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Techniques for Improving Flow performance in Bunkers and Silos

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Introduction

A prodigious variety of bulk solids are stored in bunkers and silos in quantities ranging up to hundreds and, in some cases, thousands of tonnes. A recent survey report by the Bulk Materials Handling Board states:

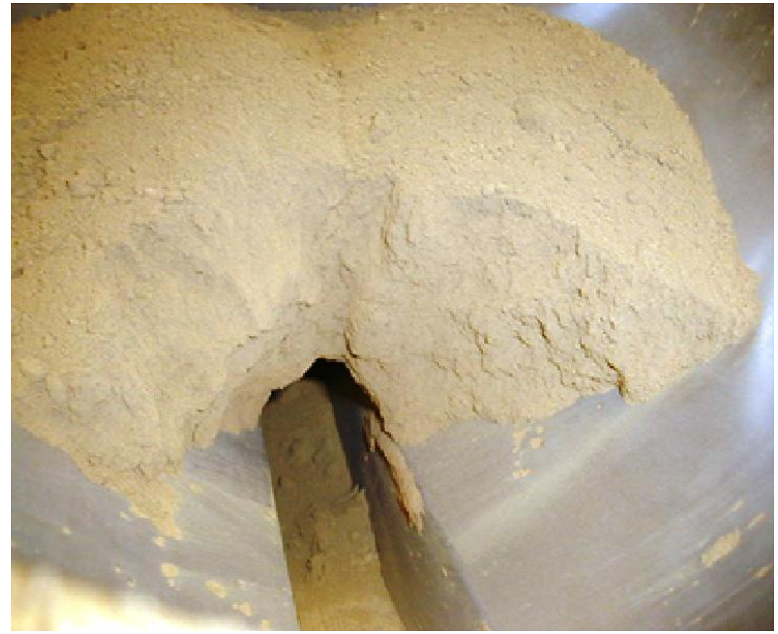
Bulk solids handling is, by far, the world's largest industrial activity. This survey shows that well over 16,000,000,000 tonnes of common bulk solids are handled every year, usually many times, plus many other bulk materials in vast quantities. It is also a mature industry, having been carried out for over 2,000 years. With all this historical and international experience, it may be questioned – Why do so many solids handling projects still go wrong?

Two case studies are presented which detail the considerations and solutions to perhaps the two most common problems: flow stoppages and inventory hang up:

- a 600m^3 aluminium silo storing a polymer powder
- a 4000t concrete bunker for storing milled coal

Making use of the flow properties of the materials being stored, each were provided with practical approaches to eliminate flow problems using new hopper geometry, insert systems and clever feeder design.

Consequences of flow problems



If a stable rathole forms then the this prevents large volumes of stock from emptying.

If product arches over the outlet then no flow is possible.

Manual poking to stimulate flow exposes operators to hazards and unhealthy working conditions. Delays in discharge demand operator involvement and is not efficient for operating cost or production.

