Eric Maynard, Jenike & Johanson, Inc., explains the implementation of proper bin and transfer chute designs for a major cement plant expansion in Southeast Asia.

Don't Get Caught in a Rathole!

The challenge

Jenike & Johanson, Inc. (J&J) was contracted to provide bulk materials testing and engineering for bins and transfer chutes as part of a major brownfield cement plant expansion in Indonesia. The existing plant has experienced major bulk materials handling issues with its raw material and cement finish mill storage bins, as well as plugging, spillage and abrasive wear problems in belt-to-belt transfer chutes. These materials handling problems resulted in poor production efficiency and costly trial-and-error fixes that never resolved the problems.

Accordingly, when faced with implementing a new cement line at the plant, the owner wanted to ensure that all bulk materials handling equipment was properly engineered to ensure reliable flow of the raw materials. A major consideration for this project was the local weather, which could range from dry conditions to sustained periods of rain (November through June) and an occasional daily deluge that could bring up to 150 mm of rain.

The analysis

Flow testing

To aid in the design of the materials handling equipment, J&J engineers recommended that flow properties tests should be performed on the raw additives (e.g. limestone, clay, sand and iron source – Figure 1) and finish mill materials (e.g. gypsum, blastfurnace slag and high-calcium limestone) at moisture contents ranging from average handling conditions to a nearly saturated state. It is well documented that poor flow of bulk materials typically occurs with elevated moisture content.

Reprinted from February 2014
World Cement

Figure 1. Raw additives.

Figure 2. Funnel flow discharge pattern that can result in ratholing with cohesive bulk materials.

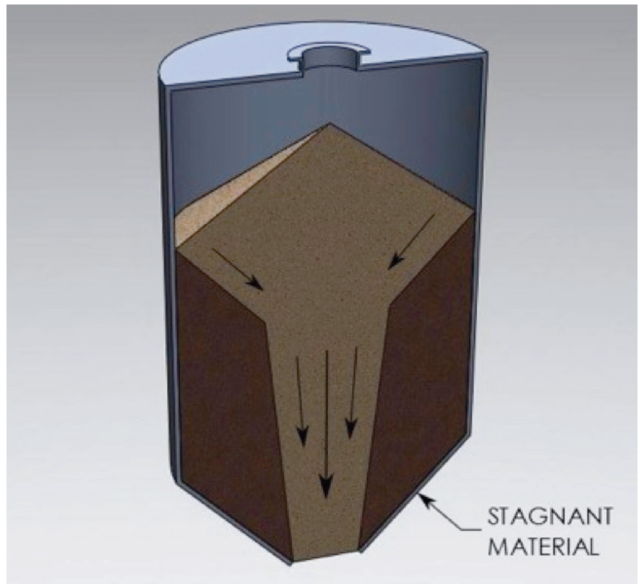
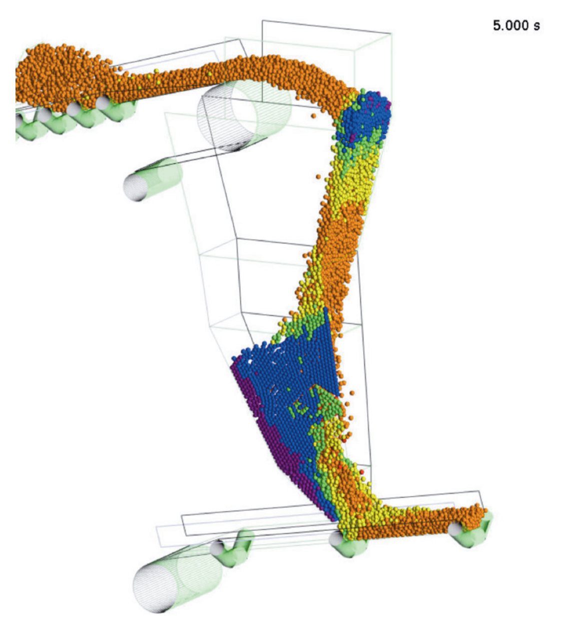


Figure 3. Result of DEM analysis indicating plugging of materials (blue colour) in the chute.



