CONCRETE MACHINES

1. Concrete Mixers

Concrete can be centrally *mixed* in a “wet” plant—a plant that has a built-in mixer—and transported to the site in truckmixers operating at agitating speed, centrally *batched* in a “dry” plant, and mixed in the truckmixer itself, which then drives to the site at agitating speed, or it can be produced on-site. On-site production is a viable solution mainly in case of exceptionally large concrete amounts or if the site is located remotely such that transport distances from the closest plant are too great. The view of a compact mobile mixing plant on a small construction site in some parts of the world (e.g., Europe) is not rare; today, this equipment is highly automated, among other things, to ensure high concrete quality control.

Where high concrete volumes are required, larger mixing plants with higher outputs are sometimes used on-site—for example, in dense urban areas with access difficulties due to traffic-congested roads. The great majority of today’s building sites, however, use ready-mixed concrete delivered to the site from the dry or wet central plant in **truckmixers**, also called *ready-mixed trucks*. Truckmixers the world over are of the *rear-discharge* type, but in North America, *frontdischarge* truckmixers are used as wellThe drum in the ready-mixed concrete truck, both of the rear- and front-discharge type, is a *freefall*type mixer. Freefall mixers blend concrete by lifting the ingredients with the aid of fixed blades inside the rotating drum (in the case of a truckmixer, the blades are spiral) and then letting them drop by gravitation (hence, the term *gravity mixer* is also used for freefall mixers). This is unlike *power* mixers, which blend the concrete by rapid rotary motion of paddles, making them particularly suitable for dry mixes. The drum of the truckmixer is rotated in one direction for loading and in the opposite direction for mixing or agitating (i.e., it is a reversible-type freefall mixer).

When planning a pour with ready-mixed concrete, several points should be considered. The rate of concrete delivery is affected by the size of the truck (namely, the effective intake volume of the drum), distance from the plant to the site, the number of truckmixers allocated by the plant for the specific operation, and possible delays that may be caused by heavy traffic. In terms of site organization, maneuvering space must be ensured for the large and heavy trucks, as well as proper ground conditions for travel.

If the site is too restricted to allow free truck movement, as is often the case in mid-city construction sites, provisions should be made to allow for the nearby waiting of trucks. Such operations require thorough planning, workers designated for traffic control, and communication means. Often, one traffic lane would have to be blocked for the duration of the pour, after coordination with the local authorities. Truckmixers come in sizes up to 20 cu yd, with 8 to 12 cu yd being the most common size range. The most popular size appears to be gradually increasing, although it has stabilized at 11 cu yd for several years now. Truckmixers are sometimes equipped with a boom pump or belt conveyor (see below), which gives them greater operational flexibility and independence and can be particularly useful for small jobs (e.g., house renovation) requiring small amounts of concrete. The drum in the front-discharge mixer is more elongated. This shape of the drum and the overall configuration of the truck result in a better weight distribution, which allows these trucks to meet road and bridge load restrictions better than the reardischarge truckmixers. The front-discharge truckmixer allows the driver a more convenient approach to the discharge location; the driver’s ability to control the operation from the cab without leaving the cab is an additional advantage in bad weather. This carrier truck, however, is specialized equipment, unlike the standard carrier truck of the rear-discharge mixer, and therefore more costly.

In Europe, the use of another type of concrete mixing equipment is quite common. This is the **selfpropelled mobile mixer**. The compact rough-terrain wheeled carrier, similar to that of the telehandler (see below), carries a self-loading drum-mixer with high-discharge capabilities. Mixer volumes in current models are in the range of 1 to 6 cu yd. Concrete can commonly be discharged with chutes up to 30 ft horizontally and at heights of 3 to 7 ft; with a special hydraulically elevated drum, height discharge can be up to 10 ft. Not used much on building construction sites, this self-contained machine is particularly useful on spread-out, low-rise civil projects, such as long concrete walls, utility lines, or small repair works on airfields, where relatively small quantities of concrete are required at different locations. If aggregates and cement are stored near these locations, the self-loading mixer can travel between them and carry out concrete placing as well. Quite often, such projects are remotely located and are inaccessible to truckmixers. Under such conditions, the use of one machine that offers a solution for aggregate loading and concrete mixing, transporting, and placing is even more attractive.

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2. Concrete Pumps

Concrete pumps transport concrete by moving it through a pipeline at high placing rates. As such, a concrete pump is a single-purpose machine—namely, it cannot be the only material transportation equipment on the site (unless concrete is the only or primary material requiring transportation, such as in the construction of culverts and retaining walls or at the foundation phase of the building). Hence, concrete pumps are commonly used on building construction sites generally serviced by cranes, for one or more of the following reasons:

(1) the crane is engaged in other lifting services,

(2) a high placing output is required (typically for large pours), or

(3) the location of the cast element is outside the reach of the crane.