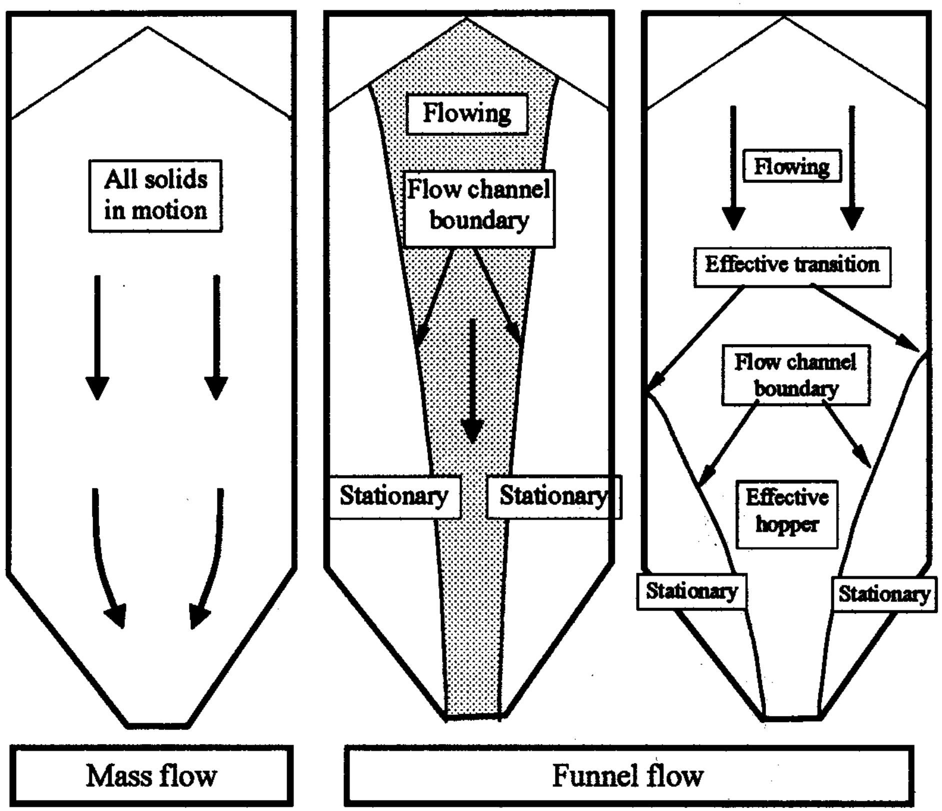
Spotting flow problems

Standing in a loading shovel and hitting a hopper with a pipe might be one way of promoting flow but its far from safe. Even if you are wearing a Hi-Vis jacket!

Hammer rash indicates the frequency and extent of problems

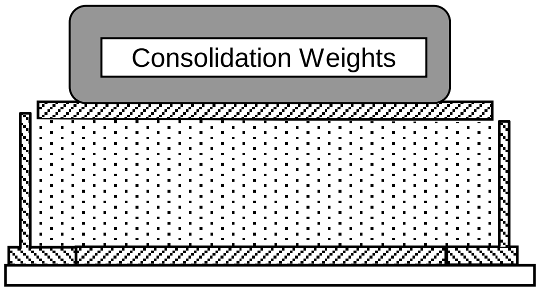
Flow patterns

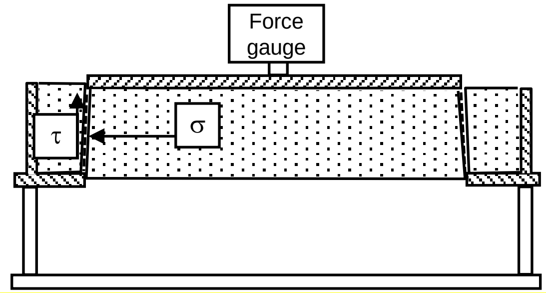
as described in Eurocode EN1991-4



Mass flow occurs when all the silos contents are in motion whenever any discharge takes place and is very effective at squeezing product through smaller outlets but is known to generate high switch stresses against the hip

