Illinois Institute of Technology, Chicago, IL
Department of Civil, Architectural and Environmental Engineering
Construction Engineering and Management Program
David Arditi, Ph.D.

Construction Equipment Management
CAE 577

Concrete Pumps

Spring 2015

by

Ivan Neri CWID: A20345421

04/07/2015

Table of Contents

Introduction

A concrete pump is a system designed to deliver concrete to a specific site using pipelines. The first pumping equipment were introduced in the United States in the early 1930´s, but those types of equipment were not extensively used in construction until 1970´s due to the increase in demand for a system that could transport concrete through longer and higher distances, for example, in multiple story building construction (South & Parker, 2009). However, there are records showing that in Europe and Asia (particularly Japan) the use of concrete pumps was highly developed in order to help rebuild the cities after World War II; the countries that held the title for manufacturing and exporting concrete pumps in large quantities for several years were Germany (under the companies of Putzmeister and Schwing) and Japan, coinciding with the theory that rebuilding city projects in construction helped to increase the market for these machines.

The pump is a fairly simple machine: the concrete is poured from the mixing truck into the inlet hopper of the pump (which is the part of the pump that receives, holds and directs the concrete inside the pump), then pressure is applied to the fresh concrete column of determined uniformity and consistency and the pressure in the system moves the material through the pipeline (sometimes with the help of a lubricating outer layer) to the desired area of application. Since concrete is very viscous, the flow inside the pipeline attached to the pump will be affected majorly by uniformity of flow and friction, so, in order to function properly, a pump will require a steady supply of *pumpable* concrete.

Typically a concrete pump will consist of a pipeline, an intake hopper and its particular configuration of valves and pistons (or pneumatic machinery). Today the piston pumps are the most common and they either use a hydraulic valve or a flapper valve. Aside from this, a concrete pump can also be either mounted on a truck or *tower-mounted* or could also be stationary and placed in the ground.

Depending on the type of job, the quantity of the concrete needed, the accessibility to the concrete pouring site and the distances that need to be covered, there will be a specific type of pump that´s best suited to do the job.

Types of pumps

In general there are three types of pumps, which are differentiated by the mechanism used to pump concrete. Also it is important to note that aside from the mechanism (either piston, pneumatic or peristaltic) there are different types of valves used in pumps. A valve is simply the mechanism inside the pump that regulates the flow of the concrete entering the system and helps to avoid shortage or surplus of material inside the pump.

The two main types of valves are:

-Mechanical Valves (Ball Check Concrete Valves): Ball Check Concrete Pumps utilize balls and mating seats to control the flow of concrete from the intake hopper through the cylinder and into the pipeline. However, these types of pumps are unable to break any trapped aggregate in the valve area and are typically used for smaller jobs where a smaller volume of concrete is required.

-Hydraulic Valves (Most commonly used): the valves can be either Flat Gate Valve or Flapper Valve, the thing that changes is how the concrete enters the two cylinders inside the pump. While both valves enable the breaking of any trapped aggregate, the flapper valve also allows the cylinders to switch roles during pumping; at first one cylinder gets filled with concrete and the other is cleared from it with a piston to feed the pipeline, with the flapper valve the roles can change and now the former receiving cylinder can now push material into the pipeline while the other cylinder feeds the system.

It is also important to note that these hydraulic pump systems can be self-lubricated by oil or water (Peurifoy, Schexnayder, Shapira, & Schmitt, 2011).

Piston Pumps:

The majority of pumps are twin-cylinder hydraulically operated machines with reciprocating pistons. The introduction of hydraulic pumps helped to greatly increase the outputs and reduce job time. How these machines work is that the piston in one cylinder discharges concrete inside the pipeline while at the same time the other piston retreats and lets concrete from the intake hopper into its cylinder. Valves are synchronized to open and close at the beginning and end of each stroke of the pistons: the inlet valve of the empty cylinder opens and the inlet valve of the full cylinder closes, allowing the empty cylinder to get full with material; after this, the outlet valve of the full cylinder opens and the outlet valve of the empty cylinder closes, allowing the piston to push the material into the pipeline.

