Getting Control
Alex Scott

QUARRY ACADEMY

LIGHTEN UP!

Lecture Overview

- A look at some of the issues which in the day to day operation influence crusher performance

- A look at some possible problems, trouble shooting tips and improvements.

QUARRY ACADEMY

Our journey

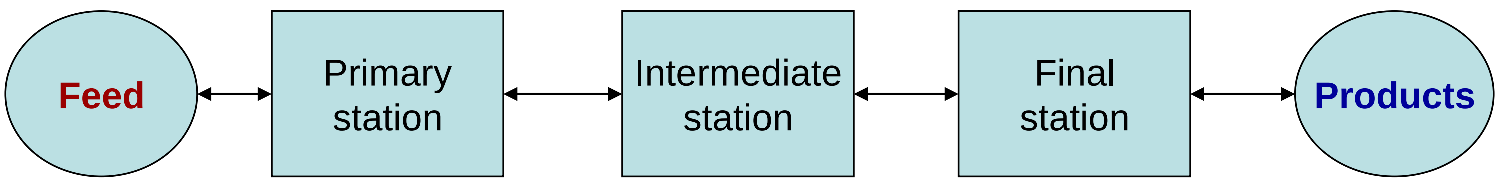
- A look at material properties and their influence on equipment performance
- A look at the machine factors influencing equipment performance
- A look at some negative factors reducing equipment performance.
- A look at some take home messages which might improve performance.

QUARRY ACADEMY

The Process

FEED

Properties	Influence	Influence	Influence
1. Loading in	1. High	1. Low	1. Low
2. Max size	2. High	2. Low	2. Low
3. Feed cap	3. Medium high	3. Medium low	3. Low
4. Feed PSD	4. Medium high	4. Medium low	4. Low
5. Wi	5. Medium	5. Medium high	5. High
6. AI	6. Medium	6. Medium high	6. High
7. Moisture	7. Medium	7. Medium low	7. Low



Influence	Influence	Influence	Properties
1. Medium low	1. Medium	1. High	1. Process
2. Low	2. Medium	2. High	2. Quantity
3. Low	3. Medium	3. High	3. Quality
4. Low	4. Medium low	4. High	4. Prod cap
5. Low	5. Medium low	5. High	5. Prod PSD
6. Low	6. Low	6. Medium	6. Loading out

PRODUCTS

QUARRY ACADEMY

Why do we need to know the material characteristics?

- The toughness of the rock is one factor affecting the performance of the crusher.
  - it will determine the power drawn by the crusher from the motor or engine and therefore will determine the minimum setting at which the crusher will operate and give satisfactory mechanical reliability.
  - it will determine the capacity.
- The abrasivity of the rock will affect the liner life and the performance of the crusher over a period of time.
- The grain structure will influence the way in which the rock fractures and therefore the cubicity of the end product.

QUARRY ACADEMY

What other performance factors will be affected by the material characteristics?

- Rock is crushed when the strength of the rock particle cannot absorb the strain energy applied by the crusher and the rock deforms beyond it's plastic limit to ultimate failure.

- Rock needs to be breakable!!!!!

- Plastic fines in the chamber will become compacted and absorb energy without deformation and failure.

- On some applications, with high plastic fines content,it will be beneficial to remove these fines before crushing, especially in secondary cone crushers.

- Feed grading of material in the shot-pile. High fines–high capacity. Blocky rock– low capacity

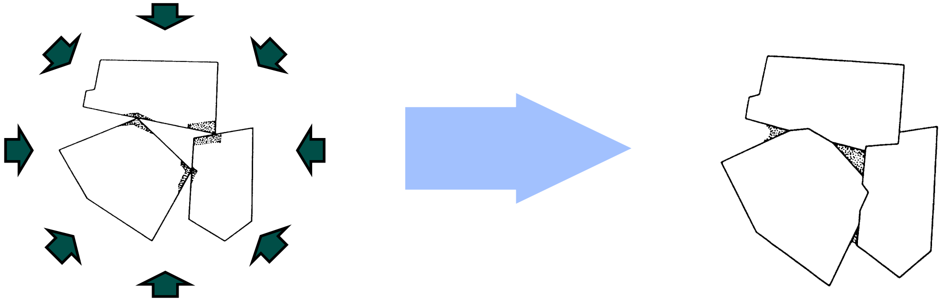
QUARRY ACADEMY

Raw Material
Species of rock

- IGNEOUS
  - ✓Surface - Fine grained
  - ✓Intrusive - Medium grained
  - ✓Deep - Coarse grained

Raw Material
Species of rock

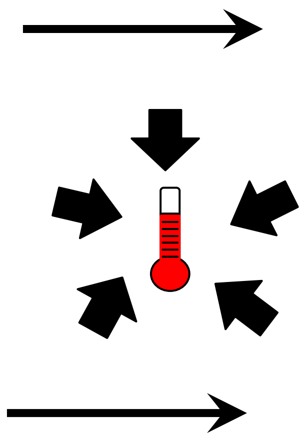
- SEDIMENTARY



Raw Material
Species of rock

- METAMORPHIC

  ROCK TRANSFORMED IN THE EARTH´S CRUST DUE TO INCREASED PRESSURE AND TEMPERATURE



Take Home Message

The grain structure of the raw material has an influence on the final shape of the finished product and the power and/or pressure pulled by the crusher

Sandvik Test Methods
Impact Work Index, WI

Impact Work Index (WI)	Description of the Crushability
< 10	Very soft
10 – 14	Soft
14 – 18	Medium
18 – 22	TOUGH
22 – 26	Very TOUGH
> 26	ExtremelyTOUGH

Bond’s formula

Bonds 3rd theorem

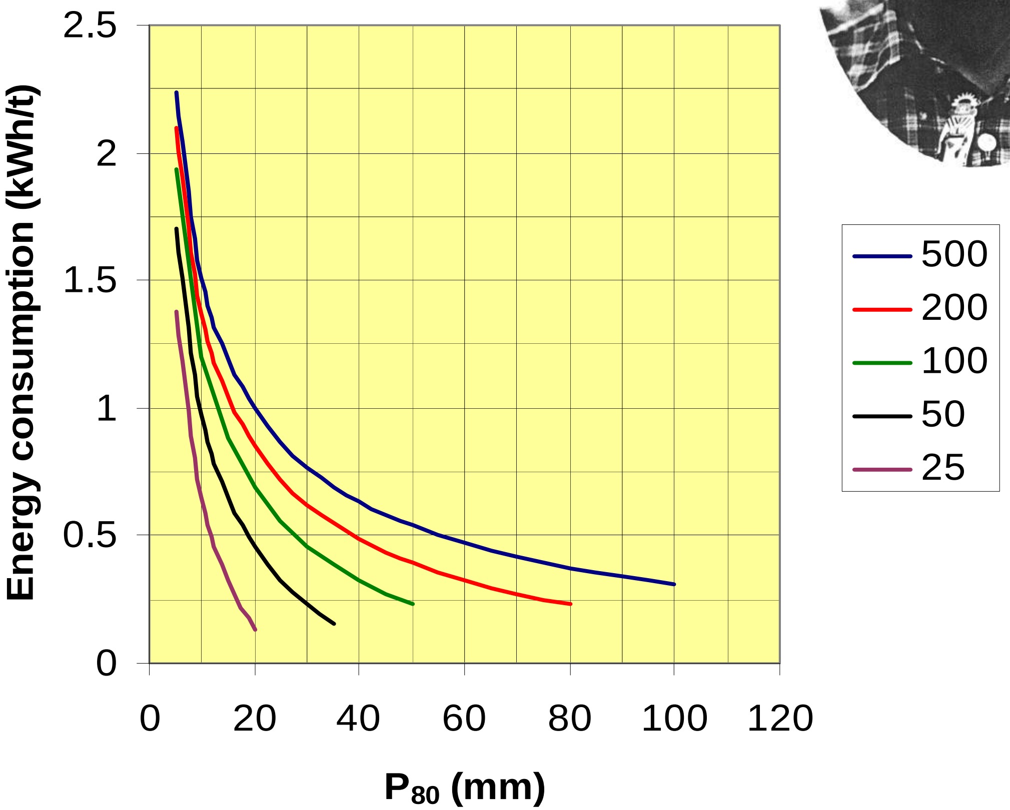
$$W = 11 \cdot WI \cdot \left(\frac{1}{\sqrt{P_{80}}} - \frac{1}{\sqrt{F_{80}}} \right)$$

W = Energy consumption (kWh/t)

WI = Impact Work Index

P_{80} = Square hole which 80 % of product is passing (mm)

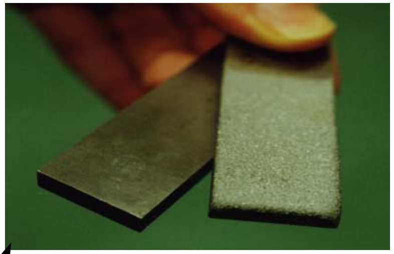
F_{80} = Square hole which 80 % of feed is passing (mm)



Put another way---the energy required to reduce a rock of a given toughness from size A to size B

QUARRY ACADEMY

Sandvik Test Methods
Abrasion Index, AI



Abrasion Index (AI)	Description of the Abrasivity.
< 0.1	Very low wear
0.1 – 0.2	Low wear
0.2 – 0.4	Intermediate wear
0.4 – 0.6	Normal medium wear
0.6 – 0.8	High wear
> 0.8	Extremely high wear

QUARRY ACADEMY

Rawmaterial Properties

Material	WI	AI	Compressive strength (lbs/in^2)
Andesite	16	0.5	24650 - 43500
Basalt	20	0.25	43500 - 58000
Diabase	18	0.28	36250 - 50750
Dolomite	12	< 0.02	7250 - 21750
Diorite	19	0.4	24650 - 43500
Gabbro	21	0.4	29000 - 50750
Greywacke	18	0.3	21750 - 43500
Gneiss	16	0.48	29000 - 43500
Granite	16	0.46	29000 - 45000
Limestone	11	< 0.01	11600 - 26100
Quartzite	16	0.75	21750 - 43500
Sandstone	10	0.75	4350 - 21750

QUARRY ACADEMY

FINAL PRODUCTS

- Size
  - ✓ Fraction Limits------- screening
  - ✓ Misplaced Particles-----screening and crushing
  - ✓ Size Distribution------top size screening and crushing
- Shape
  - ✓ Flakiness------ crushing
  - ✓ Elongation----- crushing
- Surface
  - ✓ Crushed Surface---crushing

QUARRY ACADEMY

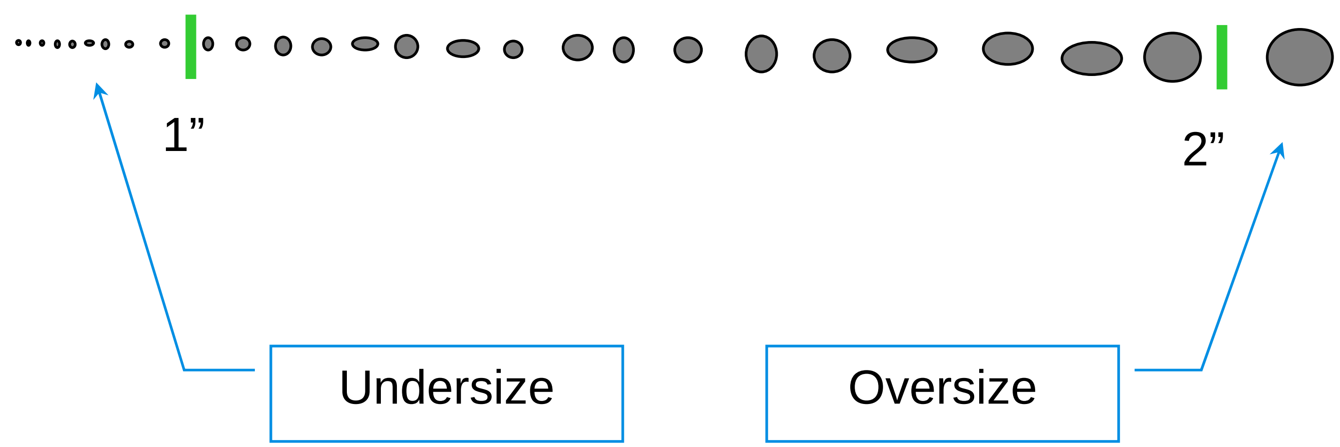
FINAL PRODUCTS
Misplaced particles

ASTM D 448-86,1988

Misplaced Particles
10/15

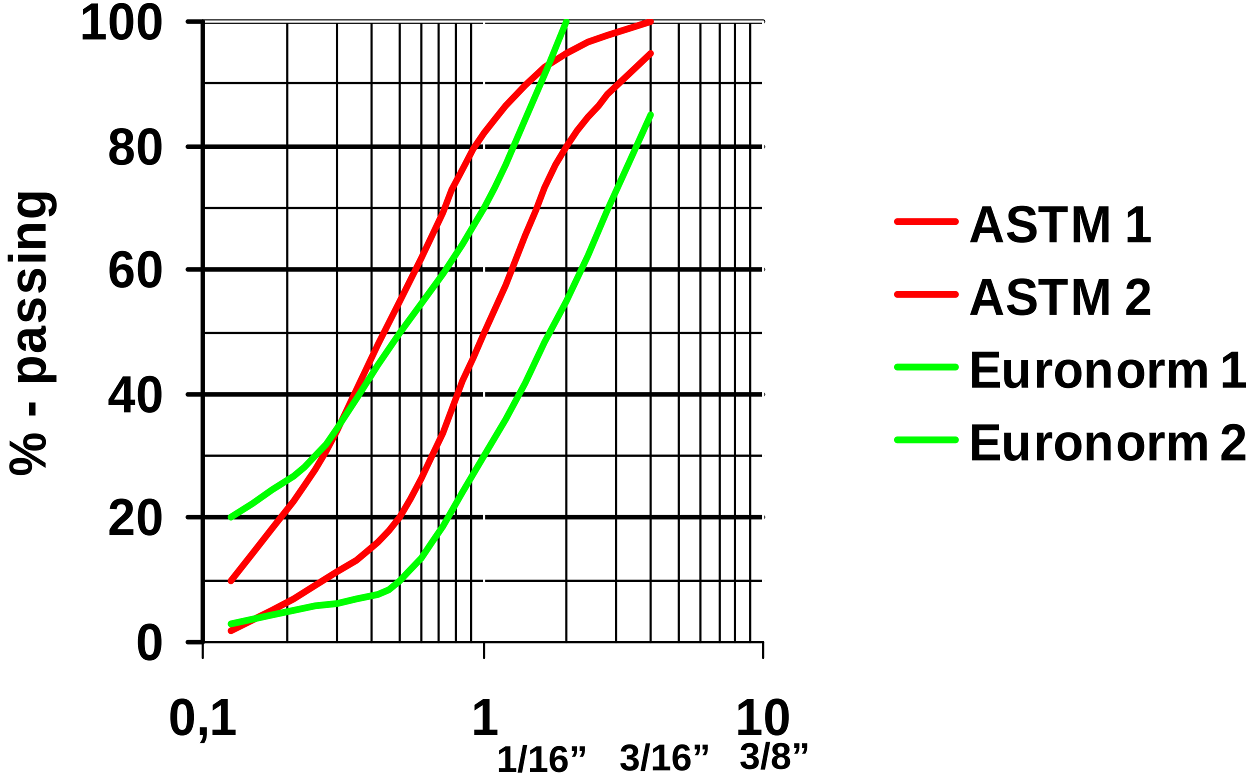
- ✓ Oversize: 10 %
- ✓ Undersize: 15 %

Fraction 1” x 2”



