Technical Conference • Awards Dinner • Exhibition
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# Sometimes one screw is not enough!

The application of multi screw feeders to avoid flow problems

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# Introduction

Solids handling is one of the largest and most common processes across almost every industrial activity. However it is often impeded by problems that arise in the storage and handling. From fine cohesive powders to shredded wastes, bulk solids can exhibit varied and awkward flow behaviour.

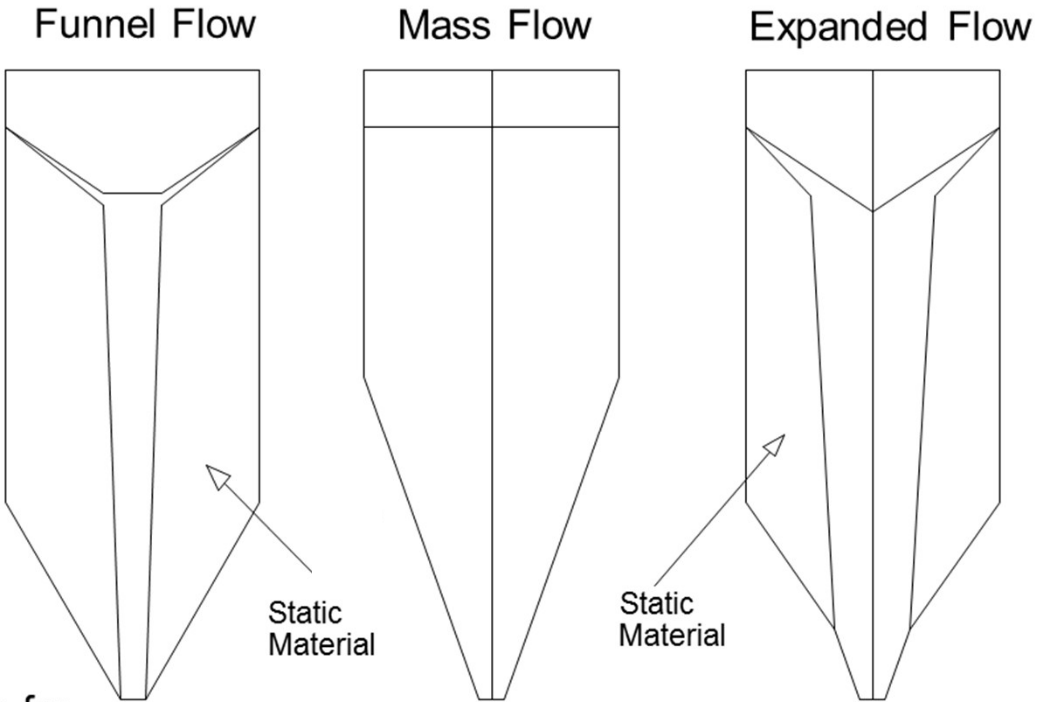
This presentation will:

- Identify some of the problems often encountered
- Describe some of the tests needed for characterisation of bulk solids *for flow*
- Highlight aspects of hopper design needed *for flow*
- Recognise the importance of the feeder selection *for interfacing and for positive transfer capability*
- Present a number of practical case studies illustrating the approach solving plant operating problems handling fine powders, shredded wastes and very low density materials
- Round up with a summary.

# Some common Flow Problems

The solution depends on getting  the correct hopper geometry, outlet size and feeder design.

# Flow Patterns in Hoppers see Eurocode EN 1991-4



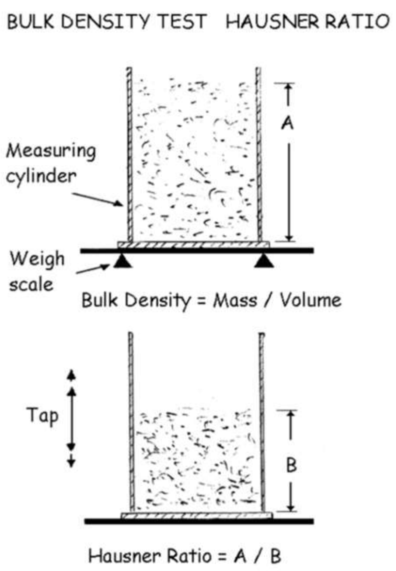

Affects stresses acting within the bulk and on the structure

Determines residence time - the order in which the contents discharge, segregation.