If necessary, there can also be a backward piston motion to clear the system. Also it is important to note that these hydraulic systems are enclosed in a lubricant, such as oil or water, to help maintain proper functioning.

FIGURE 1-Dual Cylinder Concrete Piston Pump

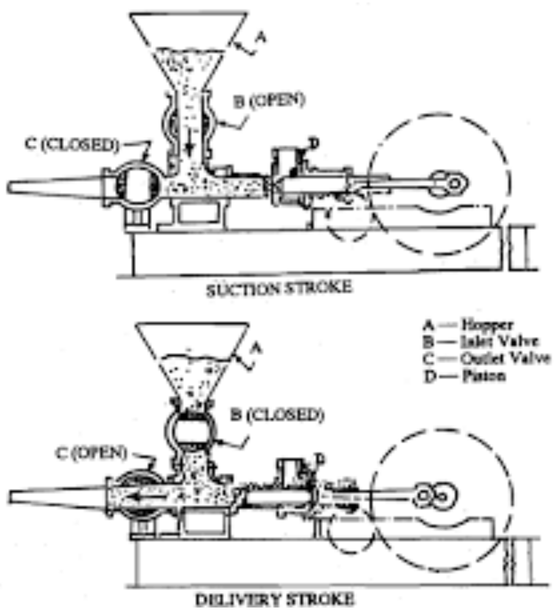


FIGURE 2-Diagram of the two types of cylinder strokes inside a Hydraulic Concrete Piston Pump

Pneumatic Pumps:

In this type of pumps the concrete is moved trough the pipeline with compressed air. There are no mechanical pieces applying pressure to the concrete. The way these pumps work is by pouring a certain quantity of concrete (typically 0.5 cubic meters) into a pump receptacle or vessel. At the inlet there is a counterbalance door that closes when the vessel is full, after this happens, compressed air is allowed into the system by a valve and the concrete is forced through a taper or reduction into the pipeline (typically the taper ranges between 150 and 200 mm).

The main concern with these pumps is not to allow too much concrete leave the vessel into the pipeline, as there is a tendency for pockets of compressed air to form and after entering the pipeline they can cause serious problems like a spraying effect of the concrete or even whiplashing, which can be dangerous to the working personnel (Peurifoy, Schexnayder, Shapira, & Schmitt, 2011). To counteract this, and as a safety measure, typically these pneumatic pumps feature a reblending discharge box at the discharge end to bleed off the excess air and to prevent segregation and spraying.

The equipment itself is relatively cheaper than the hydraulic pumps and its use is particularly destined to small jobs where small quantities of concrete are required. The equipment is mostly stationary, but can be moved if needed, however, the performance and outputs may considerably decrease as the distance from the pouring site is increased.

