# Bin Level Indication Applications in Cement Production and Concrete Batching Plants


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## Introduction

Concrete is fundamental to our modern day construction and a key part of our global economy. Concrete is an artificial stone-like material used for various structural purposes. It is made from a mixture of water, cement and aggregates such as gravel, sand and stone, and then drying by hydration. Water and cement combine to be a "binder" and the aggregate, sand and gravel are the "filler" that is bound together with the "binder".

Concrete is everywhere! It is used for roads, sidewalks, houses, bridges, skyscrapers, pipes, dams, canals, missile silos, and nuclear waste containment. There are even concrete canoes and Frisbee competitions. It is strong, inexpensive, plentiful, and easy to make. But more importantly, it's versatile. It can be molded to just about any shape.

Concrete is friendly to the environment. It's virtually all natural. It's recyclable. It is the *most frequently* used material in construction. Slightly more than a ton of concrete is produced every year for each person on the planet, approximately 6 billion tons per year. By weight, one-half to two-thirds of our infrastructures are made of concrete such as: roads, bridges, buildings, airports, sewers, canals, dams, and subways.

But exactly how is concrete made and what role do bin level indicators play in the process? That's the subject of this white paper. We'll look at cement production, concrete production and the use of bin level indicators in both.

## Cement Production Wikipedia

There can be many specialty types of cement. However, the process flow for a typical Portland cement production operation is shown on the next page. The name "Portland" originated in the early 1800's when cement was made in England that resembled a common type of building stone from the Isle of Portland in Dorset, England. A bricklayer named Joseph Aspdin was granted a patent in 1824 for a cement he called Portland cement. This cement was refined over the next two decades by his son, William Aspdin, and it is generally accepted that the cement resembling modern day Portland cement was first made by William Aspdin in about 1842.

**Figure 1: Modern day cement production plant in Texas, USA**


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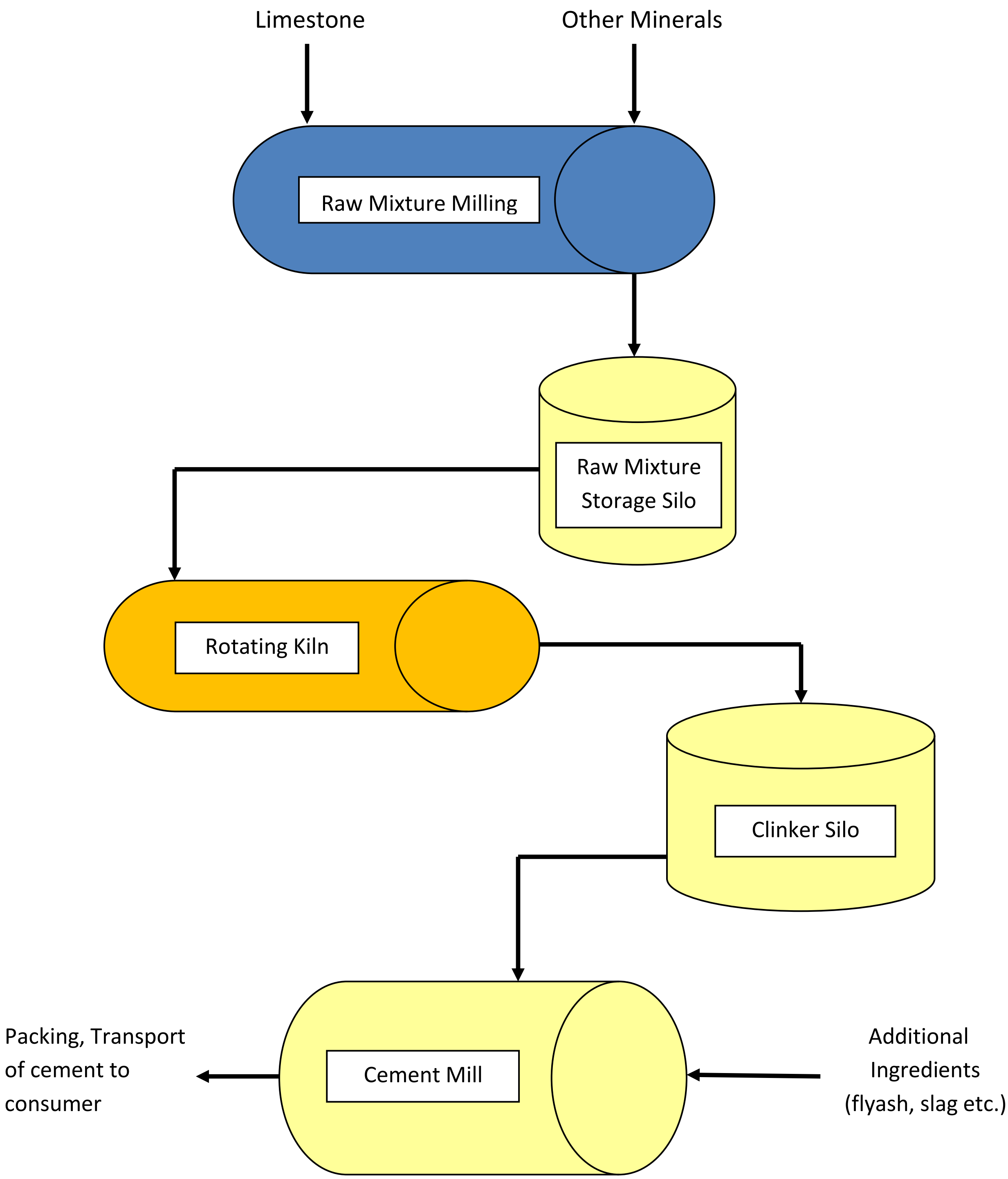
The modern production process has three parts, e.g. Raw Material Preparation, Raw Material Mixture Blending, Clinker Formation and Cement Grinding.  The Portland cement powder is made from Clinker, which is produced from raw materials that are quarried, prepared, blended and then formed into Clinker.