QUARRY ACADEMY

FINAL PRODUCTS
Curve limitations



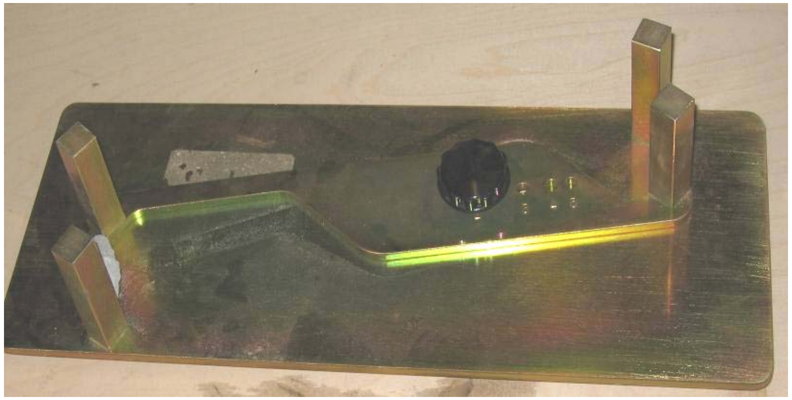
Sand limits

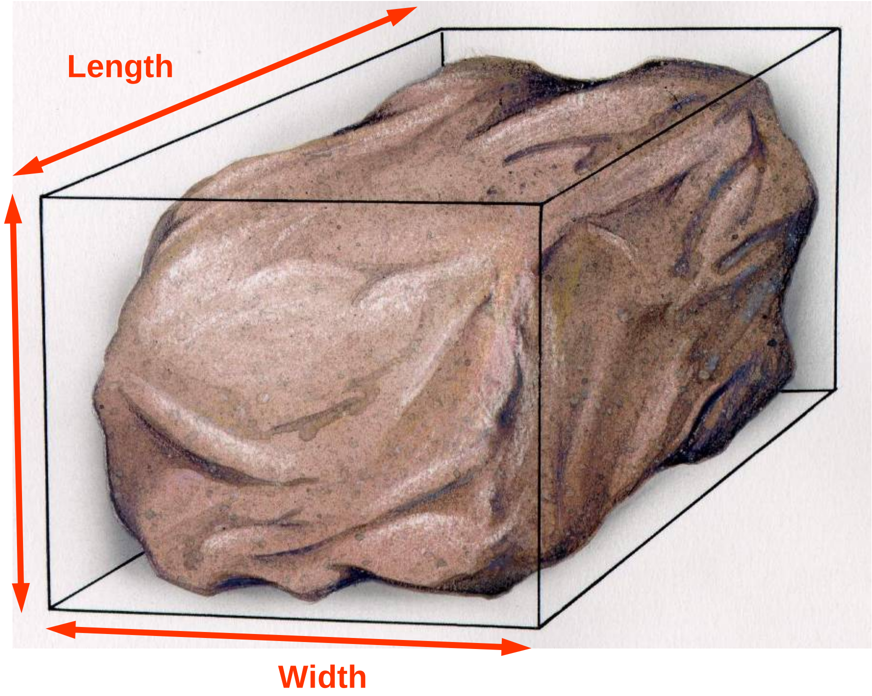
QUARRY ACADEMY

FINAL PRODUCTS
Particle shape

- Flakiness (length/thickness)
- Elongation (length/width)
- Flat (thickness/width)

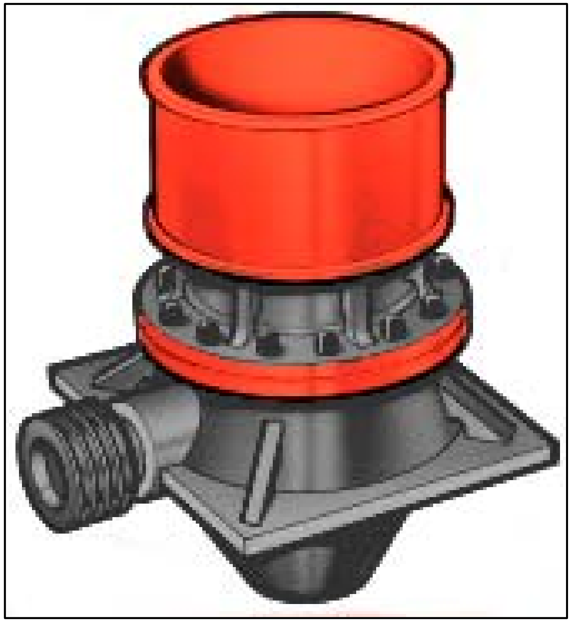
- ASTM D 4791
  - ✓ Flat (W/T ratio)
  - ✓ Elongated (W/L ratio)
- Ratio varies 1:2, 1:3, 1:4, 1:5

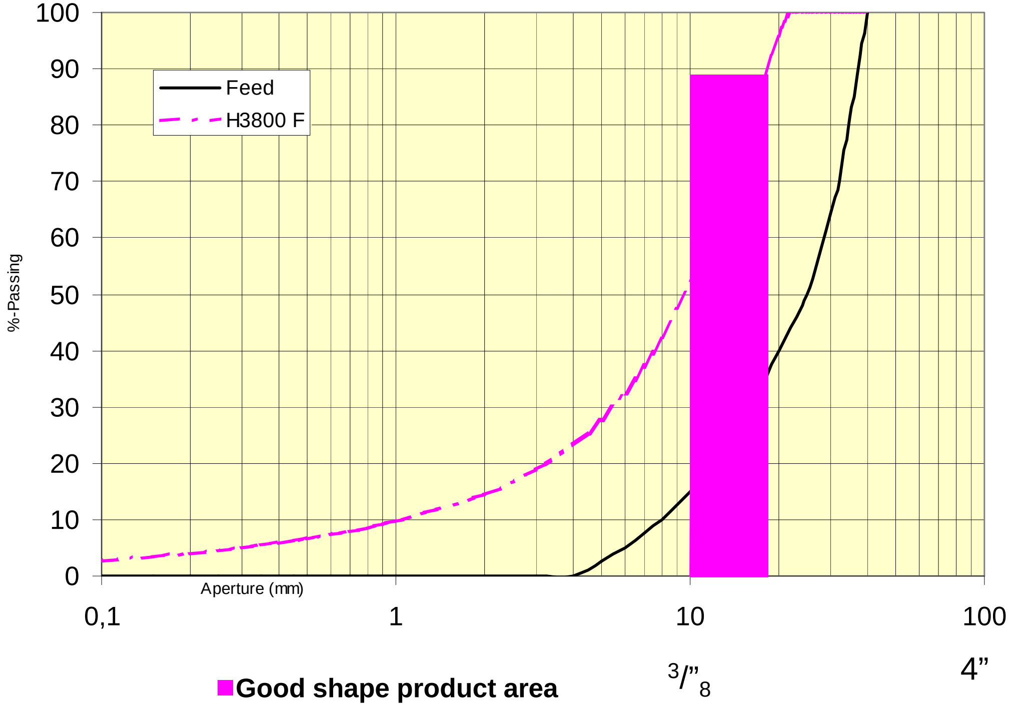




QUARRY ACADEMY

Cone Crushers
Product Quality

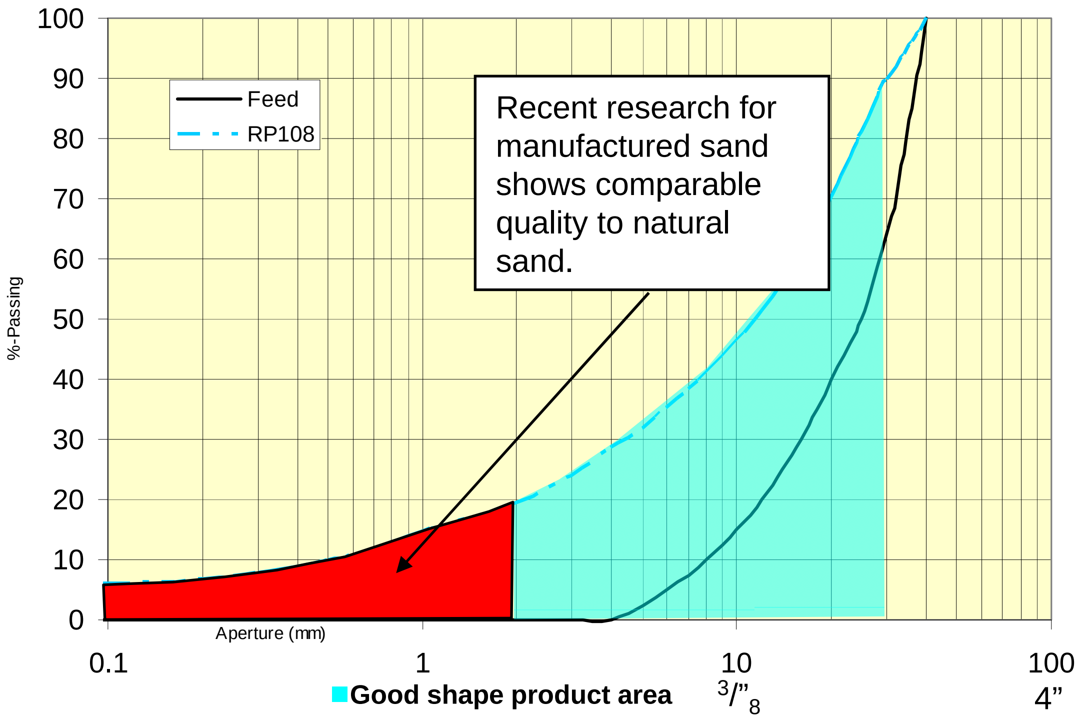




- Good Flexibility
- Higher crushing forces
- Good shape in the 5-80 mm range
- Uniform reduction ratio

QUARRY ACADEMY

Impactors – HSI and VSI
Product quality



- Better shape
- Good shape in the +40 micron range
- Uneven Reduction
- Limited topsize capacity
- High fines production

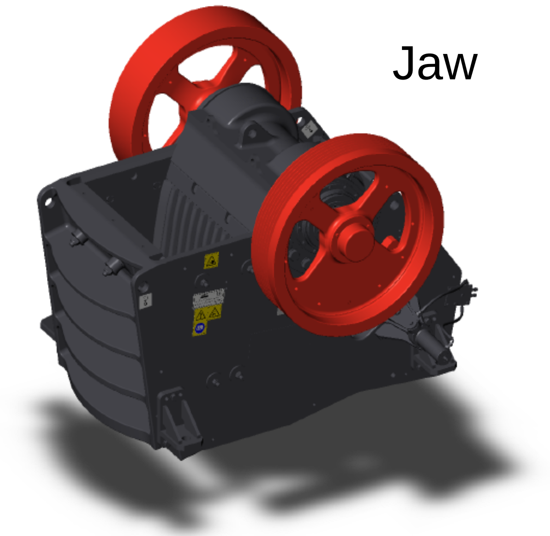
QUARRY ACADEMY

Crushers & crushing

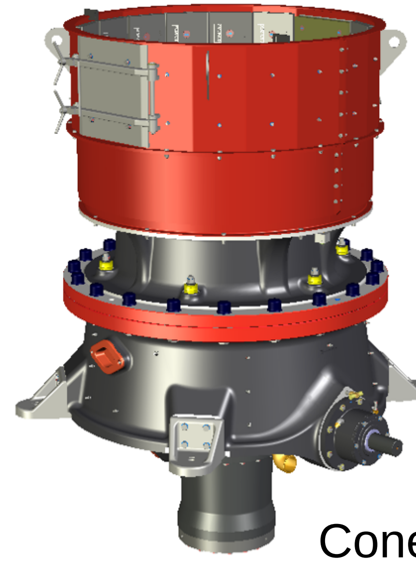
A look at crushers and the mechanical and process material influences

