UNIT 12 SPECIAL CONCRETING TECHNIQUES - I

Structure

12.1 INTRODUCTION

In Unit 6, Workability and Fresh Concrete-II, you have seen that the manufacture of concrete involves several stages, like batching, mixing, transporting, placing, compacting, curing and finishing. In any normal building construction, these stages do not involve any special or complicated technique. However, we know that as a civil engineer we have to carry out concreting in high rise buildings, below the water, in dams, for reactors and in varying seasons among other situations. In these and other similar cases we have to devise special methods to manufacture concrete so as to achieve the optimum results. Over the years, several special concreting methods and techniques have been devised all over the world to meet these special requirements. We propose to discuss these in this and the next unit. Following special concreting methods would be discussed in this unit :

a) Pumping of Concrete

b) Underwater Concreting

c) Vacuum Processed Concreting

d) Shotcrete

e) Prepacked Concrete

Other methods like Cold & Hot Weather Concreting, Ready Mixed Concrete, Mass Concreting in Dams and Ferrocement would be discussed in the next unit.

Objectives

By the end of this unit, you should be able to :

* explain the concept behind each special concreting method,
* describe special concreting methods,
* distinguish the advantages of these methods over the conventional concreting methods, and
* identify the situations where a special concreting method would be most suitable.

12.2 PUMPING OF CONCRETE

As we discussed in Unit 6, there are several methods of transporting concrete. Pumping of concrete is one of the special methods of transporting fresh concrete. This is a versatile method which is particularly useful in situation where working space is limited, like in tunnels. Though this method of transporting concrete was developed as early as 1930, it has become very popular now, and in advanced countries increasingly large amount of concrete is moved through pipelines. Concrete can be pumped almost 450 metres horizontally and 150 metres vertically but then these distances keep on increasing with advancement in pumping equipment and technology.

12.2.1 Pumping Equipment

Three types of pumping equipments are widely used :

a) Piston Pumps

b) Pneumatic Pumps

c) Squeeze Pressure Pumps

a) **Piston Pumps**

The piston concrete pump essentially consists of a hopper (A) equipped with remixing blades for receiving the mixed concrete, and inlet valve (B), an outlet valve (C) and a piston (D). Fresh concrete is poured in the hopper. When the piston executes the backward or suction stroke, the inlet valve opens while theoutlet valves closes and the concrete is drawn from the hopper.

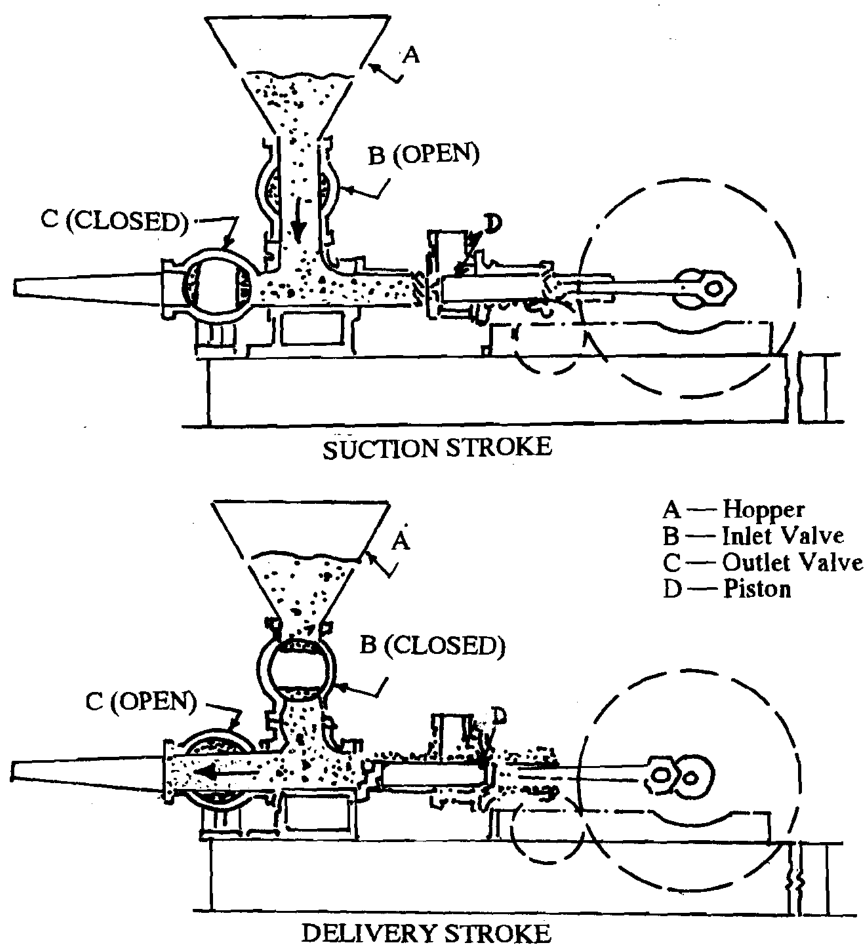


Figure 12.1 :The Working Cycle of the Piston Concrete Pump

During the forward or delivery stroke, the concrete is forced into the pipeline through the outlet valve which has now opened. Piston pumps can be operated either mechanically or hydraulically. In order to achieve steady flow of concrete, it is now usual to employ pumps with two pistons, which operate alternately such that while one is in suction stroke the other is delivering the concrete into pipeline.

b) **Pneumatic Pumps**

Pneumatic pumps essentially consist of a pressure vessel placer and a compressor. The concrete is delivered into the pressure vessel and this vessel is sealed. Compressed air is now supplied through the top of the vessel, resulting in pushing out of concrete through a pipe at the bottom, which delivers concrete in the formwork. However to bleed off air and to prevent spraying of concrete which causes segregation and may disturb reinforcement or damage formwork, a reblending discharge box is provided at the end of the line. Also to stabilise the compressed air supply, an air receiver tank is provided next to the compressor.

