Guide to Placing Concrete by Pumping Methods

Reported by ACI Committee 304

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This guide discusses the use of pumps for transporting and placing concrete. Rigid and flexible pipelines, couplings and other accessories, and the various types of concrete pumps are discussed. The importance of proportioning a pumpable concrete mixture is emphasized with reference to sources for further direction on its design. Evaluation of trial mixtures to ensure pumpability and strength is encouraged. Of specific importance is a discussion on the use of lightweight aggregates. Methods to saturate these aggregates and provide a consistent moisture content are discussed.

Preconstruction planning for equipment placement and line routing are emphasized. Discussions on achieving a consistent mixture and its critical importance are also addressed.

Keywords: blockage; boundary layer; concrete pump; coupling; mixture design; pipeline; placing boom; preprimed; pumpability; reverse pumping; valve.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Pumping concrete through metal pipelines by piston pumps was introduced to the United States in Milwaukee, WI, in 1933 (Ball 1933). This concrete pump used mechanical linkages to operate, and usually pumped through pipelines 6 in. (150 mm) or larger in diameter.

Many new developments have since been made in the concrete pumping field. These include new and improved pumps, truck-mounted and stationary placing booms, and pipelines and hoses that withstand higher pumping pressures. Pumps are available with maximum theoretical output capacities of over 250 yd^3/h (190 m^3/h). As a result of these innovations, concrete placement by pumps has become one of the most widely used practices of the construction industry.

The construction industry recognizes that concrete pumping is useful when space for construction equipment is limited. Cranes and hoists are freed up and other crafts can work unhampered while pumping is in progress. Concrete pumps are designed to deliver the best combination of volume output and concrete line pressure possible.

How well the pump performs in an application depends on many factors, both internal and external to the equipment itself—for example, ambient temperature influences pump performance. Pipe diameter, pumping direction both for vertical and horizontal distance, and concrete mixture characteristics also have an effect.

As construction designs and projects become more sophisticated, such as requiring higher strength and greater durability, concrete mixture design today is more complex than what was traditionally placed (Putzmeister America, Inc 2010; American Concrete Pumping Association 2007, 2010, 2011b).

Pumpability is one consideration the contractor can request from the designer when specifying mixtures. Engineered mixtures, using special materials and processing, must consider design details including final strength, curing characteristics, site conditions such as underwater placement, material and handling expenses, flow characteristics, delivery/placement, and sustainability impacts. In cases where these features are in direct conflict, a compromise or alternate solution is necessary. Given the popularity and benefits of placement by pumping, it could become critical to a specific application that the components and proportions of a mixture be designed with consideration of pumpability.

There are many variables that could affect the successful pumping of a mixture in an application, including the specific requirements of a specific combination of materials, equipment components, and installation circumstances, of which several will be discussed in more detail in this guide.

This guide discusses concrete placement using the pumping method and how it affects the supplied concrete mixture when considering pumpability in mixture design, and with the goal to obtain optimum concrete pumping results.

1.2—Scope

This guide for concrete pumping discusses equipment use, proper mixtures for good pumpability, and field practices. References cited provide more detailed information on specific subjects. This guide does not address shotcreting or pumping of nonstructural insulating or cellular concrete.

CHAPTER 2—DEFINITIONS

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology", https://www.concrete.org/store/productdetail.aspx?ItemID=CT13. Definitions provided herein complement that source.

boundary layer—thin coating of mortar fraction that lines the inner pipeline wall during pumping.

degree of pumpability—the amount of resistance of a specific concrete mixture to being pumped through a delivery pipeline.

pumpability—capability of a specific concrete mixture to being pumped through a delivery pipeline.

relative movement—ability of concrete components to navigate small distances within the mixture and to position differently compared to the other components.

stable concrete—concrete mixture that resists the tendency to segregate.

CHAPTER 3—PUMPING CONCRETE

Pumped concrete moves as a cylinder riding on a thin lubricating film of grout or mortar on the inside diameter of the pipeline. Before pumping begins, the entire pipeline's interior diameter must be coated with either grout or a specialized commercial primer using the methods for 100 percent coating of the pipe walls as recommended by the manufacturer. Once concrete flow through the pipeline is established, the lubrication will be maintained as long as pumping continues with a properly proportioned and consistent mixture. A steady supply of pumpable concrete, defined as a mixture that is capable of being pumped through a hose or pipe, is necessary for satisfactory pumping (U.S. Bureau of Reclamation 1981). A pumpable concrete, such as conventional concrete, requires good quality control; that is, it is uniform, has properly graded aggregate, and its materials are uniformly batched and mixed thoroughly.

3.1—Mixture component distribution

3.1.1 *Boundary layer*—From the concrete pump's delivery cylinder to the point-of-placement end hose, effective and efficient concrete pumping depends on minimizing any drag caused by the inside wall of the delivery vessel. One suggestion is to have the inside wall continuously bordered by a boundary layer that gives the least resistance to movement as possible. At the start of each placement or “pour,” to which it is sometimes referred, this boundary layer is achieved by priming the line with a thin film of grout or commercial primer. This coating provides a slicker surface with lower frictional resistance for the mixture to glide along than would a steel pipe or rubber hose.