- **Compression**

Primary & secondary gyratory



Jaw



Cone

Roll

Sizer

QUARRY ACADEMY

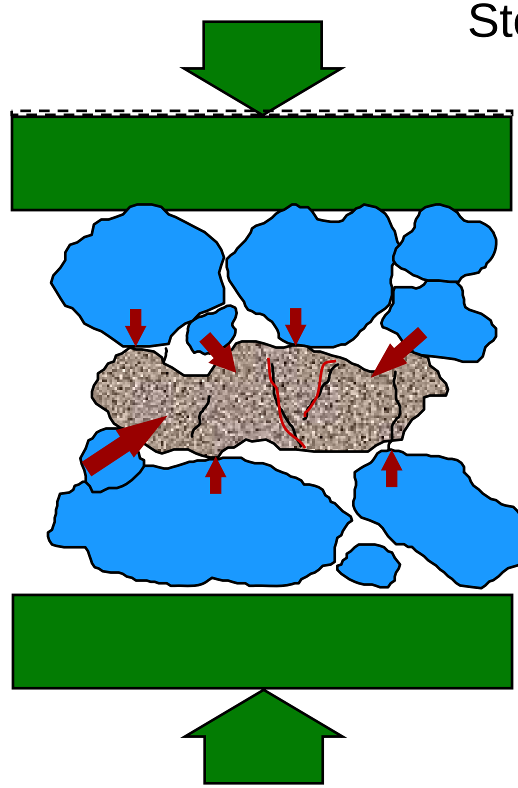
Compression Breakage

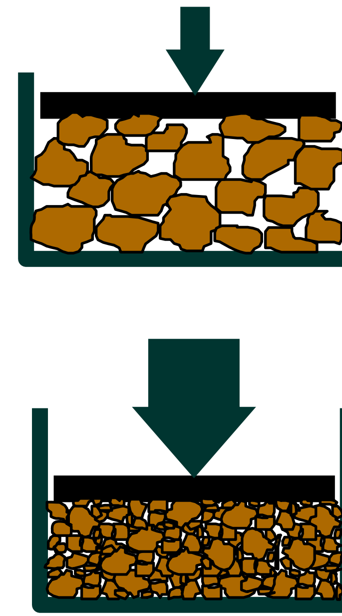
Stone on metal

Simple loading ⇨

More angular particles

Stone on stone





Complex loading ⇨

More cubical particles

QUARRY ACADEMY

Crushers & crushing

A look at crushers and the mechanical and process material influences

- **Impact**

Vertical shaft impactors

Primary & secondary
Horizontal shaft impactors

Hammer mills

QUARRY ACADEMY

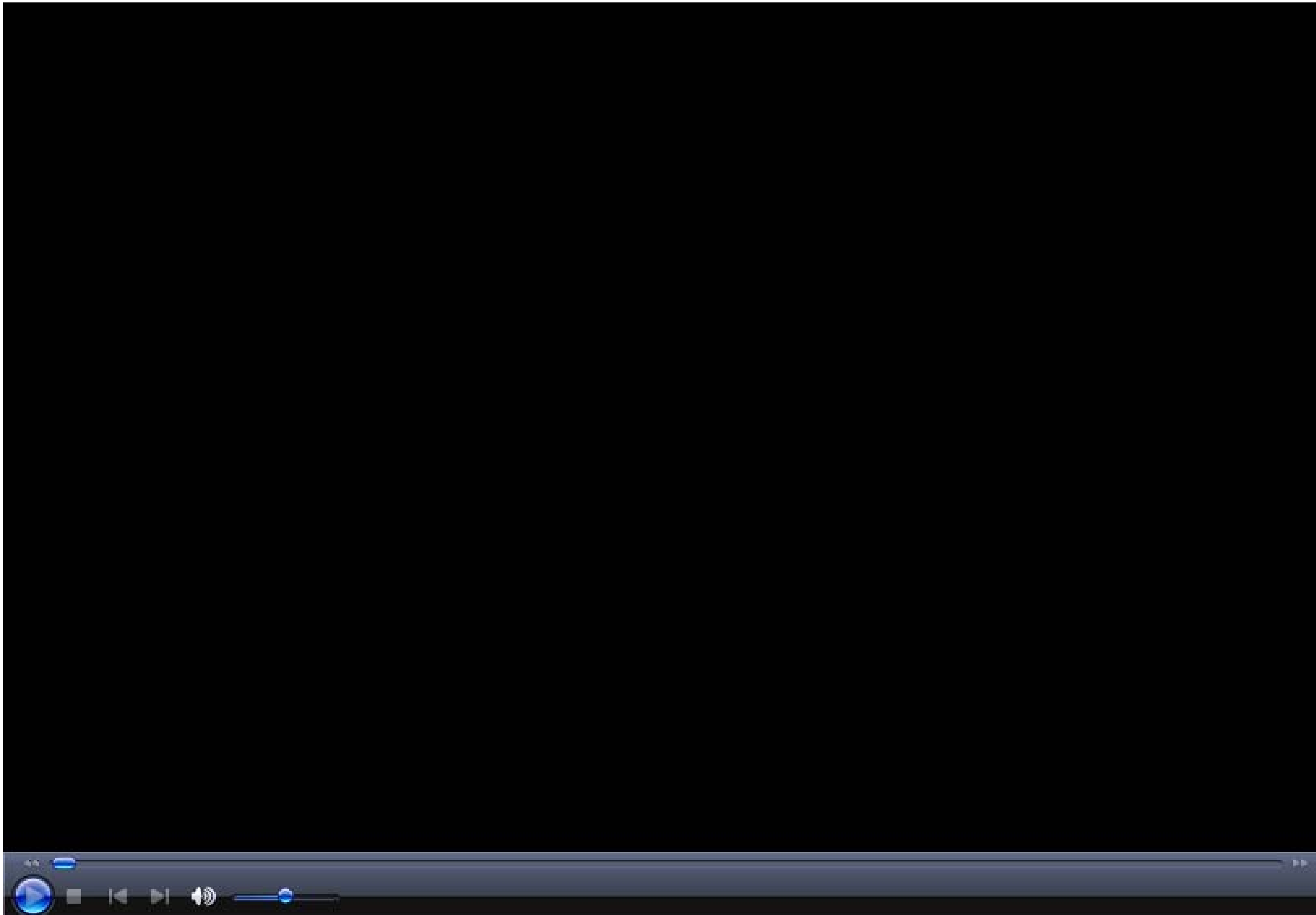
Jaw crusher

Operation

QUARRY ACADEMY

Cone crusher

Operation

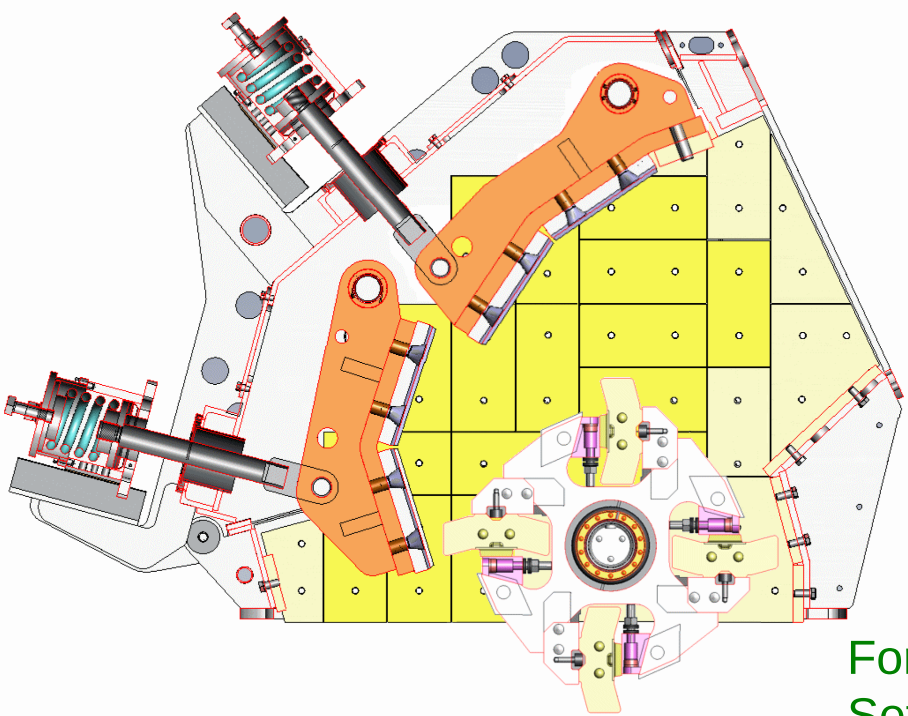


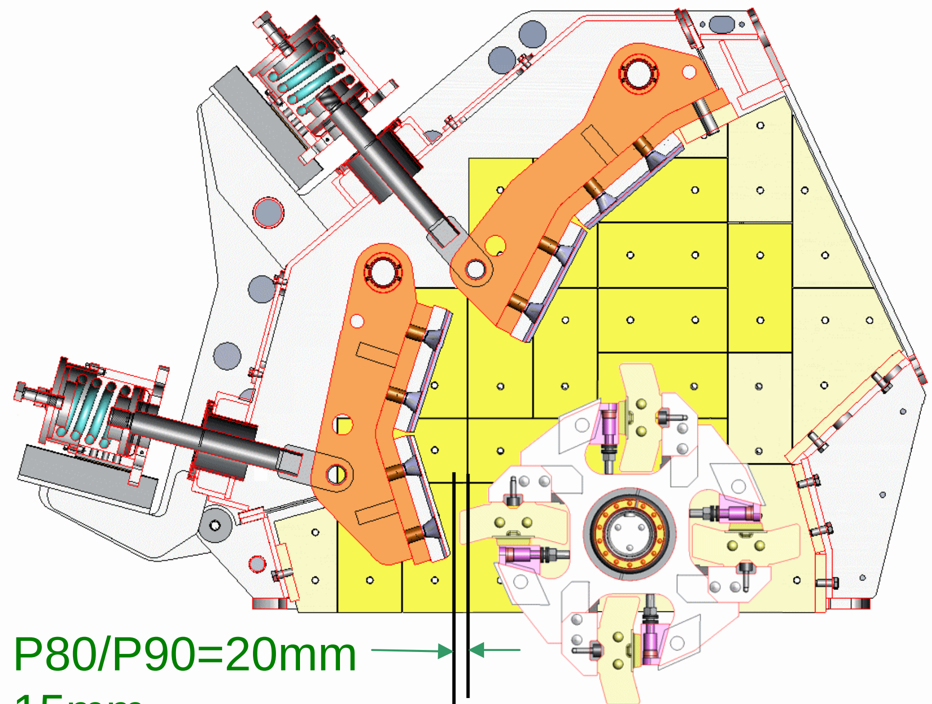
QUARRY
ACADEMY

HSI Operation

QUARRY ACADEMY

Impactor Operation





Limited volume control by setting of top curtain

Product control by setting of bottom/third curtain

VSI Operation

QUARRY ACADEMY

What do we really know about crushing?

- What are the major influences?
- From material factors?
- From equipment/mechanical factors?

QUARRY ACADEMY

What are we about to examine?

- The major influences on crusher performance, which are

- material factors such as

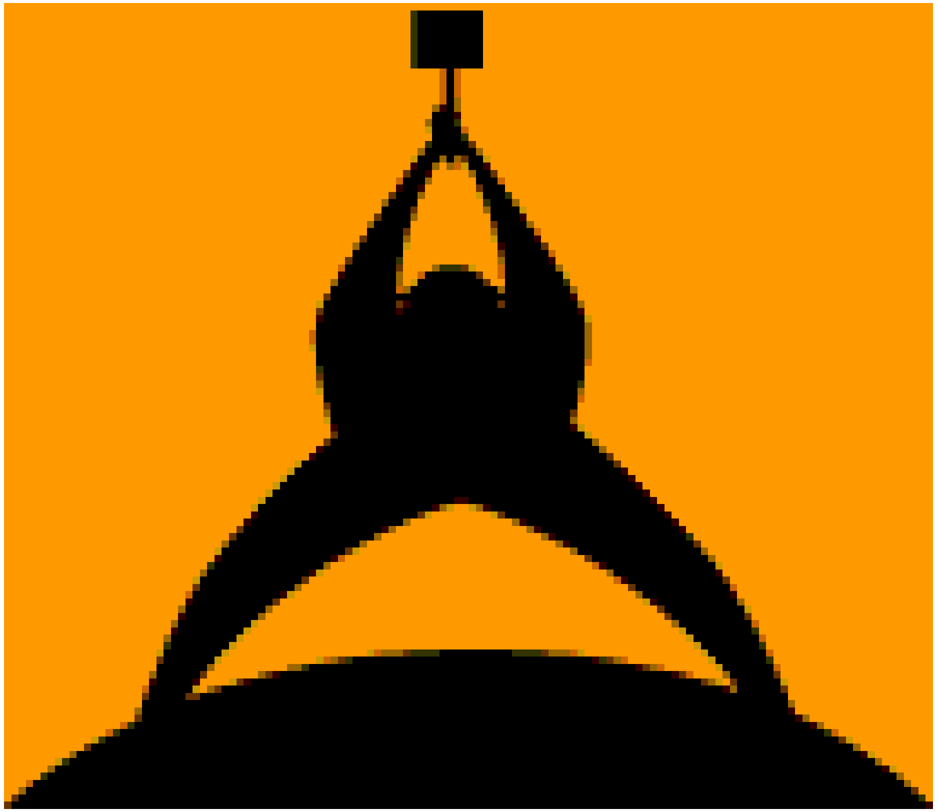
1. toughness,
2. bulk density
3. feed size analysis

- machinery factors such as

1. setting
2. throw (cone crushers)
3. chamber volume
4. speed

QUARRY ACADEMY

Crushing from a personal perspective

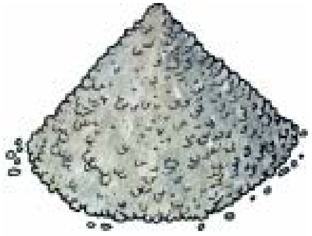


QUARRY ACADEMY

Mechanical & material

Limestone

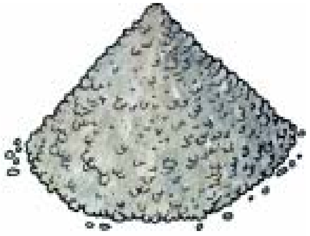
1” – 3”



0 – 1$^{1}/_{4}$”

Limestone

1” – 3”



0 – 1$^{1}/_{4}$”

The same energy is used.