**Influences the size of opening needed to ensure reliable discharge**

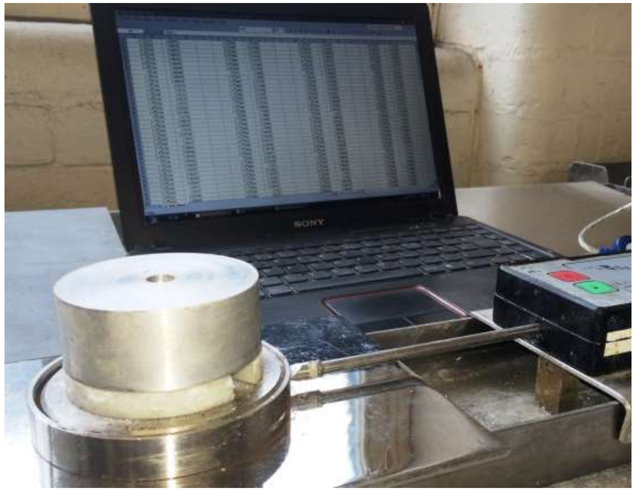
# Flow Characterisation Tests

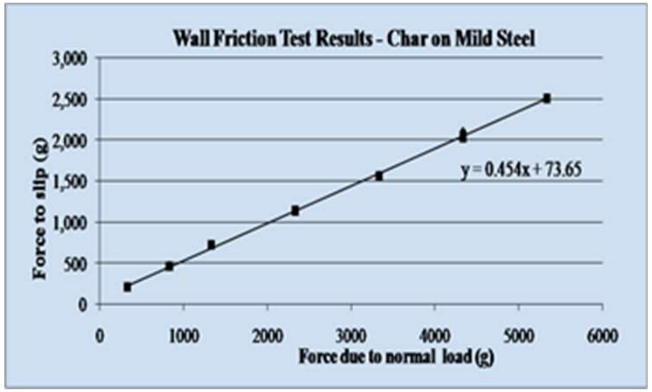
**Bulk density**
Driving Force for Flow



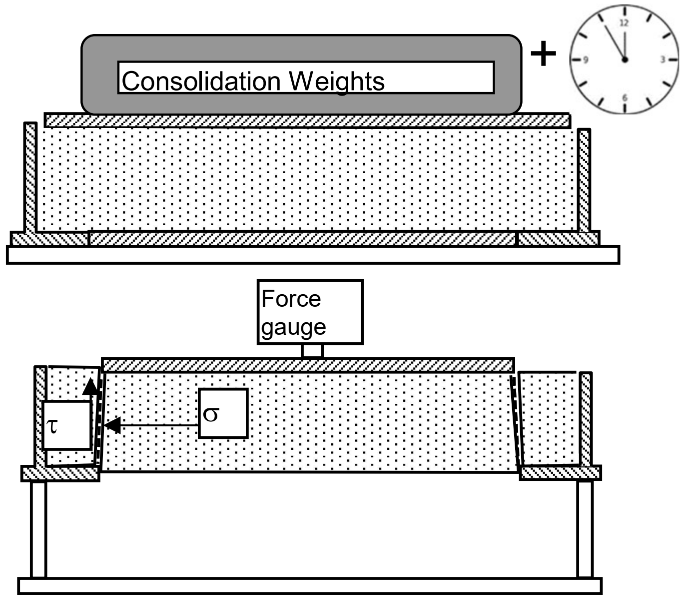

| Hausner Ratio | 'Flowability' |
|---|---|
| 1.0 – 1.1 | Free flowing |
| 1.1 – 1.25 | Medium flowing |
| 1.25 – 1.4 | Poor |
| > 1.4 | Very Poor |

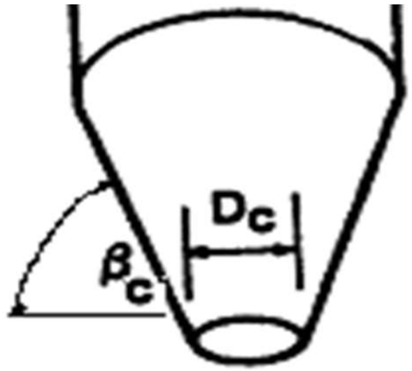
**Wall friction**
Opposes Slip on Surfaces






