtures aim at preventing this penetration of water into concrete.

These integral admixture systems are added at the batching plant or on site and react chemically within concrete.

Following types of water proofing admixtures are generally used.

a) <u>Densifiers admixtures</u>

This admixture reacts with the calcium hydroxide formed in hydration, creating another by-product that increases concrete density and slow water migration. They are typically not characterised as waterproofing materials or repellents because they have no ability to seal cracks and joints.

Water repellents are also known as " hydrophobic". These products typically come in liquid form and include oils, hydrocarbons, stearates. Induced stresses cause cracking in any concrete which creates pathways for water passages. So the effectiveness of water repellents is highly dependent on the concrete itself.

b) <u>Crystalline admixtures</u>.

These admixtures come in a dry, powdered form and are hydrophilic in nature. Unlike there hydrophobic counter parts, crystalline systems actually use available water to grow crystals inside concrete effectively closing off pathways for moisture that can damage concrete.

They block water from any direction because the concrete itself becomes the water barrier.

As the exact composition of the admixture is often unknown, care should be taken to see that they should not contain chlorides, if the concrete is likely to be used in a situation which is sensitive to chloride induced corrosion.

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9. Compaction:-

The fresh concrete contains air bubbles. If nothing is done to get rid of them, the result is blow holes or honey combing which weaken the concrete and reduce its durability and strength. Hence the purpose of compaction is to expel the entrapped air from the concrete. Compaction is generally complete when air bubbles stop rising to the surface. A glossy film of mortar on the surface is another good sign with non air entrained concrete.

9.1 Methods of Compaction:-

The following methods are used for compacting the concrete

i) Hand Compaction
   a. Rodding
   b. Tamping
ii) Compaction by Vibration
   a. Internal (Needle/ Immersion/ Poker) Vibrator
   b. External (formwork) Vibrator
   c. Table Vibrator
   d. Platform Vibrator
   e. Surface Vibrator
iii) Compaction by pressure and jolting.
iv) Compaction by spinning (ex. Concrete pipe).

i) Hand Compaction:-

This method of compacting concrete may be adopted in case of unimportant concrete work and of small magnitude.

a) Rodding:-

Rodding of the concrete is done with 2 m long, 16 mm diameter rod, to pack and compact the concrete between the reinforcement and at sharp corners and edges. Rodding over the complete area is done effectively to compact the concrete and expel the entrapped air.

b) Tamping:-

Tamping is usually done on side forms to expel air bubbles from the surface, that is by striking the shuttering by wooden or hard rubber mallet. This method is adopted in compacting roof or floor slab or road pavements where thickness of concrete is comparatively less. Tamping consist of beating the top surface by wooden beam of section about 10 x 10 cm, about 1.5 m long. Since the tamping bar is sufficiently long, it not only compacts but also levels the top surface across the entire length.

ii) Compaction by Vibration:-

For compacting concrete having workability about 100 mm or less slump, vibration is required. To compact such concrete, mechanically operated vibrator must be used.

The modern high frequency concrete vibrators make it possible to compact the concrete economically, and which would be unreliable if done by manual methods.

The use of vibration is essential for the production of good concrete where reinforcement is congested or at some positions, where hand compaction may be efficient.

The potential advantages of vibration can be realized only it proper control is exercised in the design and manufacture of concrete and certain rules are observed regarding the proper use of different types of vibrators.

a. Internal (Needle /Immersion) Vibrator:-

This type is the most commonly used vibrator. It is also called “poker or immersion” vibrator. This essentially consists of a power unit, a flexible shaft and a needle.

The power unit may be electrically driven or by petrol engine or air compressor. The vibrations are caused by eccentric weight attached to the shaft in the needle portion.

The needle diameter varies from 25 mm to 80 mm and its length varies from 30 cm to 90 cm. This vibrator is portable and can be shifted from place to place very easily during concreting operation.

b. External (or form) Vibrator:-

External vibrators are used for columns, walls or precast units. The vibrator is clamped on the external parts of the formwork supporting the shuttering. The vibration is given to the formwork so that the concrete in the vicinity of the shutter gets vibrated.

Use of external vibrator will produce a good finish to the concrete surface. The efficiency of external vibrators is lower than that of internal vibrator as they consume more power, and vibration is given to the concrete adjacent to the shutters. Inside positions away from shuttering requires internal vibrations or rodding.

c. Table Vibrator:-

This is the special case, where a mould is clamped to the table which vibrates. Any article kept on the table gets vibrated. These are adopted mostly in the laboratories and in making small precast members.

d. Platform Vibrator:-

Platform vibrator is a large table vibrator, used in the manufacture of large pre-cast concrete elements such as electric poles, railway sleepers, roofing elements, etc. Sometimes, platform vibrator is also coupled with jerking or shock giving arrangement such that a thorough compaction is given to the concrete.

e. Surface Vibrator:-

Surface vibrators are sometimes known as “screed board” vibrators or plate vibrator. A small vibrator placed on the screed board gives an effective method of compacting and leveling thin concrete members such as floor slabs, roof slabs and pavements.

Mostly floor slabs and roof slabs are so thin that internal vibrator or other type of vibrator (except surface type) cannot be employed.

iii) **Compaction by pressure and jolting:-**

These are the effective methods of compacting very dry (i.e. very low workability) concrete. This method is often used for compacting hollow blocks, cavity blocks and solid concrete blocks by using a press in combination with jolting or vibrations.

The stiff concrete can be vibrated, pressed and also given jolts. With the combined action of the jolts, vibrations and pressure, the stiff concrete gets compacted to dense form to give good strength and volume stability. By employing great pressure, a concrete of very low W/c ratio could be compacted to yield very high strength. This method is mostly practiced in the laboratory and in production of blocks, tiles and small precast units.

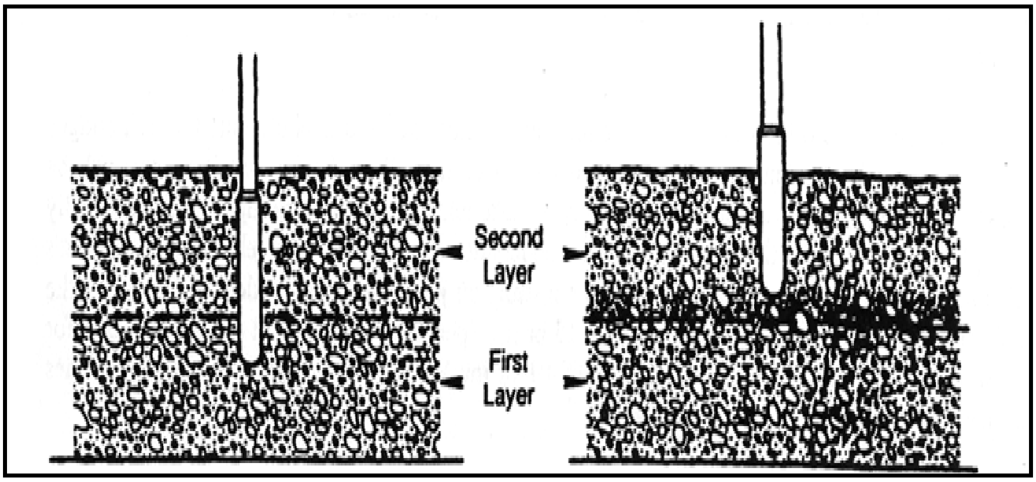
iv) **Compaction by spinning (e.g. Concrete pipe):-**

Spinning is one of the recent methods of compacting concrete. This method of compaction is adopted for the fabrication/ compacting concrete pipes. The plastic concrete when spun at a very high speed gets well compacted by centrifugal force.

9.2 Guide lines for using Vibrators:-

To ensure that needle and other vibrators work properly, it is important that these are well maintained and used with adequate safety precautions.

i. Always check the security of connections before starting works.
ii. Clear moisture out of all surfaces before connecting to vibrators.
iii. Always have a standby vibrator and an alternative power source available.
iv. Vibrators to be used should be checked a few days in advance to ascertain them to be in working order. Keep bearings well-greased.
v. Vibrate the concrete as soon as possible within it's initial setting time after placement.
vi. Needle vibrators should be inserted and withdrawn vertically and should not be dragged through the concrete. Over vibration drives the larger aggregates to sink and finer material remains near top portion.
vii. When the concrete is poured in layers, the head of the vibrator is required to penetrate through the top layer and partially through the layer underneath. (see fig.9.2)
viii. Avoid contact of the form walls with the needle vibrator as that may otherwise loosen the form and may also cause honey-combing of the concrete surface due to excessive loss of slurry.
ix. Avoid contacting the reinforcement with the vibrator so that bond between the steel and the concrete is not weakened.
x. Switch pokers off immediately when withdrawn from concrete.
xi. Thoroughly clean all compacting equipment after each pour or shift.