QUARRY ACADEMY

Material

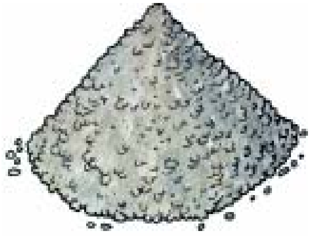
Limestone

1” – 3”

0 – $1^{1}/_{4}$ ”

Basalt

1” – 3”



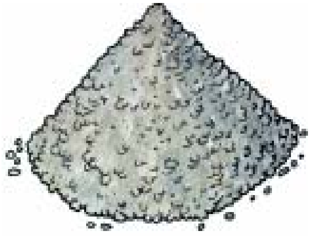
0 – $1^{1}/_{4}$ ”

Toughness is a major factor

Mechanical

Limestone

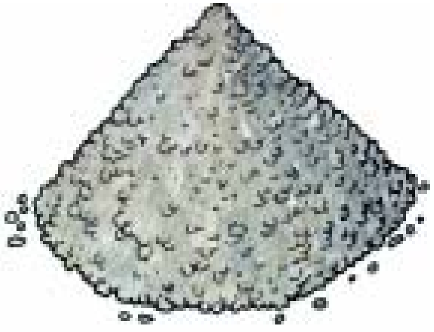
1” – 3”



0 – $1^{1}/_{4}$ ”

Limestone

1” – 3”



0 – $1^{1}/_{4}$ ”

Volume by throw,chamber profile or material bulk density & feed grading are factors

QUARRY ACADEMY

Mechanical

Basalt

1” – 3”

$0 – 1^{1}/_{4}$ ”

Basalt

1”- 5”

$0 – 1^{1}/_{4}$ ”

Reduction ratio-CSS is a factor

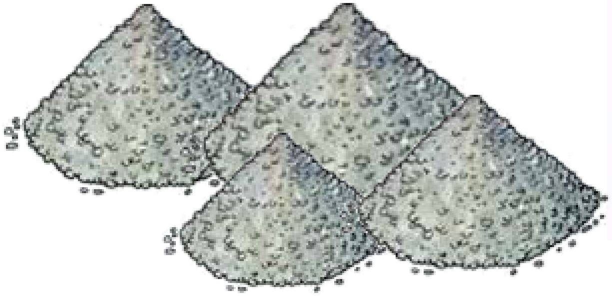
QUARRY ACADEMY

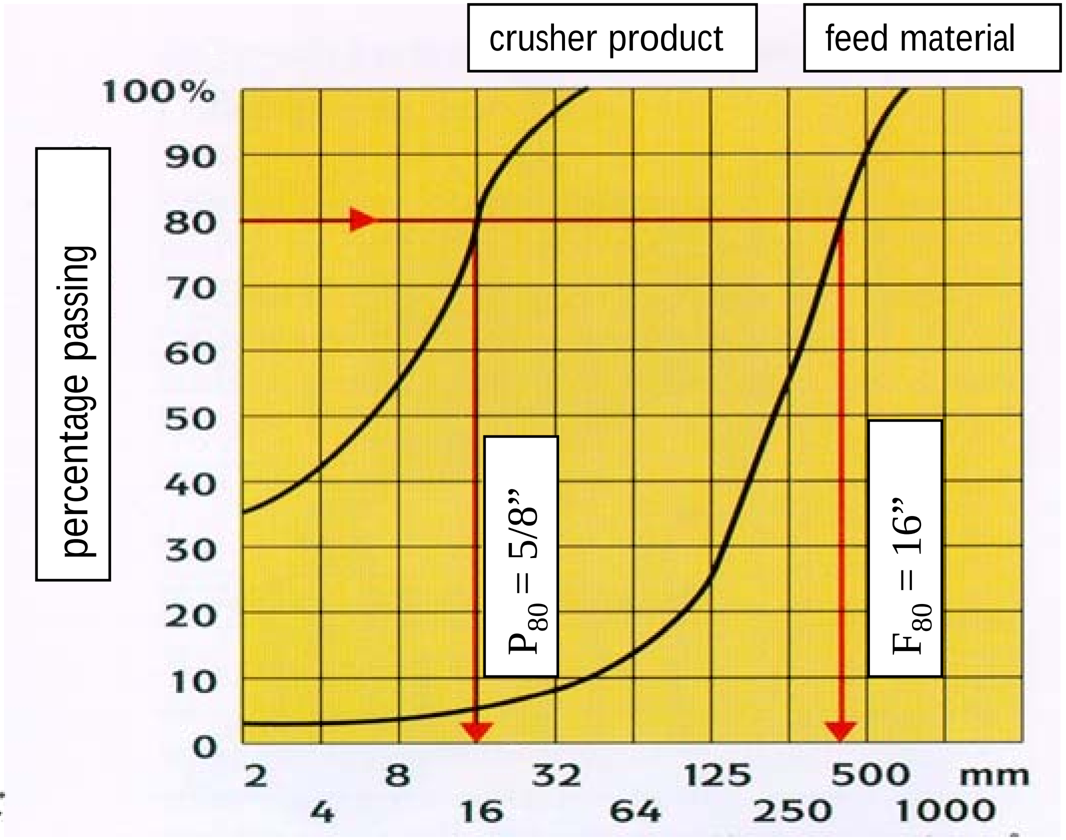
Basic Crushing and Screening Concepts
Reduction Ratio (1)

$$Reduction\ Ratio = \frac{F_{80}}{P_{80}}$$

F_{80} = (80 % of feed mtrl)

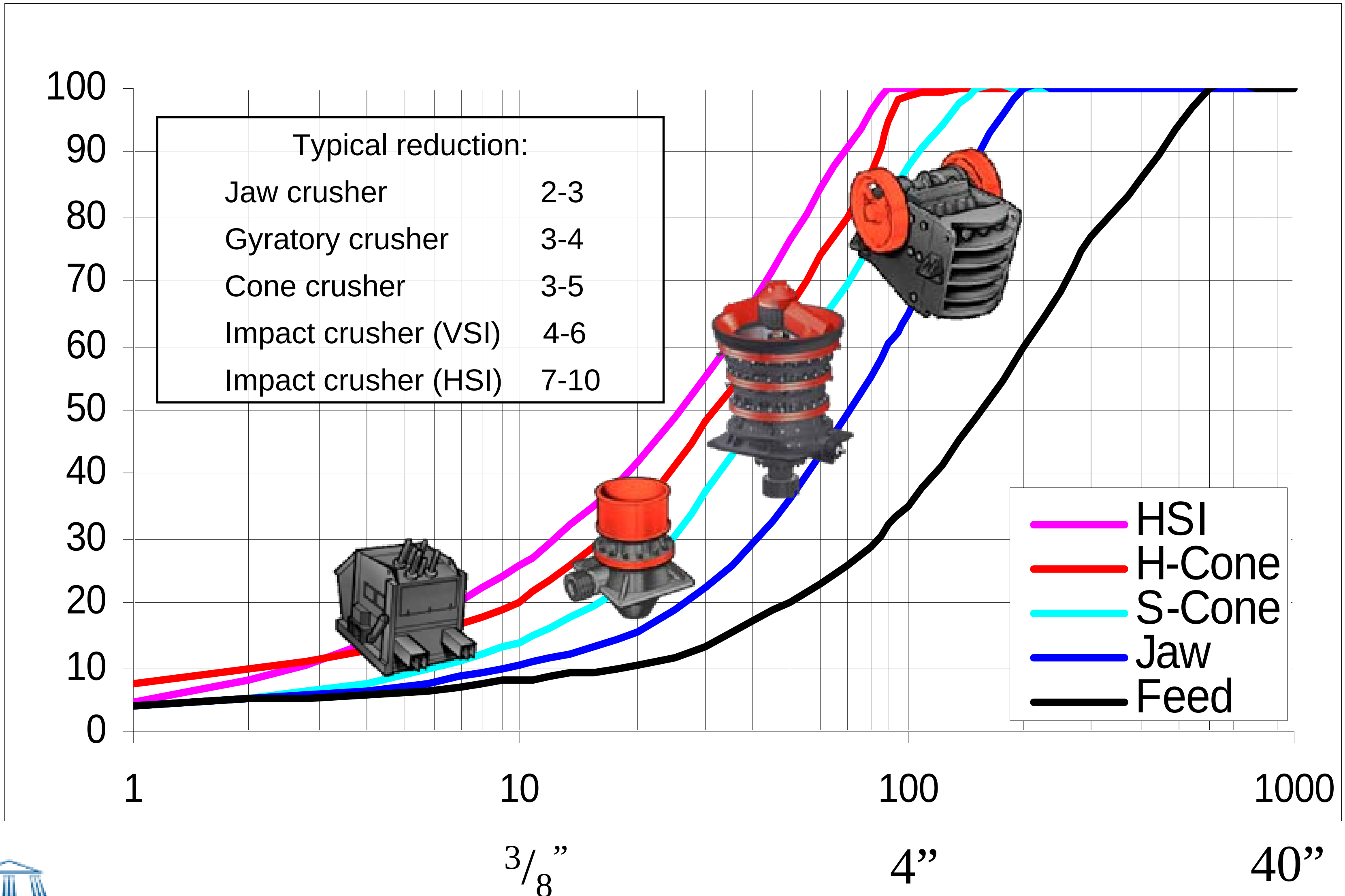
P_{80} = (80 % of the product)





QUARRY ACADEMY

Basic Crushing Concepts
Reduction Ratio



QUARRY ACADEMY

Basic Crushing and Screening Concepts
Reduction Ratio (3)

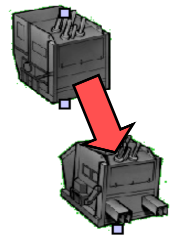
Using reduction ratio to predict required no. of crushing stages

P_{80} Feed: 16”

P_{80} Products: 5/8”

Min. required plant reduction

$16 / {}^{5}/_{8} = 25:1$



- 2-stage Impact Plant:

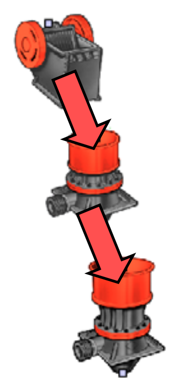
10x7=70

OK, Only for Ai <0.15

- 2-stage Jaw/cone Plant:

3x4=12

NOT OK



- 3- stage Jaw/cone Plant

3x3x4=36

OK

QUARRY ACADEMY

Machinery control factors

	Jaws	HSI	VSI	Cone
Chamber	Limited by plate profile	Limited by adjusting top curtain positon	X	Various & many
Throw	Limited	X	X	Various & many
Speed	Limited	Yes	Yes	Yes
Setting	Yes	Yes	X	Yes
Other	X	X	Bi-flow	X

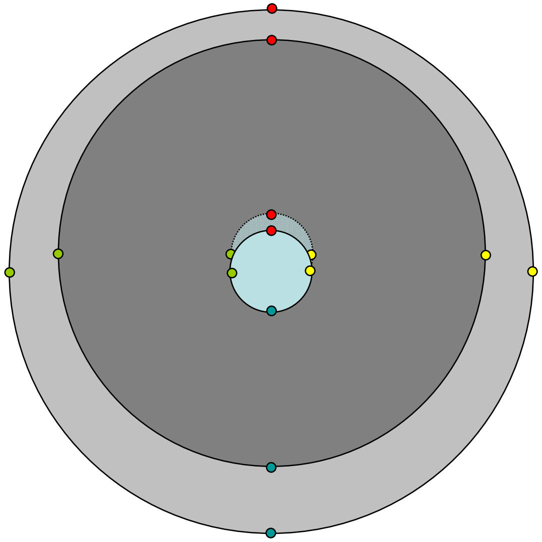
QUARRY ACADEMY

Function

- A cone crusher is a rotational device.
- The CSS runs around the circumference of the fixed concave.
- Material passes through the chamber by gravity moving into the space created by the OSS.
- One half revolution later the CSS compresses the rock and thus it is crushed and reduced.
- This occurs in most cone crushers 5-6 times per second.

QUARRY ACADEMY

Eccentric Motion

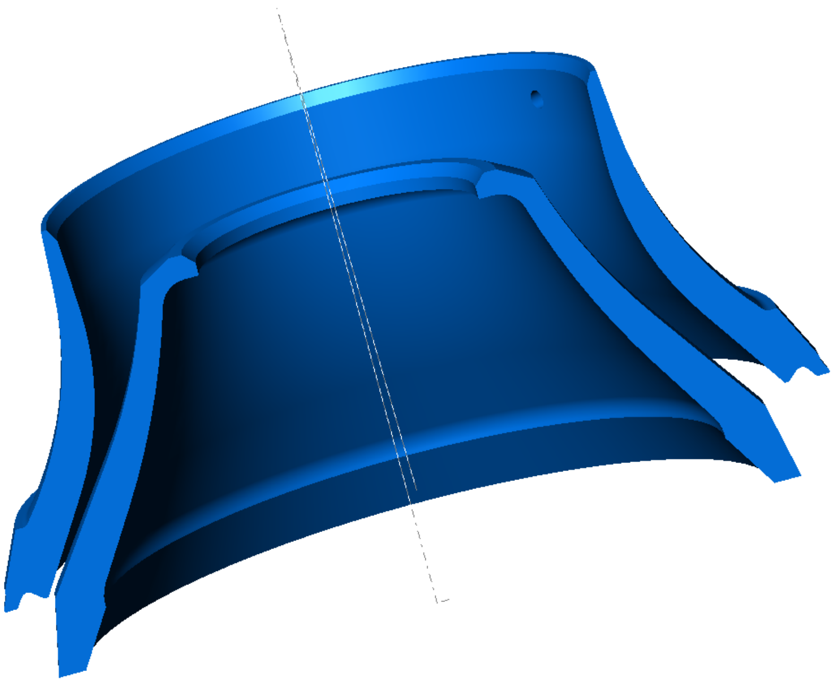


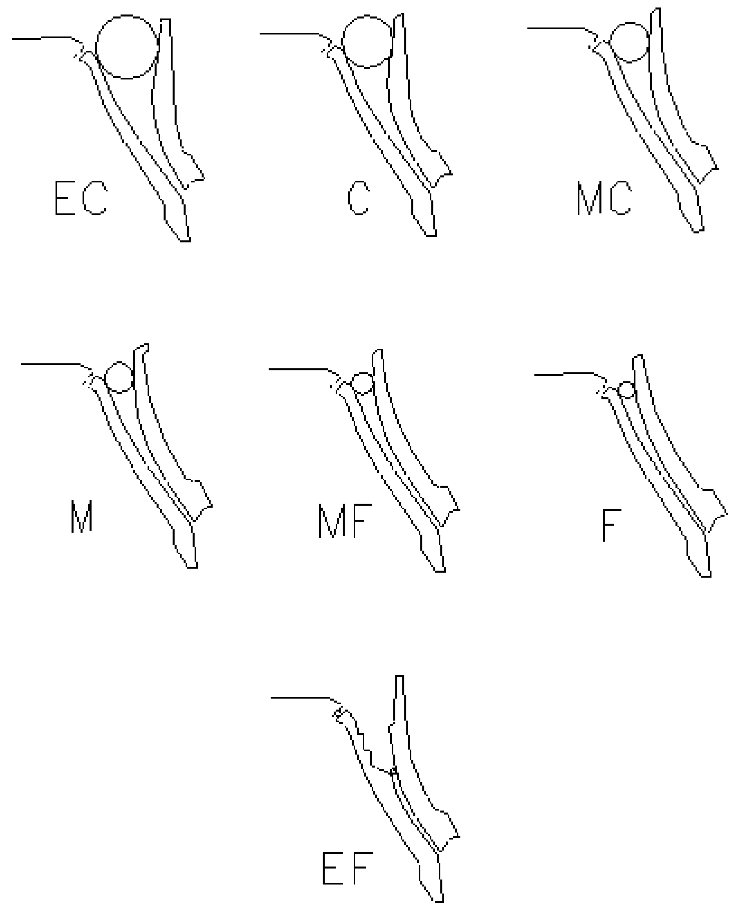
QUARRY
ACADEMY

The crushing chamber in a cone crusher is the most important part

All other parts in the crusher are ”only” there to hold the chamber in place or to create movement of the mantle.

