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# Different methods of placing concrete

**Shrikant M Harle**
Assistant Professor, Civil Engineering, Pro. Ram Meghe College of Engineering & Management, Amravati, Maharastra, India

**Abstract**
A study was made in the early 1990s of the utilization of the labour and equipment resources in the in situ concreting of buildings in Hong Kong. The study involved close observation of 154 pours on building construction sites and 38 days spent at 38 mixed concrete batching plants one day at each. Much detailed productivity information has been derived and the different concrete placing methods have been compared. This report describes pumps for transporting and placing concrete. Rigid and flexible pipelines are discussed and couplings and other accessories described. Recommendations for proportioning pumpable concrete suggest optimum gradation of aggregates; outline water, cement, and admixture requirements; and emphasize the need for evaluation of trial mixes for pumpability. The importance of saturating lightweight aggregates is stressed. Suggestions are given for layout of lines; for maintaining uniform delivery rate, as well as uniform quality of concrete at the end of the line; and for cleaning out pipelines. The report defines pumped concrete as concrete that is transported through hose or pipe by means of a pump.

**Keywords:** concrete, construction technique, transportation, pumping and production

## 1. Introduction
Concrete occupies unique position among the modern construction material. Concrete has played an increasingly important role in the efforts of architects and engineers to find a satisfactory and economical material for high-rise multi-storey buildings. The use of concrete in high-rise buildings has increased significantly in the last 20 years mainly owing to improvement in all of the technologies associated with this material: admixtures, pumping, transportation and elevation methods, etc. thus the successful production of concrete at the construction site is of prime importance.
Cement concrete is only next to water in terms of the amount of material used on our planet. Over hundreds of years, concrete has became the material of choice for constructing residential and commercial buildings, infrastructural facilities such as highways, dams and bridge, canals , ports and other important facilities .The popularity of concrete owes to its economy , ability to the cast into any shape ,ability to be fabricated practically anywhere and last but not least , its inherent durability innumerable historical land marks in concrete speak volumes about its durability and versatility.
For small height buildings (up to 3 -5 storey) the concrete whether it is site mix or RMC is transported and placed by using hoist ,wheel barrows and pulleys or sometimes lifts are also hire for the purpose of transportation of concrete. But when the building goes higher and higher, placing concrete with the hoist and wheel barrows method is become time consuming as it is not a continuous process and it hampered the productivity of concrete works. One of the techniques that have helped the construction industry tremendously is pumped concreting. Pumped concreting is an alternative method to placing the concrete using concrete pump. Most standard construction mixes can be pumped with little or modification. However several technical and managerial factors affect the productivity of pumped concrete must be considered when while concreting.
Machines and equipments used in concrete pumping such as concrete pumps are mainly used to transfer wet concrete into the building formwork. A concrete pump offers many favorable advantages, such as increased productivity. The pump delivers high volume in short period and at the places where access for human is difficult. The demand for concrete pumps varies with the performance measures as well as the type of pump. Various structures from tallest skyscrapers to the smallest convenience store require concrete and concrete pumping is great way to get it where it needs to go. Increase productivity is important because it means faster completion allowing the owner to receive a return on their investment sooner.

## 2. Methodology
### 2.1 Pumping of Concrete
Pumping is a very efficient and reliable means of placing concrete, which makes it a very economical method as well. Sometimes, a pump is the only way of placing concrete in a certain location. Such as a high rise building, or large slabs where the chutes of the concrete truck can't reach where the concrete is needed. Other times, the ease and speed of pumping concrete makes it the most economical method of concrete placement.
Placement of concrete in inaccessible areas has necessitated the use of pumps in today's construction. Especially with the growth of ready mixed concrete across India, the need for pumping has increased manifold. While the ease of pumping depends on the type of pump available, the distance over which concrete is to be pumped, and the properties of the

concrete, a number of finer aspects can affect the operation.
The technique of pumping concrete has been in general and continuous use of over sixty years. Considerable progress which has been achieved in the past decade has undoubtedly made concrete transportation and placing using the concrete pump, potentially one of the most economical and attractive methods available. Pumping of concrete is necessary when:

a) For high speed placing or when large volumes have to be poured in limited time.
b) When concrete needs to be placed in inaccessible positions or there are no other means available at the time.
c) When accuracy and control are vital.
d) When good concrete finishes are called for.
e) To reduce plant requirements or release existing plant for other work. This also reduce capital requirements.