Correct method **Incorrect method**

Photograph 9.2 Compaction using vibrator

9.3 Compaction Procedure:-

Plan the work well in advance. Study the drawing for likely trouble spot such as congested reinforcement or built in items.

Ensure that the poker hose and power lines are long enough to reach the place of pour and there is sufficient lighting arrangement to see into forms. Place the concrete uniformly and avoid dropping it from a height. To ensure proper compaction, the concrete should not be placed faster than 300 mm depth at every 20 sec. Concrete delivered by truck mixer and conveyer can be particularly advantageous in these situations.

Lower the poker down after depositing up to 300 mm depth of concrete in the first (bottom) layers. When concreting large column, it is sensible to use one poker to compact the concrete in layers, slowly with-drawing the poker and re-inserting in the next position to achieve complete compaction.

As with slabs, compact edges with a poker to ensure that edges are fully compacted and durable.

9.4 Plastic settlement

Plastic settlement may occur above reinforcement, pre-stressing ducts and void formers.

The primary cause of plastic settlement is the bleeding. Bleeding is the separation of excess water which concrete cannot hold. Plastic settlement cracks typically appear over reinforcement, or where there is sudden change in depth of section.

It is a good practice to re-vibrate or re-tamp in concrete after the bleed water has evaporated or is removed from the surface.

In modern practice, the water cement ratio is kept sufficiently low, such that the concrete does not bleed and does result in a better quality of concrete.

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10. **Curing:-**

10.1 General

Curing is the process of assuring to prevent loss of water from concrete, so that hydration of cement can continue uninterrupted at all parts of the concrete. It requires maintaining almost 100% saturation in the concrete. The hydration reaction chemically slows down as the relative humidity (RH) reduces below 100%, practically very low at 70%. Each intermittent drying (RH<70%) can result in a permanent loss of strength as a fraction of the potential balance strength (achievable with continuous curing) of concrete. Curing also involves the control regime on the temperature of the concrete over the concerned period. During curing period, high thermal gradient and thermal shocks on concrete should be avoided.

Curing is one of the most important steps in concrete construction because proper curing allows concrete to gain strength and durability. Curing ensures continuous hydration, the chemical reaction between cement and water. However hydration occurs only if water is available and if the concrete's temperature stays within a suitable range. The curing process lasts for a period such that even after discontinuing the curing, the specified characteristic strength of concrete at 28 days or as specified is achieved .However , the first 72 hrs being the most critical. The curing period should not be less than 7 days. Curing period may extend from 14 days to 28 days for satisfactory strength development of concrete. 28 days continuous curing is important because volume changes due to alternate wetting and drying promote the development of surface cracking. During the curing period (say five to seven days after placement for concrete), the concrete surface needs to be kept moist to permit the hydration process. New concrete can be wet soaking material, covered with wet berlap or sprayed by sprinklers or can be coated with commercially available curing compounds which seal in the moisture. Steeply sloping and vertical formed surfaces shall kept completely and continuously moist prior to and during forms removal by applying water to top surfaces so that it will pass down between the form and the concrete. After removal of forms, the surfaces shall be kept covered by a wet wrap or sealed by curing compound.

On exposed unformed concrete surfaces such as pavement slabs, wind is an important factor in the drying rate of concrete. Hence wind breakers shall be provided as far as possible.

On concrete surfaces, curing water shall not be much cooler than the concrete because of the possibilities of thermal stresses and resulting cracking. At the termination of curing with water, an effort shall be made to reduce the rate of drying by avoiding air circulation. This can be achieved by delay in removal of wet cover until they are dry.

10.2 Methods of curing:-

There are two basic methods of curing concrete:

(i) continuously wetting the exposed surface, or

(ii) Restricting moisture loss by covering the surface.

Continuously wetting the surface retains the most moisture within the concrete but has problems relating to supply of water, drainage of runoff and subsequent work during the curing period. Also, depending on the method of water curing, it may not be possible to commence curing directly after finishing without damaging the surface finish. Restricting moisture loss includes leaving the formwork in place or applying a relatively impermeable membrane such as plastic sheeting or a chemical curing compound to the surface.

Generally plastic sheeting (held down at joints and edges) is the next most efficient way to cure after continuous wetting, with typically only about 2% of the moisture being lost from the concrete over a 72 hr test period.

Curing compounds are liquids (or solutions) which can be applied directly onto the concrete surface. They dry to form a membrane on the surface which retards the loss of moisture from the concrete. They can be an efficient and cost-effective way of curing concrete and should be applied immediately after the finishing operation has been completed. The efficiency of chemical curing compounds varies quite widely, depending on the material and strength of the emulsion.

Australian Standard: Curing compounds are covered in AS 3799 – 1998.

ASTM Standard C309-11: Liquid membrane-forming curing compounds for concrete.

Five basic classes of compounds are covered in the Standard, viz:

- **Class A** Wax-based compounds, consisting of either natural paraffin or synthetic waxes, can be either emulsified with water or dissolved in solvents. While both types work by depositing the wax on the surface. As the water or solvent evaporates, emulsified waxes are more commonly used. However, as the wax particles are only in suspension, they can float out if the emulsion stability is poor, requiring remixing before use.
- **Class B** Resin-based compounds (commonly known as hydrocarbon resins), consisting basically of petroleum hydrocarbon resin dissolved in a low aromatic hydrocarbon solvent such as white spirits. Again the resins may be natural or synthetic. More recently, aliphatic resins have been developed.
- **Class C** Chlorinated rubber-based compounds, consisting of rubber polymers that have been treated with chlorination process which gives a higher resistance to sunlight, and makes the compound more resistant to chemical attack and to embrittlement. The rubber is dissolved in a solvent to allow application.
- **Class D** Synthetic polymer-based compounds, generally consisting of synthetic polymers in an emulsion or solution form. Polymers are large molecules that have been formed by joining together small molecules (or monomers). Due to the variety of polymers available, the efficiency of the membrane also varies.
- **Class Z** Other membrane-forming compounds (not included in the above classes) such as bitumen or epoxy based compounds or compounds that are neither water nor solvent borne. Compounds that do not form a membrane, but are designed to impregnate the surface such as silicones and silanes are not included.

Within each class, there are various types, and these are grouped basically by colour.

- Type 1- Clear or translucent without dye.
- Type 1-D Clear or translucent with fugitive dye. A fugitive dye allows the compound to be seen after application, but becomes inconspicuous within seven days if exposed to sunlight.
- Type 2- White pigmented or containing aluminum reflective pigments.
- Type 3- Black or coloured, other than white.

10.3 Selecting a Method of Curing

For large external pavements, roads and civil projects, the wax-based emulsions and hydrocarbon resin solutions are the most appropriate compounds to be used. In the case of pavements, wax-based compounds are generally only used as a slip coating over the bottom concrete layer. Other compounds are generally for internal concrete work, with PVA emulsions not recommended due to their poor curing efficiency.

As curing compounds can affect the bonding of subsequent surface treatments such as line-marking and other pavement markers, special care in the choice of a suitable compound needs to be exercised, particularly with wax emulsions.

Curing compounds should be applied to the surface of the concrete after it has been finished, and as soon as the free water on the surface has evaporated and no water sheet is visible. Applying too early dilutes the membrane and too late results in it being absorbed into the concrete and not forming a membrane. Both situations may reduce the effectiveness of the curing compound.

One of the benefits of water curing is the control of concrete temperatures and hence less curling problems due to the high thermal variations that can occur within the slab. Pigmented chemical curing compounds not only help ensure complete coverage, but they can also be advantageous in reducing curling problems by assisting concrete surfaces to reflect rather than absorb heat.

The Roads and Traffic Authority of NSW, in its R83 Specification, calls for a Type 2 compound containing titanium oxide reflective pigment to be used over the hotter months from November to March. At other times, a Type 1-D compound must be used. The compounds nominated are either:

- Class B: Hydrocarbon resin.
- Class Z: Water-borne hydrocarbon resin or styrene butadiene resin (SBR).
- Bitumen emulsion grade CRS/170 complying with RTA 3254.