Why so many chambers?

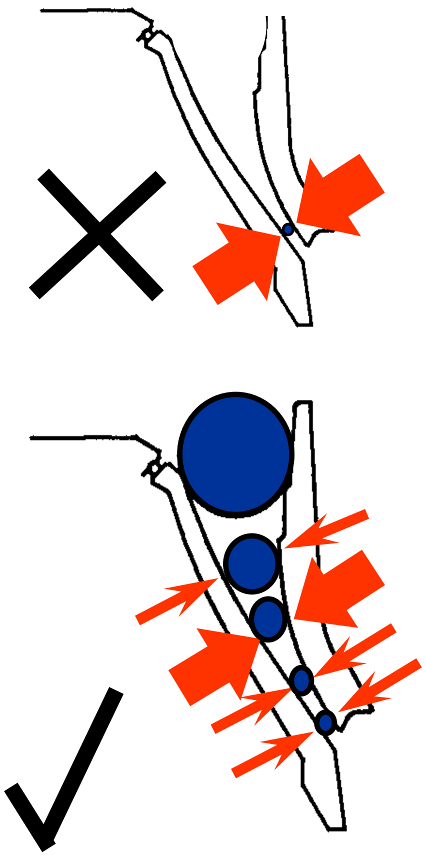




All crushing starts with the chamber!

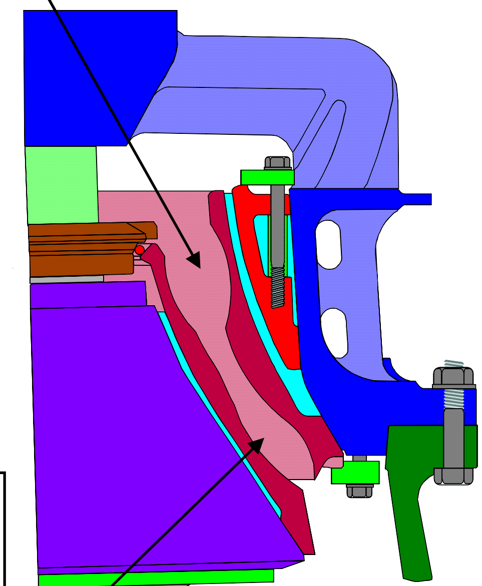
QUARRY ACADEMY

Why different chambers?



- Maximum energy utilisation.Consider mechanical advantage
- Avoid peak loads
- Prevent uneven wear

Excessive wear
- due to oversized feed
- single sized feed

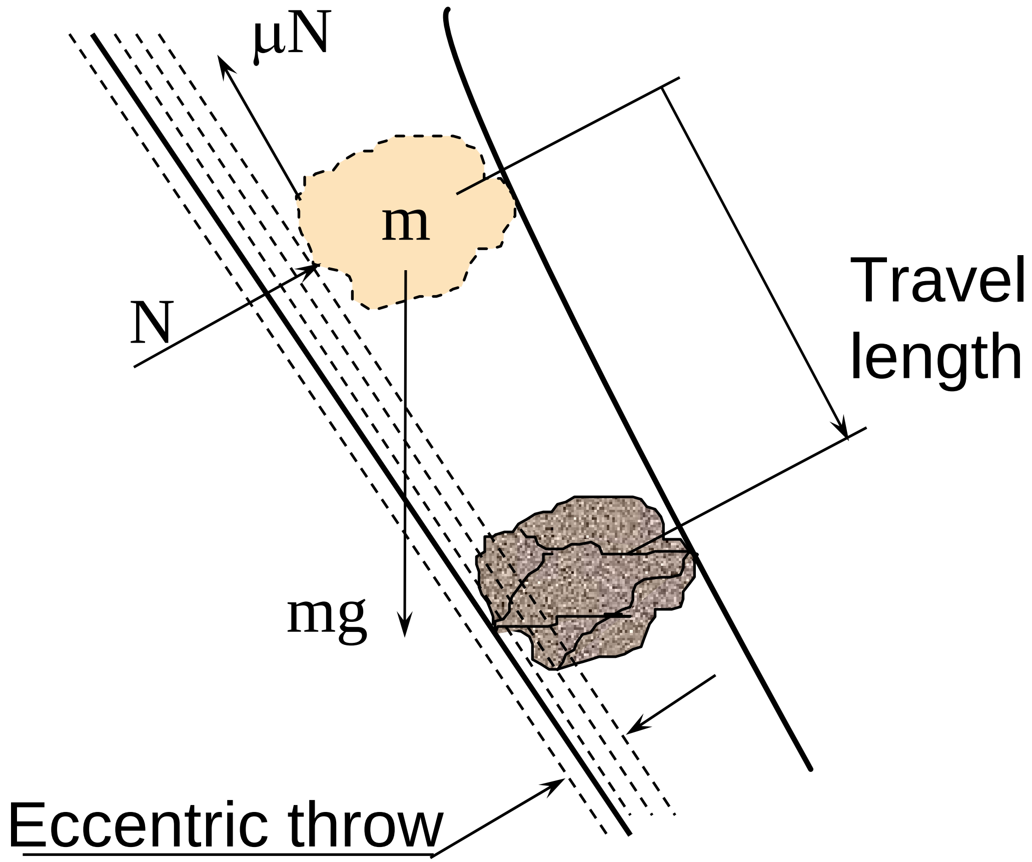


Excessive wear

- due to a high percentage of fines in feed
- under feeding

QUARRY ACADEMY

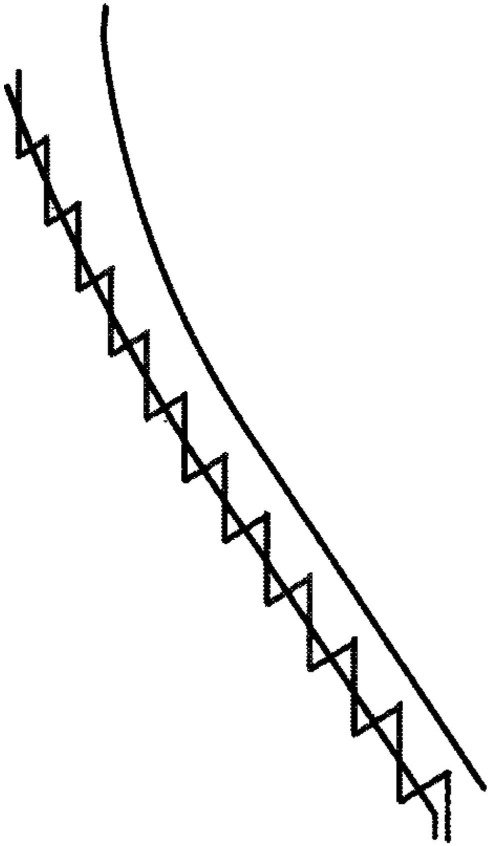
Each eccentric revolution means a crushing stage

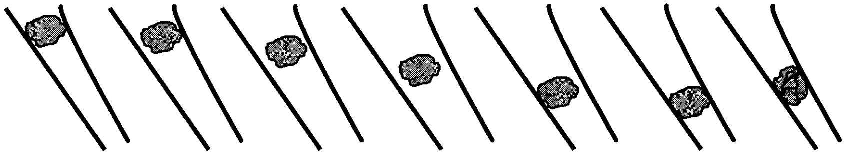


QUARRY ACADEMY

Influence of speed

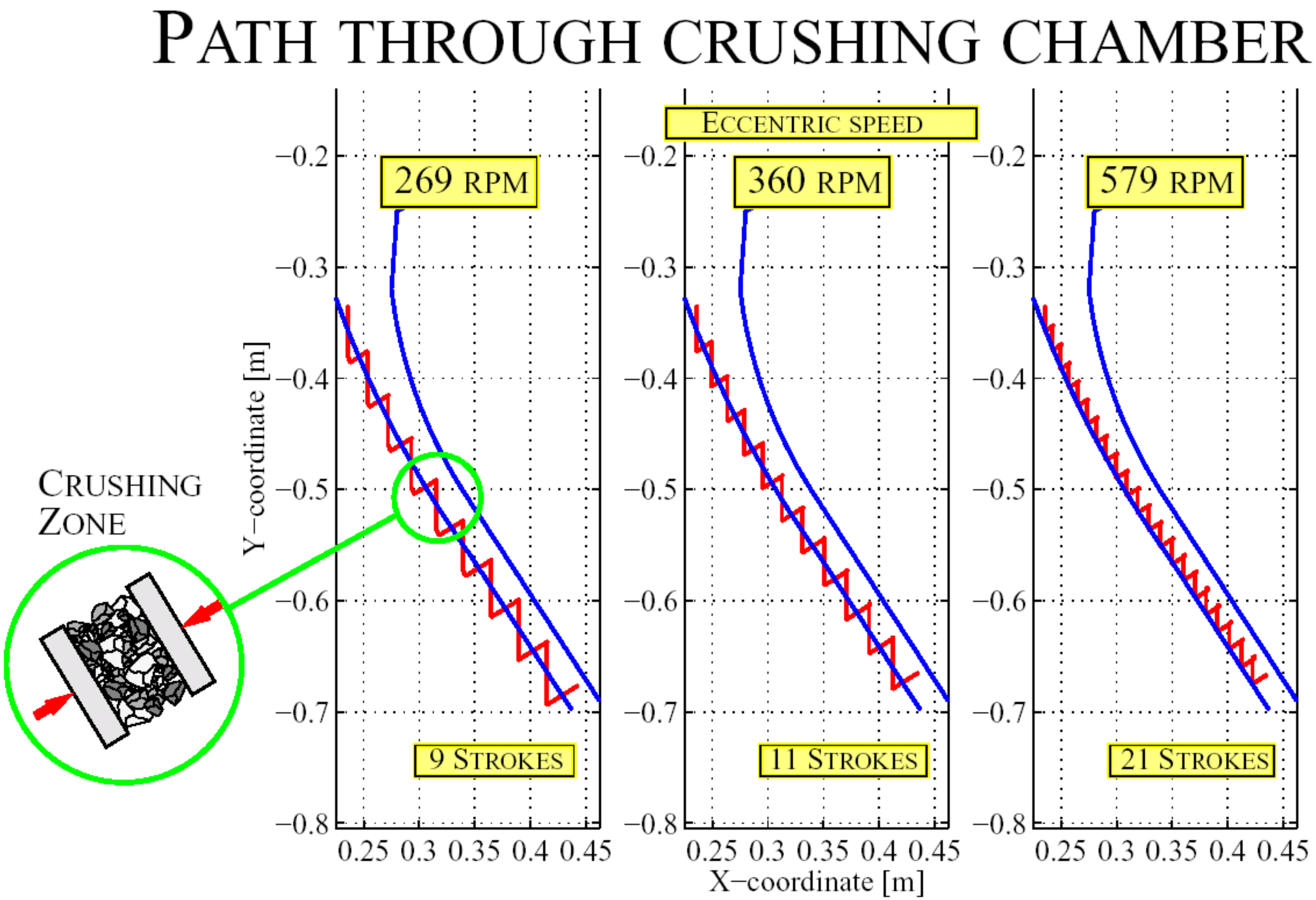
There are several crushing stages in the chamber





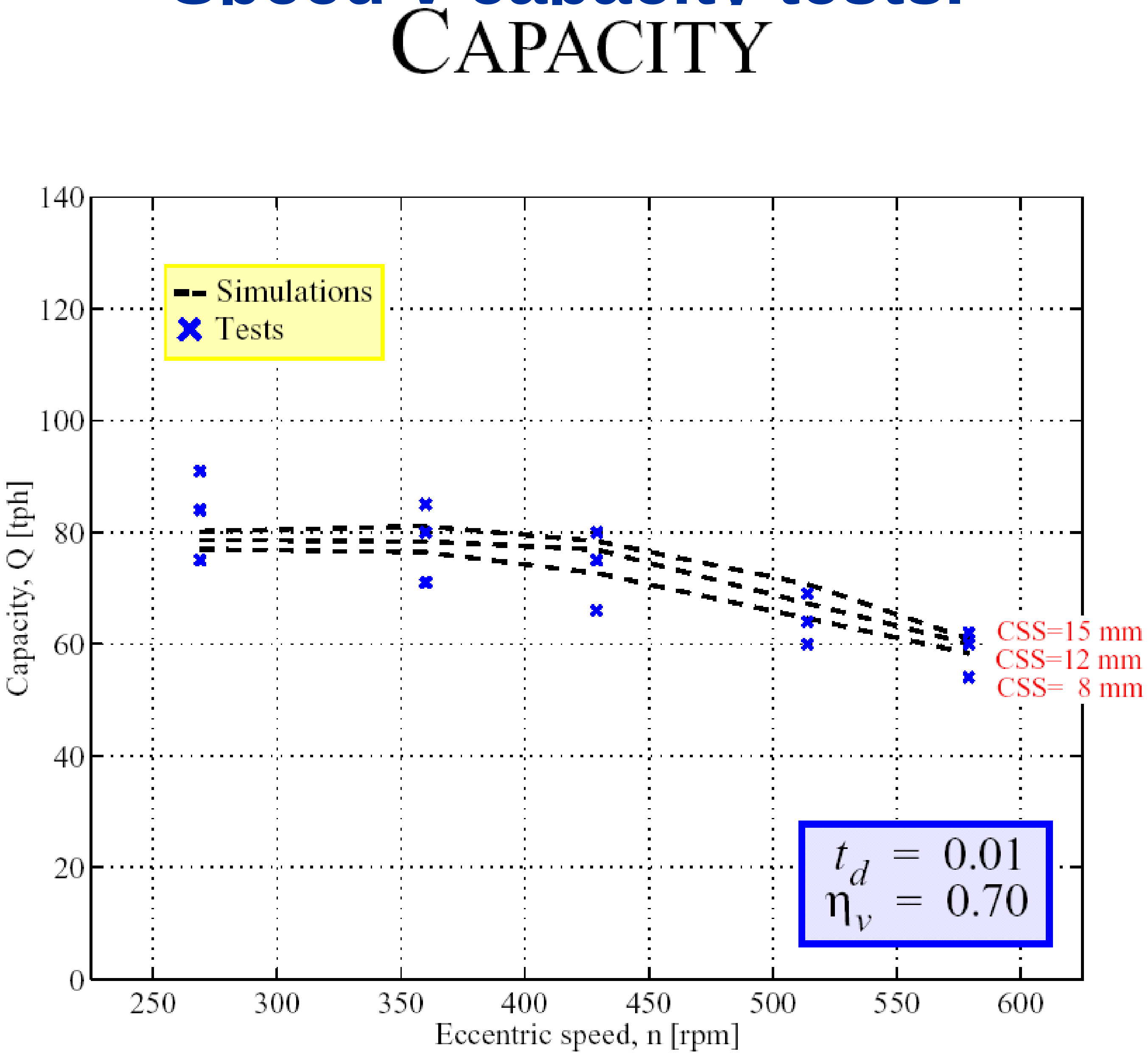
When the falling stone is caught, it is trapped and to some degree pushed upwards.