**Shear strength**
Resists Deformation for Flow

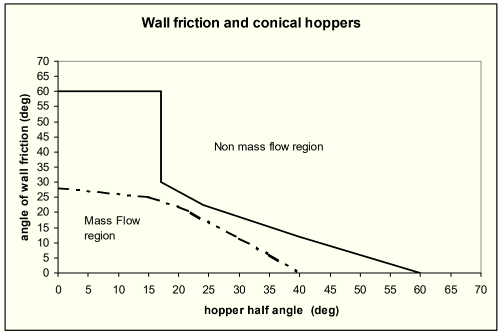


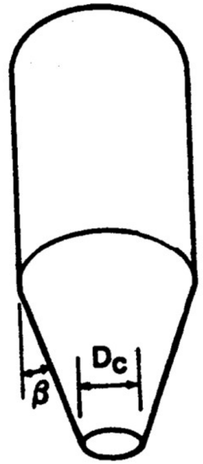



# Mass Flow

## Advantages of Mass Flow

- Makes flow through smaller outlets possible
- Mitigates segregation - all material moves during discharge
- ‘Live’ storage – no ‘dead’ zone
- **First in - First out**

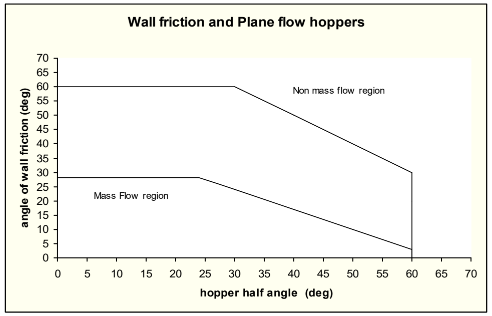


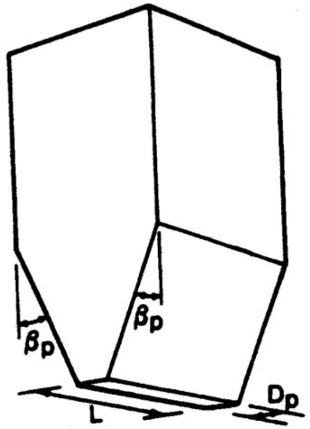




$$D_{\min} \approx \frac{2.\sigma_{crit}}{g.\rho_b}$$

## Extra Advantages of Plane Flow

- Flow possible at shallower angles
- Reliable flow through even narrower outlets, typically half the width