Note that the R82 specification contains the compliance requirements for the above compounds.

While curing may be seen as an inconvenience (especially on some projects), the damage done to the long-term strength and durability of the concrete rarely justifies the cost saved by not curing. It should always be possible to select a method of curing that will be both effective and economic.

Issues to be considered when selecting a curing method include:

- Type of member to be cured, eg slab, wall, column.
- Bonding of a specified finish or line-marking to the surface.
- An acrylic paint may be able to be applied over an acrylic curing compound, but other treatments will generally require the curing compound to be removed.
- The effect of the curing process on the appearance of the concrete. Wax emulsion materials will leave a tacky surface which will pick up dirt and dust.
- The construction schedule, i.e. Will work need to proceed in the area during curing? Wax emulsion materials can be very slippery, especially on wet, smooth surfaces.
- Cost and availability of curing materials – a small saving in initial cost could result in a large cost to remove the compound if the incorrect material is used, i.e. not suitable for a subsequent coating.
- Safety restrictions, i.e. toxic fumes in enclosed spaces, slippery plastic sheeting – the use of solvent-based products such as chlorinated rubber solutions are effectively banned on many CBD construction sites.

- Weather conditions, exposure and location – weather and UV exposure help to degrade/breakdown curing compounds making them easier to remove.

Some of the advantages and limitations of the different curing methods are listed in Table 10.4.

Table 10.4 Advantages and limitations of curing methods*

Curing Method	**Advantages**	**Limitations**
Continuous wetting / Ponding, sprinkling, wet coverings	Does not affect surface adhesion, Maintains constant moisture.	High water usage, High maintenance, Labour intensive, Not practical for large jobs.
Plastic sheeting	Does not affect surface adhesion, Controls evaporation of moisture.	Labour intensive to cover surface and difficult to secure edges to maintain damp conditions. Material usage, Waxes on surface of plastic may affect adhesion of other materials.
Wax-based emulsions	Generally most effective of membranes, Most meet AS 3799 requirements, Can be used as bond breaker, economical.	Leaves slippery finish, Do not break down over time, Difficult to remove Not suitable for subsequent coatings.
Hydrocarbon resins – Aliphatic / aromatic blends	Meet AS 3799 requirements, Can be coloured	Always solvent based, Slow to break down.
Hydrocarbon resins– Aliphatic resins	Meet AS 3799 requirements, Break down in 45 to 60 days, Can be water or solvent dispersed, Can be coloured.	More expensive than aromatic type.
Chlorinated rubber	Can meet AS 3799 requirements, Can be coloured.	Do not break down, High solvent level, Carbon tetrachloride is suspected carcinogen, No longer favoured for OH&S reasons.
Polymer based compounds – SBR Modified	Can meet AS 3799 requirements, Low cost.	Slow to break down, Yellow, Must be removed prior to adhesion of other materials.
Acrylic emulsions	Only a few can meet AS 3799, Can improve adhesion of cementitious systems, Easily removed by grit blasting.	Expensive, Removal difficult, Some will affect adhesives used for line-marking.
PVA compounds	Inexpensive, Water based.	Can not meet AS 3799 requirements.

*The assistance of both Parbury Technologies and MBT in compiling this table is acknowledged.

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11. Placing of concrete by pump

Now a days, concrete is conveyed under pressure through either rigid pipe or flexible hose and discharged directly into the desired location. This is called as placing concrete by pump. Pumping may be used for most of all concrete constructions, but especially useful where spaces or access for construction equipment is limited.

Placement of concrete in inaccessible areas has necessitated the use of pumps in today's construction.

Photograph 11: Placement of concrete by pump

Specifically with growth of ready mixed concrete, the need of pumping has increased in many situations.

Pumping depends on the type of pump available, the distance over which concrete is to be pumped and the concrete properties (i.e. workability and cohesiveness). The mix proportioning is also governed by the force required to pump the mix through the pump. Alternately, the pumps brought shall be of the capacity to pump the designed concrete mix.

The main use of pumped concrete is that it can be delivered to points over a wide area otherwise not easily accessible, with the mixing plant clearly off the site i.e. away from the site. This is especially valuable on congested project sites or in special applications such as tunnel linings etc. Pumping delivers the concrete direct from the mixer to the forms and avoid multiple handling. Placing can proceed at the rate of the mixer output and is not held back by the limitations of the transporting and placing equipment. A high proportion of ready mixed concrete in now a days pumped.

11.1 Basic Considerations about ingredients of concrete for pumping

The concrete mix design must be properly proportioned so that the concrete should flow easily and uniformly through the pipeline. Important factor in mix proportioning (design) is the workability / consistency (slump) of the concrete. A higher workability (consistency) will allow the concrete to move more readily within the pump and pipeline. However an excessively high slump can cause the concrete to segregate resulting in plugs of coarse dry material in the pump or pipeline, the paste being squeezed out. As the workability increases, the cohesiveness of the mix also increases.

Also a concrete mix must be such that the concrete can pass through reducers in the pipeline system and can go round bends in the lines. In order to obtain this type of pumpability, the mix must be dense, cohesive, homogeneous, and have a sufficient paste and mortar fraction to minimize problems.

The mortar volume required depends on the line size, efficiency of concrete pump and pressure available for pumping concrete.

Provisions contained in IS 456-2000: Plain and reinforced concrete (fourth revision); and IS 10262-2009: Concrete mix proportioning guidelines (first revision) should be followed for concrete mix design.

11.1.1 Cementatious Content

As compared to normal concrete, the pumped concrete requires higher paste content. Use of lesser cementitious content may cause segregation within the pipeline. Concrete with higher cementitious content without admixtures are liable to prove difficult to pump because of high friction between the concrete and the pipeline.

11.1.2 Fine aggregate

Natural sand is often suitable for pumping because of their rounded shape. Sand having fineness modules between 2.4 to 3.0 is generally satisfactory for pumpable concrete. Manufactured (artificial) or crushed sand may also be used provided it complies with the relevant IS Codes and suitability is established through mix proportioning.

Fine aggregate of zone II as per IS 383-1970 is generally suitable for pumped concrete provided 15 to 30% sand should pass 300 micron sieve and 5 to 10 percent should pass the 150 micron sieve.

11.1.3 Aggregates

The maximum size of crushed aggregate is limited to one third of the smallest inside diameter of the hose or pipe. For pebble (natural / un-crushed) aggregate, the maximum size should be limited to 40% of the pipe hose diameter.

The shape of the coarse aggregate whether crushed or uncrushed has an influence on the mix proportions for pumpability, although both shapes can be pumped satisfactorily.

The crushed pieces have a large surface area per unit volume as compared to uncrushed pieces and thus require relatively more paste to coat the surface.

Difficulties with pump have often been experienced when too large a proportion of coarse aggregate is used in an attempt to achieve economy by reducing the amount of cement. Such mixes are also more difficult and costly to compact and finish.

The grading of coarse aggregate should be as per IS 383- 1970, with grading (refer grading curve) drifting towards finer fractions.

11.1.4 Workability

Generally for pumped concrete, workability ranges between 75 to 100 mm.[10]

- A concrete of less than 50 mm slump is impractical for pumping and slump above 125 mm should be avoided.
- In mixture with high slump, the aggregate will segregate from the mortar and paste and may cause blockage in the pump lines.
- The mixing water requirement vary from different maximum sizes and shapes of aggregates.
- In high strength concrete, due to lower w/c ratio and high cement content, workability is reduced with the given quantity of water per cum of concrete. In such case water reducing admixtures are required.

11.2 Requirements for pumped concrete

Concrete to be pumped**,** must be uniformly mixed before feeding and sometimes a stirrer can help the feeding.

Following are some of the requirements of pumped concrete.