FIGURE 3-Typical Pneumatic Pump from LLC Construction Machinery

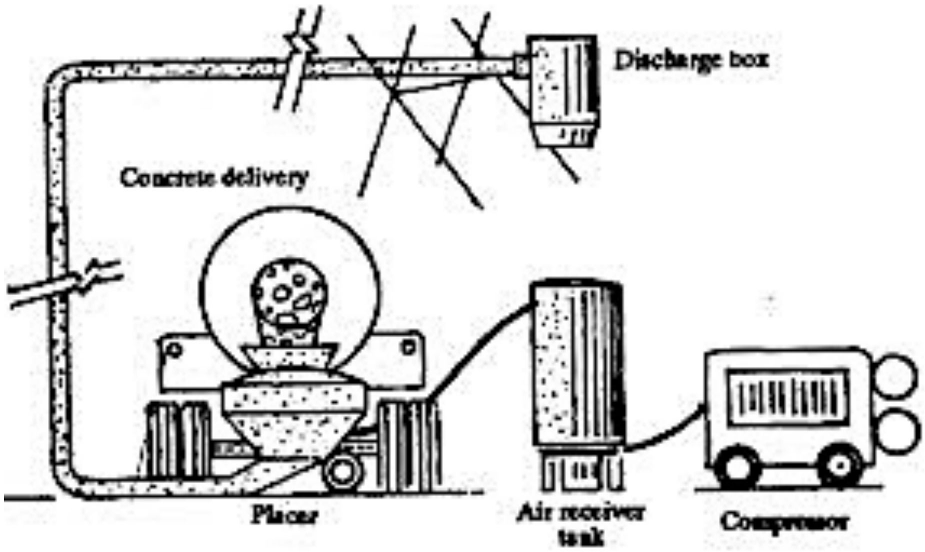


FIGURE 4-Diagram of a Typical Pneumatic Pump with a Reblending Discharge Box at the pipeline end

Peristaltic Pumps (Squeeze Pressure Pumps):

These pumps work on the same principle as the pumps used in hospitals to administrate fluids at a constant rate, as a matter of fact, some experts consider them as an enlarged version of these hospital pumps modified to meet construction needs.

The pump works by receiving the concrete in the intake hopper; the concrete is kept in a cohesive and appropriate condition by rotator blades inside the intake hopper. These rotating blades are also designed to spin the concrete and help it towards the inlet tube of the pump, which has a typical diameter of 75 mm. This inlet tube (also called a peristaltic hose) is made of a resilient material like flexible nylon rubber, and after its full, the tube is flattened by a linked pair of rollers that rotate in a circling or planetary motion around the pump chamber. As the rollers advance, they squeeze the peristaltic hose, moving forward the concrete and driving it along the pipeline (which typically ranges from 75 mm to 100 mm in diameter). This technique is called a “live seal” and prevents material from being accumulated and crushed in between the advancing rollers, also, a pressure of approximately 1 bar (14.50 psi) is maintained in the system throughout the process (Williams, 2013).

The main use for Peristaltic Pumps is in jobs where there is little space to accommodate a pump and where there´s a small volume of concrete to be poured. Even though other types of pumps may provide higher outputs and shorter job times, these pumps are cheaper and the repair costs are also considerably lower than, for example, Hydraulic Pumps. However, a steady supply of concrete must be introduced in the intake hopper to have a better functioning of the pump.

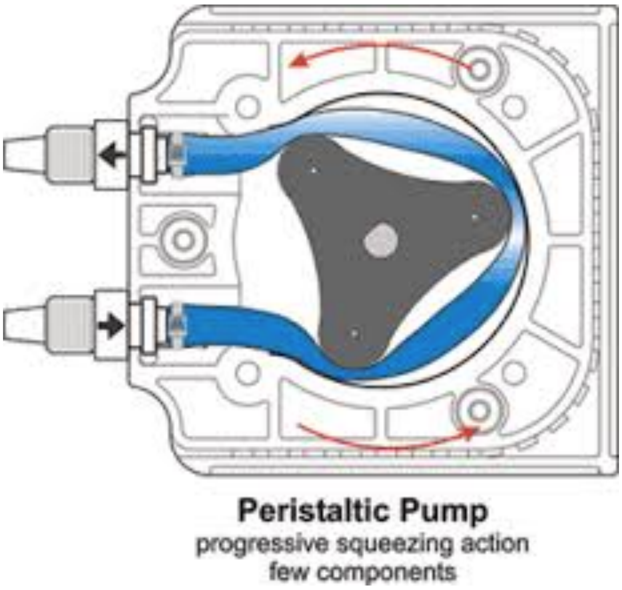


FIGURE 5-Example of Peristaltic Concrete Pump components: Rollers, Peristaltic Hose, and Inlet.