Flow property tests

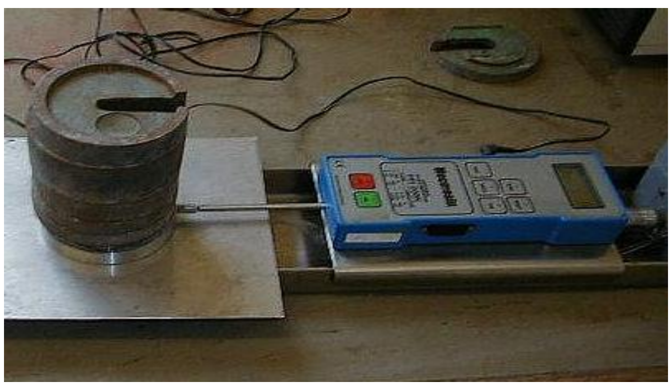




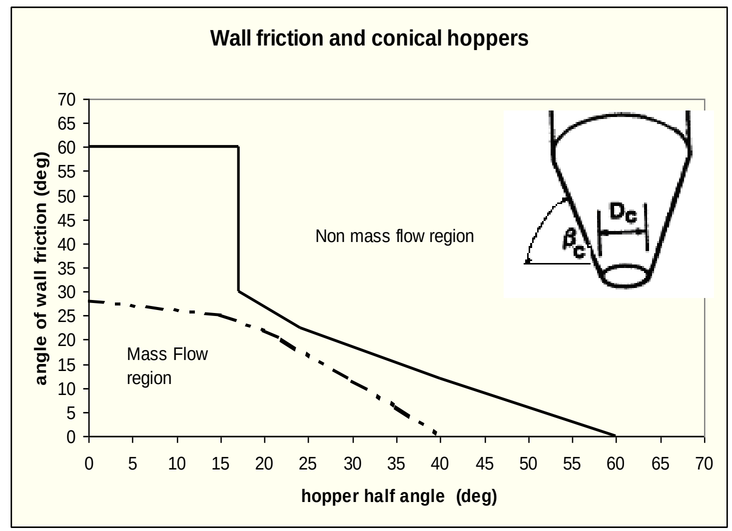
$$D_{crit} = \frac{4 * \tau_s}{\rho_b * g}$$