- Concrete mixture should neither be too harsh nor too sticky; also, neither too dry nor too wet.
- A slump between 75 to100 mm is recommended (note that pumping induces partial compaction, so the slump at delivery point may be decreased).
- If the water content in the mixture is low, the coarse particles would exert pressure on the pipe walls. The presence of a lubricating film of mortar at the walls of the pipe also greatly reduces the friction.
- Water is the only pumpable fluid component in the concrete, and transmits the pressure on to the other components.
- Blockages to make pumping inefficient - Water can escape from the mixture if the voids are not small enough; this implies that closely packed fines would be needed in the mixture to avoid any segregation. The pressure at which segregation occurs must be greater than that needed to pump concrete.
- Other factors about mix that could affect pumping are the cement content, shape of aggregate, presence of admixtures such as pumping aids. Air entrainment is helpful in moderate amounts, but too much air can make pumping very inefficient and also reduce strength.
- When flowing concrete is being pumped, an over-cohesive mixture with high sand content is recommended. For lightweight aggregate concrete, pumping pressure force water in the voids of the aggregate with water, reducing the free water in the mix and thus reducing workability.

11.3 Sequence of a typical concrete pump pouring process.

- On arriving pump at site, the operator should make the arrangement for setting up the pump, pipeline (if required) and preparing the grout.
- The concrete mixer truck will arrive and pour concrete in to the pump hopper.
- Before actual start of the pumping, a rubber sponge ball is passed through the line along with water and cement slurry. This ensures that the pipeline is through and also it coats the pipeline internally with cement slurry. This operation (without

[10] AS per IS 456-2000 amendment no 1 June 2001

cement slurry) shall also be done at the close of pumping to ensure that no concrete remains in the pipeline.

- The pump operator will then grouts the line and commences pumping. It is good site practice to pump excess grout to waste, and not into the pour.
- The concrete will be placed into position using the boom where possible. Where ground-line is used, the concreting gang will need to move the pipeline around as the pour progresses (Cautionary note: Concrete is pumped at high pressure. All workers should be made aware of the risks and dangers associated with end hose usage)
- When the truck mixer has discharged its load, the mixer chutes will be cleaned before the mixer leaves. The washed material should not be put into the hopper of pump as this could cause a blockage and affect the quality of the concrete.
- The next transit mixer will there after arrive back on to the pump and discharge its load.
- At the end of the pour, the pump operator will clean all the concrete from the pump and pipeline. This operation will take approximately one hour, more if the job involves a long pipeline
- The pump operator will then put the boom back into its travel position and load all the ancillary equipment onto the pump.

11.4 Types of concrete pumps

Two types of concrete pumps (Figure 11.4 (i) and (ii)) are used:

i. Direct acting piston pump

Direct-acting, horizontal piston type with semi-rotary valves set to permit always the passage of the largest aggregate particles. This type of pump can cover a horizontal distance of 1000 m and a vertical distance of 120 m. The concrete is fed in by gravity and is also partially sucked in during the suction stroke. The valves open and close with definite pauses so that concrete moves in a series of impulses, but the pipe always remains full. These pumps are capable of pumping 130 m^3 of concrete per hour with 200 mm. pipes.

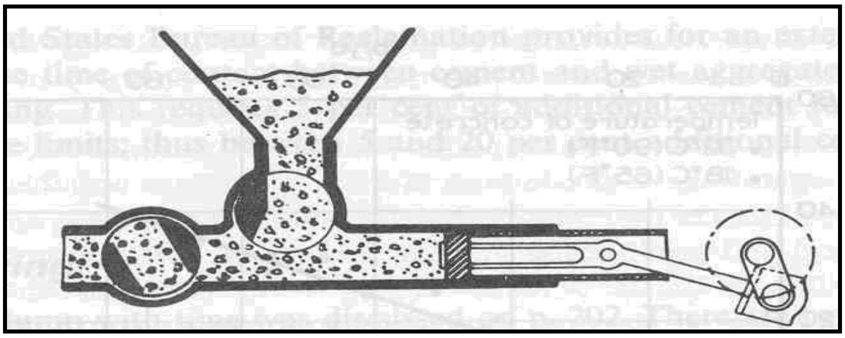

Figure 11.4 (i): Direct acting piston pump

ii. Squeeze pump

Squeeze pumps are the one that use vacuum pumping. These pumps can cover a distance of 90 m horizontally and 30 m vertically, and are capable of pumping 20 m^3 of concrete per hour using 75 mm pipes.

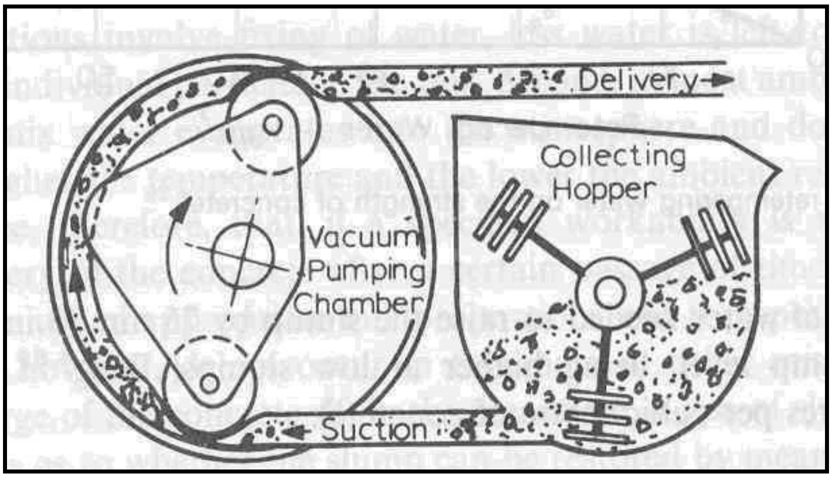

Figure 11.4 (ii): Squeeze pump

The bends in the pipes conveying concrete from the pump should be minimum in order to avoid losses. In addition, these should not be sharp. (Each 10^{o} bend is equivalent to an extra length of pipe of 1 m.)

The pipe diameter should be at least 3 times the maximum aggregate size. Large aggregates can especially tend to get blocked near the bends.

The economy of pumping depends on the number of interruptions. Each time, the priming of the pipes using mortar is required (0.25 m^3/100 m for 150 mm. pipe), and the pipe also has to be cleaned.

Aluminum pipes should be avoided, as it attracts with alkalis in the cement, and leads to the evolution of hydrogen gas. These gases tend to introduce voids in the concrete, which reduce the efficiency of pumping.

Pumping enables concreting of inaccessible areas. Moreover, the direct conveyance of concrete from the truck to formwork can avoid double handling of the concrete.

Other accessories of pumping units are rigid pipelines, flexible hose and couplings etc.

A pumpable concrete, like conventional concrete mixes, requires good quality control, i.e. properly graded uniform aggregates, materials uniformly and consistently batched and mixed thoroughly. Depending on the equipment, pumping rates may vary from 8 to 130 m^3 of concrete per hour. Effective pumping range varies from 90 to 400 meters horizontally, or 30 to 100 meters vertically.

11.5 Proper sizing of pipeline and equipment

In order to optimize the concrete pumping operations, the most efficient configuration of the system must be determined. A specific line pressure must be determined to move concrete at a specified rate of flow through a pipeline of a particular length and diameter. The major factors affecting pipe line pressure are.

a) Pumping rate.
b) Line diameter.
c) Horizontal and Vertical distance.
d) Configuration including reducing sections.

In addition, a number of other factor must be taken into account when determining line pressure including

a) Vertical rise.
b) Number of bends.
c) The amount of flexible hose used in the line.

- **Line Diameter :**

  In general, the larger the inside diameter of the pipeline, the less pressure required to move the concrete through the pipeline at a given rate. There is a major drawback to large diameter pipelines. However, larger the line, the more labour, blocking and bracing it will require.

  Thumb-rule: (The max size of aggregate should not be more than one third of inside diameter of delivery system.)

- **Line length:**

  Friction between the pumped concrete and the internal pipeline wall directly affects the pressure equipment.

  i. The convenience of easy access for truck mixers must be weighed against the desirability of locating the pump closer to the placement point.
  ii. Consider using two lines and two pumps when there is a larger distance between the pump and the farthest placement point. The end of the first pump feeds into the hopper of the second pump. This may operate more efficiently than a single system operating at excessive line.

- **Pipeline layout:**

  The pipeline layout should be such that it contains a minimum number of bends. This is because an increased resistance to movement of the concrete corresponding to an increased number of changes in the direction.

  Reduction in pipe diameter within the same line also increases resistance, so the same diameter line should be used throughout wherever possible. For reducing diameter, reducer should be used.

- **Equipment:**

  To run the line pumps at full speed without danger of a form blowout, 50 mm diameter hose is the ideal size for placement.