### 2.2 Concrete Pumps

A concrete pump is a machine used for transferring liquid concrete by pumping. Concrete pumps have been known for more than 50 years. In modern times, large quantities of concrete can be transported by means of pumping through pipelines over appreciable distances, often to locations that may not be easily accessible by other means of delivery.
The system for pumping concrete essentially consists of a hopper into which the concrete is discharged from the mixer, which in turn, feeds the concrete pump itself and finally the delivery pipelines through which the concrete is delivered. There are two types of concrete pumps. The first type of concrete pump is attached to a truck or longer units are on semi-trailers. It is known as a boom concrete pump because it uses a remote-controlled articulating robotic arm (called a boom) to place concrete accurately. Boom pumps are used on most of the larger construction projects as they are capable of pumping at very high volumes and because of the labour saving nature of the placing boom. They are a revolutionary alternative to truck-mounted concrete pumps.
The second main type of concrete pump is either mounted on a truck or placed on a trailer, and it is commonly referred to as a line pump or trailer-mounted concrete pump. This pump requires steel or flexible concrete placing hoses to be manually attached to the outlet of the machine. Those hoses are linked together and lead to wherever the concrete needs to be placed. Line pumps normally pump concrete at lower volumes than boom pumps and are used for smaller volume concrete placing applications such as swimming pools, sidewalks, and single family home concrete slabs and most ground slabs.
There are also skid mounted and rail mounted concrete pumps, but these are uncommon and only used on specialized jobsites such as mines and tunnels. Further the pumps used for pumping are being classified based on their mode of operations, quantity of concrete to be discharged, power required etc. They are classified in next section of this report.

### 2.3 Types of Concrete Pumps

#### 2.3.1 Based on Support Mounting

**i) Line Pumps:** Line pumps are versatile, portable units typically used to pump not only structural concrete, but also grout, wet screeds, mortar, shotcrete, foamed concrete, and sludge. Pump manufacturers offer a variety of different line pumps to meet a wide variety of needs. Line pumps typically employ ball-valve-type pumps. While the smaller models are often called grout pumps, many can be used for structural concrete and shotcreting where low-volume output is suitable. They're also used for repairing underwater concrete, filling fabric forms, placing concrete in heavily reinforced sections, and building bond beams for masonry walls. Some hydraulically driven models have pumped structural concrete at outputs exceeding 150 cubic yards per hour. Cost for ball-valve pumps are relatively low and there are few wear parts. Because of its simple design, the pump is easy to clean and maintain. The units are small ande, and the hoses easy to handle.

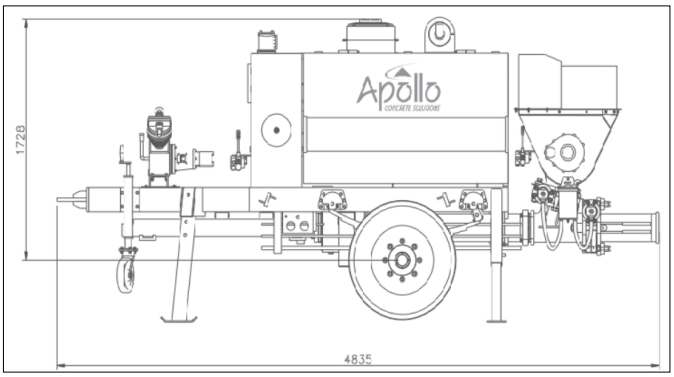


**Fig 1:** Line Pump

**ii) Boom Pumps:** Boom trucks are self-contained units consisting of a truck and frame, and the pump itself. Boom trucks are used for concrete pours for everything from slabs and medium high-rise buildings, to large volume commercial and industrial projects. They range from single-axle truck mounted pumps used for their high maneuverability, suitability for confined areas, and cost/performance value, to huge, six-axle rigs used for their powerful pumps and long reach on high-rise and other large-scale projects. Booms for these trucks can come in configurations of three and four sections, with a low unfolding height of about 16 feet. This low unfolding height is ideal for placing concrete in confined areas. Longer, five-part booms can reach up or out more than 200 feet. Because of their reach, boom trucks often remain in the same place for an entire pour. This allows ready mix trucks to discharge their loads directly into the pumps hopper at one central location and helps to create a more efficient jobsite traffic flow.