Apply consolidation load to sample. Measure ρ_b

Measure load to failure and calculate shear failure stress, τ_s

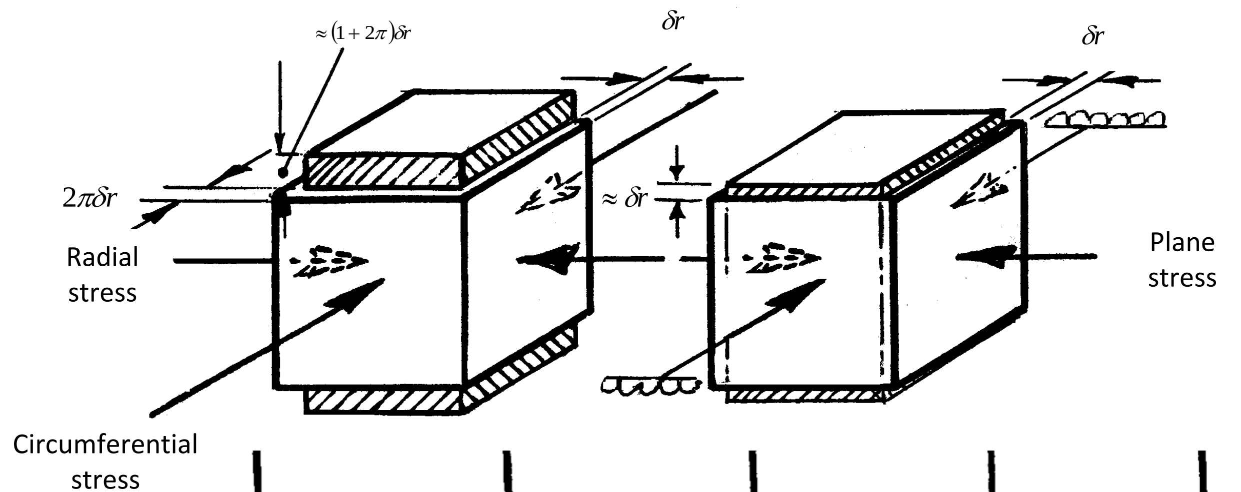


$$\phi_w = \tan^{-1}(\tau / \sigma_n)$$

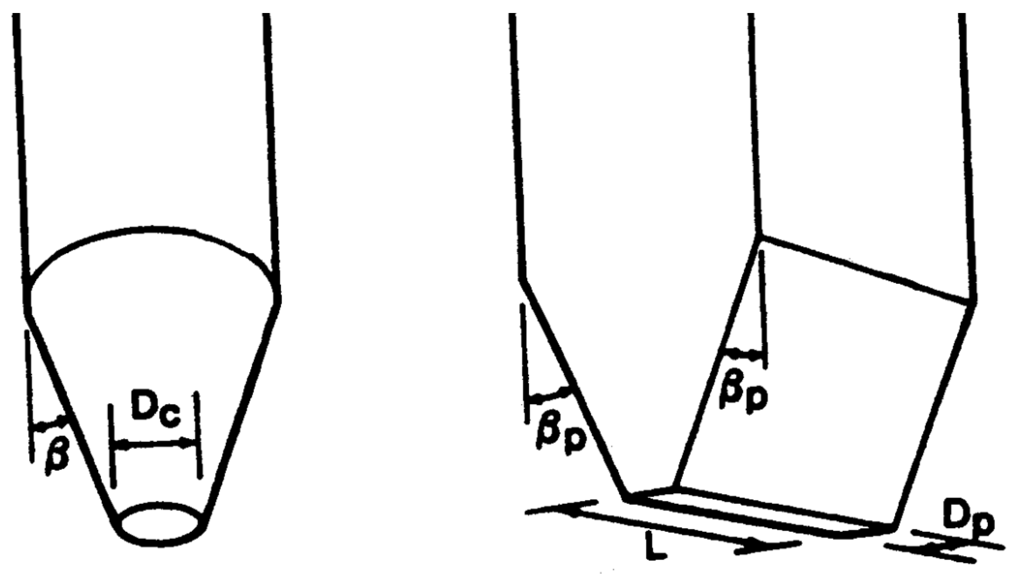


Measure: the strength of the material and its friction!

Hopper shape influences flow

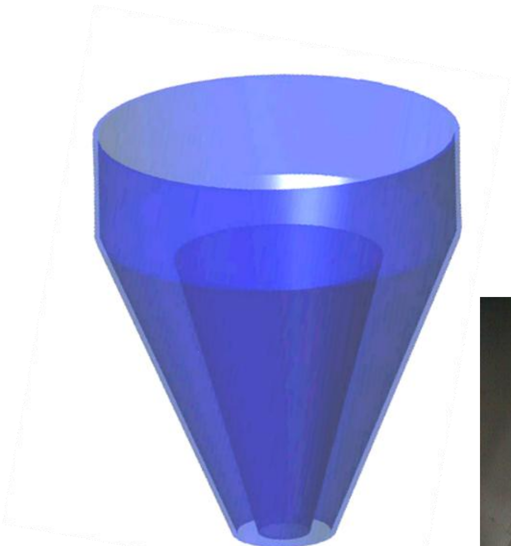


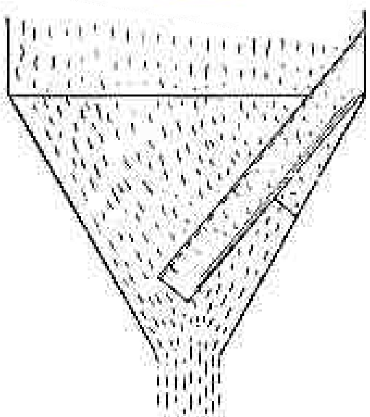
Steep walls and large outlet diameter needed