  In addition, the smaller diameter slows the flow of concrete, giving the hose operator better control of the placement. Reducers may be used on a boom pump to bring the diameter down to 50 mm or 75 mm and 90^0 elbow fittings attached at the end of the hose assembly creates 'S' in the line breaking the long fall of concrete

- **Hose:** Hose should be used only at placement point for discharge.

  <u>Thumb Rule :-</u> Never use a discharge hose bent less than 60 cm radius.

  For boom truck application, a specially reinforced hose is recommended.

  <u>Thumb Rule :-</u> Never use a boom hose less than 75 cm radius.

11.6 Pumping operation

Before the pumping of concrete is started, the conduit should be primed by pumping a batch of mortar through the line to lubricate it.

a. In a pump line, concrete moves in the form of a cylinder or slug separated from the pump line wall by a lubricating layer of water, cement and fine sand. When concrete is pumped, if spaces or voids between aggregates are not filled with mortar, or if the mortar is too thin and runny, pump pressure cause segregation forcing water through the mix. When this happens, the lubricating layer is lost, causing coarse particles interlock friction to increase and the concrete to stop moving. To prevent plugs, the pressure at which segregation occurs must be greater than the pressure needed to pump the concrete. This can be accomplished by filling spaces between aggregate particles with smaller aggregate.

b. Before the start of pumping, a rubber sponge ball is passed through the pipe under pressure along with water and cement slurry. This ensures that the pipeline is through and also coating the pipe line. This operation shall also be done at the close of pumping to ensure that no concrete shall remained in the pipeline.
c. The properties of coarse aggregates that affect permeability are maximum size, shape, surface texture, porosity and gradation. Generally, the line diameter should be maximum 3 times the maximum size of aggregates. Shape and surface texture are important because concrete made with angular, rough particles usually have a high mortar content to be pumpable. For best pumpability, the gradation of the coarse aggregate should fall in the center of the gradation specifications.
d. Porosity will affect permeability if a significant amount of mix water is absorbed by the aggregate during pumping. When absorption causes problems, the solution is to thoroughly wet the aggregate stock piles before batching the concrete.
e. Once pumping has started, it should not be interrupted, as concrete standing idle in the line is liable to cause a plug.
f. The pump should be as near the placing area as practicable and the entire surrounding area must have adequate bearing strength to support the concrete delivery trucks, thus assuring a continuous supply of concrete. Lines from the pump to the placing area should be laid out with a minimum of bends. For large placing areas, alternate lines should be installed for rapid connection when required.
g. When pumping downward 15 m or more, it is desirable to provide an air release valve at the middle of the top bend to prevent vacuum. Air built up when pumping upwards. It is desirable to have a valve near the pump to prevent the reverse flow of concrete during the fitting of clean up equipment or when working on the pump.

11.7 Testing for pumpability

Any mix selection of concrete to be pumped must be subjected to a test. Although laboratory pumps have been used to predict the pumpability of concrete, the performance of any given mix has to be assessed under the actual site conditions, including the equipment to be used and the distance through which the concrete is to be pumped.

11.8 Inspection and maintenance

11.8.1 Blockage

a. Locating a blockage

Concrete pumping crew must be constantly aware of the possibility of a pump line blockage and be able to remove them promptly and safely.

A rising in line resistance as shown on the pump pressure gauge indicates the blockages. The first suspect spot for blockage is the reducer, which connects the concrete pump to the pipeline system. A quick build up pressure prior to the joint indicates that the blockage is most likely in the pump area.

The operator needs to examine the system at the elbows or discharge hose. This can be done by tapping the hammer along the pipe line. Where concrete is jammed, the hammer will produce a dull thud, as opposed to a more ringing sound where the line is clear. All pipes, joints, should also be inspected for grout leakage.

Main causes of blockages are :

- Wrong mix proportion of concrete
- Problem with the pipe line
- Operational error

b. Clearing the blockage

By alternatively reversing the pump and resuming pumping for a few cycles, the pump operator may be able to break loose minor block jam.

This should not be tried more than a couple of times however, as it can jam the pipelines even tighter.

If the reversal method does not work, the operator must locate the blockage, then break back the line and clear it out.

Always make sure, the line is no longer under pressure prior to clearing a blockage. Stand to one side of the line and remove the coupling nearest the jam. All the free flowing concrete should run out of the open end of the line by lifting the lines, then bend the hose or tap on the pipe line in the area of the jam and shake out the material and loose particles.

11.8.2 Checking for Wear

Pumping performance as well as safe operation of the pumping system may be affected by worn couplings, which may let air into the line or allow grout to escape.

a) Couplings typically wear on the surface that comes into contact with pipe
b) Gaskets need to be cleaned if they have concrete remaining in the cavity. The gasket should be replaced if the center lip is worn out.
c) Valves should be routinely inspected for wear and proper setting.
d) The most accurate way to inspect the worn pipe line is with a gauge specifically designed to measures the thickness of steel pipe. In addition, the pipe ends must be inspected for wear.

11.8.3 Cleaning the System

Water should be used for cleaning since it is the best and safest cleaning method available.

If cleaning with compressed air, remember that the pressure build up and may remain in the line even after the supply is shut off, so a bleed off valve should always be installed on the system when using compressive air.

While using water or air pressure, install end cap and a bucket to prevent injury to workers or damage to property.

11.8.4 Securing the system

Improper tie-down is one of the most common cause of accidents when pumping concrete. Support brackets designed to hold pipe line in either horizontal or vertical position should be spaced every 3 m to 5 m in order to take weight off the coupling joints and to transfer the pumping torque to a building column or beam.

11.8.5 Pipe testing

It shall be ensured that the manufacturer has completed all the requirements of supporting pipe, testing, identification, and marking.

11.9 Safety equipment[11]

Personal protective equipment (PPE) is the least effective method for controlling risk.

Before beginning any pumping operation, the concrete pump operator and the person in control of the work place should assess the conditions likely to affect the health and safety of workers and arrange for the provision and of appropriate personal protective equipment.

The following items of PPE are required when pumping concrete

a. Safety helmets
b. Eye protection
c. Safety vest
d. Rubber safety boots
e. Hearing protection
f. Gloves

Additional equipment

Each pump unit should be equipped with the following items,

a. First aid kit (Must include eye wash)
b. Protective cream
c. Reflective traffic cones.
d. Signs e.g. exclusion zone.

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[11] Code of practice 2005 : Concrete pumping

12. Quality Control :-

12.1 Quality Control Plan (QCP) for placement of concrete:-

a. General:-

The Quality Control Plan (QCP) shall be prepared well in advance and should be site and contract specific and state how the process control of materials, equipment and operations shall be maintained. As a minimum, the QCP shall include the following information.

i. The name, telephone No's, duties of employer of all Quality Control personnel necessary to implement the QCP.
ii. A list of testing equipment proposed for process control testing, and the test methods and frequency of calibration and verification of equipment.
iii. The procedure, location, and type of equipment to be utilized during the trial batch demonstration.
iv. The location and frequency for sampling and testing the concrete mix for slump, air content etc.
v. The equipment and methods for delivery of the concrete. The description of the plan and drawing of the traffic patterns for delivery of the concrete mix to the site of work shall be included.
vi. The procedure for placement of concrete to include as a minimum the placing sequence, identification of the placing equipment and description of the pumping procedure if applicable.
vii. The method for finishing, texturing, and curing concrete, description, and identification of the equipment shall be included.

b. QCP approval:-

The QCP is required to be submitted to the competent authority for review and approval well before start of the activity of placement of concrete. Concrete placement shall not begin before the QCP has been accepted by the competent authority and a successful trial batch demonstration is completed.

c. QCP addenda:-

The QCP shall be maintained to reflect the current status of the operations and revisions are required to be provided in writing prior to initiating the change.

The change shall not be implemented until the revision has been accepted; however traffic patterns for delivery of concrete mix to the site of work may be adjusted for un-anticipated conditions without adding addendum to the QCP.

12.2 Testing fresh concrete at point of placement:-

Testing fresh concrete at point of placement ensure that the contract requirements are being met for the concrete as placed. As placed concrete will differ from as delivered concrete, if conveyed by means that might alter the properties of fresh concrete.