Influence of speed



QUARRY ACADEMY

Speed v capacity tests.



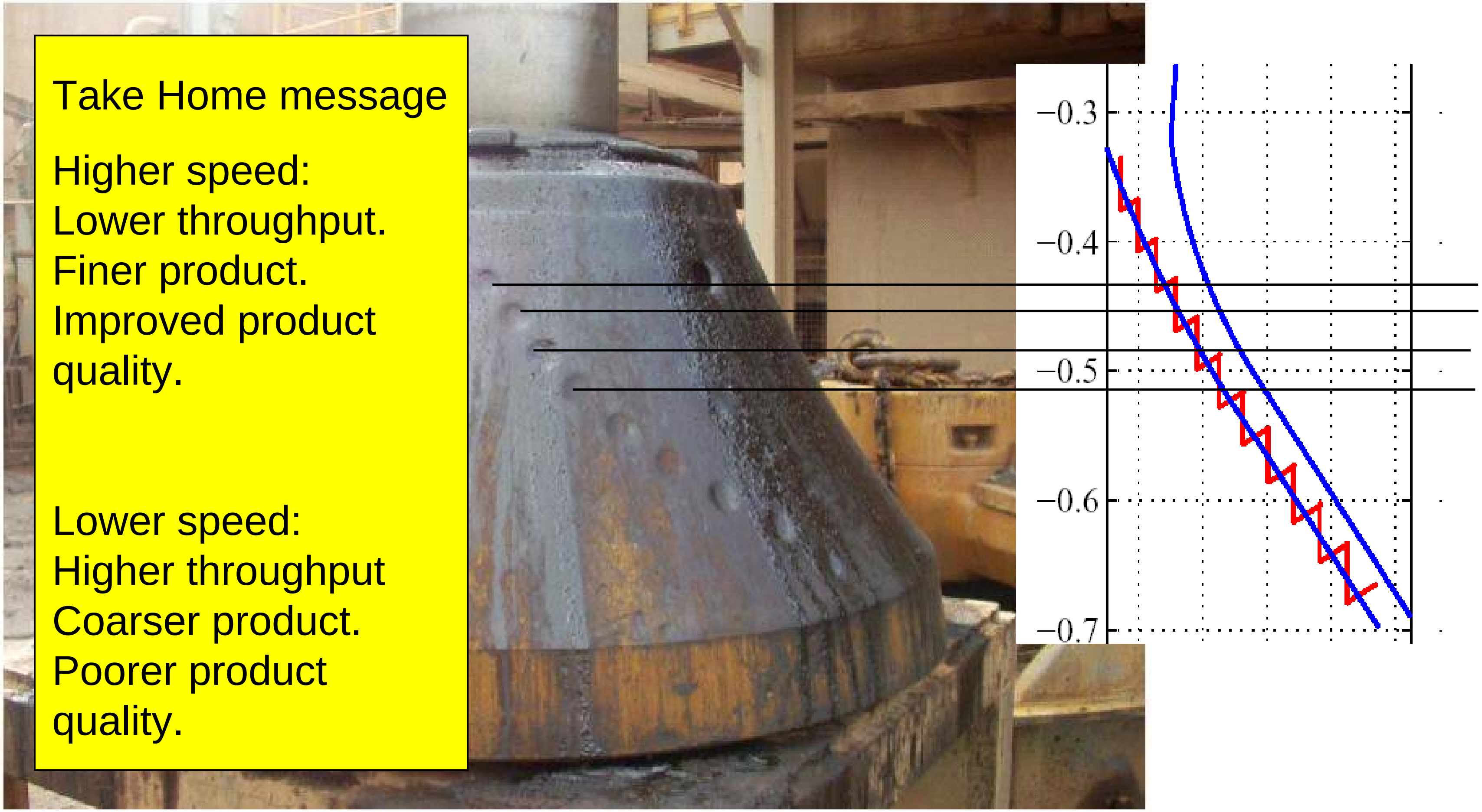
QUARRY ACADEMY

Practice prooves theory!

Take Home message

Higher speed:
Lower throughput.
Finer product.
Improved product quality.

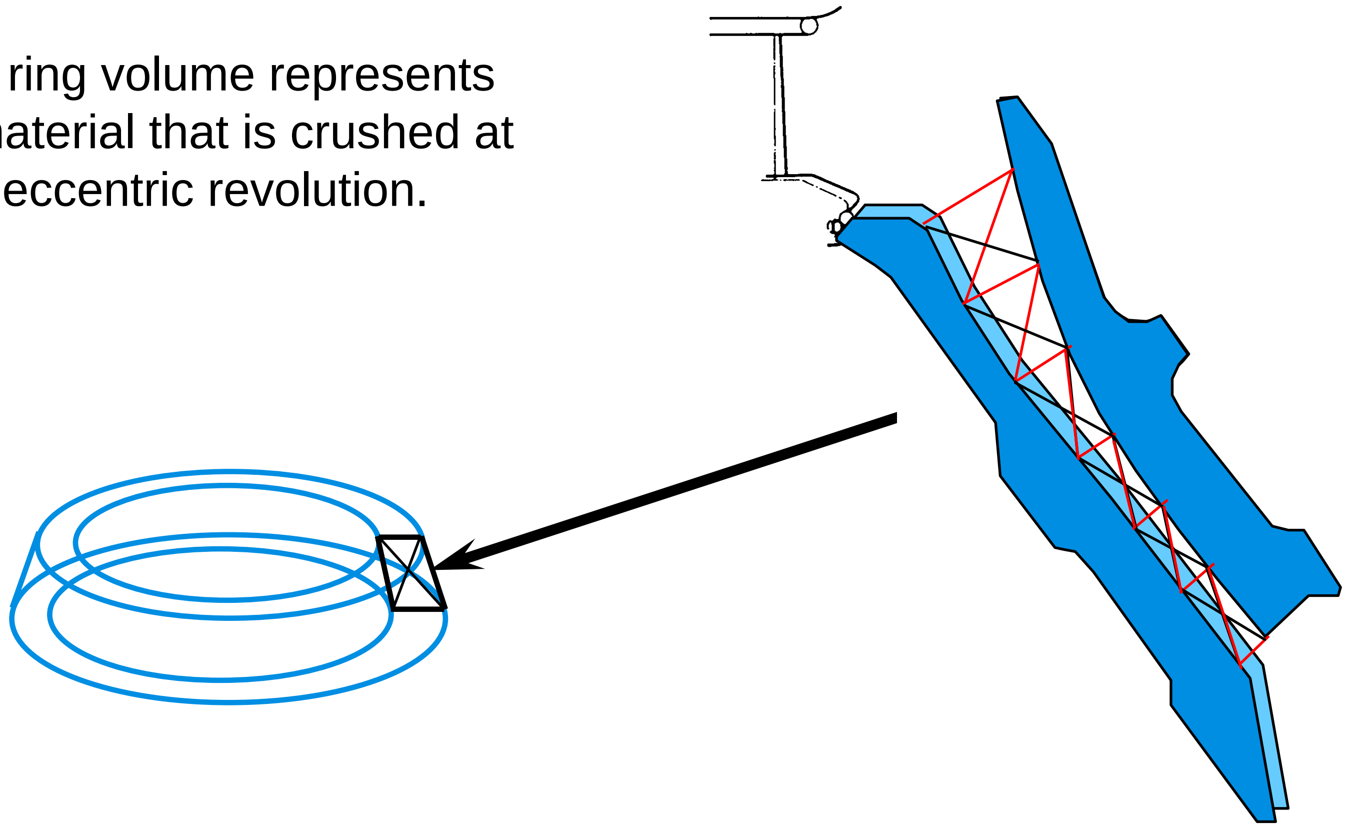
Lower speed:
Higher throughput
Coarser product.
Poorer product quality.



QUARRY ACADEMY

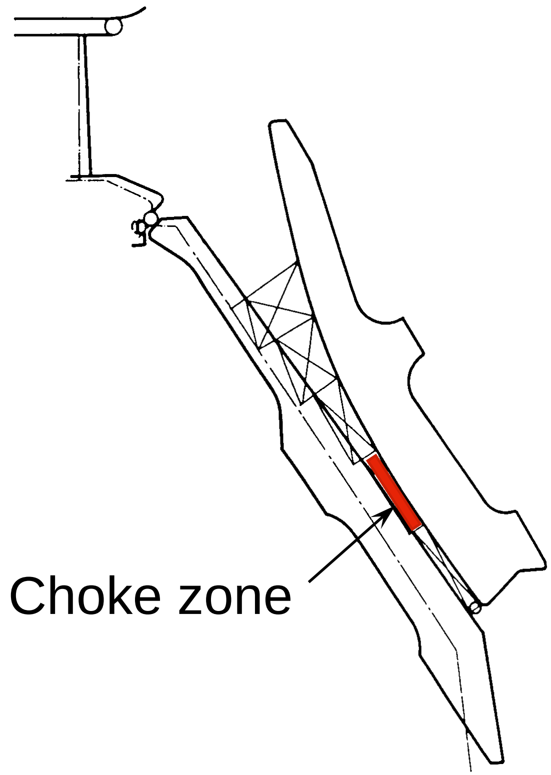
Each stage is represented by a crushing zone

Each ring volume represents the material that is crushed at each eccentric revolution.



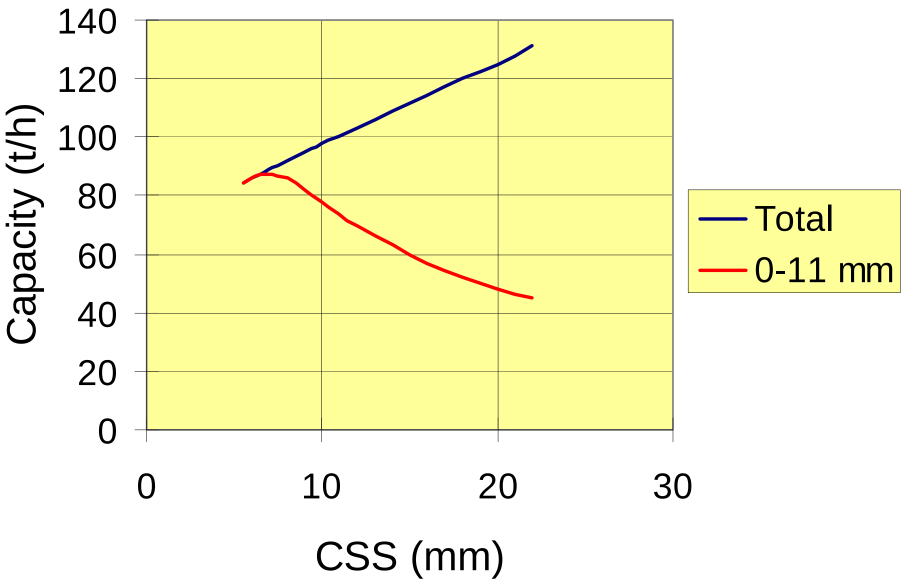
QUARRY ACADEMY

The zone with the smallest volume determines the capacity



The capacity is volumetric

Reduced C.S.S.: Increased net capacity



Small volume reduction in feed zone ➔ small total capacity reduction
Much smaller volume in discharge zone ➔ high size reduction ratio