FIGURE 6-Example of a functioning Peristaltic Concrete Pump

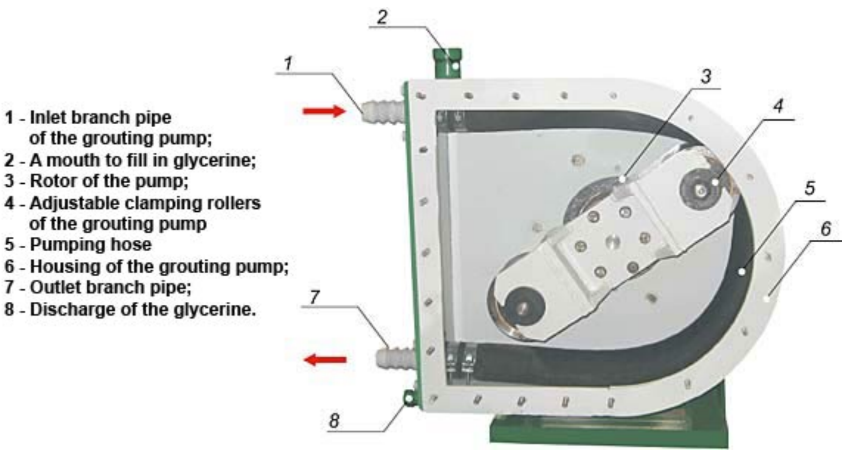


FIGURE 7-Detailed example of a Peristaltic Concrete Pump

Configuration of Pumps

Concrete pumping equipment can be found in different configurations; what this means is the way the pump is either mounted on a truck, tower-mounted or stationary on the ground. Depending on the type of job, conditions, altitude of the construction and space available, there is a specific type of configuration for concrete pumps that´s more efficient in delivering concrete to the desired site.

In terms of pump mobility there are three main options (Newman & Choo, 2003):

Stationary Pump: which means the pump is mounted on a steel frame and stationed on the ground with zero mobility. A pipeline is commonly attached to the pump in order to deliver the concrete to a specific site.

FIGURE 8- Example of a Stationary Concrete Pump connected to a pipeline

Trailer Pump: the pump is mounted on a one or two-axle trailer in order to provide mobility. In this case, several pipelines can be attached too, just as with a stationary pump, in order to deliver concrete to several sites, however, the advantage is that the pump may be relocated in order to ease the delivery of concrete.

FIGURE 9- Example of a Trailer Pump attached to a Concrete Mixer Truck

Truck Pump: this is a quick setup pump, not very common, that is mounted on a standard truck chassis. This option is used when there is a need to cover longer distances in one-time concrete operations or small projects.

FIGURE 10- Example of a Truck Pump

Pump with Separate Pipeline (Line Pump):

In this type of configuration, the concrete pump comes with a separate pipeline that is attached to it. The pipeline is a separate system and must be connected to the pump before starting operations. Most of the time the pipeline will be laid from the site where the pump is stationed until the delivery area where the concrete is being poured. A recommendation for these types of jobs is that the pump is located in a space where concrete trucks can also access in order to supply the pump with material. This type of configuration is common among some rental equipment companies and if the job requires it, several pipelines can be attached to reach longer distances, for example: high-rise buildings.

A pump in this configuration can be mounted on a truck, attached to a trailer or just be stationary.

FIGURE 11- Example of Pump and Separate Pipeline configuration being supplied by a Concrete Mixer Truck

Pump and Boom Combination (Boom Pump):

This type of pump is mounted on a truck and is equipped with a revolving boom connected to a fixed-length delivery line. The line is made of a steel pipe (5 in. diameter) and at the end there is a flexible pipe called the *end hose,* the purpose of this hose is to facilitate the pouring of concrete for the worker while also increasing slightly the boom´s reach. These booms are hydraulically operated and the length can vary from 60 to 200 ft. The booms are divided in sections and are commonly composed of 4 or 5.

It is important to note that a boom´s length is an indication of the maximum vertical reach measured from the ground, while the boom´s maximum horizontal reach is measured from its slewing axis and is always considerably shorter (approx. 13 ft.). The *Effective Reach* generally refers to the net horizontal reach, and is always smaller than the maximum horizontal reach. This *Effective Reach* depends on different factors: truck make, size, extension of outriggers, terrain and rate of pumping. It is important to check the boom charts and truck manuals before starting a concrete operation (Reed, 2009).