The project engineer who wants to test at the point of placement may have concerns such as preventing a potential loss of durability caused by a low air content in the structure or making sure the pump operator doesn't add water to the pump hopper to reduce pump pressure. However an experienced construction team usually can avoid significant changes in concrete properties between discharge from the truck and the point of placement, allowing most of the testing to be done at the point of discharge.

Slump Test:-

Slump tests are conducted to determine the consistency of fresh concrete and to check the uniformity of concrete from batch to batch. Unacceptable slump measurements usually indicate improper mix properties, especially the water content. The concrete shall not be re-tampered with water at the time of placement. (IS 456:2000, Amendment No.1, June 2001 recommended various values of slump range according to placing conditions of concrete and degree of workability).

Wet density (Plastic density test):

Wet density of fresh concrete at the point of placement should be tested. It should match fairly with the density of design mix.

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13. Safety precautions in concrete placement:-

When portland cement is mixed with water or even when it becomes damp, alkalis are released which can be harmful to the human skin. The harmful effect depends on the period of contact, prior abrasion, individual's health and the part of the body involved.

To avoid harmful effects according to type of injury, following remedial measures should be adopted. [Ref. Literature of TL products ltd. (concrete pumping risk assessment)

Table 13. Safety precautions in concrete placement

Type of Injury and Cause	Person at Risk	Risk level*	Severity of Injury	How to Prevent
Concrete splashing into eyes from the end hose	Concrete Crew	H	Low	Goggles must be worn.
Concrete burns to hands and feet	Concrete Crew	L	Medium to Severe	Gloves, safety boots and barrier cream must be worn.
Falls or injury to hands, arms, ankles, legs etc from falling on mesh	Concrete Crew / Pump Operator	M	Medium to Severe	Plywood sheets must be provided on mesh in the laying area.
Back injury due to moving ground pipes	Concrete Crew / Pump Operator	M	Medium to Severe	Use of ropes and good manual handling practices to be adopted.
High pressure concrete and aggregate going into eyes, face or any exposed skin due to standing or working in front of end hose, or opening up pipe joints when pumping	Concrete Crew Persons working around concreting area General Public	M/H	Severe – can result in loss of sight	Concrete crew should wear a safety helmet, safety footwear, impervious gloves / gauntlets, high impact goggles and high visibility clothing. Until concrete is flowing smoothly out of the end of the delivery hose or when a blockage occurs in the boom pipeline, all personnel should remain clear of the delivery hose and placing boom. Under no circumstances, any unauthorized person should attempt to open the pipeline. All unnecessary personnel including the general public should be kept well away from the concreting area in the lower floors and staircases.

Type of Injury and Cause	Person at Risk	Risk level*	Severity of Injury	How to Prevent
Head injury from suspended hoses from boom	Concrete Crew	L	Medium to Severe (possible death)	Move away from end hose during boom movement. Concrete Crew to be alert.
Broken limbs, severe injury caused by whiplash of placing hoses.	Concrete Crew	L	Severe or death	Do not kink placing hoses in the ground line. Do not attempt to pump very old concrete or concrete other than a pump mix. The danger zone is the area around the end hose in which it can strike out. The diameter of the zone is twice the length of the end hose.
Injury from splash due to blow back from concrete pump hopper	Truck Mixer Drivers	L	Eye injuries possible	Keep hopper full and inform mixer driver of risk.
Crushing when mixer truck is backing onto the pump hopper	Person backing truck mixer into pump hopper	L	Severe or death	High visibility clothing must be worn and do not back truck on out of view of mixer driver who will be reversing using mirrors. Keep site personnel out of reversing area.

*** (H=high, M=medium, L=low)**

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14. Finishing concrete surface:-

After the forms are removed at appropriate time, surface defects shall be remedied. The temperature of the concrete, ambient air and mortar during remedial work including curing shall be above 10^0 C. Fine and loose material shall be removed. Honeycomb, aggregate pockets, voids over 13 mm in diameter and holes left by the rod or both shall be cut out to solid concrete, reamed, thoroughly wetted, brush coated with neat cement grout and filled with mortar, the colour of the mortar shall match the adjoining concrete colour. Mortar shall be thoroughly compacted in place. After the paste grout takes the initial set, the surface of the concrete is scraped with a steel knife to remove paste from the surface. Holes passing entirely through walls shall be completely filled from the inside face by forcing mortar through the outside face.

Holes which do not pass entirely through wall shall be packed full. Patchwork shall be finished to match adjoining surface in texture and colour. Patchwork shall be damp cured for 72 hrs. Dusting of finished surfaces with dry material or adding water to concrete surfaces will not be permitted.

14.1 Bug holes and sand streak

Bug holes are defined as small holes or voids that appear on the surface of concrete.

Free water and entrapped air found in fresh concrete migrate to the formed surface of the concrete and form bubbles of air or water. After the concrete harden and the free water evaporates, there remains at the surface visible empty void spaces. These are bug holes.

Photograph 14.1 Bug holes

a. **Entrapped air :** Air can be entrapped in concrete in two ways :
   i. The inability of the cement paste to fill all the voids between the aggregate particles and
   ii. Air can be entrapped in the cement paste during mixing of concrete.
b. **Water:** Free water in concrete causes problem with surface defects including sand streaking.

Free water, as it is not chemically bonded to cement paste or physically trapped inside the aggregate, is free to migrate through plastic concrete and may produce bug holes and sand streak.

Generally bug holes are found at the surface or just below the surface, behind a thin skin of dried cement paste. Also there are disproportionate number of voids in this area in comparison with interior of the concrete.

To overcome the problem of bug holes and stand streak following precautions should be taken

a) Use external form vibrators to draw mortar to the form face. This will help to fill any voids that form at the form face, thus reducing the formation of bug holes.
b) Internal vibrator should not be allowed to come to close to the form face. If this happen, entrapped air can migrate to the form face and become bug holes.
c) Form work should be maintained in good condition and clean.
d) For super plasticized concrete, reduce the size of the internal vibrators and duration of vibration.
e) Select a high quality form release agent, which will enable clean release.

14.2 Finished bearing area:-

The bridge seats and areas in between, require special treatment at the finishing stage. The tops of the bridge seats are required to be finished at exactly the right elevation and be completely level to ensure full contact with the bottom of the bearing device. The areas in between the bridge seats are required to be sloped or crowned slightly to ensure adequate surface drainage. Both results are obtained through proper finishing techniques.

14.3 Other surface treatment:-

The surface of pier and bent cap are required to be sealed against moisture penetration with an approved concrete sealer. The surfaces to be sealed are sand blasted to remove form oil and other foreign matter and are required to be completely dry before the applications.

14.4 Concrete finishing details[12]:-

a. **Concrete paving:-** After concrete is placed and consolidated, slabs shall be screeded or struck off . No further finish is required. [Normally grading (called sceeding) is to be done before consolidation/ vibrations.]

b. **Smooth finish:** It is required only when specified. After surface moisture has disappeared and laitance has been removed, the surface shall be finished by float and steel trowel (troweled if specified) [Trowelling is specified where smooth industrial floor is required, and not for pavement which have enough friction). Smooth finish shall consist of thoroughly wetting and then brush coating the surface with cement mortar.

[12] As per technical specification: reinforced concrete

c. **Broom Finish:-** It is required for paving, stair landing etc. The concrete shall be screeded and floated to the required finish level with no coarse aggregate visible. After the surface moisture has disappeared and laitance has been removed, surface shall be float finished to an even smooth finish. The floated surface shall be broomed with a fiber bristle brush in a direction transverse to the direction of the main traffic. (Finish by bristle brush is roughening and not brooming).