The flow tests were determined using American Society for Testing and Materials (ASTM) International protocols.[1] The key properties investigated included:

- Cohesive strength: provides critical outlet size needed to prevent bridging and ratholing.
- Wall friction: delivers coefficient of sliding friction for mass flow hopper angles.
- Compressibility: gives bulk density needed for feeder design and bin capacity/loading.

Not surprisingly, the results of the flow tests confirmed that the majority of the materials were cohesive (prone to bridge and rathole), frictional (stick to surfaces) and compressible (have a wide bulk density range). The flow test results were essential for predicting materials flow problems with preliminary (proposed) equipment designs, as well as for providing recommendations for handling equipment to prevent these costly problems.

Besides flow tests on the bulk materials, abrasive wear tests were conducted by J&J to assess the wear life of abrasion-resistant liners under consideration for bins and chutes. Wear tests were carried out with bulk materials and the liners to predict service life, assuming a design mass flow rate and 85% usage throughout the year.[2] The abrasive wear tests indicated that one of the abrasion-resistant liners would provide a wear life of up to 20 years, which far exceeded that of the ordinary mild carbon steel. The wear tests also illustrated that a plastic liner, under consideration for its good release properties (e.g. a slick surface for sticky materials), would not work with abrasive materials like limestone or slag.

Bin, feeder and chute review

Using the flow properties test results, the preliminary designs for bins, feeders and belt-to-belt transfer chutes were reviewed to ensure that they could reliably handle the cohesive bulk materials. The analysis showed that bins would discharge the additives in a funnel flow pattern (Figure 2), whereby the majority of the material in the bin would be stagnant during discharge. In most cases, severe ratholing with the wet bulk materials was predicted. If the bins were to be implemented then frequent flow interruptions would occur, reducing plant efficiency and cutting production capability. Given that the cement plant was in a highly competitive cement supply market, these consequences would not be acceptable.

J&J also performed an analysis of the proposed belt-to-belt transfer chutes using the bulk materials flow properties and proposed design arrangements. The company used its proprietary discrete element method (DEM) tool to understand how the materials move through the chutes, taking into account particle-to-particle and particle-to-surface interactions, along with design operating parameters such as conveyor belt speeds and flow rates.

Based on the DEM analysis, many of the proposed chutes will experience material buildup, eventually leading to plugging (Figure 3). Besides plugging, the chutes would experience nonuniform loading of the receiving belt, resulting in belt-off tracking and spillage. Several of the chutes would also receive high-speed direct impact of abrasive materials, leading to premature liner damage.

Figure 4a. Mass flow discharge pattern that prevents ratholing and ensures reliable material flow.

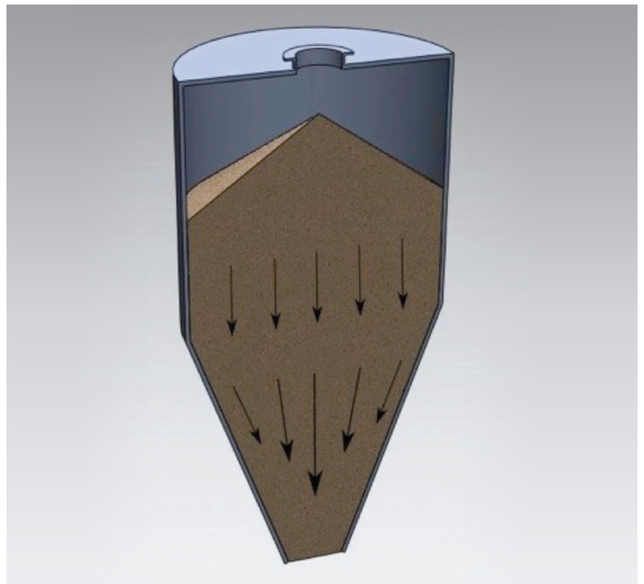


Figure 4b. Mass flow bin and feeder arrangement.