To ensure that this low resistance-force action continues, the mixture should have enough mortar content to maintain a boundary layer between the body of mixture and the pipeline wall. This is similar to the need for a certain level of workability resulting from the mortar fraction when finishing concrete.

A boundary layer allows the concrete mass to move through the pipeline without the aggregates scraping the pipe wall. If scraping occurs, the contact friction causes resistance to pumping. The magnitude of the pumping resistance depends on the aggregate, pipe wall composition, and line pressure pushing the aggregate into the wall. This resistance is somewhat self-perpetuating because the line pressure increases the friction of the concrete being pumped, which in turn increases the amount of pressure in the line.

The boundary layer also increases the useful life of the pipeline. If the pipeline wall is not subjected to frictional scraping, it is more likely to remain coated and less likely to be worn down or damaged. This extends the amount of material that can be safely pumped through it before a replacement is needed.

3.1.2 *Mortar content*—In addition to the need for a mortar-based boundary layer, the remaining concrete mass also requires a minimum amount of mortar to transport efficiently through the pipeline (Fig. 3.1.2). With a properly proportioned mortar content, the concrete mixture will:

a) Provide enough mortar fraction to suspend the aggregate during pumping, as well as facilitate finishing and strength development.

b) Quickly achieve a preferred arrangement with all components located in positions that best arranges them to both physical and electrostatic attraction/repulsion characteristics. This spatial arrangement remains intact unless it is forced to change to navigate pipeline elbows and reducers.

c) Create a shear-style flow. Because concrete pumping is not done completely through straight pipes of a constant diameter, the mixture requires a relative movement of components as it is transported through elbows and reducers. A mixture with a low barrier to movement or low viscosity will have the ability to change component locations more easily through this shear-style flow. The components near the pipe axis will flow faster than those closer to the pipeline wall. In a high-viscosity mixture, relative movement and component shifts are minimized, which could cause aggregate/wall abrasion and frictional resistance. The objective is to avoid working with a difficult mixture.

3.1.3 *Fiber reinforcement*—The addition of reinforcing fibers binds up the components in the pipeline into a preferred arrangement, effectively increasing the viscosity of the mixture. Their effect on pumpability is dependent on how much the fibers restrict component shifting, and how often they can penetrate the boundary layer and scrape the pipe wall.

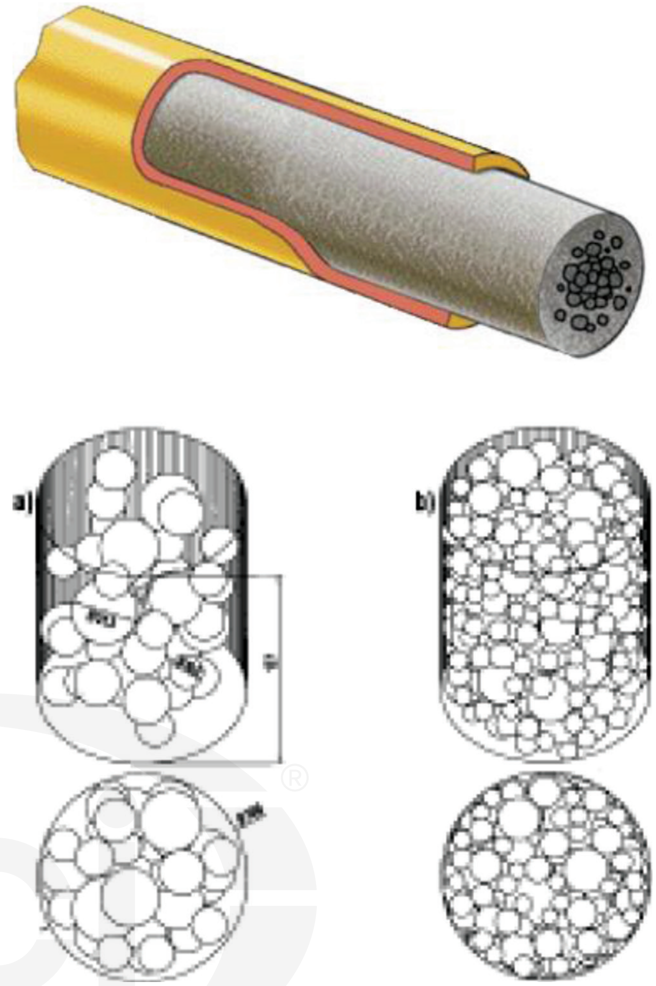

Fig. 3.1.2—Mixture component spatial arrangement.

3.2—Disruptions to flow

3.2.1 *Turbulence makers*—Pipeline components can interfere with the orderly flow of mixture, which can both increase pressure needed to pump at the desired volume output and decrease the useful life of the pipeline. Because these disruptive sources can be found to some degree between the delivery cylinder and delivery pipeline, if a difficult mixture makes it through the first 20 ft (6.1 m) of a delivery system, it has a greater chance of success from a pumpability standpoint.

3.2.1.1 *Elbows*—The mixture has a momentum during pumping that tends to carry the aggregate away from the center of the pipeline and toward the outside wall of an elbow. In addition, due to the increased surface area at the outside radius, there is typically a decrease in the boundary layer thickness at the outside radius and an increase in the boundary layer at the inside radius. Depending on the conditions and mixture, the aggregate could then temporarily pierce through the boundary layer and contact the inner