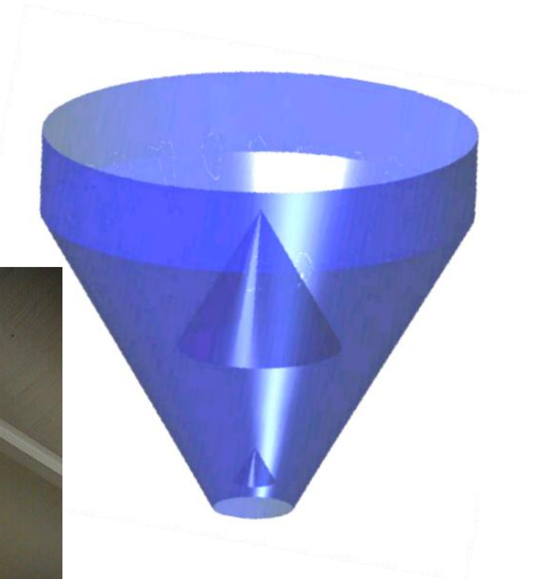


Shallower walls and narrower slot outlet can be used

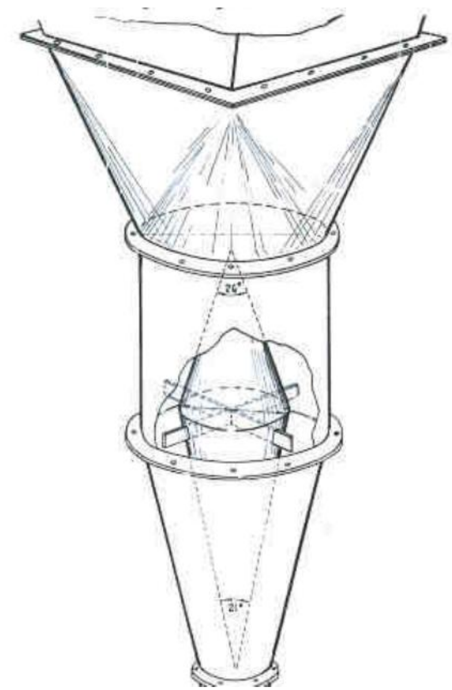
Insert technology







Conversion of a conicalchannel into an annular, psudo plane flow channel



Inserts offer the possibility to generate slip more easily at the walls, convert axi-symmetric flow to plane flow, shield the outlet region to reduce consolidating stresses.

Case Study 1: Polymer silo

Silo 12 – 7.6m dia x 14.2m tall with conical bottom
at 56.5 degrees
to 3m dia bin activator
to 250mm dia down bifurcated chute

Silo skirt access
3.4m x 1.7m

Polymer flow property test results

Material	As Poured	Tapped x 50	Hausner ratio
Grade A	320 kg/m^3	356 Kg/m^3	1.11
Grade B	330 kg/m^3	379 Kg/m^3	1.15

<u>BULK DENSITY</u>

Hausner ratio is defined as the ratio of tapped bulk density to loose bulk density

Product and Wall Material	Friction Angle	Recommended Min. Wall Angles for Conical Hoppers
A on aluminium	25^0	75^0
A on stainless 2B	18^0	67^0
B on aluminium	26^0	76^0
B on stainless 2B	17^0	66^0

<u>WALL FRICTION ANGLES & MASS FLOW WALL ANGLES</u>

All wall angles are from the horizontal.

Material	Compacted Bulk Density (kg/m^3)	Shear Strength (N/m^2)	Rat hole Diameter (cm)
A	359	2197	250
B	379	2525	271

<u>SHEAR STRENGTH AND RAT HOLE SIZES</u>

The loading conditions were three days at 13 kN/m^2

Recommendations from tests

Use the lower friction benefits of 2B stainless steel

Exploit the benefits of single plane convergence to ensure reliable flow through the outlet

Make sure the feeder mechanism offers a fully live extraction pattern at the silo outlet.

To guarantee retrieval of contents fit a liner and insert system in the silo, which will destabilise any rat hole that might form.

New Hopper bottom and multi screw feeder

Outcomes

Converted silo stores 180t of the new polymer product

Reliably feeds 8tph to either pneumatic conveying line

Case Study 2: Appleby Coal Bunker

The concrete service bunker above the Appleby Coke Oven batteries.

Built in 1937 the bunker is 17.5 m tall x 13m wide and in two sections:

the 3000t section is 20m long, the 1000t section 8m.