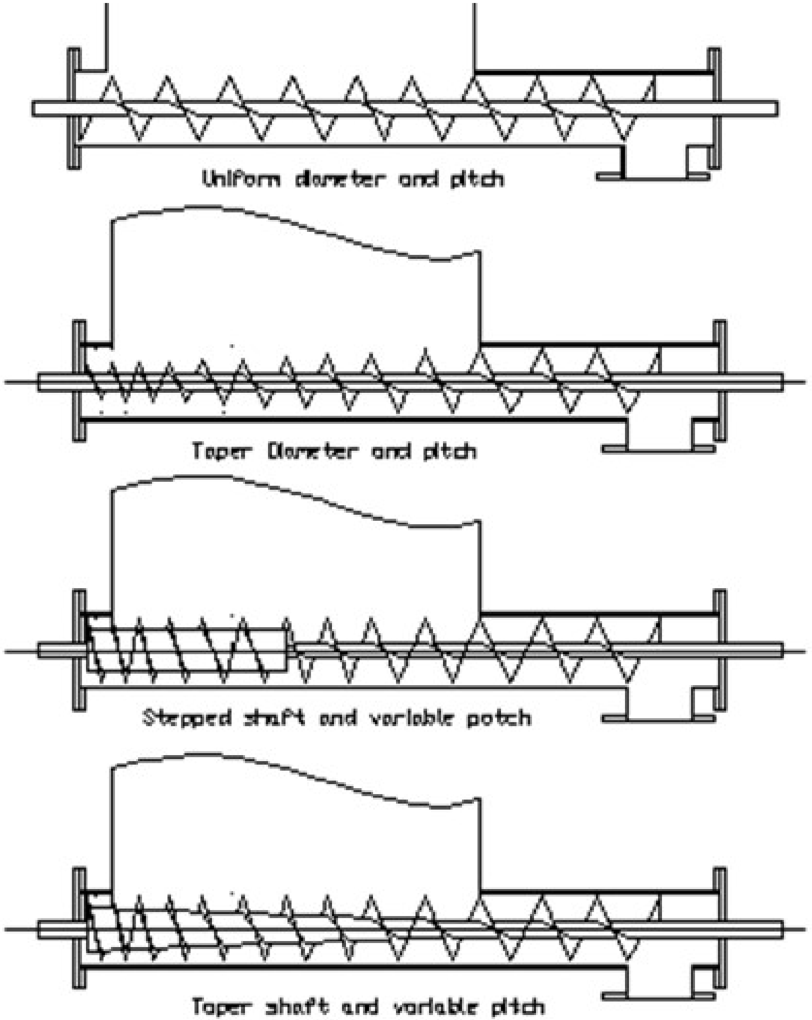

$$B_{\min} \approx \frac{1.\sigma_{crit}}{g.\rho_b}$$

*IMPORTANT: Vee Shape Hoppers need ‘fully live’ Slot outlets*

# Virtues of Screw Feeders

- Provide positive transfer
- Starts and stops discharge.
- Controls the rate of feed.
- Totally contains product
- Compact construction
- Can serve **long hopper outlets** (so enhance capacity/save headroom)

# Screw Feeders



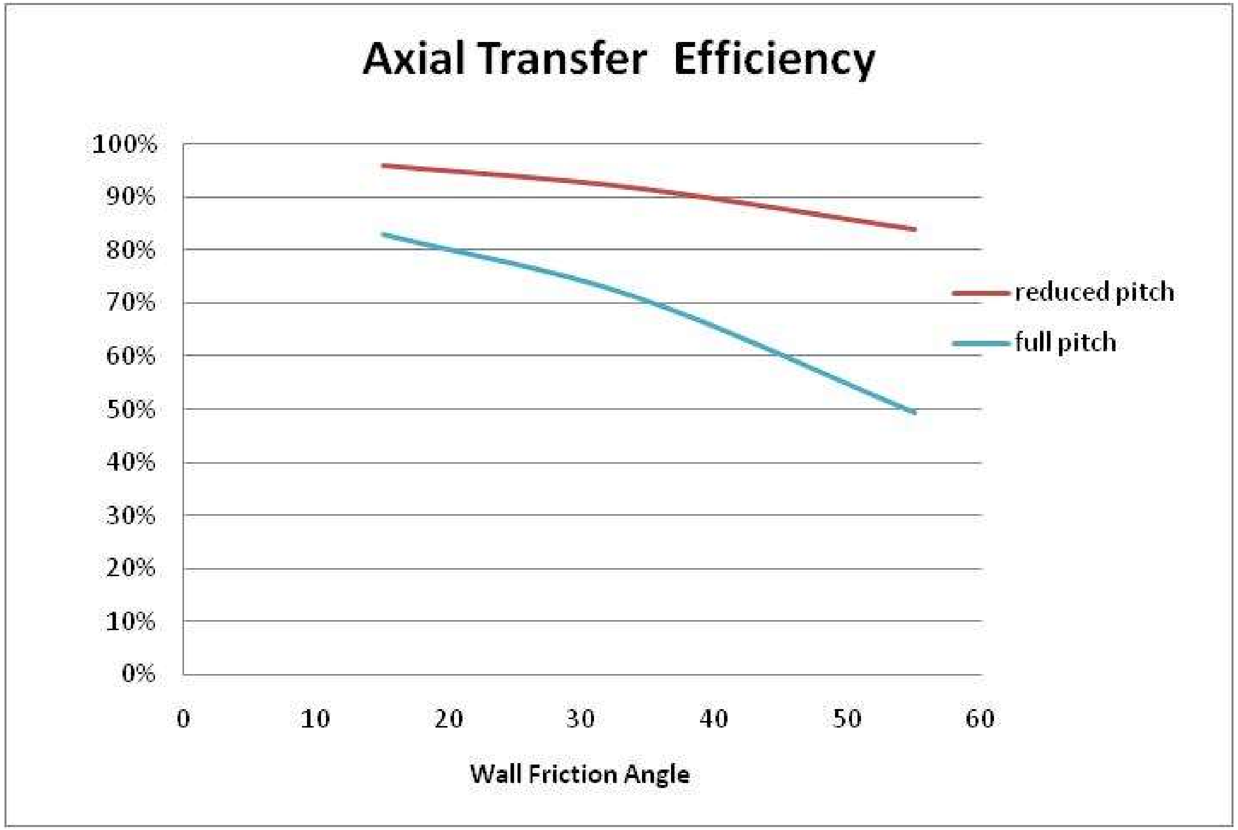

Uniform pitch: 'Dead' regions of extraction unless short inlet.