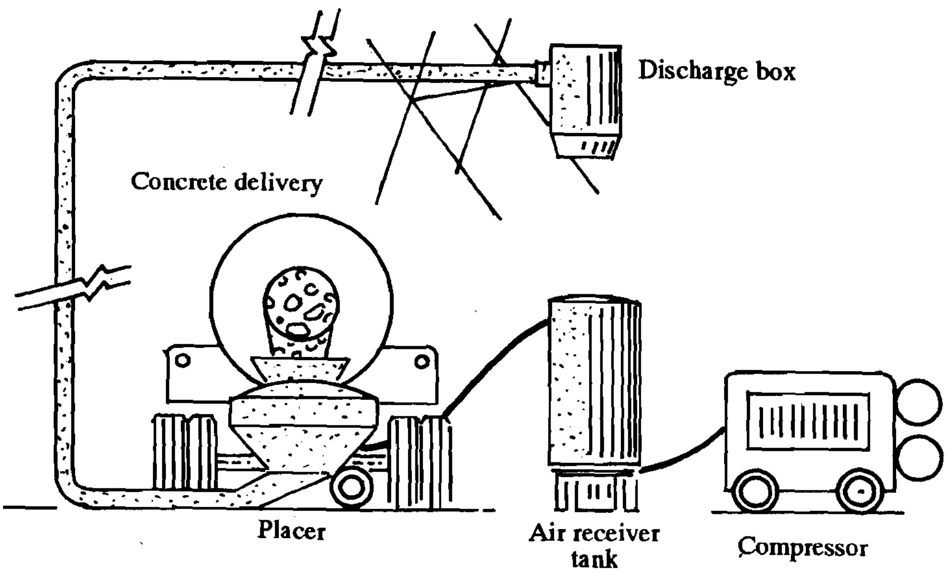


Figure 12.2 : Pneumatic Pump

c) **Squeeze Pressure Pumps**

The squeeze pressure pump comprises a collecting hopper with rotating blades, pumping tube, and rollers operating inside a pump chamber which is maintained under high vacuum. The concrete received in the collecting hopper is pushed towards the pumping tube by the rotating blades. The rollers press the concrete through the tube into a flexible material hose which runs inside the periphery of the pump chamber. The rotating rollers which are generally hydraulically powered, rotate on the flexible hose and squeeze out the concrete at the top under pressure. The vacuum in the chamber aids steady flow of concrete. Squeeze pumps are often mounted on a truck and may deliver concrete through a folding boom.

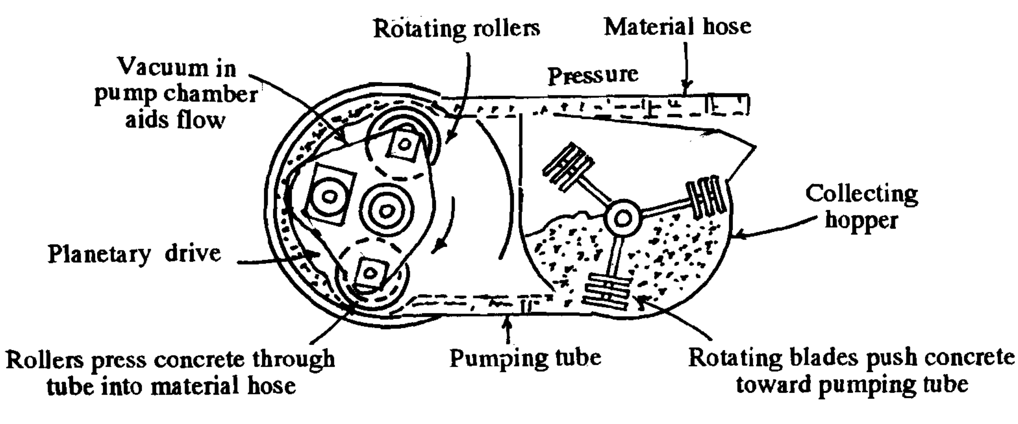


Figure 12.3 : Squeeze Pressure Pump

12.2.2 Pumping Lines

The pipelines can be made either of rigid pipe or heavy duty flexible hose. The rigid pipe could be of steel or other metal. The flexible conduits could be of rubber or plastic. The flexible pipes are used in the rigid lines for curves and to reach difficult placement areas where flexibility is required. Generally, flexible hose pipes of internal diameter larger than 100 mm are difficult to handle comfortably whereas rigid pipes upto 200 mm diameter are regularly used. The rigid pipes or flexible hose material should be wear and abrasion resistant and light weight and should not react with concrete. Aluminium pipe is therefore not recommended as it reacts with alkalies in the cement resulting in formation of hydrogen gas. This gas introduces voids in hardened concrete with a consequent loss of strength. The various couplings between pipe sections should be strong and watertight and should provide free flow to concrete. Sometimes mobile pumping units, comprising small bore pumps are used which can be moved rapidly from one site to another and can conveniently handle small quantities of concrete. You may find them very useful in small work sites. These units have hydraulically operated boom for horizontal and vertical placements. It is observed that a pipeline of 75 to 100 mm can deliver concrete upto the rate of 60 cubic metre per hour upto distances of 170 to 240 m horizontally and 40 to 60 metres vertically. The Table 12.1 gives data on pumping lines for pumped concrete.

Table 12.1 : Data on Lines for Pumped Concrete

Line Diameter	Cross-sectional area	Nominal maximum size aggregate (mm)		Volume of concrete, per 30.5 m of line	Line length per m^3 of concrete	Weight of concrete per 3.1 m section of line	Delivery capacity, m^3/hr, for average not peak velocities indicated (m/sec.)			
(mm)	(cm^2)	Rich Mix	Lean Mix	(m^3)	(m)	(kg)	0.3	0.6	0.9	1.2
76.1 OD 14 gauge wall	41.3	1.9	1.9	0.1	191	30.5	4.5	9.0	14	18
102 OD 14 gauge wall	75.5	2.5	1.9	0.2	102	55.8	8.3	17	25	33
102 ID	81.0	2.5	2.5	0.2	95.4	59.4	8.9	18	27	36
127 ID	127	3.8	2.5	0.4	61.0	92.5	14	28	41	55
152 ID	182	5.0	3.8	0.6	41.8	133	20	40	60	80
178 OD	227	5.0	3.8	0.7	33.8	166	25	50	74	–
200 ID	324	6.3	5.0	1.0	23.8	238	35	71	–	–

OD indicates Outside Diameter; ID indicates Inside Diameter.

12.2.3 Pumping Distances

Just like any other pumping activity, you will appreciate that the distance to which the concrete can be pumped, depends on several factors like :

a) The capacity of the pump employed

b) The velocity of pumping

c) The size and type of pipeline

d) The number of bends and other obstructions, and

e) The characteristics of concrete to be pumped.