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Raw Material Preparation: The raw materials are usually quarried from local rock, which in some places is already at the desired composition, or close, and in other places requires the addition of clay and limestone, as well as iron ore, bauxite or other recycled materials. Raw materials are first crushed, typically to < 50mm particle size. In many plants, some or all of the raw materials are then roughly blended in a “pre-homogenization pile".

Raw materials are next ground together in a raw material mill. Silos[1] of individual raw materials are arranged over the feed conveyor belt[2]. Accurately controlled proportions of each material are delivered onto the belt by weigh-feeders. Passing into the raw material mill, the mixture is ground to for the raw material mixture. The fineness of the raw material mixture is specified in terms of the size of the largest particles, and is usually controlled so that there are less than 5-15% by mass of particles exceeding 90µm in diameter. It is important that the raw material mixture contains no large particles in order to complete the chemical reactions in the kiln, and to ensure that the mix is chemically homogenous.

In the case of a dry process, the raw material mill also dries the raw materials, usually by passing hot exhaust gases from the kiln through the mill so that the raw material mixture emerges as a fine powder. This is conveyed to the blending system by conveyor belt[2] or by a powder pump. In the case of a wet process, water is added to the raw material mill feed, and the mill product becomes a slurry with moisture content usually in the range of 25-45% by mass. This slurry is conveyed to the blending system by conventional liquid pumps.

*Bin level indicators are used* in applications as noted by 1 and 2 above:

- In “1” bin level indicators will be used for high level monitoring and possibly low level monitoring. High level monitoring uses point level sensors to detect and indicate the presence or absence of material at the desired high point in the silos and bins. This application may utilize rotary paddle or tilt switch type of devices for high level. If some raw materials are stored in outdoor open piles the tilt switch is preferred.
- In application “2” a tilt switch level indicator is used to detect the presence of material flowing on a belt conveyor. This switch will indicate to the control system that material has begun to flow into the process or indicate a problem with equipment or material supply if flow is not detected when it is expected.


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Raw Material Mixture Blending: The raw material mixture is formulated to a very tight chemical specification. Different cement producers may vary this to suit their production and branding needs. Typically, the content of individual components in the raw material mixture must be controlled to within 0.1% or better.

Calcium and silicon are present in order to form the strength-producing calcium silicates. Aluminum and iron are used in order to produce liquid ("flux") in the kiln burning zone. The liquid acts as a solvent for the silicate-forming reactions, and allows these to occur at an economically low temperature. Insufficient aluminum and iron lead to difficult burning of the clinker, while excessive amounts lead to low strength due to dilution of the silicates by aluminates and ferrites.

Very small changes in calcium content lead to large changes in the ratio of alite to belite minerals in the clinker, and to corresponding changes in the cement's strength-growth characteristics. The relative amounts of each oxide are therefore kept constant in order to maintain steady conditions in the kiln, and to maintain constant product properties.

In practice, the raw material mix is controlled by frequent chemical analysis (hourly by X-Ray fluorescence), or every 3 minutes by prompt gamma neutron activation analysis. The analysis data is used to make automatic adjustments to raw material feed rates. Remaining chemical variation is minimized by passing the raw material mix through a blending system that homogenizes up to a day's supply of raw material mix (15,000 metric tons in the case of a large kiln).

Clinker Formation: The raw material mixture is heated in a cement kiln, a slowly rotating and sloped cylinder, with temperatures increasing over the length of the cylinder up to a peak temperature of 1400-1450° C. A complex succession of chemical reactions take place as the temperature rises.

The peak temperature in the kiln is regulated so that the product contains sintered but not fused lumps. Sintering consists of the melting of 25-30% of the mass of the material. The resulting liquid draws the remaining solid particles together by surface tension, and acts as a solvent for the final chemical reaction in which alite is formed. Too low a temperature causes insufficient sintering and incomplete reaction, but too high a temperature results in a molten mass of glass, destruction of the kiln lining, and waste of fuel.