Concrete pumps are often also seen on sites where their ability to deliver the concrete while bypassing obstructions becomes useful, such as inside low-roofed spaces (e.g., tunnels), for renovation work on existing buildings, and on sites located such that access of any other transportation means is impossible (e.g., in old cities with narrow lanes). The effective pumping distance of common concrete pumps is 300 to 1000 ft horizontally and 100 to 300 ft vertically (although special pumps have moved concrete for much greater distances). The maximum theoretical output of commonly used pumps is 80 to 200 cu yd/hr, or even up to 300 cu yd/hr for the largest pumps available today, but these rates are rarely realized. Placing rates are determined in practice by the type and dimensions of the cast element, the size of the concrete placing crew, and the rate at which the concrete is fed into the intake hopper of the pump, the latter being dictated most commonly by gross truckmixer discharge cycle time. Effective outputs, in a properly organized placing operation and under normal conditions, are as follows:

- ✓ Common building elements of regular dimensions, 40 cu yd/hr;
- ✓ Thick slabs and similar elements, 60 cu yd/hr;
- ✓ Mass concreting of large elements (e.g., raft foundations), 80 cu yd/hr.

The three main configurations of concrete pumping equipment are (1) a pump-and-boom combination, (2) a pump with a separate pipeline, and (3) a pump and pipeline with a separate, tower-mounted boom.

The first of these is particularly efficient and cost-effective in saving labor and eliminating the need for pipelines to transport the concrete. The last of these, used mostly in high-rise construction, combines elements from the former two and is a less common configuration.

2.1 Pump-and-Boom Combination

In this configuration, also termed a *boom pump*, the pump is mounted on a truck and equipped with a slewing boom to which a fixed-length delivery line is connected. The line is made of a steel pipe, commonly 5 in. in diameter. The free end of the line has a flexible rubber pipe (end hose), 9 to 12 ft long, connected to it.

The end hose eases the task of the worker who holds it and can also be used to slightly extend the boom's reach.

Booms come in lengths of 60 to 210 ft, but the more commonly used booms are in the range of 80 to 140 ft. Hydraulically operated and articulated, booms in most truck-mounted pump models have four or five sections, but three sections for short booms and six sections for the longest ones are available, too. For a given boom length, a greater number of sections provides the boom with greater maneuverability, which may be an advantage in confined areas. Note that boom length is a nominal length and not the effective length of the boom. It indicates the maximum vertical reach of the boom, measured from the ground, which includes the dead length from the ground to the first boom joint. Because this dead part is around 13 ft for most makes and models of truck-mounted pumps, the maximum horizontal reach of the boom, measured from the slewing axis of the boom, is always shorter by about 13 ft from the nominal boom length. Effective horizontal reach is even shorter, as loss of distance measured from the slewing axis to the front of the truck or to the truck side must be taken into account. Depending on truck make and size, the extended outriggers, by which the truck is stabilized while in operation, may also contribute to the shortening of the effective horizontal reach.

Truck-mounted pumps use one of two types of booms that differ from each other in their articulation mode. One type of boom extends convexly, but the other extends in a Z-like mode. Z-booms are particularly suitable for jobs with height restrictions (e.g., working under obstacles) and for confined spaces with low overhead, such as inside tunnels.

Because the reach of boom pumps is limited, these pumps use ready-mixed concrete, with the truckmounted pump optimally positioned to enable maximum coverage of the concreting area for each concreting operation. If coverage from one location is not possible, the truck is relocated in the course of the operation. Relocation, however, interrupts work continuity and may cause delays, depending on the time it takes to fold the boom, retract the outriggers, move the truck, extend the outriggers, and unfold the boom to continue concrete placing. If the relocation was not planned, a line of waiting readymixed trucks may result as well.

(a)

(b)

Pump and boom combination (boom pump): (a) arriving at site, with folded boom; (b) in operation, with extended boom.

Truck-mounted booms are available in two additional equipment configurations: as separate trailer placing booms and in combination with a trailer-type pump (see below). The trailer boom uses a twowheel carriage with counterweights to help balance the extended boom. When combined with a trailer pump, the pump serves as a partial counterweight. In both configurations, the equipment is stabilized on outriggers when in operation. Booms in both cases are shorter than truck-mounted booms, and their maximum operation range is around 60 ft.