Rat holes in the bunker

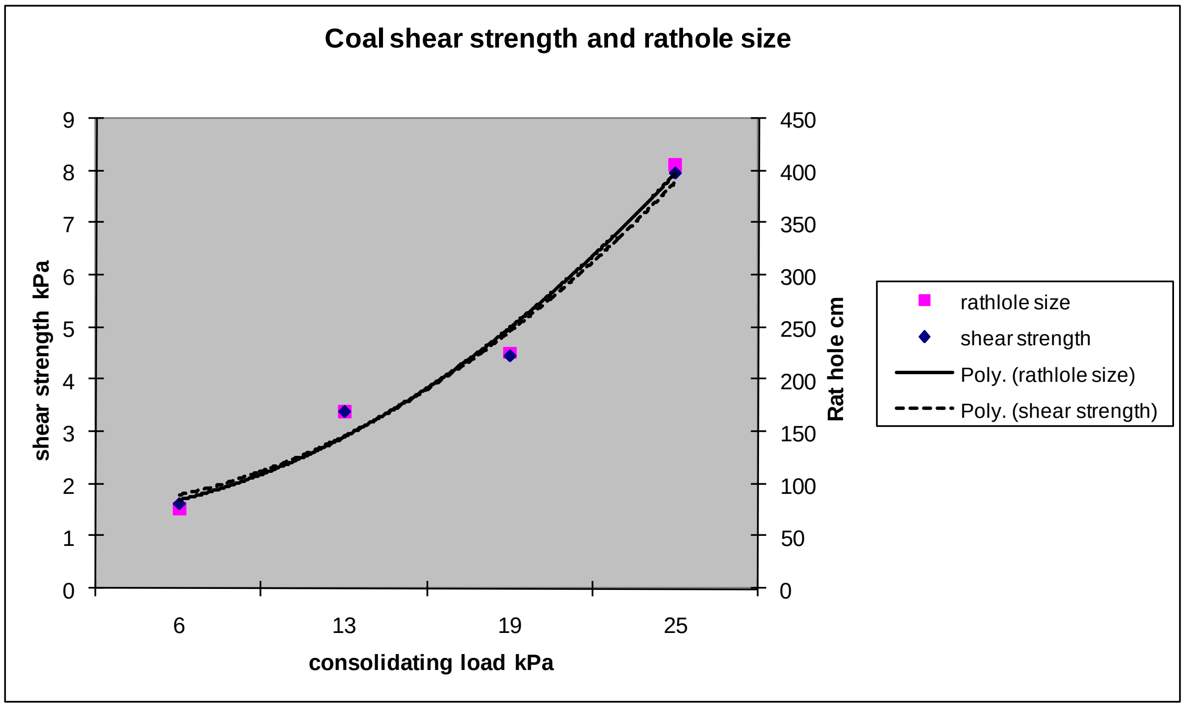
Flow channel develops from the 64cm diameter outlet that flares to approximately 1m diameter over a depth of up to 10m.

Stagnant coal severely reduces bunkers operational capacity.

Working capacity has been estimated at nearly half the contents.

Flow property tests on Coal

Wall Material	Wall Friction Angle	Adhesion N/m^2	Min. Wall Angles for Mass Flow Conical Hoppers	Vee Hoppers
Mild Steel	24.3	280	79^0	70^0
2B St. St.	19.0	350	74^0	**65^0**
UHMWPe	20.0	-	68^0	60^0



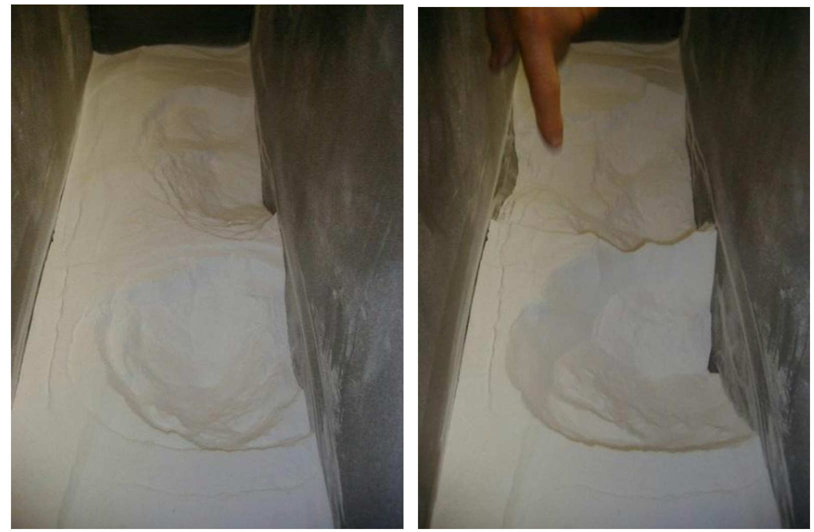
Full Jenike type shear cell tests also carried out and indicated **an outlet size of 0.97m** for mass flow

Model Tests

Model of the bunker built at 1:12.5 scale.
Simulant used - a fine grade polyethylene powder.

Narrow core flow channel develops without insert.

