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Guide to Placing Concrete with Belt Conveyors

Reported by ACI Committee 304

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Guide to Placing Concrete with Belt Conveyors

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Guide to Placing Concrete with Belt Conveyors

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This report includes a short history on the early development of conveyor belts for transporting and placing concrete; the design of conveyor systems in relation to the properties of the plastic concrete, the delivery rate, and the job specifications; as well as belt widths, speeds, and angles of inclination as they apply to specific site requirements. Also discussed are the three types of concrete conveyors (portable, feeder, and spreader types) and their particular applications; field practices in the selection, use, and maintenance of conveyors; and the economics of belt conveyor placement. The quality of the in-place concrete and inspection procedures are also stressed.

Keywords: belt conveyors; concrete construction; conveying; conveyors; economics; feeders; fresh concrete; inspection; maintenance; placing; quality control; workability.

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CHAPTER 1—INTRODUCTION**1.1—General**

Belt conveyors for handling normalweight concrete are special in that they transport plastic concrete, which is heavier than aggregate or other commonly conveyed materials. They transport plastic concrete from a supply source such as a truck mixer or a batching and mixing plant to the point of placement or to other equipment that is used to place the concrete. Concrete placement by belt conveyors should be a continuous operation. Maximum success for conveyor placing requires a constant supply of properly mixed concrete for charging the belt conveyor and a provision for moving the discharge point during placement so that the plastic concrete is deposited over the entire placement area without the need for rehandling or excessive vibration. Concrete belt conveyors are classified into three types: 1) portable or self-contained; 2) feeder or series; and 3) spreader—radial or side discharge.

1.2—History

The earliest recorded use of belt conveyors in North America was to handle grain. The first recorded use of belt conveyors to handle material heavier than grain did not come until the early 1890s when belt conveyors were installed at an ore processing plant in Edison, NJ (Rines 1920). The commercial introduction of antifriction bearings in idler rollers paved the way for the modern belt conveyor. In 1923, conveyors were first successfully used in handling coal (Conveyor Equipment Manufacturer Association 1997).

The first known successful use of concrete belt conveyors was in 1929 when a 600 ft (183 m) conveyor was used to place structural concrete for the East 238th Street Bridge, Bronx County, NY. The concrete mixture (1:2:4) contained 3/4 in. (19 mm) nominal maximum-size aggregate (NMSA).

Between 1935 and 1944, belt conveyors were used to transport concrete between the mixing plant and a central distribution point where the concrete was loaded into buckets for placement. These projects used from 320 to 432 lb/yd³ (190 to 256 kg/m³) of cement and 4 to 6 in. (100 to 150 mm) NMSA. Segregation of the largest aggregate at the transfer points and hoppers gave considerable trouble and various baffles, chutes, and hoppers were developed to reduce segregation to a minimum (Tennessee Valley Authority 2013). From 1941 to 1950, concrete belt conveyors were used successfully to place concrete on seven different dam projects (Malcolm and Young 1950).

1.3—Concrete conveyor development

The almost universal availability of ready mixed concrete for building projects in the United States in the early 1950s

created a demand for equipment to bridge the gap between the area accessible to the truck mixer and the location where the concrete was to be placed. The first commercially available portable concrete belt conveyors were marketed in the late 1950s (Cope 1963).

The transporting or feeder conveyor was developed in 1962 (Oury 1963) and the first spreading belt conveyor was a side-discharge unit used in 1963 to place the deck concrete for the elevated East 46th Avenue Freeway in Denver, CO. Radial spreaders were developed shortly thereafter.

Modification and improvement of these conveyors have been rapid and significant. Early belt conveyors were limited to capacities of 30 to 40 yd³/h (23 to 31 m³/h). Today, placement rates of 120 yd³/h (92 m³/h) on 16 in. (406 mm) wide belts and 300 yd³/h (230 m³/h) on 24 in. (610 mm) belts make concrete belt conveyors applicable to massive concrete placements as well as to building construction.