You must choose a pump capacity which is enough to pump to the required distance after overcoming the friction between the concrete and the internal surface of the pipeline. You should account for the frictional losses at the bends and at points where pipe diameter changes considerably.

When concrete is pumped, it moves as a cylindrical plug, separated from the pipeline by a thin lubricating film of mortar. Therefore the line is initially primed by pumping a properly designed mortar. It is estimated that for horizontal lines of diameter 150 to 200 mm, 0.4 m^3 of mortar will lubricate about 300 metre length of the line, which is sufficient as long as the pumping continues. Once day's work of pumping concrete is over, the pipes must be cleaned by blowing compressed air through the pipes and then flushing with water till they are clean.

12.2.4 Concrete Characteristics for Pumping

Special attention is required to be paid to mix design of the concrete which is to be pumped. The quality control assumes greater importance and materials should be uniform in properties throughout the job. The two major causes of failure to pump concrete successfully are high frictional resistance and a tendency to segregate. Hence, a badly proportioned concrete requires a greater pump capacity and is prone to cause pipe blockage.

Two types of blockages can occur. In the first one, the water escapes through the mix so that pressure is not transmitted to the solids and hence no movement occurs. This could be overcome by providing adequate amount of closely packed fine material, which would allow water phase to transmit the pressure but not escape from the mix. However if the fines content is too high then the surface area would be very large and then the frictional resistance in the pipe would increase and the pressure exerted by the pump may not be sufficient to move the concrete. This is the second type of blockage.

Keeping in view these problems, following points should be complied with to have minimum difficulty in pumping concrete.

a) The concrete must be well mixed before feeding into the pump. The mix must not be harsh or sticky, too dry or too wet. A slump of 40 to 100 mm or a compacting factor of 0.9 to 0.95 is generally recommended. High slumps may cause segregation and excessive bleeding which can cause loss of lubrication and blocking of the line. Further, water should not be added solely to correct slump as it will lower the cohesiveness of concrete. Slump of desired extent should be achieved by proper proportioning. To allow for the lubricating film to exist in the pipe a cement content slightly higher than otherwise used would be desirable.

b) Admixtures may be used to facilitate pumping of concrete. These admixtures provide additional lubrication, reduce segregation and decrease bleeding. Commonly used admixtures are water reducing, air-entraining and finely divided mineral admixtures. Air-entrained concrete can be pumped properly if air content is less than 5%. But if the air content is higher, the air becomes compressed under high pumping pressure and no longer aids the mix by its **ball-bearing** effect. The friction rises and workability drops. Air entrained concrete is usually pumped only over short distances of about 45 metres.

c) The coarse aggregate content should be high but the grading should be such that void content is low thus requiring only little of the very fine material. The content of material finer than 150 μm should be not less than 3 per cent and most of this can be finer than 75 μm.

d) In general, natural sand and rounded gravel are preferable to crushed aggregate for use in concrete being manufactured for pumping. Light weight aggregates, both fine and coarse, should be well soaked prior to use to avoid excessive slump loss in the pipeline. Some pumping aids like water soluble polymers are also available which reduce frictional resistance and bleeding in the pipeline by increasing the viscosity of water.

However, a trial mix can be made in the laboratory to determine the exact requirements of pumping concrete. Actual trial pumping operations can then be done as part of testing before resorting to actual full scale operations.

12.2.5 Advantages

The major advantages of pumping concrete are that it can be delivered to locations spread over a wide area which may not be easily accessible, with the mixing plant clear of the site. It is specially very useful in congested sites or in tunnel linings. Pumping enables direct delivery of concrete from the mixer to the formwork, thus avoiding double handling. The placing of concrete could match the rate of production of the mixer and need not be limited by the constraints of transporting and placing equipment. Also the pumped concrete is unsegregated as you have seen that lot of care is taken in its manufacture and subsequent pumping.

12.3 UNDERWATER CONCRETING

There are often situations in civil engineering projects, particularly in marine construction, when concrete is to be placed underwater. In diaphragm wall construction concrete is placed in a trench filled with bentonite slurry. The type of construction involving underwater concreting could be construction of a jetty, a slipway, piers etc.

12.3.1 Other Methods

Among several methods of placing underwater concrete is the **Pumping Method** which can be adopted to this situation. Another method is **Preplaced Aggregate Method**. In this method formwork is packed with well graded coarse aggregate and then grout is injected into this mass to fill the voids. This method can be used particularly for repairs of existing marine structures.

Another method is called **Bottom Dump Bucket**. In this special bottom dump buckets have been designed for underwater placement (Figure 12.4).

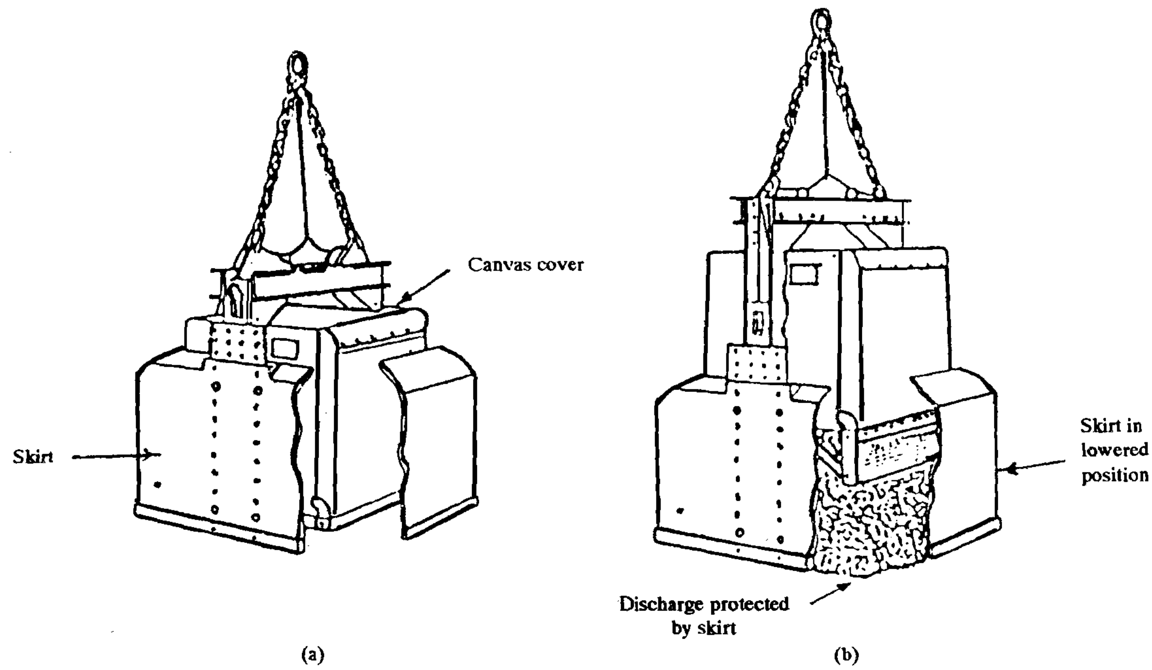


Figure 12.4 : Placement with the Bottom Dump Bucket : (a) Filled; (b) Discharging.

