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2020 IAAP Convention
Aggregates 101

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What is Aggregate?

1. Aggregate is a material or structure formed from a loosely compacted mat of fragments or particles.

2. Aggregate is a broad category of coarse to medium grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates.

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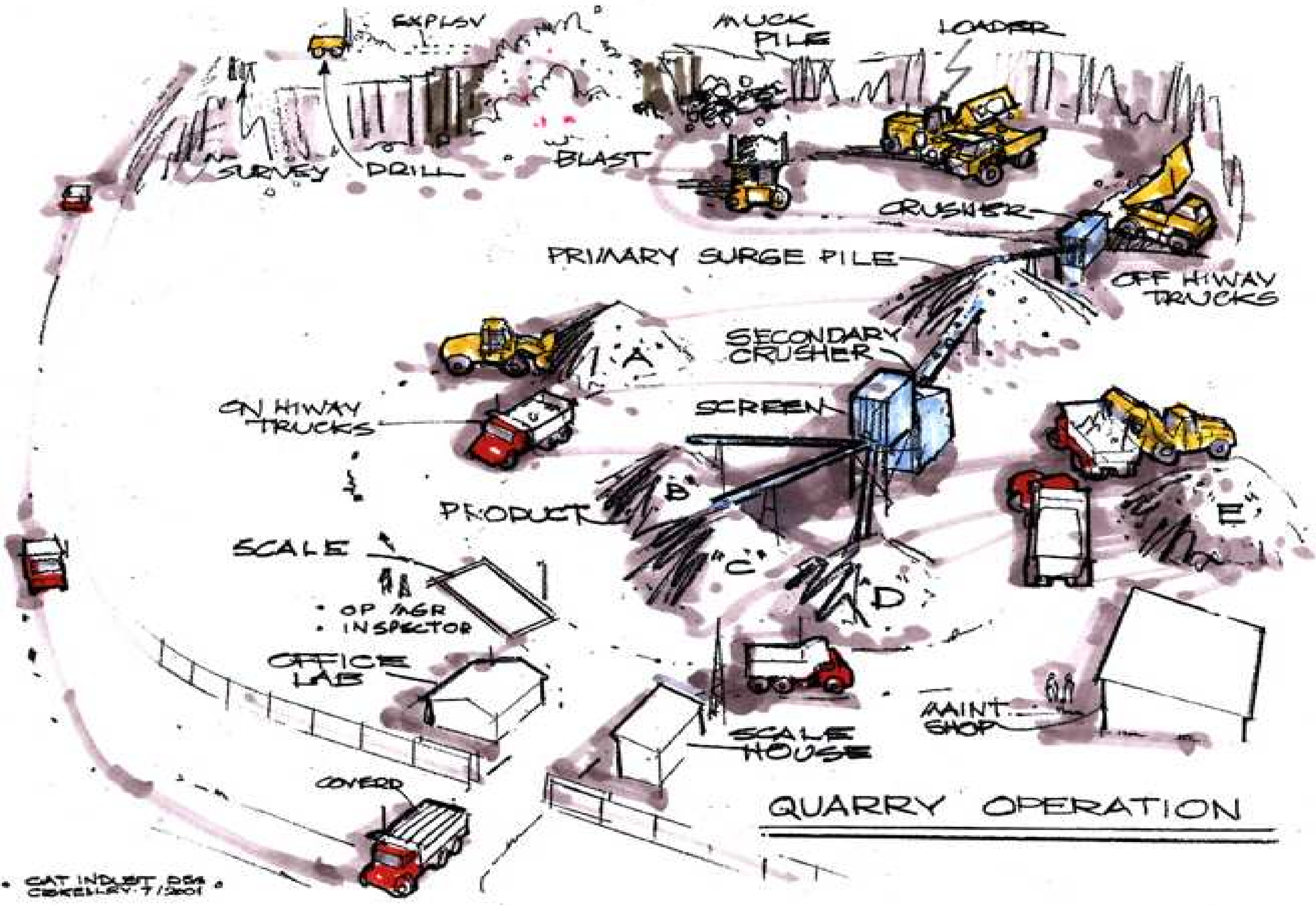
End Use