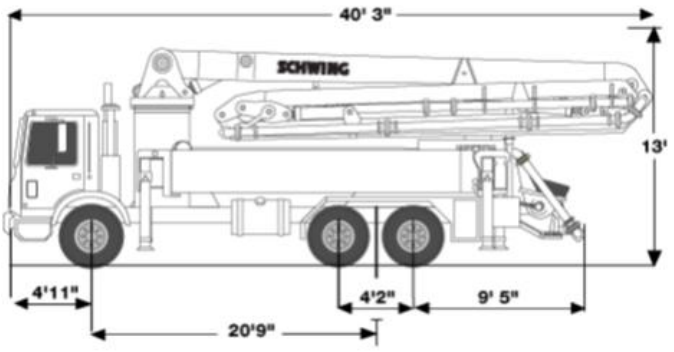


**Fig 2:** Boom Pump

### 2.3.2 Based on Operations

**i) Direct Acting Concrete Pumps:** A majority of the concrete pumps are of the direct-acting, horizontal piston-type with semi-rotary valves). The operation of the direct- acting pump is simple. The concrete is fed into the pump by gravity and partly by suction created due to the reciprocating motion of the horizontally-acting piston, while the semi-rotary valves open and close alternately. Suction pressure of the order of 0.08 N/mm2 is developed in the pumping cylinder under favorable conditions.

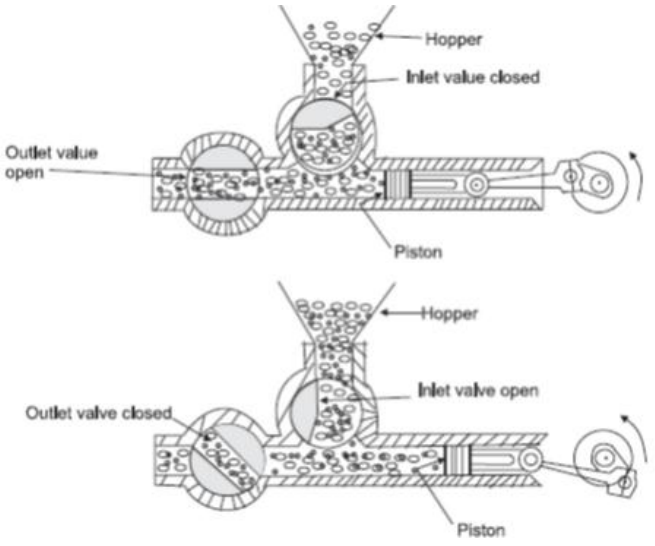


**Fig 3:** Direct Acting Concrete Pump

Best suction conditions are obtained if the diameter of the suction pipe is the same as that of the pumping cylinder so that the concrete can flow unhindered. Concrete should be able to flow freely through the full cross section of the suction pipe and possible blockages due to over-sized aggregates should be avoided. Ideally, the diameter of the suction pipe should be at least three times the maximum size of the aggregate in the concrete to be pumped. The diameter of the suction pipe therefore controls the maximum size of aggregate, which can be used in a given mix of concrete to be pumped. During the 'suction stroke' the inlet valve opens and concrete is admitted into the pumping cylinder, the outlet valve remaining closed. In the 'delivery stroke' the outlet valve gets opened and the inlet valve being closed, the concrete gets pushed into the delivery pipeline. The concrete moves in a series of impulses, the delivery pipe always remaining full. Outputs of up to 60 m3/h can be achieved in modern pumps through 220-mm diameter delivery pipes.

Conventional pumps are equipped with an agitator in the feeding hopper. The agitator maintains the flow ability of the concrete and prevents the setting of the concrete or building-up of aggregate bridges across the opening of the suction pipes. In case the pump is required to be shut down temporarily for some reason it may be possible to remix the concrete at the commencement of pump operations using the agitator. Direct-acting concrete pumps may be static or portable, in the latter case the pump can be mounted on Lorries. Lorry mounted concrete pumps operate with relatively shorter delivery pipelines. The pump feeds concrete to the delivery pipeline attached to a hydraulically-maneuvered articulated telescopic arm known as the placing boom. The pipeline length thus corresponds to the horizontal reach of the placing boom. Using direct acting pumps, concrete can be readily pumped up to distances of 450 m horizontally or 50 m vertically. For larger distances, relay pumping using pumps in series may be adopted.

**ii) Squeeze type Concrete Pumps:** Besides direct-acting pumps, smaller portable peristaltic type pumps, called as squeeze pumps are also available for pumping concrete, Squeeze type pumps are smaller portable peristaltic type pumps. The concrete from the collecting hopper is fed by rotating blades into a flexible pipe connected to the pumping chamber, which is under a vacuum of about 0.08 N/mm2. The vacuum ensures that, except when being squeezed by the rotating rollers, the pipe shape remains cylindrical and thus permits a continuous flow of concrete. The two rotating rollers mounted on planetary drives progressively squeeze the flexible pipe and thus push the concrete into the delivery pipe. Outputs of up to 20 m3/h can be obtained with squeeze pumps using 75-mm diameter pipelines. Squeeze pumps can transport concrete up to a maximum distance of 90 m horizontally or 30 m vertically. Due to the cumbersome mechanics of squeeze pumps, direct acting pumps find greater field applications compared to squeeze pumps.