Such a bucket has protective skirts around. When the bucket touches the bed, the skirts get lowered and the bucket is opened by a mechanism and the concrete is discharged. The lowered skirts protect the concrete from surrounding water. However, the results may not be fully satisfactory as certain amount of cement in the concrete may still be washed off due to water. In certain situations, empty cement bags filled with dry or semi-dry mixture of cement, fine and coarse aggregate are also deposited on the river bed. But then this method is also not satisfactory because of the presence of the gunny bags.

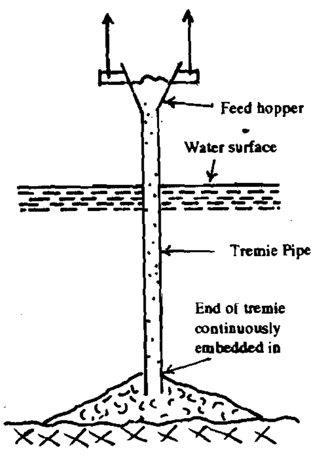


Figure 12.5 : Tremie Method of Concreting

12.3.2 Tremie Method

The most satisfactory method of underwater concreting is the Tremie Method of placement which can also be used for placement in deep forms or where conventional methods of consolidation cannot be used. This method of concreting can be seen in Figure 12.5.

A tremie pipe is of about 20 cms diameter and so designed that additional lengths of pipe can be coupled to it for increasing or decreasing the length. A funnel is fitted to the top of this pipe for easy pouring of concrete. The bottom end is closed with a thick polyethylene sheet or similar material to prevent ingress of water. The pipe is now lowered into the water and made to rest at the location of concreting. Since it is essential that concrete must flow into place, therefore, it is designed to have high slump of 150 to 250 mm without a tendency to segregate or bleed. In order to obtain cohesive and easy flowing concrete it is necessary to use a high percentage of sand, say about 40 to 50% by weight of the total aggregate. Also the mixes will therefore, have high cement content. The concrete characteristics can be further improved by use of water reducing admixtures, air-entraining agents and pozzollonas. The maximum coarse aggregate size for 20 cm tremie pipe is recommended to be 40 mm and 20 mm for 150 mm pipe.

When the whole length of pipe is full of concrete, the tremie pipe is lifted up and a slight jerk is given by a winch and pulley arrangement. This helps the concrete to remove the bottom cover and the concrete gets discharged in place. However, care must be taken to ensure that the bottom end of the pipe remains embedded in the discharged concrete, so that no water can enter the tremie pipe from bottom. This way you are actually ensuring that the tremie pipe remains plugged at the lower end by concrete. Now, the concrete is again poured through the funnel and when the whole length of pipe is filled with concrete, it is slightly lifted and jerked taking care that the lower end remains embedded in concrete. This way the tremie pipe is filled with concrete and discharged continuously till the concrete attains the level higher than water level. This continuous operation has the advantage that the poured concrete does not get affected by water except the top or last layer. This top layer is scrubbed or cut off at the end of the operation to remove the damaged concrete.

The tremie method is designed to minimize the occurrence of entrapped air and other voids and it has the advantage of causing minimum surface disturbance at the concrete-water interface. For good results, it is essential that a steady, uninterrupted flow of concrete is maintained through the tremie pipe. Blockages in the pipe can occur even when short delays take place and it will require the tremie pipe to be withdrawn, cleaned and lowered again. Also during the course of concreting, pumping of water should not be permitted as it may suck the cement particles of the laid concrete. An inherent advantage is that underwater concrete need not be compacted as it gets automatically compacted due to hydrostatic pressure of water. The concrete poured is also of such consistency that it does not require compaction.

SAQ 1

a) What types of pumps are used for pumping concrete ?

b) Would you recommend use of aluminium pipe for pumping concrete ?

c) What factors control pumping distances ?

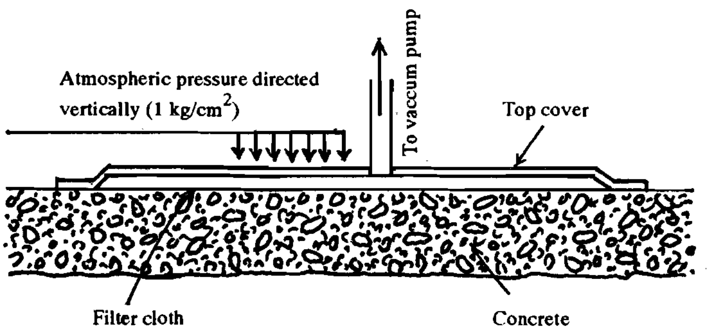
d) Fill in the Blanks :

A slump of .... or a compacting factor of .... is generally recommended for pumped concrete.

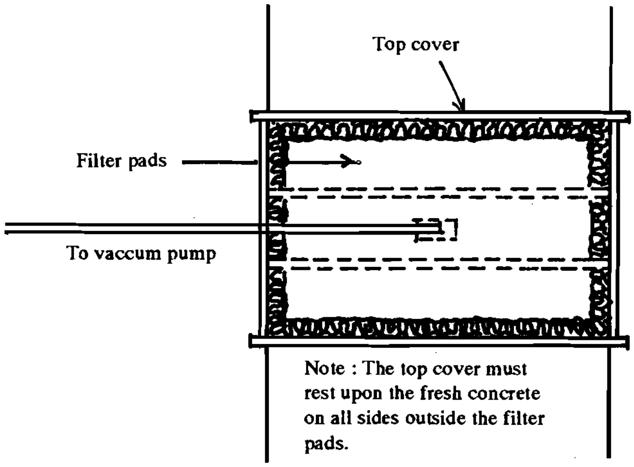
e) What major precaution should be taken while doing underwater concreting with tremie pipe ?