This type of equipment suffers from decrease in productivity due to relocation, since the boom has to be folded, outriggers have to be retracted and the truck moved. It is recommended that a space is left available where concrete-mixing trucks can access in order to supply the pump with material to avoid delays.

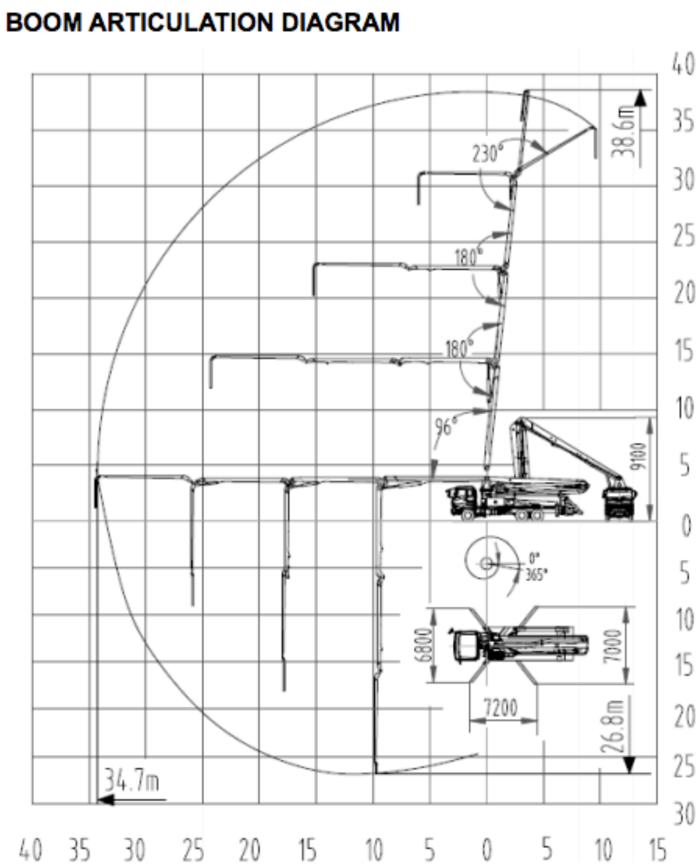
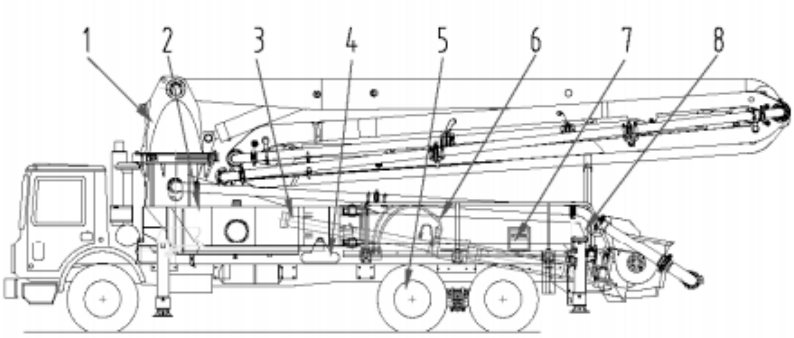


FIGURE 12- An example of a Boom Chart for a Boom Pump. (Reed, 2009)



No.	Description	Group Number	Material	Parent	Weight	Quantity
1	boom	XBC39.1		XT39R4V00		1
2	pedestal	XBC39.2		XT39R4V00		1
3	pumping system	XBC39.3		XT39R4V00		1
4	subframe	XBC39.4		XT39R4V00		1
5	chassis	XBC39.5		XT39R4V00		1
6	hydraulic system	XBC39.6		XT39R4V00		1
7	electrical system	XBC39.7		XT39R4V00		1
8	lubrication system	XBC39.8		XT39R4V00		1

FIGURE 13- Detailed example of a Pump and Boom Combination mounted on a truck (also called Truck-mounted pump).