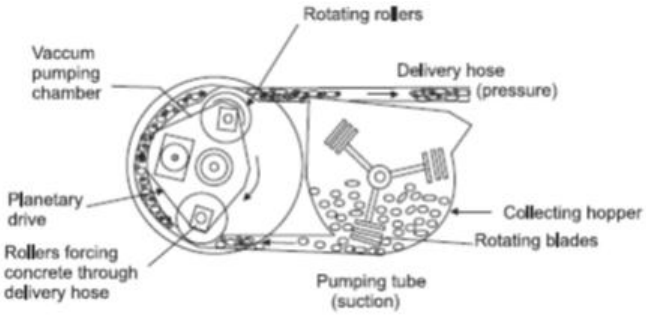


**Fig 4:** Squeeze type Concrete Pumps

### 3. Requirements for pumped concrete

- Concrete mixture should neither be too harsh nor too sticky; also, neither too dry nor too wet.
- A slump between 80 and 150 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. Friction is minimized at the correct water contents. The presence of a lubricating film of mortar at the walls of the pipe also greatly reduces the friction
- High cement content in concrete is generally beneficial for pumping
- Water is the only pumpable component in the concrete, and transmits the pressure on to the other components
- Two types of blockage to efficient pumping could occur: (1) 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. (2) When the fines content is too high, there could be too much frictional resistance offered by the pipe. The first type of blockage occurs in irregular or gap-graded normal strength mixtures, while the second type occurs in high strength mixtures with fillers. In order to avoid these two types of failure, the mixture should be proportioned appropriately

- Other mixture factors that could affect pumping are the cement content, shape of aggregate, presence of admixtures such as pumping aids or air entrainment. Air entrainment is helpful in moderate amounts, but too much air can make pumping very inefficient
- When flowing concrete is being pumped, an over-cohesive mixture with high sand content is recommended. For lightweight aggregate concrete, pumping can fill up the voids in the aggregate with water, making the mixture dry.

## 4. Concreting productivity

Productivity has been expressed and described in terms of a ratio of 'outputs' to 'inputs'. Productivity can be defined in different ways depending on the purpose of measurement. In construction, trade productivity is usually defined for conceptual and analytical simplification as the ratio of the output in a particular trade as related to the tradesman's inputs and can be expressed in quantitative terms as physical productivity. It is important to specify the input and output to be measured when calculating productivity because there are many inputs like labour, materials, equipment, tools, capital and design to the construction system while the conversion process from input to outputs associated with construction operations is also complex. Even for an operation like concreting, with well-known equipment and work methods, construction productivity estimation can be challenging, owing to the unique study requirements and changeable environment of each construction project as well as the complexity of the influences of job and management factors on operational productivity. Different yardsticks are usually employed for measuring the productivity of concrete placing by giving the placing labour or equipment productivity as the ratio between the quantity of concrete placed to the man-hours (mh) or equipment hours (eh) committed by the placing gang or equipment respectively, the mixer productivity as the ratio between the quantity of concrete placed to the mixer-hours spent on site.

The overall productivity for an entire concreting operation, which is the placing rate, is thus appropriately measured as the ratio of the quantity of concrete placed to the total time of the operation in m3/h while the labor productivity is measured as operative hours per unit of work, or wh/m3 of concrete.

## 5. Factors Affecting the Productivity of Pumped Concrete

Concrete placing productivity is influenced by many factors. The placing method is major determinant of the speed of pacing, but the shape of the pour and its location are technical factors that also influence the productivity. The skill and enthusiasm of the enthusiasm of the placing gang are obviously relevant as is the timely supply of concrete to the site. The latter involves good coordination with a RMC supplier, the preparation needed for the pour to be completed on time, accurate estimation of the quantities of concrete and truck mixer movements and parking arrangements that bring about an uninterrupted supply at the truck mixer discharge point. Site congestion and other access conditions can make uninterrupted supply difficult or impossible, even when the concrete supplier is able to maintain a regular delivery. The concrete supplier scheduling problem is complicated by the fact that during the pour almost half of the sites change their order quantities, sometimes considerably. Because an RMC plant is serving many sites, "swing and roundabouts" result in actual quantity supplied to all sites being on average, 97% of the total quantity ordered.