Note: Capacity - C.S.S. relation is approx. linear

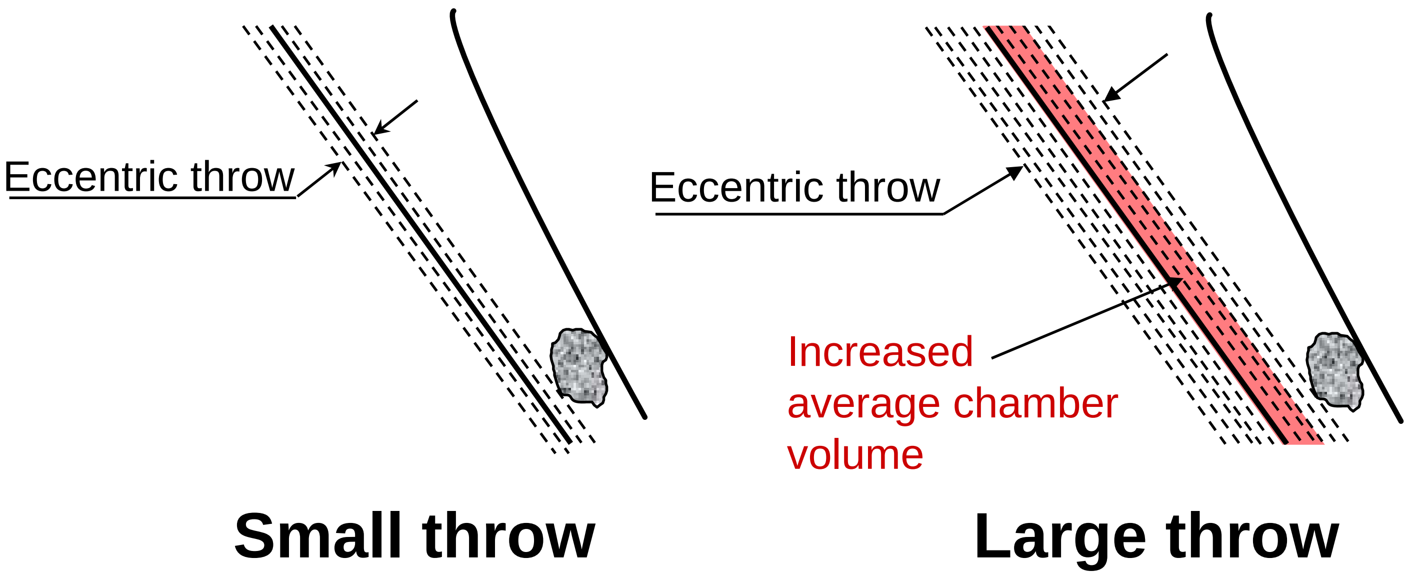
QUARRY ACADEMY

Reduced C.S.S.: Consequence map

C.S.S. reduction

QUARRY ACADEMY

Increased throw: Larger chamber volume



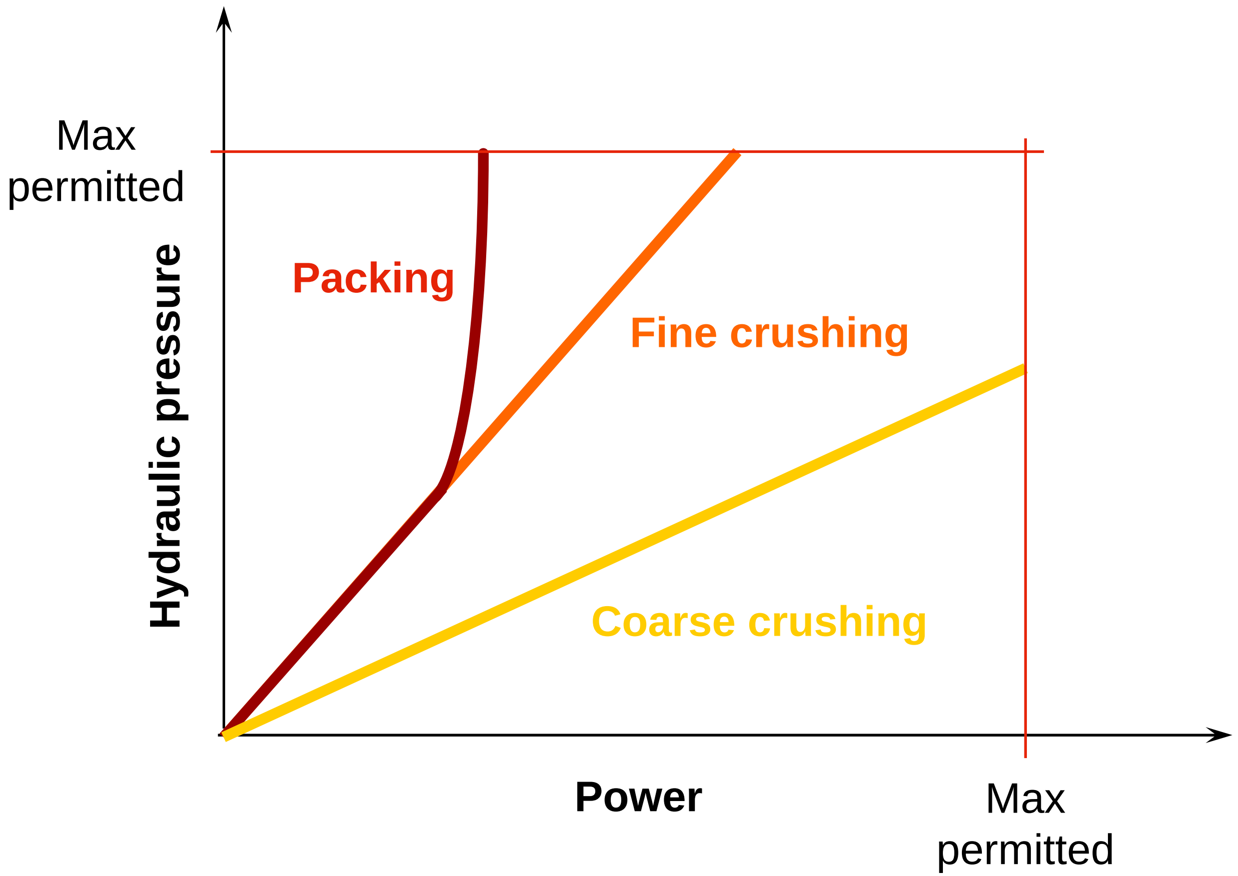
Increased throw resulting in increased chamber volume means

- **higher capacity**
- **more stones in the chamber to compress**

QUARRY ACADEMY

Increased throw: Consequence map

Relation between power and pressure



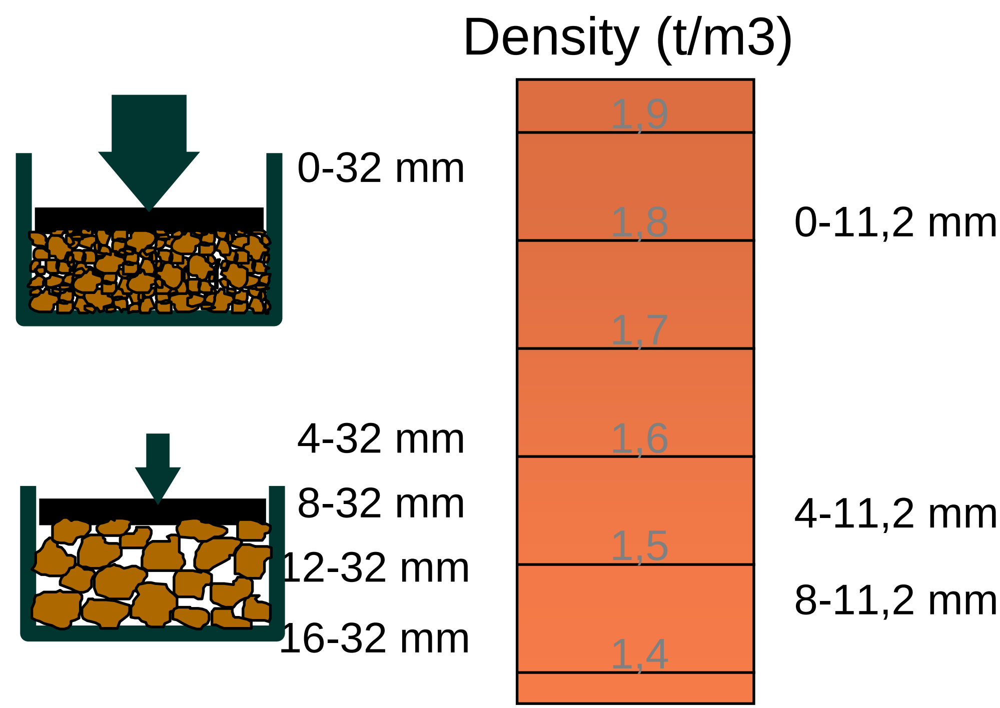
Power & pressure are a reflection of the crushing force

QUARRY ACADEMY

What happens if the feed size changes ?

Smaller feed size ➔ Capacity up
Finer product
Better shape

Bulk density increases - higher risk of packing as feed becomes finer.



QUARRY ACADEMY

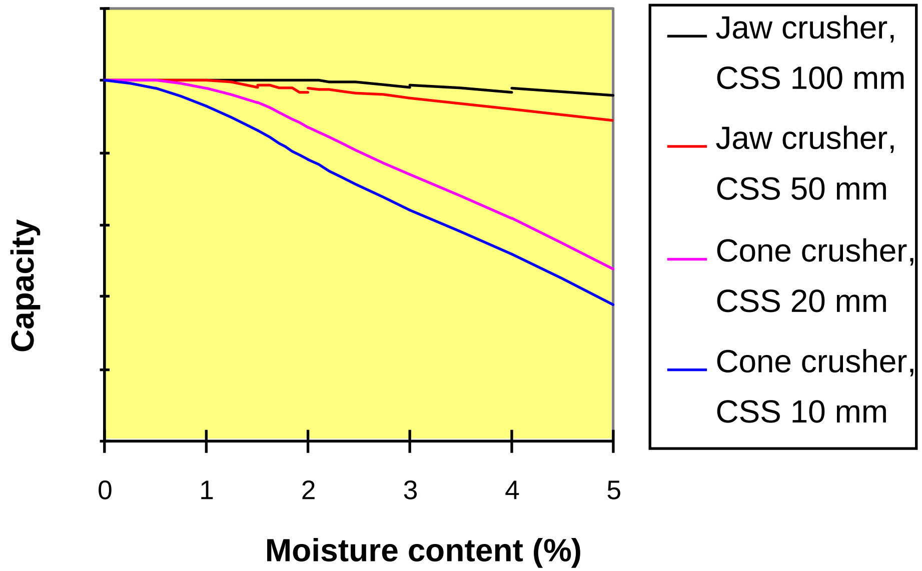
What happens if other feed characteristics change?

Tougher rock

- Increased crushing force and power draw
- Coarser product size

Increased moisture content

- Lower capacity



What happens if other feed characteristics change ?

Higher density ➡ Higher capacity

Improved feed particle shape

More cubical
Rounder shape ➡ Faster flow ➡ Higher capacity

QUARRY ACADEMY

Crushing General

Take Home Messages

1. Do you have the optimum chamber fitted to your crusher

2. Where available, do you have the optimum throw

   1&2 are volumetric issues and may well determine the utilisation of the crusher ---remember all crushers work best when continuously choke fed

3. Do you have the crusher setting optimised.

4. Is the feed condition correct—have you removed the risk of packing

5. Do you have the optimum speed

QUARRY ACADEMY

Operating principles

The crushing result is difficult to predict

Input parameters

Crushing result

	Chamber size	Chamber design	Eccentric speed	Eccentric throw	Setting (CSS)	Feed material strength	Feed size	Feed shape	Feed moisture content
Capacity	X	X	X	X	X		X		X
Power consumption	X	X	X	X	X	X	X	X	X
Crushing force	X	X	X	X	X	X	X	X	X
Product size	X	X	X	X	X	X	X	X	X
Product shape		X	X	X	X	X	X	X	
Product strength	X	X	X	X	X	X			

X = Interdependency

Influencing factors

Take Home Message

All crushers have a volumetric and a mechanical limit.

Toughness of material, feed material grading analysis ,volume and reduction ratio all play their part in the ability of the crusher to perform the duty over an acceptable lifecycle.

If any combination of these factors overstress the mechanical capability of the crusher it will be necessary to reduce the influence of another.

EG -The demand for greater throughput at the expense of reduction.

QUARRY ACADEMY

Conclusions

- the work done in a crusher is dependant on

- material factors such as

1. toughness,
2. bulk density
3. feed size analysis

- machinery factors such as

1. setting
2. throw
3. chamber volume
4. speed

Take Home Message

There are so many variables that to maximise performance it is necessary to understand how these factors and any consequent wear affect the end result.

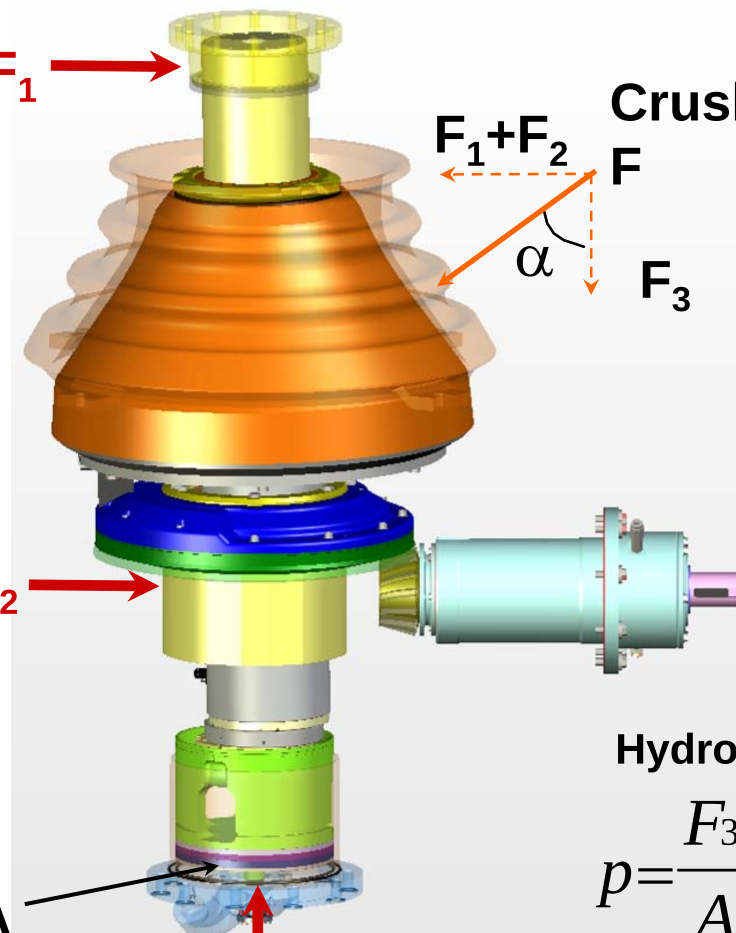
This can only be done by in-process testing.

Problems

Some areas of concern which destroy good operation with cone crushers

Cone crusher

Pressure Reflects Crushing Force

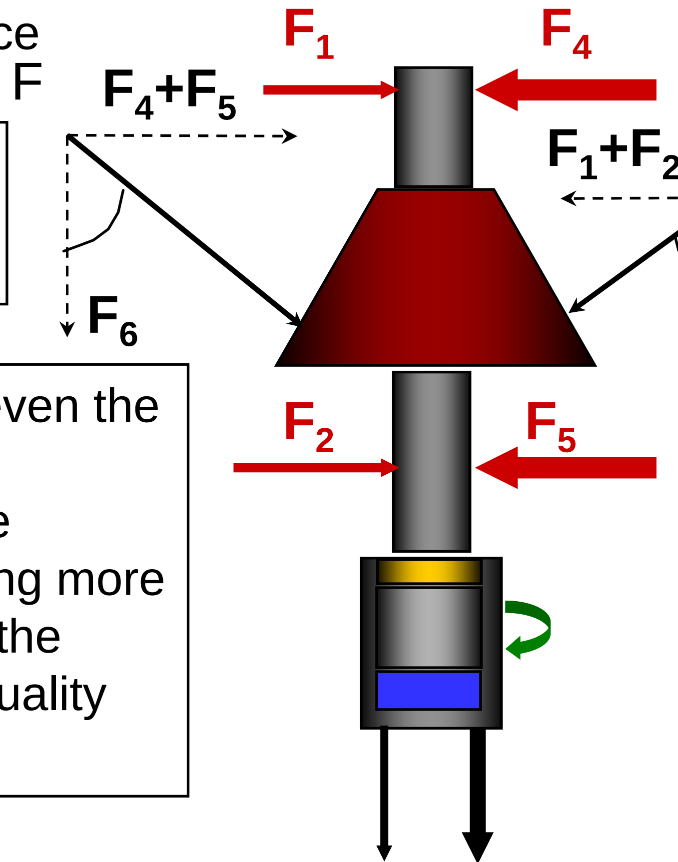


Hydroset pressure

$$p = \frac{F_3}{A} = \frac{F \cdot \cos a}{A}$$

i.e. proportional to F

Reaction to uneven, segregated feed



F4 +F5 > F1+F2

F3< F6

As wear becomes uneven the power and pressure fluctuation will become exaggerated, the setting more difficult to control and the product grading and quality will deteriorate.