Concrete belt conveyors are an excellent method for moving concrete from the batch plant to the lift surface on roller-compacted concrete (RCC) projects because they eliminate tracking mud onto the lift surface and damage from turning haul vehicles. All concrete conveyors require charge and discharge hoppers, belt wipers, and proper combinations of belt support idlers and belt speed to prevent segregation of the concrete. Any normalweight or lightweight aggregate concrete that can be discharged by a truck mixer can be placed by a concrete belt conveyor. In addition, concrete containing 3 and 6 in. (75 and 150 mm) coarse aggregate has been transported successfully on 16 and 24 in. (406 and 610 mm) wide belt conveyors, respectively (Cope 1972b). Belt conveyors were used successfully on Upper Stillwater, Elk Creek, and Middle Fork dams (Hansen 1991).

CHAPTER 2—DEFINITIONS

Please refer to the latest version of ACI Concrete Terminology for a comprehensive list of definitions.

CHAPTER 3—DESIGN CONSIDERATIONS**3.1—General requirements**

Not all belt conveyors can successfully place concrete. Concrete conveyors should be designed specifically for concrete transport (Illingworth 1972). Concrete conveyors running at the correct belt speed and with properly functioning charging hoppers, transfer devices, and belt wipers have only a minor effect on the strength, slump, or air content of the concrete that they carry (Panarese 1972; Saucier 1974). Successful layout of concrete belt conveyors for specific job applications depends on an understanding of the interaction of the many variables involved, such as slump, placement rate, site location, travel paths required, aggregate size, and others too numerous to mention. Most unsuccessful attempts to place concrete with belt conveyors can be traced directly to a failure to incorporate in the design the capability of meeting the following handling and placing requirements:

- a) All components of the conveyor should be sized to accommodate the weight of concrete, especially the drive

unit, support frame, and belt support idlers. Normalweight concrete is approximately 50 percent heavier than commonly conveyed materials such as aggregates.

b) The conveyor itself, or at least the concrete discharge mechanism, should be capable of movement over the entire placement area without significantly interrupting or delaying concrete placement. This is because the concrete needs to be distributed uniformly over the entire placement area. When placement in lifts is required for proper consolidation of the concrete, the discharge mechanism need for movement is greatly increased to allow access for vibration.

c) Concrete belt conveyors should be able to stop, hold the concrete on the belt, and restart the fully loaded belt. This is because placement cannot progress faster than the concrete can be spread and consolidated. This is especially important when conveyors place concrete in wall and column forms because it is difficult to control filling of the form by varying only the rate of charging of concrete onto the conveyor.

d) Concrete belt conveyors should be designed to operate dependably under capacity loads without mechanical failures. Once placement begins, it should continue without interruptions that could result in cold joints. Reliability and dependability cannot be achieved simply by making components larger and heavier because this conflicts with the requirements of mobility over the placement area. To meet the requirements of mobility and dependability, the booms of most concrete belt conveyors are constructed of steel trusses or aluminum extrusions. Lightweight belt support idlers and drive components are used wherever possible.

3.2—Concrete ribbon parameters

The characteristics of the ribbon of concrete on a conveyor belt are determined by the angle of surcharge of the concrete, the required minimum edge distance, and the load cross section.

3.2.1 Angle of surcharge—Each plastic concrete mixture has its own angle of repose. This is the angle that the surface of a normal, freely formed pile makes to the horizontal. The angle of repose for 2 to 6 in. (50 to 150 mm) slump concrete will usually range from 20 to 30 degrees. The angle of surcharge is the angle to the horizontal that the surface of the same concrete assumes while it is being carried on a moving (horizontal) belt conveyor. The angle of surcharge for most concrete falls in a range from 0 to 10 degrees (Conveyor Equipment Manufacturer Association 1997). A lower angle of surcharge results in a shallower ribbon of concrete. The angle of surcharge is influenced by slump/slump flow, aggregate characteristics, and mixture proportions, meaning that the ability of the concrete to flow by its own weight (rheology) properties will also affect the angle of surcharge. Such properties include:

- a) Size and shape of the aggregate
- b) Surface texture of the coarse aggregate
- c) Ratio of fine aggregate to coarse aggregate (F_A/C_A)
- d) Ratio of aggregate to cementitious materials (a/cm)
- e) Ratio of water to cementitious materials (w/cm)
- f) Additives such as fly ash, slag, metakaolin, and others, which affect cohesiveness