12.4 VACUUM PROCESSED CONCRETING

You are aware by now that high water/cement ratio is detrimental to quality of concrete while low water/cement ratio affects workability and proper compaction. A solution to the problem of combining high workability with low water/cement ratio is available in the form of vacuum processing of freshly laid concrete. In this process excess water required for higher workability is withdrawn by means of a vacuum process soon after placing of concrete. This process when applied properly results in production of quality concrete. The equipment is shown in the Figure 12.6.



(a) Side view



(b) Top view

Figure 12.6 : Vacuum Dewatering

12.4.1 Equipment and Process

It essentially consists of filter pads, top cover and vacuum pump. The filter pad has sheet of wire gauge and expanded metal. The top cover is rigid and provides water tightness with a rubber seal all round the periphery. The top of the suction mat is connected to the vacuum pump. When the vacuum pump operates, suction is created within the boundary of the filter paid/suction mat and the excess water is sucked through the filter pads. At least one face of the concrete must be open to the atmosphere to create pressure difference. The filter pads prevent fine particles from being removed with the water. Though the capacity of vacuum pump is governed by the perimeter of the mat, it is usually in the range of 400 to 650 mm of mercury. The mat size is generally not less than 90 cm × 60 cm.

Vacuum dewatering is started after the concrete has been vibrated and screeded. Subsequently, regular finishing can begin immediately so that dewatering can actually speed up the finishing process. The surface becomes very hard and so power finishing is needed. Initially a planing disc should be used to remove slight irregularities caused by the vacuum process which can be followed by final trowelling. The effect of vacuum dewatering on the strength of concrete can be appreciated from the following Figure 12.7.

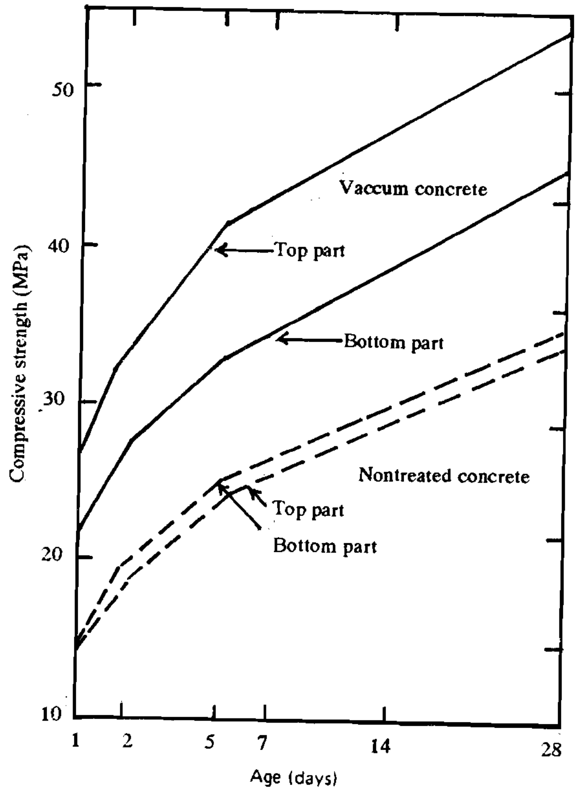


Figure 12.7 : Effect of Vacuum Dewatering on the Strength of Concrete

In general, the following points need to be noted about vacuum processed concrete:

a) In vacuum processing 15 to 25% of original water can be removed from the upper 150 to 300 mm thickness of the slab. The reduction is greater in the zone nearer to the mat and it may be assumed that suction is fully effective upto a depth of 150 mm. Hence a 300 mm slab should have vacuum applied from two opposite faces. The withdrawal of water causes settlement of concrete upto 3 per cent of the depth over which the suction acts. The rate of suction of water reduces with time and it has been observed that most economical processing is during 15 to 25 minutes. The maximum period could be 30 minutes.

b) The amount of water which may be withdrawn is dependent on the initial workability. So, higher initial water/cement ratio, higher is the amount of water withdrawn.

c) If the initial water/cement ratio is kept the same, then the amount of water which can be sucked is increased by increasing the maximum size of aggregate or by reducing the amount of fines in the mix.

d) The greater the depth of the concrete processed, the smaller is the depression of the average water/cement ratio.

e) The ability of the concrete to stand up immediately after processing is improved if a reasonable amount of fine material is present, if the maximum aggregate size is limited to 19 mm and if the continuous grading is employed.

f) There is a general tendency for the mix to be richer in cement content near the processed face. Also the water/cement ratio near the surface is lower in value by 0.16 to 0.30 as compared to the original value.

Because of above reasons, the vacuum processed concrete will not be of uniform strength. This shortcoming is overcome to some extent by subsequent vibration or simultaneous vibration of concrete. If vibration of concrete is not done then the continuous capillary channels formed during vacuum processing may not get filled or brought to original state and may therefore reduce the strength inspite of decrease in water/cement ratio. You will get a better idea of the comparison of strength of processed and unprocessed concrete cubes having the same water/cement ratio from the Table 12.2.

Table 12.2 : Comparison of Strength of Processed and Unprocessed Cubes having the Same Water/Cement Ratio

Initial water/cement ratio of processed cubes	0.74	0.71	0.65	0.60
Average final water/cement ratio of processed cubes	0.68	0.59	0.57	0.55
Strength of unprocessed cubes of the same water/cement ratio as the initial water/cement ratio of the processed cubes kg/cm^2	180	153	191	301
Strength of fully vibrated processed cubes and increase of strength due to processing kg/cm^2 (per cent) :	233 30	226 48	275 43	334 11
Strength of unprocessed cubes of the same water/cement ratio as the average final water/ cement ratio of the processed cubes and increase of strength due to the reduction in water/ cement ratio kg/cm^2 (per cent) :	249 38	337 74	365 91	394 30
Increase in strength due to the reduction in water/cement ratio according to Road Note No.4 (per cent) :	20	44	27	16

12.4.2 Advantages

The vacuum processed concrete possesses several advantages over conventional concrete in addition to the high strength which is achieved :

a) The vacuum processed concrete stiffens very rapidly and so the formwork can be removed within about thirty minutes of casting even on columns of 4.5 metre height. This proves very economical, particularly in prefabrication industry where the formwork can be reused frequently.

b) The surface of vacuum processed concrete is entirely free from pitting and the top 1mm is highly resistant to abrasion. These characteristics make it suitable for use in surfaces which remain in contact with water flowing at high velocity and also in pavements.

c) The vacuum processed concrete bonds well with old concrete and therefore is suited for overlays and resurfacing of pavements and repair work.