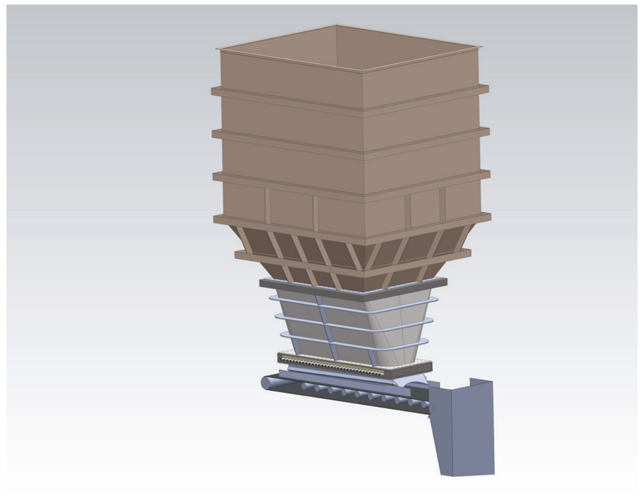
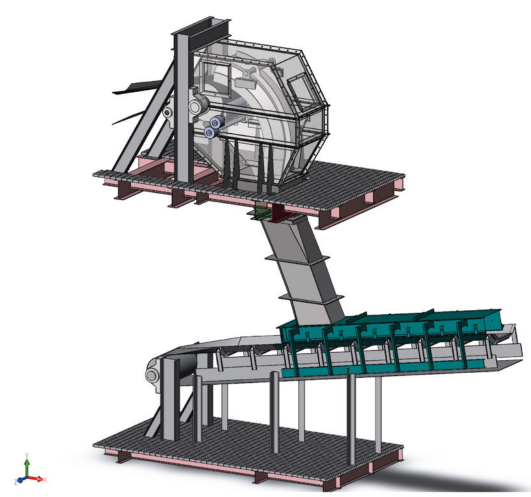


Figure 5. DEM used to design "hood" and "spoon" transfer chute technology.



The solution

Based on the findings of the bin, feeder and chute review, J&J provided proper functional designs for vital materials handling equipment. For all storage bins, it was recommended that a mass flow pattern be implemented (Figure 4a), which allows a first-in, first-out discharge that prevents ratholing. This ensures consistent flow, eliminates sifting segregation and reduces the loads on the apron feeder.

In order to achieve mass flow, two conditions must be met: the sloping hopper walls must be steep and low enough in friction for the material to slide along them and the hopper outlet must be large enough to prevent bridging. A proven, practical approach to achieving mass flow is outlined in Dr Andrew Jenike's work presented in *Bulletin 123*.[3]

The mass flow bin and feeder (Figure 4b) were engineered to ensure that the required storage capacity and discharge rate would be met. The belt and apron feeders, and their interfaces, were properly designed to ensure complete withdrawal of the additives along the entire length of the hopper outlet, thereby maintaining mass flow discharge. The rising capacity along the length is achieved by the increase in the height and width of the steel interface above the feeder. Photos of mass flow bins and feeders successfully deployed at a cement plant are presented in a prior *World Cement* article by this author.[4]

The transfer chutes that were identified to be problematic in handling the cohesive and abrasive bulk materials were reconfigured to prevent plugging, spillage and belt-off tracking. Abrasion-resistant liners were incorporated to ensure long wear life.

Additionally, DEM technology was vital for proper chute design. Several of the transfer chutes were designed with "hood" and "spoon" technology (Figure 5), which allows for reliable transport of sticky materials from the delivery belt to the receiving belt by maintaining the stream momentum.

The results

Although the engineering for the plant has not yet been completed, the engineering of the bins, feeders and transfer chutes has been undertaken to ensure reliable flow of the cohesive bulk additives. The mass flow designs for bins and momentum-based chute designs will prevent costly bulk material bottlenecks from developing when the plant is commissioned and ensure efficient operation in the future.

References

1. 'Standard Test Method for Shear Testing of Bulk Solids Using the Jenike Shear Cell', *Annual Book of ASTM Standards*, Designation D 6128-97, Vol. 4, No. 9 (2000).
2. JOHANSON, J. R., and ROYAL, T. A., 'Measuring and Use of Wear Properties for Predicting Life of Bulk Materials Handling Equipment', *Bulk Solids Handling*, Vol. 2, No. 3 (September 1982).
3. JENIKE, A., 'Storage and Flow of Solids', *Rev. 1980*, University of Utah, Salt Lake City, Utah, 16th Printing (July 1994).
4. MAYNARD, E., 'In Safe Hands – Designs for Reliable Bin Flow', *World Cement* (May 2005).