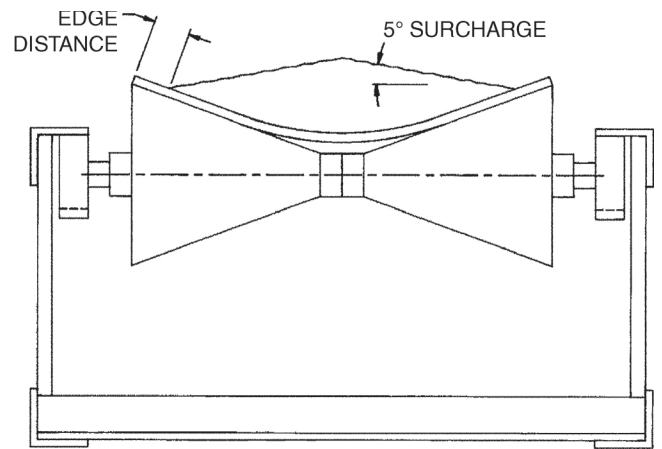


Fig. 3.2.1—Belt cross-sectional area.

g) Chemical admixtures that effect concrete properties

The angle of surcharge of plastic concrete is influenced by all its components. Small aggregates; water; and smooth, rounded, and uniform size aggregate tend to reduce the angle of surcharge. Irregular, rough aggregate; cement; and additives that make the mixture more cohesive or reduce the water requirement tend to increase the angle of surcharge. The angle of surcharge determines the cross section of the concrete ribbon that can be efficiently carried on the belt. It is also an indication of the maximum angle of incline or decline at which concrete can be handled by a belt conveyor. Angle of incline and angle of decline refer to the angle to the horizontal formed by the load-carrying belt of the conveyor.

The many variables that influence the angle of surcharge of concrete make it difficult to predict the maximum permissible angle of incline or decline. A good rule of thumb is that a concrete belt conveyor can operate with less than a 10 percent loss of cross-sectional area (refer to Fig. 3.2.1) at an angle of 20 to 25 degrees when equipped with a smooth belt and up to an angle of 30 to 35 degrees when the belt is equipped with small straight corrugations or ribs on the load-carrying surface (Conveyor Equipment Manufacturer Association 1997). Concrete has been successfully conveyed at greater angles of incline or decline with close control of factors that affect the angle of surcharge.

As the belt passes successively over each belt-supporting idler, the concrete on the belt is disturbed. This tends to work pieces of coarse aggregate to the surface of the concrete and to flatten the concrete ribbon. This is the primary reason that the angle of surcharge is less than the angle of repose. A proper combination of belt tension, belt speed, and idler spacing is necessary to prevent objectionable segregation (3.5.7). Belt speeds of 300 to 600 ft/min (92 to 183 m/min) with 3 ft (0.9 m) idler spacing and belt speed of 600 ft/min (183 m/min) on idlers spaced approximately 5 ft (1.5 m) apart have been used successfully on many projects.

3.2.2 Minimum edge distance—Concrete cannot be carried across the entire face of a belt. The ribbon of concrete should be centered on the belt with equal widths of clear belt or edge distance between it and each edge of the belt. The following equation is used to determine minimum edge distance:

$$\text{minimum edge distance, in.} = 0.05 \text{ belt width} + 0.9 \text{ in.} \quad (0.05 \text{ m belt width} + 0.023 \text{ m})$$

belt width + 23 mm)—that is, for a 16 in. belt, minimum edge distance is $(0.05 \times 16 \text{ in.} + 0.9 \text{ in.}) = 1.7 \text{ in.}$ (40 mm).

Failure to observe the minimum edge distance requirement will result in excessive spilling and loss of large aggregate off the edge of the belt.

All concrete belt conveyors use idlers that trough or cup the belt, enabling it to carry a deeper ribbon of concrete than would be possible on a flat belt. The head pulley is usually slightly crowned to provide belt alignment or training (3.5.3). Because the belt flattens as it goes over the head pulley, the ribbon of concrete tends to flow toward the belt edges in the area between the last belt support idler and the head pulley. The loss of edge distance in this area and in the area where concrete is charged on the belt will establish the maximum load cross section of any given concrete mixture that can be handled by a given concrete belt conveyor.

3.2.3 Load cross section—The nominal cross section of the ribbon of concrete on a belt conveyor is measured in a vertical plane. All capacity calculations are based on this cross-sectional area and the belt speed.