Pump with Pipeline and Tower-Mounted Boom:

This configuration of pump combines elements of the other two configurations: it uses a stationary or truck mounted pump, a separate boom that is mounted on a climbing tower (*mast*) and a pipeline that goes from the pump until the end of the boom. It is important to note that this type of pump configuration is used as a common solution in high-rise structures (Ali, 2001).

The boom is hydraulically operated and is placed on top of two main types of masts:

1) A robust, hollow-tubular steel column that runs vertically through openings in the building´s floors.

2) A *lattice mast,* which is very similar to a mast of a tower crane, that is stationed inside or outside of the building and can be either freestanding or attached to the building.

These separate booms come in lengths ranging from 65 to 150 ft. and can have a short section of ballasted counter-boom if the length is too great. There´s also an optional attachment on the base of the boom that helps change it faster to other masts if needed in bigger construction projects.

FIGURE 14- A construction project using several Tower-Mounted Booms for concrete pouring.

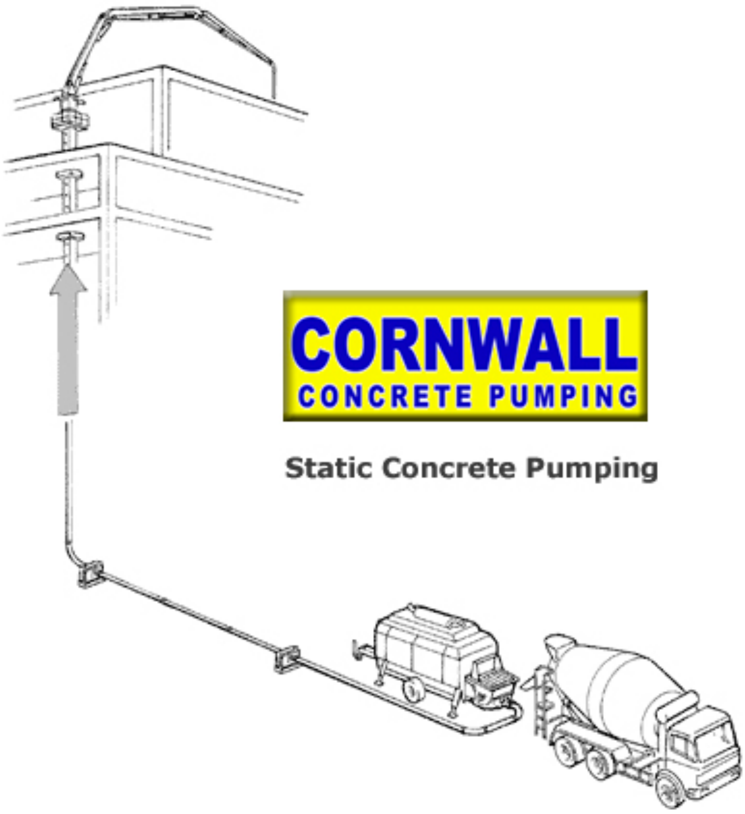


FIGURE 15- Example of the functioning of a concrete pump with separate pipeline connected to a Tower-Mounted boom. *Photo taken from Cornwall Concrete Company.*

Pipelines

The pipeline is the part that is connected to the pump and delivers the concrete to the specific site. They are composed of straight or curved steel pipe sections with a diameter that can range from 3 to 8 in. (being 5 and 6 in. the common sizes).

Attached at the end of the steel sections there is an end hose that is made of a flexible material, like rubber, with a length 10 to 30 ft. long, which helps the workers maneuver better the pouring of the concrete at the discharge location (Peurifoy, Schexnayder, Shapira, & Schmitt, 2011). Due to the weight of the concrete inside the end hose, sometimes there is an attachment similar to an articulated boom (called a distribution or placing boom) that can be connected to the end of the steel pipeline and is supported by a ballasted base, allowing an easier, more precise maneuver of pouring concrete.