12.5 SHOTCRETE

When concrete is applied pneumatically by spraying it from a nozzle by means of compressed air, it is called shotcreting or gunniting. The term gunniting is more commonly used and is a registered trade mark of a company which first developed it commercially in early 1900. Gunniting is mostly used for pneumatical application of mortar of small thickness while shotcrete is a recent development which working on similar principles enables to achieve greater thickness using small size coarse aggregate of upto 10 mm size and sand although aggregates upto 20 mm maximum size can be used.

Gunnite can also be defined as conveyance of mortar through a hose, which is pneumatically projected at a high velocity onto the surface. Normally fresh mortar with zero slump can self support without sagging or peeling off. However, the force of the jet which impinges the material onto the surface, also compacts it. The aid of accelerators is taken in overhead placements. A schematic view of the shotcreting equipment is shown below.

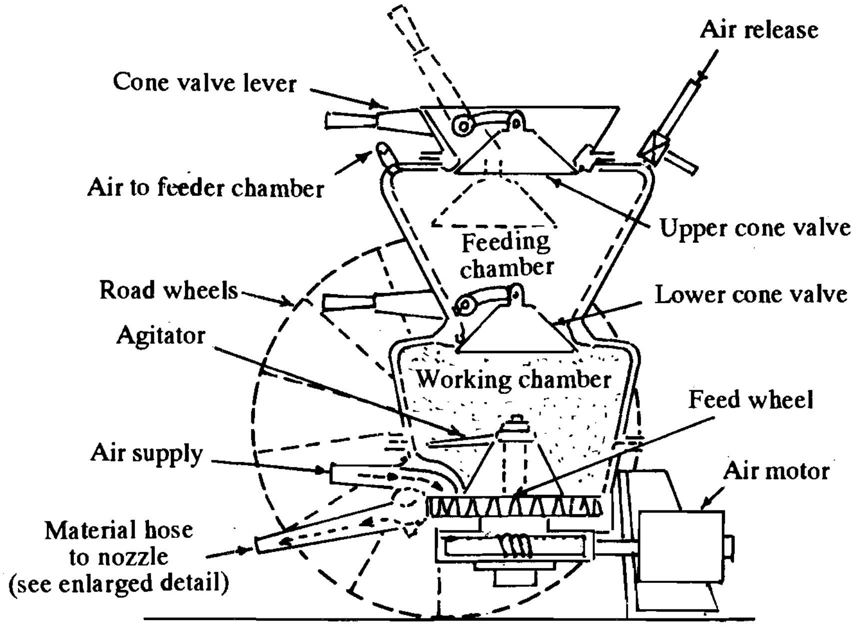


Figure 12.8 : Schematic View of Shotcreting Equipment

There are two different processes in use :

a) Dry mix process, and

b) Wet mix process.

12.5.1 Dry Mix Process

This process makes use of a specialised plant to carry out the work in stages. A typical plant set up is shown below :

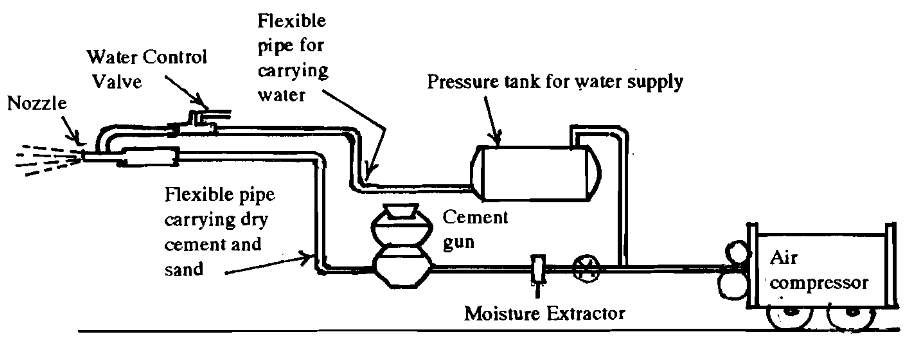


Figure 12.9 : A Typical Plant Layout of Gunniting Equipment

The typical stages involved in the dry mix process are briefly given now :

i) The cement and sand are thoroughly mixed in dry state.

ii) This mixture is fed into a special air-pressurised mechanical feeder known as **Gun**.

iii) The dry mixture is then metered into the flexible delivery hose by a feed wheel or distributor within the gun.

iv) This mixture is conveyed by compressed air through the delivery hose to a special nozzle. Here, the water is sprayed under pressure intimately mixed with the mixture in jet form.

v) The wet mortar is jetted out from the nozzle at high velocity onto the surface to be gunnited.

The dry mix method makes use of high velocity or low velocity system. The high velocity gunnite is produced by using a small nozzle and high air pressure to achieve velocities of 90 to 120 metres per second. Thus a dense concrete with a low water/cement ratio can result in compressive strengths of 40 to 50 MPa at 28 days. This forms good bond with the surface and with steel reinforcement. But about half to quarter quantity of the material rebounds on impact and is not retained which is mostly the coarser material. Use of admixtures reduces the rebound and give very rapid development of strength in few hours. The lower velocity gunnite is produced by using large diameter hose which gives large output but the compaction is not very high.

12.5.2 Wet Mix Process

In this process the concrete is mixed with water as in conventional concrete before carrying through the delivery hose to the nozzle. At the nozzle it is jetted by compressed air onto the desired surface. However wet mix has not been found to be very successful and has generally been discarded in favour of dry mix process.

12.5.3 Relative Merits of Dry and Wet Mix Process

The dry process is considered suitable for pumping light weight aggregate concrete as it is difficult to pump in wet process.

Though it is possible to achieve more accurate control of the water/cement ratio with the wet process, the dry process overcomes this by the fact that the water/cement ratio can be kept very low with its use. The lower water/cement ratio results in lesser creep and greater durability. However, durability in wet process can also be increased by use of air-entraining agents.