ANNEXURE- A
List of referred standards and literature

(A)	Indian Standards	Title
	456-2000	Plane and reinforced concrete (Fourth revision)
	383-1970	Specification for "coarse and fine aggregates from natural sources for concrete" (Second revision)
	10262-2009	Concrete mix proportioning (First revision)
	7861-1975 (Part I and II) (Reaffirmed 1997)	Indian Standard Code of practice for extreme weather concreting (For hot weather of cold weather)
	14687-1999 Reaffirmed 2005	False work for concrete structures -guidelines
(B)	**Other codes**	
	ACI 304 and ACI 309	Placing concrete
	Code of practice 2005	Concrete pumping (work place health and safety Queensland Department of justice and Attorney-General/Queensland government)
	BS : 8476-2007	Code of practice for safe use of concrete pump
	ASTM standard C309-11	Liquid membrane forming curing compounds for concrete
(C)	**Specifications / manual**	
	Technical specifications (Sec. 20 to 24)	Reinforced concrete
	Construction standard specification (Section 03351) (Jan 15, 2003)	Exposed aggregate concrete
	Facilities master specifications Revised (10/6/2011)	Cast-in-Place concrete (Section 033000)
	Concrete manual (Sep 1, 2003)	Placement operations
	Installation manual (Poly steel) PS. 3000	Step-by-step procedures (Concrete placement)
	Construction manual for building structure Vol.1	Placing concrete
(D)	**Literatures**	
i)	Publication COODO61 on testing fresh concrete at point of placement.	
ii)	Literature; (May 29, 2010) by Kstlelsel Archieve-2004-2008 on concrete placement equipments.	
iii)	Literature; Massive concrete placement from Advanced construction technology services, ACTS)	
iv)	Literature of Nilkanth Engg. Works, Ahmedabad on concrete mixers.	

v)	Literature of American society of concrete contractors on pumping RMC
vi)	Literature; TL products Ltd (Feb- 16, 2013) on guidelines for concrete pumping.
vii)	Literature; Concrete news: USA and Canada 800-362-3331
viii)	Literature; National ready mixed concrete associations, MERI Land
ix)	Literature; Best practice placement guide concept ^{TM}, Architectural concrete : CEMEX
x)	Literature; Chapter Four : Concrete Placement (State of Indiana)
xi)	Literature; Chapter Seven : Quality Control (State of Indiana)
xii)	Literature; The concrete society, UK; concrete for pumping
xiii)	Literature; NBM Media, India : Mix design for pumped concrete.
xiv)	Literature; Concrete pumping midlands : concrete pumping
xv)	Literature; Concrete network : concrete pumps and pumping information
xvi)	Literature; Planet TP : The world of public works : The Placement of Concrete
xvii)	Literature; TL Products Ltd. Concrete placement – Concrete pumping risk assessment.
(E)	**Books**
i)	Properties of concrete by A.M. Neville
ii)	Concrete Technology by M.S. Shetty

Annexure-B
Committee Composition

(Ref. Hon. Director General, Maharashtra Engineering Research Institute, Nashik Marathi Letter No. 13/2013, Date: 3/1/2013)

Sr.No.	Name	Organization
1	Shri. V.B. Pandhre	Chairman of committee and Chief Engineer, DTR&S, META, Nashik.
2	Shri. S.M. Sukare	Chief Engineer and Administrator, CADA, Aurangabad (Special Invitee)
3	Shri. R.D. Patankar	Superintending Engineer and Dy. Director, MERI Nashik and Committee member
4	Shri. R.V. Shrigiriwar	Superintending Engineer (Masonry dam), CDO Nashik and Committee member
5	Shri. K.M. Shah	Superintending Engineer, Quality Control Circle, Pune and Committee member
6	Shri. V.D. Nemade	Superintending Engineer, Quality Control Circle, Aurangabad and Committee member
7	Shri. R.M. Chauhan	Superintending Engineer, Quality Control Circle, Nagpur and Committee member
8	Shri. S.D. Kulkarni	Scientific Research Officer, Material testing Division, MERI, Nashik and Member Secretary of committee.
9	Shri. K.C. Tayade	Executive Engineer and Principal, Regional training centre, Nagpur and committee member.
10	Shri. Rajiv G. Mundada	Executive Engineer, Quality Control Division Nanded and Committee member.

Annexure C
Specifications

CONSTRUCTION (COLD) JOINTS :

Construction joints are introduced for convenience in construction. Measures should be taken to ensure subsequent continuity in concrete i.e. monolithic action, & there should be no chance for future relative moment at the joint.

Construction joints are positions of structural weaknesses in the member. Across joint, strength is affected and also liquid percolation may increase. Shear strength reduction may be assumed 15 to 50 % depending upon the detailing and workmanship at the joint. Hence at all specified positions of construction joint, shear strength must be checked. Reduction of tensile strengths (both direct & flexural) are substantial across the joint, thus the estimated crackwidth may exceed (1.2 to 1.5 times). Hence if a joint is proposed, the possible weakness should be accounted in design.

Construction joints are source of weakness hence it is desirable to minimize their number, really the total lengths, and better to avoid them. Concreting should be carried out continuously up to construction joint.

The position and arrangement of these should be indicated by the designer. These should be planned at accessible locations, to facilitate treatment to the surface of joint. Concreting operation should be carried out continuously up to the preplanned construction joint.

A reinforcement bars should not lay in the plane of construction joint, or in a parallel plane within 25 mm (or 2× diameter of bar whichever more) of joint as far as possible. At the construction joint (i.e. plane of the joint), the materials (water, solutions, chemicals, gases or ions) causing loss of durability will have higher permeability for movement through member. Hence bars in this region may be much more prone to corrosion or loss of durability. And for the same reason, the construction joint on the face of concrete should be sealed to reduce entry of the materials. (e.g. water)

In horizontal members like slabs or beams, the joint can be nearly vertical. For vertical members like walls or columns, the joint should be horizontal. Joint may be specified by designer at an inclination which is perpendicular to principal compressive stress so as to result in least shear stress in the plane of joint.

At the construction joint, two concreting phases are with a time gap. If the time gap is less than the initial setting time of concrete, the concrete become monolithic and cold joint or construction joint is not formed. Concrete in both phases independently should be fully compacted without segregation, to result in an impermeable concrete at and near joint.

At end of first phase, care is needed to fully compact the concrete simultaneously avoiding loose aggregates at the joint surface. While ensuring full compaction, there is a possibility that due to over vibration / compaction, in small thickness (may be 2 to 10 mm) at top, concrete at the joint may have coarse aggregate sunk and only mortar remain in top portion. In top few millimeter thickness (may be 1 to 3 mm), water cement ratio may also be higher due to bleed water. At the interface surface, as soon as possible after concrete is set, laitance, portion having bubbles, mortar layer, portions of un-compacted concrete if any, any loose material / aggregate or aggregates having cavities around them should be removed.

Concrete on the two sides of joints should be bonded adequately. At the joint interface, the surface of the earlier pour should be roughened to increase the bond strength (between concrete on two sides of joints) and to provide aggregate interlock. This may be done by applying a retarder to the concrete surface immediately after compacting the concrete in earlier phase. For vertical surface, the retarder can be applied to the formwork.

At the joint, larger aggregate should be exposed, leaving solid & rough concrete surface. This requires removal of some mortar from the surface which is covering larger aggregates. Use of excessive energy, which may otherwise cause damage to concrete by dislodging or fracturing aggregates, should be avoided. Average amplitude of roughness of about 1□5 mm is satisfactory; it can be up to 5 mm, larger roughness is not required. Roughness more than 5 mm has no advantage in normal concrete unless section is subjected to very high shear strength. Hence larger roughness or shear key or shear dowels are required only if designer specify the same. Concrete surface at joint would be prepared rough to get better interlock and to restrict relative movement at the interface, which will result in nearly monolithic behaviour of concrete subsequently.

After chipping and removing mortar and loose material mechanically, the surface should be washed clean, preferably by jet of water. The removal of mortar and loose material can also be done by high pressure jet. Before placing fresh concrete, the old concrete should be saturated, without leaving free water at the surface of joint i.e. it should be saturated and surface dry at the start of concreting of second phase. If free water remains on the surface, it should be removed by air blow, suction, evaporation etc.

A common practice had been to use thin cement slurry (say water-cement ratio 5:1) to wet the surface of old concrete. This cement slurry should be applied in portion to the surface being treated, it should be in such a quantity that it is absorbed by the old concrete, and no free slurry should remain on the surface. This practice does hardly serve any specific purpose. If the slurry is very thin which do not form a layer and in small quantity which is absorbed by old concrete, the practice is not harmful. Thick slurry (sizeable thickness) will form a paste layer on the surface with high water cement ratio and on old concrete, such a layer or a mortar layer is undesirable.

At a horizontal joint, placing of the concrete of second phase involves fall of concrete. While the fresh concrete falls on the hard surface, the larger particles of coarse aggregate rebound and collect near the surface of formwork, thus introducing segregation. Higher is the free fall of concrete, more will be the rebound and more segregation. Thus just above the joint, honey-comb is formed at the face of concrete (formed against the vertical shutter). After a small padding layer of the concrete is deposited (on the previous hard concrete), the aggregate from the falling concrete gets embedded in the padding concrete and segregation is not seen at the formed surface of concrete. Hence at horizontal construction joint, honey-comb is seen only for a few centimeter heights. This height of likely honey-comb is proportional to the height of freefall of concrete. Solutions to this problem are as below.