FIGURE 16- Example of a Distribution Boom being used to facilitate the pouring of concrete.

Attachments to the end of the pipeline (Nozzle):

Sometimes attachments are connected to the end hose in order to facilitate a specific type of job, for example, spraying concrete. In that case a nozzle is used to spray the material over the desired surface, like walls or ceiling, however, in this type of jobs there is a considerable amount of wasted material.

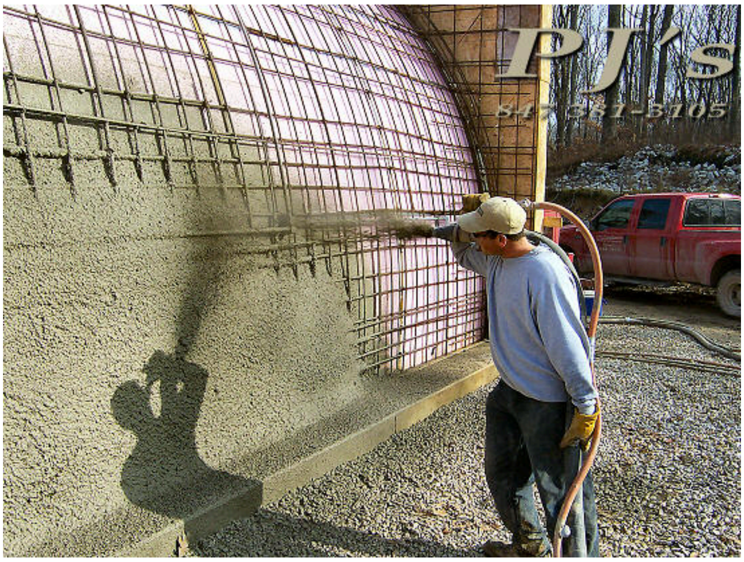


FIGURE 17- Example of a Nozzle attachment spraying concrete

Pumping Outputs and Efficiency Guidelines

The outputs of concrete pumps vary greatly due to various factors, but can achieve theoretical outputs of up to 5 cu yards/ min. However, the outputs are generally lower than this but can still be maintained to a decent level by following some of these guidelines ((Newman & Choo, 2003):

1) The size and the expertise of the working crew affects greatly the placing rate of concrete. A decent size crew (between 4 to 6 workers) is recommended for a good operation.

2) The pump can greatly increase its output rate if it is supplemented by a steady amount of concrete. Several concrete mixing trucks are recommended in order to constantly supply the pump and avoid interruptions.

3) Sizing the job is crucial. Select a pump according the size of the project being realized, a bigger pump than the one needed will cause the working crew to fall behind schedule; a smaller pump than the one required will have trouble delivering concrete to the various sites in the project.

4) Another important factor is the lateral hydrostatic pressure of the concrete on walls and columns, so a plan of how to proceed with the pouring of concrete

(specially the rate of placing it) is recommended to avoid mistakes and damages to any structure.

Typically these are the outputs for different types of construction projects under normal conditions:

Common building elements of regular dimensions	40 cy/hr.
Thick slabs and similar elements	60 cy/hr.
Mass concreting of large elements (i.e., dams, raft foundations)	80 cy/hr.

Information on this table was extracted from the book by Peurifoy, Schexnayder, Shapira, & Schmitt, 2011: *Construction Planning and Equipment Methods*

Basic Pumping Rules

Aside from the guidelines presented above, there are a couple of rules that manuals recommend in order to successfully pump concrete (Peurifoy, Schexnayder, Shapira, & Schmitt, 2011):

- Concrete is ideally supposed to move inside the pipeline as a cylinder when it is being pumped. Use a minimum cement factor of 307 kg per 1 m^3 of concrete.