As the angle of the belt (either incline or decline) is increased, the ribbon of concrete on the belt becomes shallower. This reduction in ribbon size increases the tendency for larger pieces of coarse aggregate to break loose from the ribbon of concrete and roll away. The size, shape, and surface characteristics of the coarse aggregate have an important effect on this tendency. As the angle of incline is increased, the tendency of the concrete to flow or slide back reduces the belt capacity for a given belt speed. The maximum angle at which a given concrete can be conveyed is determined when one of these factors identified in 3.2.1 becomes objectionable.

3.3—Belt charging

As concrete is loaded on a belt conveyor, any difference between its velocity in the direction of belt travel and the speed of the belt should be equalized by acceleration or deceleration of the concrete, which results in turbulence. Properly designed charging hoppers use this turbulence to produce a remixing of the concrete as it flows onto the belt. The turbulence should not be severe and result in concrete spillage off the edges of the belt or a loss of individual pieces of coarse aggregate. Concrete with a low angle of surcharge accelerates to belt speed quicker and easier than concrete with a higher angle of surcharge.

A concrete belt conveyor should be equipped with a charging hopper that levels out surges of concrete flow and delivers a uniform ribbon of concrete onto the belt with proper edge distance. An alternative is a metering belt (Illingworth 1972) (4.2).

The wider belt can accept more concrete from a charging hopper without spilling and its speed is adjusted to charge the conveyor system at its maximum capacity. A metering belt conveyor is used as the first unit in a system of conveyors to achieve a higher capacity than could be achieved by feeding concrete directly to the conveyor system from a charging hopper. It is a conveyor with a belt that is wider and travels slower than those used in the rest of the system.

3.4—Belt discharge

Plastic concrete is traveling at the same speed as the belt when it is discharged from a belt conveyor. Plastic concrete would leave the belt as a cohesive mass except that the inertia and impetus of the larger pieces of coarse aggregate tend to separate from the stream and some mortar will cling to the belt. The energy contained in the concrete mass should be dissipated or redirected by a discharge hopper to prevent segregation. The turbulence created by this dissipation of energy produces a remixing action in properly designed hoppers. As the angle of incline or decline of a concrete belt conveyor is changed, the angle of the discharge hopper with respect to the horizontal is also changed. While most discharge hoppers function properly if slightly tilted, they may plug and delay operation.

Each end-discharge concrete belt conveyor should be equipped with a belt wiper or scraper to limit mortar loss (Panarese 1972). The wiper or scraper should be positioned so that the mortar is directed into the discharge hopper for remixing. Belt wipers depend on moisture in the concrete for lubrication and cooling. Dry belts should not be operated unless the belt wipers are removed.

Properly designed discharge hoppers, chutes, drop-chutes, or “elephant trunks” will eliminate concrete segregation problems at transfer and discharge locations. Job conditions frequently limit the size of such accessories, so numerous designs have been developed through trial and error that produce satisfactory results with the specific concrete mixture being placed. ACI 304 and The U.S. Bureau of Reclamation (1988) provide for a 24 in. (610 mm) minimum length drop-chute or elephant trunk. This length has been found to produce acceptable results in most cases; however, this should not preclude the use of other designs that demonstrate satisfactory performance under job conditions (6.2).

3.5—Belt conveyor design principles

3.5.1 Belt materials—Recent improvements in conveyor belt carcass material and construction have greatly reduced the restrictions on capacity that were made necessary by conveyor belt limitations in the past. Substitution of stronger synthetic materials such as nylon for cotton fabric have made it possible to use higher horsepower drives and to increase capacity by deep troughing or cupping of the belt. New cover compounds have extreme resistance to abrasion from the concrete and the belt wipers. The synthetic materials have also eliminated the mildew problems that had been associated with conveyor belts exposed to weather and moisture. Concrete conveyor belts should be flexible because they operate at high speeds over relatively small-diameter head and tail pulleys.

3.5.2 Belt splicing—Almost all conveyor belting is made in long lengths and is cut to fit the conveyor on which it is installed. The ends of the belt should be spliced to make the belt endless. Two types of splices are used: mechanical (clips that hold ends together), and vulcanized (adhesive splice). Each splice type has advantages and disadvantages (Conveyor Equipment Manufacturer Association 1997).

3.5.2.1 Mechanically fastened splice—This type of splice has the advantages of quick, easy installation with simple