The concrete placing should be done by chute / pipe without any appreciable freefall for initial placement of concrete. This requires sufficient space between the reinforcement mesh for insertion of chute or pipe.

For smaller members having insufficient thickness (for pipe insertion), the alternate method could be as follows. For the first pour of concrete to be placed over hard surface at a joint, maximum size of aggregate should be restricted depending upon the freefall of concrete. If the height of freefall is about a meter, the maximum size of aggregate in the concrete can be about 5 mm size, and for 300 mm fall, it can be 10 mm. This will need a concrete mix designed for the smaller aggregate size and it should be highly cohesive and should be batched and produced. However if the quantity, the padding concrete needed is very small, one can remove larger size aggregate fraction from the normal concrete supply and this modified concrete can be used. Bigger size aggregate can be removed by sieving or hand picking.

Concrete of second phase as placed should be fully compacted against old concrete, without leaving any air pocket, & segregation.

After the second phase of concreting is done, grouting of all construction joints is a good practice. Vertical construction joints in wall must be grouted with cement slurry, after a time gap as late as possible (for shrinkage to take place). For grouting, cement can be mixed with flyash & or fine siliceous sand.

For joints subjected water pressure, if ratio of head of liquid to thickness of member (H/t) is less than 20, and tension across the joint is low (less than half the permissible tension), it is not necessary to seal the joint or incorporate water-stops (water-bar) in properly worked construction joint. Water-bar /water-stop (GI / PVC / rubber etc.) should not be provided at the joint unless specified by designer in the drawing. If necessary, interface can be grouted to get a leakage free joint. Use of water-bar introduces weakness at the joint. It is very difficult to get proper compaction of concrete around water-bar & it is strongly recommended that water-bar should not be used in normal cases unless water pressures are very high. Without use of water-bar, well compacted concrete (& no honey-comb) should be obtained at the joint. If concrete at a joint is found to be porous or leaky, the joint should be grouted to make it leak-proof.

It should also be noted that for the joints with water-stop at middle, for proper workmanship, the member thickness more than 300 mm is needed. Hence first option should be, to increase thickness at construction joint rather inserting a water bar. Better sealing options at surface are also available and may be preferred over water-stop. If ‘H/t ratio’ is high (say >30), water stops may be necessary.

If tension across the joint is high, sealing at the surface (which is in contact with liquid under pressure) is required.

Similar to water-stop, provision of shear key is also associated with problems of workmanship. Provision of groove /shear key at construction joint is not required unless such shear key is designed and specified in drawings. Due to additional operations required for formation of groove or key, workmanship at the interface can remain significantly poor (incomplete compaction, high porosity, local cracking in immature concrete etc.). Good job can be done with rough joint, without key and water-bar. Water-bar, groove or shear key should not be provided unless designed and specified in drawing.

Horizontal construction joints in wall will be after each lift of wall, 0.8 to 3 m height as may be convenient in construction. Thicker walls can be constructed in higher lifts (say 300 mm thickness in about 3 to 4 m lift).

Vertical construction joints in wall shall be fully grouted with neat cement slurry. For grouting, cement can be mixed with flyash.

CHECK LIST -No. I
General

(A) Delivery of concrete : (Section 5)

(i) Is the grade and MSA of concrete and mix design verified? ☐

(ii) Is the plant location and number of equipment finalized? ☐

(iii) Is the list of employees involved in placement operation given? ☐

(iv) Is the desired rate of delivery decided? ☐

(v) Is starting time of delivery finalized? ☐

(vi) Is quantity of pour per batch is calculated? ☐

(vii) Is arrangement made for checking temperature of concrete? ☐

(viii) Are the precautions for weather condition taken? ☐

(B) Before placement of concrete (Section 7.2.1)

i) Is the entire perimeter of the work place (Concrete–Placement area) demarcated? ☐

ii) Are walls straight and in plumb? ☐

iii) Are all courses tied? ☐

iv) Are additional support on all corners of forms provided?

v) Is the reinforcement secured in place?

vi) Is correct concrete mix and volume decided?

vii) Are pumps of proper diameter and required capacity procurred on site?

viii) Is standby arrangement made?

ix) Are all qualities of material collected at site as per norms?

x) Is field inspection completed and approved?

xi) In case of pumped concrete, whether original pipe line is thoroughly cleaned before start of pumping operation?

Form Work :-

i) Are horizontal load bearing members not eccentric upon vertical members?

ii) Are steel sections adequately restrained against tilting and overturning?

iii) Are enough restraints provided in the formwork and all securing devices and bracings tightened?

iv) Are adequate measures taken to prevent accidental impacts?

v) Have washers under all bolt heads and nuts had adequate bearing area?

vi) Are supports in plumb within the specified tolerance?

vii) Are props directly one under another in multistage form work?

viii) Are adequate provision provided for the movement and operation of vibrators and other construction plant?

ix) Are cambers provided as per drawing?

(C) <u>During placement of concrete (Section 7.2.2</u>)

(i) Is access to the placement of concrete is clear?

(ii) Is the placement set up sufficient and ready in all respect?

(iii) Are the construction joints located?

(iv) Whether arrangement for compaction is made including standby vibrator?

(v) Whether arrangement for checking slump and wet density at the point of the placement of concrete made?

(vi) Is the sufficient arrangement for curing & finishing of the concrete made?

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CHECK LIST NO. II

Placing of concrete by pump (as per section 11)

Project : ---

Location : ---

Directions : --

(Map on back) : ---

1. Contacts

Who	Name	Phone	Mobile	Fax	E-Mail
Civil Contractor					
Pump Contractor					

2. General Conditions

Start time	Pump:	am/pm	Concrete:	am/pm
Placement Location	☐ Slabs	☐ Walls	☐ Footings	☐ Other
Placement Rate, cy/hr.		Volume		
Type of pump	☐ Regular	☐ Boom	☐ Telescoping	☐ Trailer
Size of Pump,(m and HP)				
Pumping Distance m.	Vertical		Horizontal	
Slump / Air content	☐ Point of Discharge		☐ Point of Discharge	
Testing	☐ Point of Discharge		☐ Point of Discharge	
Priming Agent	☐ Grout		☐ Slick pack	

3. Concrete Mixture

Strength. Psi	28 days:	am/pm	Other _______:	
Max Size of aggregate		(no larger than 1/3 pipeline diameter		
Density, Kg/m^3		Lightweight	Yes	No
Slump (mm)		Air, %		
Water reducer used	☐ Regular	☐ Other		
Fibers	☐ Yes	☐ No		
Special Requirements				
Set time Requirements	Initial:		Final:	
Water Permitted at job	☐ Yes	☐ No		

4. Jobsite / Safety

Wash out area	☐ Yes	☐ No	
Power Lines	☐ Yes	☐ No	
Safe Set up area	☐ Yes	☐ No	Restrictions
Clean water available for washout	☐ Yes	☐ No	

5. Notes

CHECK LIST -III

Safety equipment (as per section 11) para 11.9

Whether following safety equipments are made available at site?

i) Safety helmets	☐
ii) Eye protection	☐
iii) Safety vest	☐
iv) Rubber safety boots	☐
v) Hearing protection	☐
vi) Gloves	☐
vii) First aid kit	☐
viii) Protective cream	☐
ix) Reflective traffic cone	☐
x) Signs: ex. exclusion zone	☐

CHECK LIST -No. IV

(A) Quality control plan (QCP) (as per section 12)

(i) Whether approval of the competent authority to the QCP before placement of concrete taken? ☐

(ii) Whether the information about telephone nos., duties of employers of all quality control personnel etc., procured? ☐

(ii) Whether the procedure, Location and type of equipment to be used during the trial batch demonstration of concreting finalized? ☐

(iii) Whether the location and frequency of sampling and testing Concrete mix for slump and wet density decided? ☐

(iv) Whether the plan showing description and the route from the point of mixing up to the placement location produced? ☐

(v) Whether details regarding procedure for placement of concrete including placing sequence, identification of placing equipment and description of pumping procedure if applicable given? ☐