- One of the most overlooked aspects that promote bad pumping is bad gradation of coarse and fine aggregates. Use a combined gradation that ensures no big gap between sizes, this will prevent any squeezing of the concrete paste through the coarse aggregates (Feys, De Schutter, Verhoeven, & Khayat, 2009).

- Always use a minimum diameter pipeline of 5 in. and lubricate the line of the pump with mortar before operating.

-Avoid reductions of the pipeline, especially at the end hose. One common misconception is that by reducing the size of the pipeline helps the workers maneuver better the pouring of concrete, but this interferes with the required pressure to pump concrete and creates a constriction.

-Never use aluminum pipelines. Aluminum can be scraped from the inside of the pipe and will react with the cement causing weakening of the concrete.

Conclusion

Concrete pumps are a solution that facilitates the placing of concrete in different construction projects. There is a variety of configurations and possibilities as to how a pump is equipped in order to deal with a specific type of job. This type of equipment can be relatively cheap (for example, a stationary pump that deals with placing a small volume of concrete) or can turn out to be as expensive as the complexity that the project demands (for example a high rise project with many tower-mounted booms with several stationary pumps and pipelines supplying them).

When using concrete pumps it is important, according to expert manuals, to always consider the factors of the job that affect the outputs of the pump, so that there can always be a good rate of placing concrete and the time schedule is followed (Reed, 2009). The factors can be several, as listed above, like the size of the project, the amount of people handling the pump and pipeline or the type of cement and the ratio used in the mix, but when they are taken care of properly the efficiency of the pump is greatly increased, translating into benefits for the company using it.

One last thing to consider is that it’s better to use the rent option when the pump is being used for sporadic periods of time with small volumes of concrete being placed. This is especially true with bigger equipment like the Pump and Boom combination, which is installed on a truck, because it is expensive to buy and the investment may not pay off after some time if there’s not enough use.

List of References

Ali, M. M. (2001). Evolution of Concrete Skyscrapers. *Electronic Journal of Structural Engineering* , 23.

Feys, D., De Schutter, G., Verhoeven, R., & Khayat, K. (2009). Similarities and Differences of Pumping Conventional and Self-Compacting Concrete. *Civil Engineering Journal* .

Newman, J., & Choo, B. S. (2003). *Advanced Concrete Technology 3: Processes.* Tucson, Az, United States: Butterworth-Heinemann.

Pumps, Reed. (2009). *Concrete Pumps Operation Manual.* Oklahoma, Ok, United States: Reed Concrete Pumps.

Peurifoy, R. L., Schexnayder, C. J., Shapira, A., & Schmitt, L. R. (2011). *Construction Planning, Equipment, and Methods* (8th ed.). New York, NY, United States: Mc Graw Hill.

South, D., & Parker, F. (2009, 04 21). *A Brief History of Concrete Pumps and What Monolithic Recommends*. Retrieved 04 01, 2015, from Monolithic.org: http://www.monolithic.org/equipment/concrete-pumps/more-info/a-brief-history-of-concrete-pumps-and-what-monolithic-recommends

Williams, J. (2013, 08 23). *Concrete Pumps and Pumping Information*. Retrieved 04 01, 2015, from Concrete Network: http://www.concretenetwork.com/concrete/concrete_pumping/

Bibliography

- Shotcrete / Gunite - PJ's Concrete in Barrington - http://pjsconcretepools.net/shotcrete.htm
- http://cornwallconcretepumping.co.uk/statics.html
- http://www.reedpumps.com/manuals/XT39R4V00_operation_maintenance_parts.pdf
- Peristaltic Pump Diagram http://www.prompolistirol.ru/eng/kornet.html
- http://www.starpumping.com/concrete-pumping-history-2/
- http://www.tandfonline.com/doi/pdf/10.3846/1392-3730.2009.15.369-376
- http://www.ritchiewiki.com/wiki/index.php/Concrete_Pump
- http://www2.worksafebc.com/PDFs/investigations/IIR2007105910285.pdf