The dry process is very sensitive to moisture content in the sand and too wet sand can cause blockade of pipeline, but this problem does not arise in wet process.

In dry process pockets of lean mix and rebound can occur. Also an area is required by the nozzle operator to dispose off unsatisfactory shotcrete which generally occurs when he is adjusting water supply in the nozzle or having trouble with the equipment. This kind of problems are less frequent in wet process, but this process produces less dense concrete.

Wet process can be carried out even in windy weather compared to dry process.

In view of high capacities obtainable with concrete pumps, a higher rate of laying of shotcrete can be achieved in wet process compared to dry process.

The quality of the work is liable to vary, more so in case of dry process as it depends on the skill of the nozzle operator. Quality control is very difficult and it is not possible to cast reliable test cubes or cylinders. So the only way of testing the strength of the work carried out is by drilling cores or by making a parallel slab by gunniting with identical mix.

It is difficult to remove rebound material as it tends to collect inside corners and behind reinforcing bars or other obstructions. Such pockets together with bad work on account of lack of skill of nozzle operator form weak and porous patches. Too low an air pressure and surges in the air and water supply can also cause patches of relatively dry material. This can cause formation of porous concrete contributing to high permeability.

In dry mix process, it is generally difficult to obtain a satisfactory surface finish, because due to low water content, it is almost impossible to trowel the surface. Often one has to resort to application of a 2 cm thick screed over the gunnited surface to obtain smooth finish.

The maximum rate of deposition of concrete is about 15 cubic metre per hour for the dry process while it is more in case of wet process.

Additional Points to Note

The low water/cement ratio, the thinness of the deposited section and the fact that only one side of the concrete can be covered, strengthens the need for paying more attention to curing in case of shotcrete, compared to conventional concrete.

In shotcrete, any cement can be used as long as it does not set too quickly. The general specifications with regard to cement, aggregate and water also apply here. However, it is desirable that the aggregate should be harder than normal to cater for the attrition occurring in shotcrete.

Admixtures can be used in shotcrete for effects similar to that in normal concrete. In case of dry process, they can be added to the water. However, some difficulty may be experienced in obtaining correct proportions to variations in the rate of feed of the dry materials. In view of this, admixtures whose effects are very sensitive to the proportion added in the mix, may not be used. In the wet process, caution is required to be exercised while using accelerators, but in dry process accelerators causing an initial set within 30 seconds are used in very wet conditions and for sealing of leakages. These very rapid accelerators are expensive and sometimes inspite of their use it has been found that adhesion of concrete to the wet surface is not proper.

Though much information is not available about the drying shrinkage and creep properties of shotcrete, but low water/cement ratio indicates that it will be low for dry process. The resistance to frost action is also good.

12.5.4 Applications

The use of shotcrete (particularly gunniting) has been on the increase in U.S.A. and European countries because of the good performance in the past. It has been established that the strength and other properties of shotcrete are the same as those of conventional mortar or concrete of similar proportion and water content. Shotcrete is a mix with high cement content and very low water/cement ratio. Shotcrete work carried out under ideal conditions by trained personnel can give strengths of 350 kg/cm^2 and above. The high cost of shotcrete limits its application to certain situations only, where it can be adopted easily and results in savings.

a) **Use in Overlay**

One of the strong points of shotcrete is its excellent bond with old concrete, rock face and even with metallic members. The shotcrete applied as overlay to old concrete slab has been found to have good bond strength at the interface.

b) **Use in Thin Sections**

In shotcreting, shuttering and formwork is required to be erected only on one side and it does not have to be as strong as is required for poured concrete. This saving in shuttering costs makes it particularly suitable for thin sections. It is generally limited to a thickness of 200 mm. The possible rate of application is low in case of dry process. In case of overhead work not more than 80mm thickness is deposited in one day.

c) **Use in Tunelling**

The very fact that shotcrete can be conveyed over a considerable distance in a small diameter pipe makes it suitable for sites where access is difficult. The other method that can be used in such situations is pumped concrete. But it cannot be used in confined spaces as the expansion of compressed air will cause air turbulence which makes it difficult to place concrete. It has been reported that in a large shotcrete tunnel support job in California, there was an apparent saving of about two million dollars by using shotcrete support in lieu of steel support. It is also reported that it is difficult to obtain strengths of more than 280 kg/cm^2 without very rigid quality control at high cost and hence strengths exceeding 280 kg/cm^2 should not be specified.

12.5.5 Recent Developments

One of the innovation in shotcreting is the use of fibre reinforcement. Here, steel fibres of about 30 gauge and 20 mm length are mixed with shotcrete mortar and then applied pneumatically in the usual manner. This results in increased tensile strength of shotcrete.

Another development is that of polymer shotcrete. In this process monomer is mixed with shotcrete and then used. The difference being that the monomer replaces portland cement and water. The results of polymer shotcrete indicate a great potential for this material because of high strength and durability.

SAQ 2

a) How can you combine high workability with low water/cement ratio in concreting ?

b) How much water can be removed in vacuum processing ?

c) Why is vacuum processed concrete considered suitable for prefabrication industry ?

d) What is shotcreting or gunniting ?

e) What processes are used in shotcreting ?

f) Which process of shotcreting would you prefer, dry mix process or wet mix process ?

12.6 PREPACKED CONCRETE

You have learnt in unit 6 – Workability and Fresh Concrete-II, that concrete is manufactured by mixing all the constituents like cement, aggregates, water and admixture in a mixer. This concrete is then poured or placed in the formwork for the member to be concreted. You could also imagine that this process could be completed by first placing and packing the aggregate in the formwork and then grouting it with the specially prepared mortar. This process is actually employed in situations where there is heavy reinforcement or large number of fixtures like conduits are closely located and it is not possible to carry out concreting in the conventional manner properly. Such a process is called Prepacked Concreting, where the aggregates are packed/placed in position first and then the space around them is grouted with mortar.