Geology

Production Methods

Testing for Characteristics


EXPLSV
MUCK PILE
LOADER
SURVEY
DRILL
BLAST
CRUSHER
PRIMARY SURGE PILE
OFF HIWAY TRUCKS
SECONDARY CRUSHER
"A"
ON HIWAY TRUCKS
SCREEN
"B"
PRODUCT
"C"
"D"
"E"
SCALE
• OP MGR
• INSPECTOR
OFFICE LAB
SCALE HOUSE
MAINT. SHOP
COVERD
QUARRY OPERATION
CAT INDUST DSG
CBKELLEY 7/2001

End Use

End use determines the characteristics demanded in the aggregate used

End Use

- Highway Construction/Maintenance
- Building Construction
- Agricultural/Manufacturing Uses
- Specialty Uses
- Decorative Uses

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Highway Construction/Maintenance

- Concrete Pavements/Etc.
- Hot Mix Asphalt
- Seal Coat/Cover Coat
- Granular Base, Subbase, Shoulder
- RipRap, Erosional Protection

Building Construction

- Concrete Floors and Walls
- Concrete/HMA Driveways and Parking Lots
- Concrete Sidewalks, Curb and Gutters, Medians
- Footings
- Granular Fill
- Drainage Systems

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Agricultural/Manufacturing Uses

- Agricultural Limestone
- Paints, cleaners, toothpaste, etc.
- Fillers of All Kinds
- Flux Stone

Specialty Uses

- Golf Course Sand
- Sewage Treatment Filter Stone
- Sand Blasting
- Recreational Sand

Decorative Stone

- Facing for New Buildings
- Fence Use
- Landscaping

Highway Construction/Maintenance

- Concrete Pavements/Etc.
- Hot Mix Asphalt
- Seal Coat/Cover Coat
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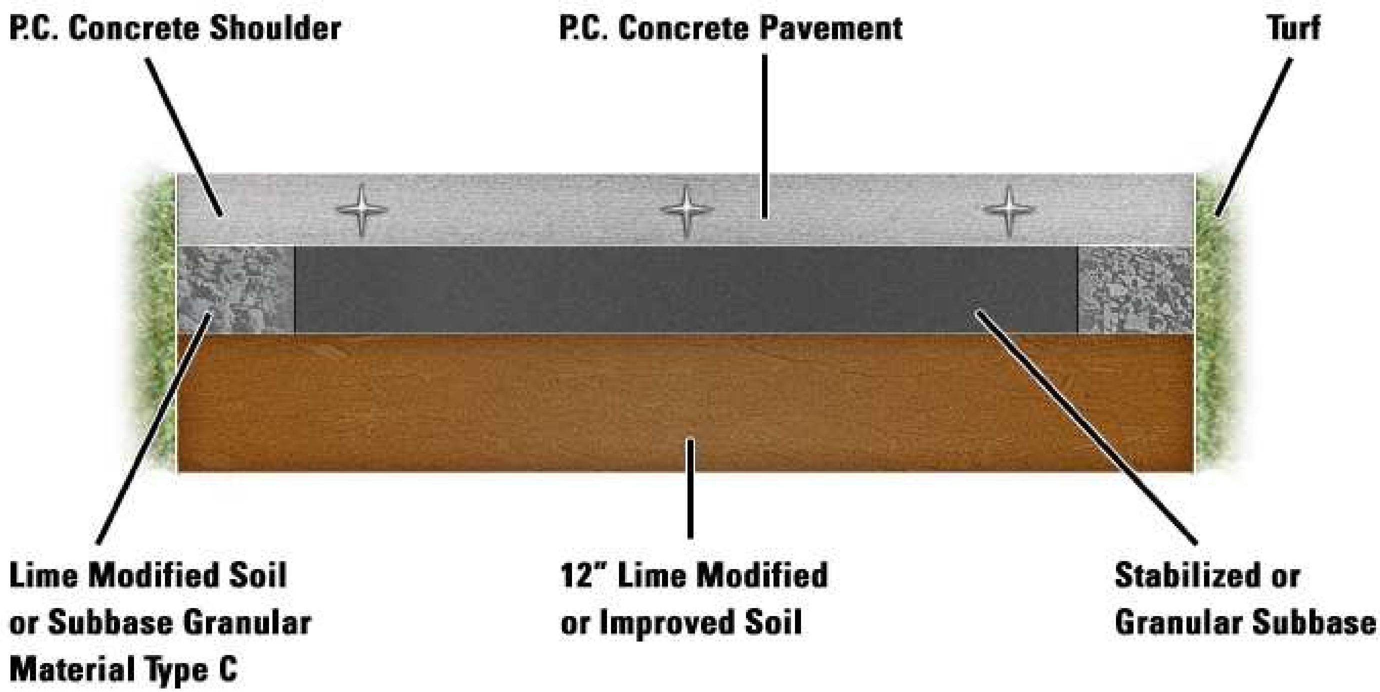
Concrete Pavements