2.2 Pump with a Pipeline

In this configuration, also termed a *line pump*, the pipeline is a separate system that must be assembled and connected to the pump before pumping operations begin. The pipeline is laid from the location of the pump to the concrete casting area. The pump is located such that the ready-mixed concrete trucks have good access to it. In the case of on-site-mixed concrete, the pump would be placed with the hopper just under the discharge opening of the mixer. On spread-out projects, sizeable floor-area buildings, or high-rise projects comprised of more than one building, several pipelines can be stretched from one pump to various project zones, thus eliminating the need to relocate the pipeline with each change in casting location. A special pipeline gate is used to control which line is being used to any given pumping operation. Another option is to prepare several pipelines and relocate the pump according to the placement location. This latter option requires the use of truck-delivered ready-mixed concrete. In terms of its mobility, the pump is a stationary pump, trailer pump, or truck pump (not to be confused with the truck-mounted pump-and-boom combination).

Two mixers position themselves at the pump and feed it alternately such that concrete supply for the pump is continuous and a higher placing rate is achieved. Pipelines for concrete transportation use pipe diameters of 3 to 8 in. (with 5 and 6 in. being the most common sizes). The pipeline is assembled of straight and curved steel pipe sections connected to each other by quick couplings. Similar to the boom pump, here, too, the free end of the line has a 10- to 30-ft long flexible rubber pipe connected to it for better control of the concrete discharge location and for easier handling by the workers who have to direct the spreading of the concrete. To help with the difficult work of holding and moving the end of the concrete-filled pipe, a special lightweight distribution (or placing) boom can be used and crane-lifted for relocation as the concreting progresses.

2.3 Pump with a Pipeline and Tower-Mounted Boom

Given their limited boom length, boom pumps cannot provide solutions for high-rise buildings. Even the longest boom available, nominally 210 ft long, can practically place concrete in buildings no higher than 14 floors. The solution is, then, to use the basic pump-and-pipeline configuration, render it with climbing capability similar to that of the internal-climbing tower crane, and enhance horizontal distribution reach and convenience by use of a boom-pump-type hydraulic articulated placing boom. This configuration is today the preferred solution for concrete placing in high-rise structures. Depending on the size of the floor in the constructed building, two such systems may be used concurrently (with one or two pumps). In this case, either two booms are used or one detachable boom, with a quick boom–mast connection, is transferred as required between the two climbing masts.

The hollow-section or lattice-type climbing mast on which the boom is mounted and the pipeline running from the pump to the boom are located next to each other inside the building. However, an external climbing mast, similar to the mast of a topslewing tower crane, can also be used.

Climbing placing booms

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3. Power Trowels

The final operations in the production of concrete elements that involve equipment are consolidating and finishing. Immediately following placement, concrete has to be consolidated by the use of vibrators. Finishing may actually be required only in the form-free faces of the cast element. Typical faces are the upper surfaces in floor slabs, where finishing to a smooth face-if required—is attained by the use of power trowels. The main part of the power trowel is the rotating blade system, commonly termed *rotor* or *spider*. When the blades rotate at high speed, frictionally engaging the concrete surface, they improve the density of the upper concrete layer, seal plastic cracks, and polish the surface to obtain a smooth and hardened concrete face. Maximum rotating speed is in the range of 90 to 180 rpm. Several steps are involved in troweling (the first step of which is termed *floating*), and with each step and successive troweling cycle the blades are slightly angled. Power trowels come in various rotor sizes (diameters). Large-size rotors are advantageous in large open areas, where high production rates can be realized; in tight spaces and mainly for finishing around various obstructions, small-size rotors or small troweling discs must be used.

Powered by electric motors or by diesel or gasoline engines, trowels come in either a walk-behind or a ride-on configuration. In terms of number of rotors, the most common are single-rotor and double-rotor trowels, but triple-rotor trowels are also available. Singlerotor trowels are of the walk-behind type, and the two others are of the ride-on type.

(a)

(b)

(c)

Finishing of concrete floor by troweling: (a) walk-behind single trowel; (b) ride-on double trowel; (c) ride-on triple trowel.

Rotor diameter varies from 2 to 5 ft, and the number of blades per rotor varies from four to six. Power trowels can be quite heavy, ranging from 100 to 300 lb for the single-rotor trowels and up to 500 to 3000 lb for double-rotor and triple-rotor trowels; the two latter owe their additional weight to the extra rotors, riding engine, and operator deck. To be crane-lifted around the jobsite and for loading and unloading, the lighter weight machines are fitted with a lifting hook, whereas the heavier machines have a robust lifting system. The latter are often moved around the workplace on transport dollies and transported between sites on trailers.

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