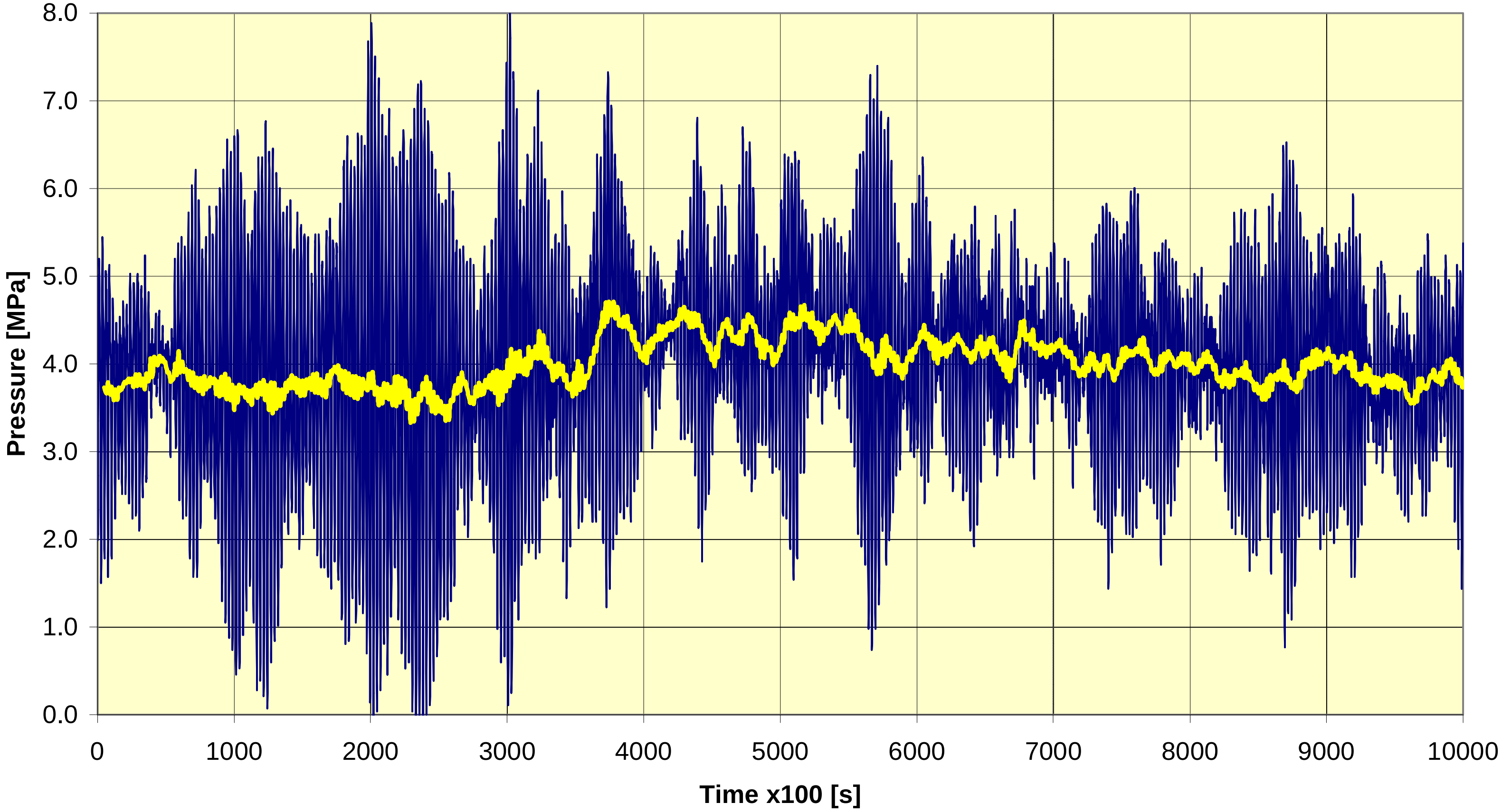
Throughout every revolution both power and pressure will fluctuate considerably, causing extreme cyclic stress on machine component parts. This will require the setting to be run wider than necessary

Zero reaction at any point during the revolution will suggest a portion of the chamber is empty

QUARRY ACADEMY

Misaligned feeding at El Teniente,Chile CH880
Tertiary application

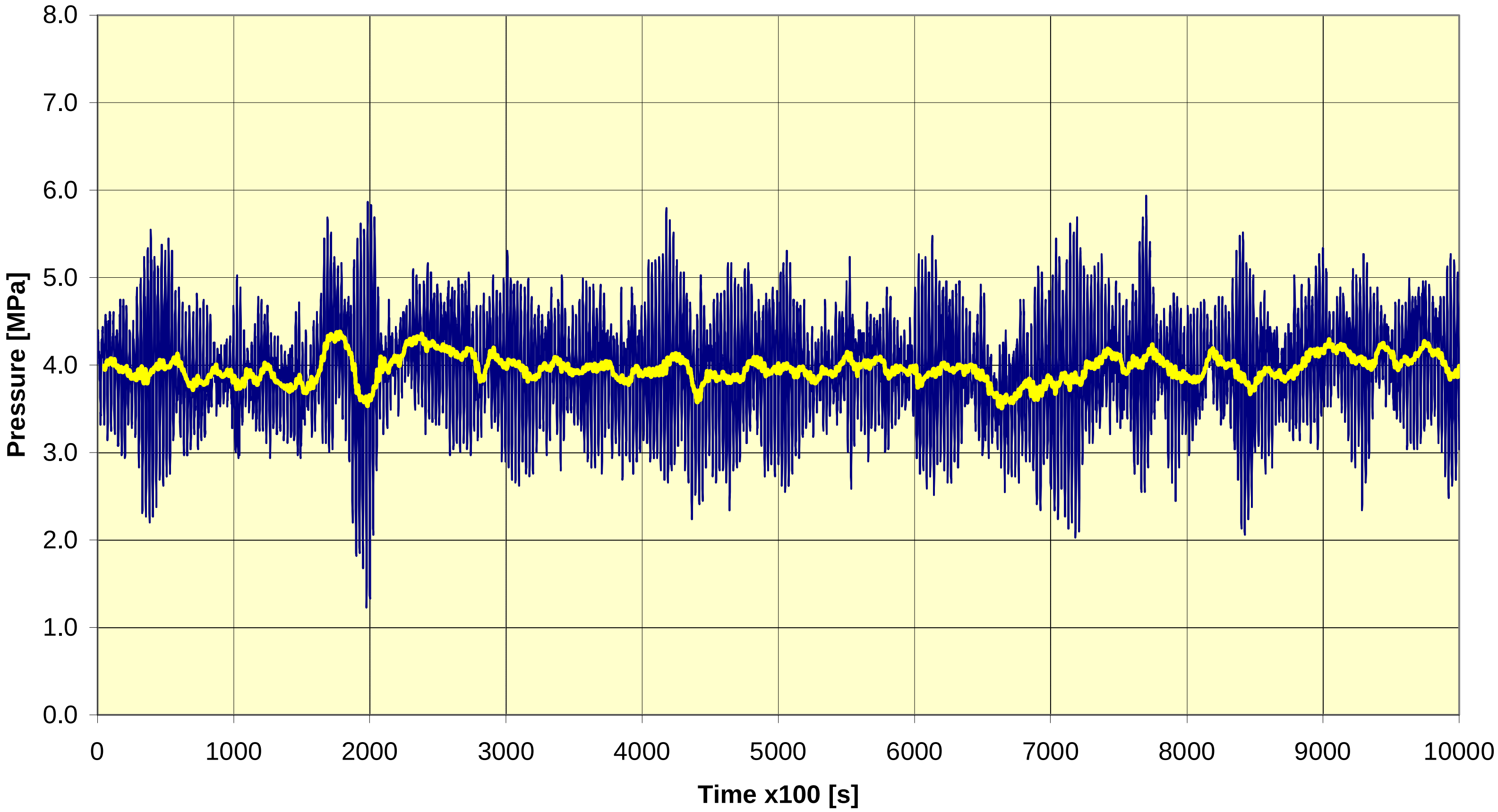
Segregated feed- High pressure amplitudes



QUARRY ACADEMY

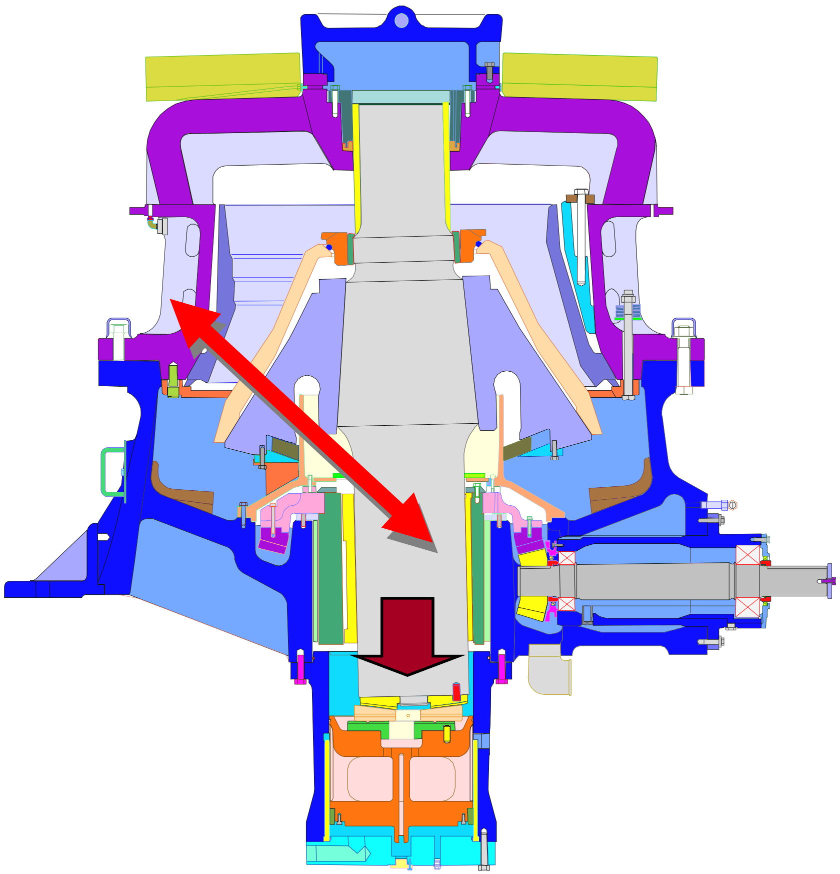
Improved segregation

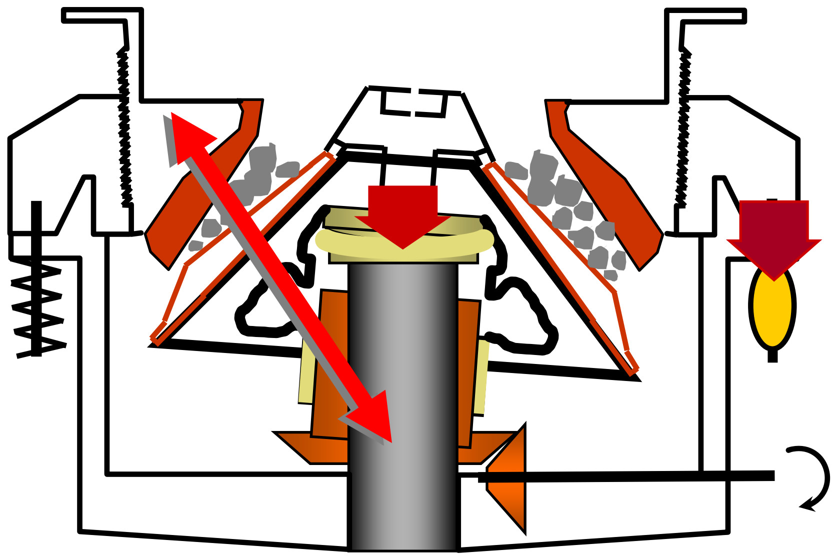
Unsegregated feed- Low pressure amplitudes



QUARRY ACADEMY

Effects of vertical crushing force





Vertical force taken by single hydraulic cylinder

Vertical force taken by cylinders used to hold topshell to bottomshell

QUARRY ACADEMY

What are the negative effects?

- High power and pressure will cause the crusher to be run at wider than necessary settings resulting in coarser product producing higher recirculating loads with increased conveying, wear and crushing costs. Energy costs /ton of product will significantly increase
- Occasionally the necessity for increased crushing will demand increased capital investment**.**
- Segregated and poorly distributed feeds will cause the crusher liners to wear unevenly,again with deteriorating performance and associated costs.
- This applies also to poorly fed HSI crushers where hammer wear and curtain liner wear is biased to one side.

QUARRY ACADEMY

What are the negative effects?

- Product will become coarser and cubicity, often in critical products, will deteriorate**.** What cost??

- Segregation and uneven wear will cause reduction in liner life through premature exchange**.** What cost??

- Segregation and uneven wear will cause reduction in mechanical component life, sometimes leading to traumatic failure and the costs of unplanned stoppages.

- THE CUMMULATIVE EFFECT **-----** CONSIDERABLE COST TO THE OPERATION.

QUARRY ACADEMY

Poor feeds-Inclined belt conveyors

A common feed method, but unless considerable care is taken,possibly the most unsatisfactory method of feeding cone crushers.

- Material is segregated by the “tamping” action of the idler sets as material passes over.

- Belt speed.

1. Material leaving the end pulley follows a parabola. The path depends on the speed of the belt.
2. Coarse material, with greater mass, will tend to travel further than finer material.
3. This segregation will become more pronounced the greater the differential size and the higher the conveyor speed.

- Belt width. Improvement in materials and restrictions on capital investment have possibly created a trend towards narrower but higher speed belts. These not only segregate but lack the capability to distribute sufficiently.

- Discharge height.

QUARRY ACADEMY

Wear profiles

QUARRY ACADEMY

Wear profiles

QUARRY ACADEMY

www.quarryacademy.com

QUARRY
ACADEMY

LIGHTEN UP!