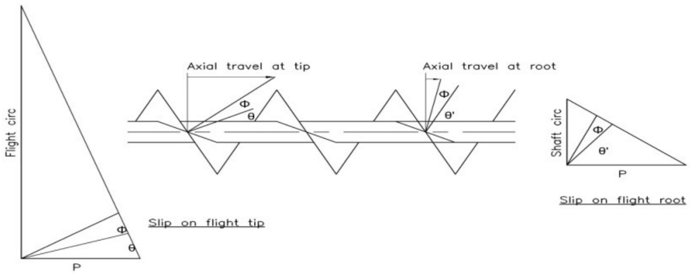
Taper diameter: Has narrow width at start of screw

Both generate progressive extraction along slot.

Can generate more even extraction profile

# Mechanics of Screw Transfer



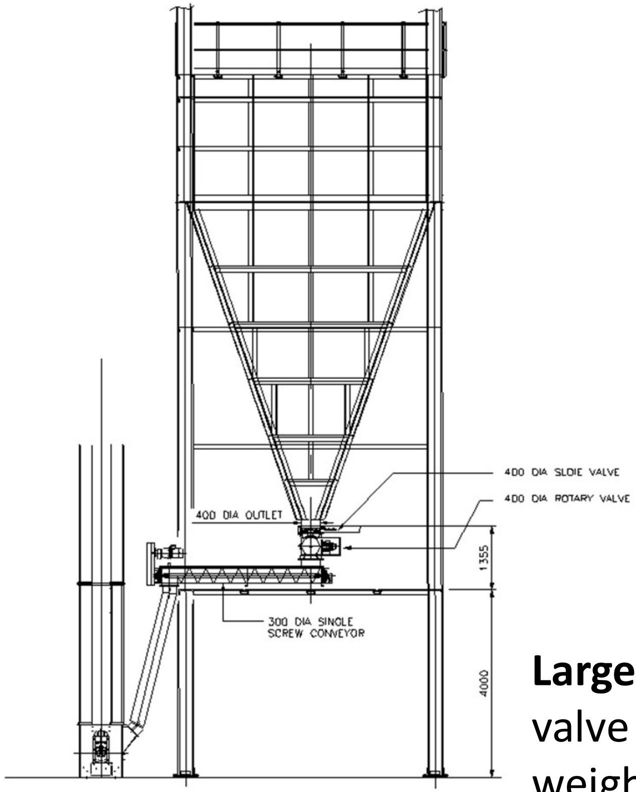




$$\eta h = \left(\frac{\tan \beta h}{\tan \alpha h + \tan \beta h}\right)$$

$$\beta_h = 90^0 - \alpha_h - \phi_w \qquad \alpha h = \tan^{-1}\left(\frac{P}{2\pi R}\right)$$

Axial transfer is a function of the helix and wall friction angles.

# Hopper and handling system for milled phosphate




**Large pyramidal silo** filled by pneumatic transfer from the mill. A rotary valve at the outlet and a screw conveys to a bucket elevator, then check weighed and into mixer.

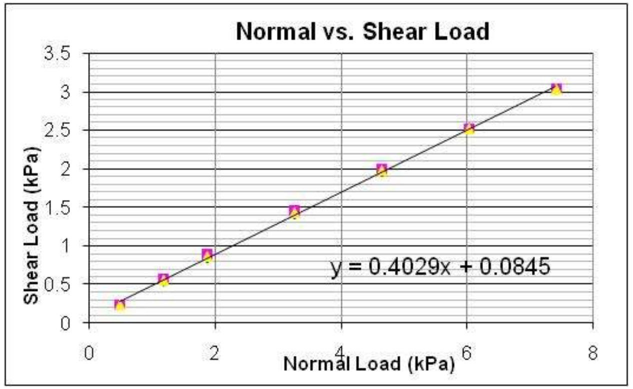
**Inconsistent flow** (fine powder, very loose condition, variable composition, temperature, residence time and consolidation)

**Flow exacerbated by narrow flow channel** formed during discharge (wall angles too shallow to induce slip at walls; gullies less than 55 degrees)

**Significant proportion remains static** and consolidates to resist flow even as the level falls.

**Deep rat holes can collapse causing flushing**

# Flow property test results - milled phosphate




| | Bulk Density |
|---|---|
| aerated | 989 kg/m³ |
| loose | 1061 kg/m³ |
| Tapped | 1450 kg/m³ |
| | |
| Hausner Ratio | 1.47 |

| Consolidating Load (kg) | 51.0 | 25.5 |
|---|---|---|
| Equivalent Pressure (kN/m²) | 32.50 | 16.25 |
| Effective Head (m) | 2.34 | 1.24 |
| Bulk Density (kg/m³) | 1418 | 1341 |
| Force Gauge Max Reading (g) | 1946 | 1378 |
| Load to Failure (g) | 2249.00 | 1620.00 |
| Shear Strength (N/m²) | 3574 | 1855 |
| Rathole Diameter (cm) | 102.7 | 56.4 |