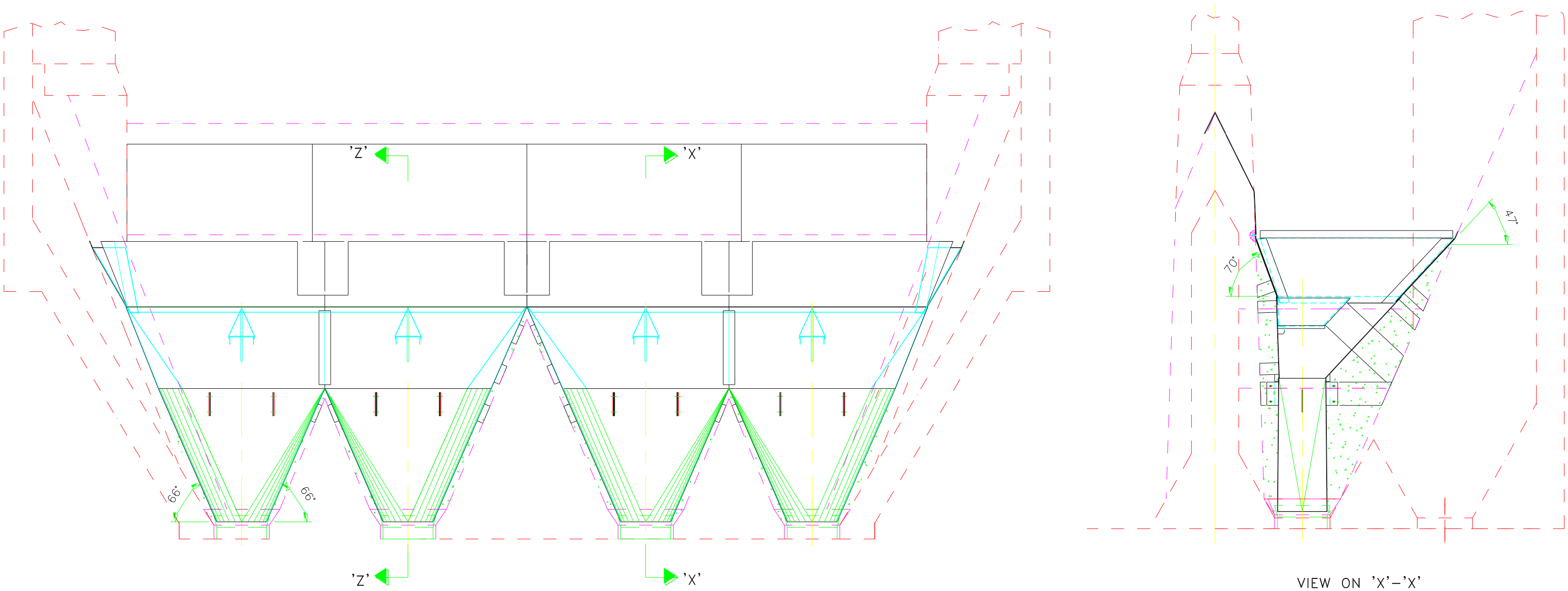
Behaviour reflects that seen at the full scale with coal.



With inserts the material develops a far wider flow channel.

As the flow matures the flow channels spread and merge together.

Multi stage insert system



- Plane flow hoppers to suit the existing the outlets and with mass flow walls.
- Expand the flow channel to a reliable flow width and connect a row of outlets together.
- Insert member used to reduce compacting pressures.
- Final stage was not mass flow but provides self-clearing walls.

Outcomes

Poking for coal used to be required at least once per shift from November to March. This is no longer necessary and there have been no reportable injuries sustained from poking activities from the service bunker since the inserts were installed

Better filling of the charge cars is achieved and gives improved oven filling and a higher coke yield.

The live capacity of the 1000 tonne section is now approaching 80%.

Summary

The approach used:

- flow property testing as key to design
- design development using a model
- careful consideration of the existing structures' strength
- multi-stage plane flow hoppers and insert systems
- a multi screw feeder which established a large active flow area

These successful installations elegantly use gravity flow to improve production requirements at the Appleby coke ovens and to remedy flow problems in an existing plastics plant and show how a multi-stage approach and insert system can achieve fundamental change of flow potential in existing installations which suffer from poor geometry and flow problems.

Thank you for your attention

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