A factor that may have a helpful psychological effect on site productivity is the over provision of truck mixers. Placing crew is not immune to the pressure caused by a queue of truck mixers waiting to be unloaded. However, overprovision of truck mixers clearly wastes truck mixer time.

In the majority of concrete pours it is possible to determine a number of factors that are detrimental to the quality of the concrete placing process. Establishing these factors, which are the cause of the stochastic nature of the system, may well allow a reduction in the variability of concrete operations and so reduce wastage and improve productivity. The factors have been evenly split into two groups, technical and managerial factors, which show that equal emphasis should be placed on good managerial practice.

From the previous researches, Productivity can be affected by technical issues on actual site as well as the managerial factors. All those technical, managerial are classified as following Table 4.1

**Table 1:** Factors That Can Affect the Productivity of Pumped Concrete

| Technical Factors | Managerial Factors |
|---|---|
| Gradient of the Site | Planning |
| Site Congestion | Rate of Progress Required |
| Site Location | Engineer's Experience and Intuition |
| Placing Method | Skill of Placing Team |
| Location of Supplier | Supply of Material |
| Pour Size | Accidents |
| Pour Location | Weather Conditions |
| Age of Pump and Trucks | Competency of Management Team |
| Formwork | Experience of Site Team |
| Concrete Specifications | Labor Requirements |
| Height of Pour | Motivation of Engineer |
| Access Conditions | Company Structure |
| Spillage | Maintenance of Plant |
| Vandalism | Joiner and Steel Fixer Efficiency |

## 6. Field Practices

Preplanning for concrete pumping is essential for successful placements, with increasing detail and coordination required as the size of the placement and the project increases. At a minimum, the preplanning and preparation should involve the following:

a) Notification to the concrete supplier that the concrete is to be pumped and confirmation that the appropriate provisions have been made to produce and provide, at the rate and in the quantity needed, concrete properly proportioned for pumping that also complies with all project specifications or other requirements.
b) Establish the distance concrete is to be pumped

(horizontal, elevation, and decline) and the maximum rate of placing required so the proper size and capacity pump will be supplied.

c) Establish the time the pump is to be ready for setup and provision for any required pipeline including supply of the material and arrangements for the required labor to assemble it.
d) Agreement between the pump operator and the placement crew as to the placement sequence, total volume to be placed, pump location as near the placing area as practical, and required access to allow two ready-mixed concrete trucks to discharge into the pump receiving hopper at the same time. Two ready-mix trucks should be positioned to discharge into the pump receiving hopper to maintain constant flow of concrete to the pump and to enable blending of the last concrete discharged from the first ready-mix truck, which frequently has a higher percentage of coarse aggregate larger sizes, with concrete from the second ready-mix truck.
e) Agreement on who is responsible for providing material to grout the pipeline.
f) Provision for clearing and cleaning the pump and pipeline when the placement is completed. Frequently the best arrangement is to arrange the placing system so concrete remaining in the pump hopper and pipeline can be discharged into a ready-mix truck. A continuous supply of concrete is required because if the pumping is stopped for any appreciable time, concrete in the line may stiffen and it may be difficult to start pumping again.

## 7. Conclusion

- The study provides factual information on the industry's outputs and capacity and the productivity achieved in concrete pours on big buildings have been provided, and profile of concreting productivity measures for hong-kong has been proposed as a bench mark. The profile covers concrete supply and site placing aspects. The data distinguish the productivities being achieved between different placing methods. pumping has less labour intensive than other placing method and get job completed more quickly, labour productivity during pumping is roughly twice that of crane-and-skip or hoist and barrow placing.
- The influence of various parameters related to concrete characteristics and mechanical appurtenances on the pumping of concrete have been presented. The concrete output, concrete consistency, horizontal and vertical lead and the diameter of the delivery pipeline have an important bearing on the pumping pressure, which is a critical design parameter. The required power of the pump prime mover can be estimated from the desired concrete output and the pumping pressure.
- The case studies in Hong Kong, together with the literature, have confirmed the need to formulate a framework of realistic productivity indicators, an example of which is proposed, and to establish productivity benchmarks at macro and micro levels. More reliable and realistic productivity evaluations will also point to areas for improvements at project, organisational and industry levels.
- Concrete pumping is more and more popular and is in constant evolution around the world. Over the last decade, the increasing use of wet mix shotcretes and the more stringent requirements with regards to shotcrete performance have raised the importance of concrete pumping in the industry.

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