When all goes to plan, the resulting material is clinker. On cooling, it is conveyed to storage[3]. Some effort is usually made to blend the clinker, because although the chemistry of the raw material mixture may have been tightly controlled, the kiln process potentially introduces new sources of chemical variability. The clinker can be stored for


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a number of years before use.  Prolonged exposure to water decreases the reactivity of cement produced from weathered clinker.

The enthalpy (a description of thermodynamic potential of a system) of formation of clinker from calcium carbonate and clay minerals is ~1700 kJ/kg (kilo Joule of energy per kilogram of material).  However, because of heat loss during production, actual values can be much higher.  The high energy requirements and the release of significant amounts of carbon dioxide makes cement production a concern for those believing in global warming.

*Bin level indicators are used* as indicated by "3" above.  In this situation when clinker is stored, some manner of indicating a high level condition is typically needed.  They can be either of the rotary paddle or tilt switch types.  Tilt switches will be preferred in domes and both rotary paddle and tilt switches can be used in silo storage.  They tend to be more rugged than solid-state devices in this application where particle size can impact the quality of sensing and range from 3-30mm in size.

<u>Cement Grinding</u>:  In order to achieve the desired setting qualities in the finished product, a quantity (2-8%, but typically 5%) of calcium sulfate (usually gypsum or anhydrite) is added to the clinker and the mixture is finely ground to form the finished cement powder.  This is achieved in a cement mill.

The grinding process is controlled to obtain a powder with a broad particle size range, in which typically 15% by mass consists of particles below 5µm diameter, and 5% of particles above 45µm.  The measure of fineness usually used is the "specific surface", which is the total particle surface area of a unit mass of cement.

The rate of initial reaction (up to 24 hours) of the cement on addition of water is directly proportional to the "specific surface".  Typical values are 320-380$m^2 \cdot kg^{-1}$ for general purpose cements, and 450-650$m^2 \cdot kg^{-1}$ for "rapid hardening" cements.  The cement is conveyed by belt[4] or powder pump to silos[5] for storage.  Cement plants normally have sufficient silo space for 1-20 weeks production, depending upon local demand cycles. The cement is delivered to end-users either in bags or as bulk powder blown from a pressure vehicle into the customers' silos[6].  In developed countries, 80% or more of cement is delivered in bulk, and many cement plants have no bag-packing facility.  In developing countries, bags are a more normal mode of delivery.

*Bin level indicators are used* as indicated in "4", "5" and "6" as noted above.  A tilt switch can be used to indicate the flow of material existing on a conveyor belt to aid process control.  Rotary paddle, RF capacitance/admittance and tilt switch devices can be used in powder storage silos for high level and low level monitoring.  High level is used for preventing overfill and low level to indicate material outage.  These devices will


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compliment an inventory monitoring system based on a continuous level sensor. Continuous level sensors in powder applications can be problematic and should not be relied on solely for silo overfilling or outage monitoring.

**Concrete Batching Plants** LaFarge

Simply put, water + cement + aggregate = concrete. The production process is fairly simple. This and the longevity of concrete and its many structural uses is why there are thousands of concrete manufacturing plants (a.k.a. ready-mix plant, concrete batch plant etc.) in the United States and far more around the world. Concrete batch plants come in many varieties and brands. Some are fixed in place and some are portable. They come in a variety of sizes in terms of their hourly production rates. But it's always the same, water + cement + aggregate = concrete. Some additives may be included for special properties such as improved surface finish, different strengths or to add color.


Figure 2: Stationary batch plant by R&S Industries

The typical stationary concrete batch plant is as shown in Figure 2. A typical portable plant is shown in Figure 3. Both plants blend the mix of ingredients together in the proper proportion for the intended purpose, and the mix ratios can and do change depending on the use.

No matter what the mix or use, the cement powder and aggregate materials are stored in bins and silos. Aggregate material is often conveyed into bins using a belt conveyor. However, sometimes the aggregate material is also stored in outside piles. In all the storage conditions there are application and need for bin level indicators as noted below. Portable plants are used to put the concrete production right at the construction site. This is convenient and cost effective. Many construction companies own their portable plants.

*Bin level indicators are used*[7, 8, 9] to monitor for the high and low level in aggregate bins, cement and flyash silos as well as in aggregate piles. The rotary paddle bin level indicator is the standard choice for the concrete industry due to its low cost, rugged nature and resiliency and long-term history in the industry.


Figure 3: Portable concrete plant



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## Conclusion

Bin level indicators are an integral part of the production and operation of cement and concrete plants. They are critical to the protection against costly spills from overfilling and against material outages. In addition, continuous level sensors are used for inventory management of critical materials such as cement and flyash in the concrete production process. Rotary paddle and tilt switch point level monitors are staples in the industry. They are rugged, reliable and very cost effective. Other sensors, such as RF capacitance/admittance sensors can be considered for some applications as well. In the inventory monitoring area the weight & cable inventory monitor is one of the most common that is used by concrete batch plants to monitor flyash, cement and aggregate inventories.


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