12.6.1 Methods

There are several proprietary methods of executing prepacked concreting. They are :

a) Colcrete Process

b) Grouted Concrete Process

c) Intrusion Grouting

The essential requirement of prepacked concrete is that the grout should fill the voids fully and develop full bond with the aggregate. The pressure to be applied should be just enough so that the grout just fills the voids but does not disturb or lift up the aggregate. You can use workability agent or expanding admixture like aluminium powder, if required. The grout mixture should be sufficiently fluid so that it can be pumped easily. It should be fairly thick grout with pumpable consistency which can be obtained by mixing it well in a high speed mixer. Such a grout can travel uniformly into the aggregate voids and is referred to as Colloidal Grout. The main property to be looked for in the grout when using it for underwater grouting, is that it should be able to maintain its identity while pushing out the water from the voids between the aggregates.

12.6.2 Colcrete Process

In this process of prepacked concreting, the mortar grout is prepared in a special high speed double drum type of mixer. Cement and water are mixed in one drum and the sand is added and mixed with cement slurry in the second drum. The high speed action of the mixer produces a very cohesive mix which is more fluid than a normal grout and is comparatively immiscible with water. The ratio of the grout may vary from 1: 1¼ to 1:4. The richer mix is used for underwater concreting or for grouting pre-stressed concrete members.

The grouting can be done by three methods :

i) In the first method the grout mix is poured on the prepacked aggregates and it is allowed to penetrate as it moves downwards. This method is generally used for thin concrete members such as floor slabs and road pavements. If the thickness of aggregate bed is more, the grout may not be able to completely traverse the whole depth.

ii) In another method, the mould is partially filled up with grout first and then the aggregates are deposited on it. Vibration at this stage would help distributing, sinking and smearing of grout all over the aggregate.

iii) The third method consists of pumping the grout into the prepacked aggregate at the bottom of the mould. A perforated injection pipe (one or more in number) is used to spread the grout into the aggregate mass. The injection pipe is extracted upwards by certain distance and the grout is injected out from the perforations. This is repeated as the pipe is moved upwards thus grouting the entire depth. It should be ensured that less pressure is used to inject the grout in the top layers of concrete. Sometimes, perforated horizontal pipes are embedded in the prepacked aggregate at different depths and grout is injected through them. The pipe may then be withdrawn if possible or may be left in the concrete.

12.6.3 Precautions to be Taken

If the grout is forced at high pressure with total disregard to the overburden pressure of prepacked aggregate, then this pressure may cause dislodging of the aggregate. This may result in excessive consumption of grout. Therefore, it is necessary that the pressure at which the grout is to be injected, is decided carefully. This aspect becomes more important when grouting is done near the top surface. Sometimes a plywood covering is provided at the top to prevent the floating effect of the aggregate in the event of high pressure and low viscosity of the grout.

12.6.4 Advantages

The major advantage of prepacked aggregate is that it undergoes little drying shrinkage. Since, the aggregates are prepacked and so are in point to point contact with each other, while the grout only fills the voids, therefore the concrete as a whole does not undergo much drying shrinkage. Both single sized or graded aggregate can be used without much difficulty. Vibrating the aggregate before grouting improves the quality of concrete.

12.6.5 Applications

The prepacked aggregate method is most suitable for situations where there is congestion of reinforcement or it is to be placed in a complicated way, or there are several fitments like pipes, conduits and openings, etc. which make it difficult to place the concrete and compact it in the conventional manner.

This method is also employed in mass concreting, in bridge abutments, piers and well steinings.

It is one of the practicable methods of doing underwater concreting, in which aggregates are placed in position under water and then subsequently grout is injected to displace the water.

12.7 SUMMARY

In this unit you have learnt about a few special concreting methods like pumping of concrete, underwater concreting, vacuum processed concreting, shotcrete and prepacked concrete. In pumping of concrete, you learnt that it is particularly useful for narrow places like tunnels using pumps and pipelines. The pumping distance is a function of several factors including the characteristics of the concrete to be pumped which should have a slump of 40 to 100 mm. The maintenance of pipeline at the end of the day is important to prevent blockages.

Tremie method is most suitable for underwater concreting. However, at all times it must be ensured that when the concrete is discharged and tremie pipe is moved up, its lower end always remains embedded in concrete.

The vacuum processed concrete is a unique method of obtaining quality concrete with high workability and low water/cement ratio. The vacuum dewatering can remove 15 to 25% of the original water from the upper 150 to 300 mm thickness. Because of early stiffening of this concrete, the formwork can be removed early and reused thus resulting in economy.

Also the top surface is resistant to abrasion.

Shotcreting or gunniting is application of concrete pneumatically by spraying it from a nozzle by means of compressed air. The nozzle operator should be well skilled in the operation to obtain optimum results.

Prepacked concrete is ideal for congested situations where conventional concrete cannot be placed. The aggregates are prepacked in position and then grout can be injected in different ways to fill the voids. This is very useful for bridge abutments, piers and underwater concreting.

12.8 KEY WORDS

Colcrete	:	A type of prepacked concrete.
Marine Structures	:	Structures constructed in the sea.
Prepacked	:	Placed/packed in position before hand.
Shotcrete	:	Concrete applied pneumatically from a nozzle.
Tremie Pipe	:	A pipe used for underwater concreting.

12.9 ANSWER TO SAQs

SAQ 1

a) The pumps are

i) Piston Pumps

ii) Pneumatic Pumps

iii) Squeeze Pressure Pumps

b) No. Because it reacts with alkalies in the cement resulting in formation of hydrogen gas. This gas introduces voids in hardened concrete with a consequent loss of strength.

c) The factors are :

i) Pump capacity

ii) Velocity of Pumping

iii) Size and type of pipeline

iv) Bends and obstructions, and

v) Characteristics of concrete.

d) A slump of 40 to 100 mm or a compacting factor of 0.9 to 0.95 is generally recommended for pumped concrete.

e) Care must be taken to ensure that the bottom end of tremie pipe must remain embedded in the discharged concrete, so that no water can enter the tremie pipe from bottom.

SAQ 2

a) This can be done by using vacuum processed concrete.

b) In vacuum processing of concrete 15 to 25% of original water can be removed from the upper 150 to 300 mm thickness of slab.

c) The vacuum processed concrete stiffens very rapidly and so the formwork can be removed within about 30 minutes of casting even on columns of 4.5 metre height. This will prove very economical in prefabrication industry as the formwork can be reused very frequently.

d) When concrete is applied pneumatically by spraying it from a nozzle by means of compressed air, it is called shotcreting or guniting.

e) There are two processes namely

i) Dry mix process and

ii) Wet Mix Process.