**Wall friction angle**
Measured at 21.9 degrees against 2B stainless steel (nearly 27 degrees against mild steel) so steep walls are needed for mass flow

**Bulk density**
Varies greatly – can be very loose fluid like and can settle to a much denser condition. A high Hausner ratio – 1.47 characterises as 'poor flow '

**Shear strength**
> 3.5kN/$m^2$ so very strong when consolidated. Can form very stable arches and rat holes. Large outlet needed to promote flow from a settled condition

# New twin screw feeder and the installation

Twin screws *serve the full width of the new hopper outlet*. Each screw has both variable pitch and stepped centre shafts to *give progressive extraction geometry* so as to **satisfy the mass flow requirement of the hopper.**

New twin screw feeder made by Ajax in UK.

New hopper bottom made locally to drawings by Ajax.

# Avoiding feed issues with RDF & Practical Trials

RDF waste with a low, variable bulk density and a tendency to ‘bird’s nest’ inevitably presents a challenge for any feed technology. The shear cell approach for establishing design parameters is awkward to apply with shredded waste materials so practical trial work is often required.

Practical trials with a large Ajax screw feeder helped establish sizing needs and form of feeder – positive transfer capability and the ability to serve the full width and length of the hopper outlet are key.

# Quadruple Screw Feeder

To fully serve the length and width of a storage bunker four screws were used. These combined as quadruple screw feeder with four 11-metre-long large diameter screws in a casing over 3.5m wide.

# Drive considerations

As the RDF waste is irregularly shaped as well as poor flow, considerations over drive sizing are critical as are features needed to ensure reliable handling and avoid jamming within the multiple rotating parts of this complex feeder arrangement.

Planetary gearboxes were selected for this high torque, slow running application.

# Getting the job out the door


This bespoke supersized screw quadruple feeder was challenging to both design and build.

The entire assembly was built in Ajax works for FAT but at almost 18T and with a large footprint the quadruple feeder was made in kit form for transporting to site in sections suitable for site build

# Flow Properties of Fibre & Powder

| Sample | Loose | Tapped | Compacted | Hausner |
|---|---|---|---|---|
| | (kg/m3) | (kg/m3) | (kg/m3)* | Ratio** |
| Powder | 317 | 395 | 535 | 1.25 |
| Fibre | 95 | 126 | 440 | 1.32 |

| Sample | Wall Friction | Conical Hopper |
|---|---|---|
| | Angle (deg) | Wall Angle (deg) |
| Powder | 26 | 74.5 |
| Fibre | 18.4 | 65.2 |

| Sample | Consolidating Load (kN/m2) | Effective head (m) | Compacted bulk density (kg/m3) | Shear Strength (N/m2) | Min. Dia (cm) |
|---|---|---|---|---|---|
| Powder | 6.37 | 1.23 | 535 | 244 | 19 |
| Fibre | 6.37 | 1.48 | 440 | 1778 | 166 |

One screw with a steep Vee shaped hopper is enough for milled powder though screw needs progressive geometry along its length to satisfy mass flow condition.

# Sextuple Screw Feeder

Fibre is really poor flow and process required it to be stored in a 10m$^3$ silo.

No convergence is possible in the silo due to the arching capability and so a fully live multi screw feeder is needed.

Six screws used, driven as a pair of triple screws

# Final Assembly


Plant supplied integrates the silo with the sextuple screw feeder, a collecting screw with de-clumping features which is reversible to serve two mill systems.

# To summarise..

- Screw feeders offer very positive means of extracting a wide range of bulk solids, ranging from fine cohesive materials to shredded wastes, stored in hoppers, silos and bunkers.
- Flow characterisation techniques help identify minimum arching and slot dimensions for reliable flow. Practical trials can be useful too.
- Screws with progressive extraction geometry can serve longs slots.
- Wide hopper outlets can be served well by twin and other multiples of screw.
- Multi screw feeders offer lower headroom than single large screw.
- They provide well regulated feed rate – with correct phasing can even mitigate the natural cyclic feed effects of single screw.

# Thank you for your attention

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