74
JOHNSON
H2O
MAY 13 2004

Extended Life Concrete Pavements

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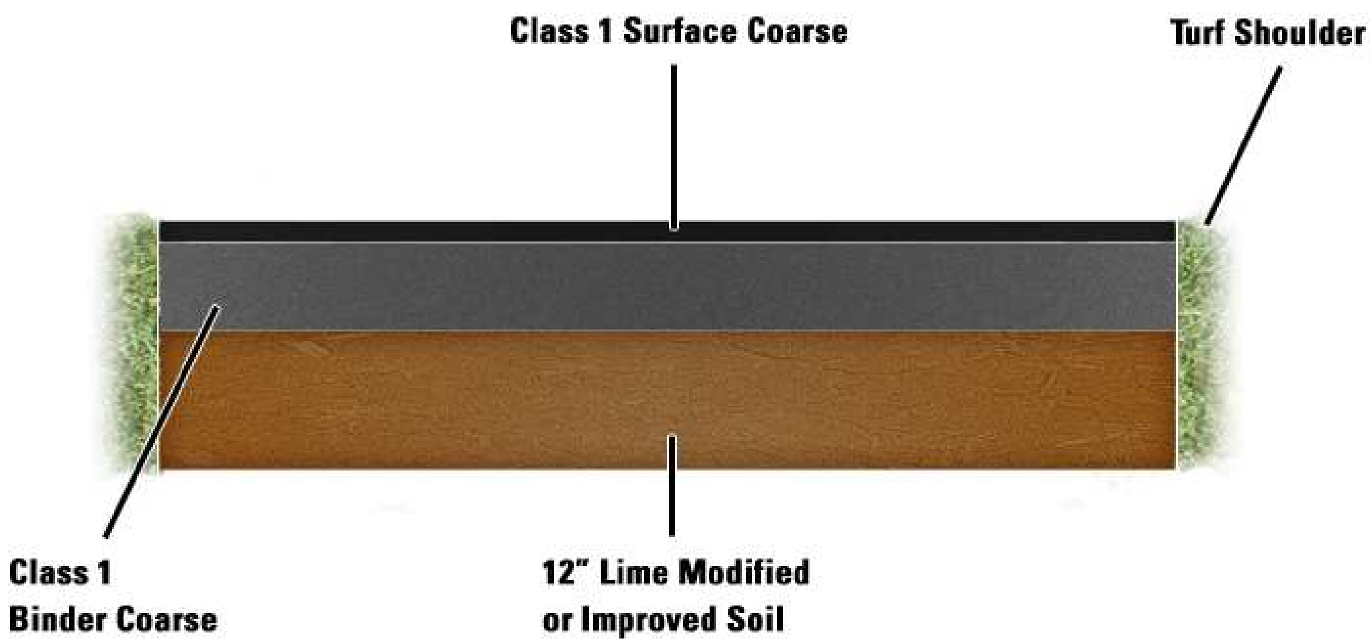
HMA Pavements




8
7
6
5
4
3
2
1

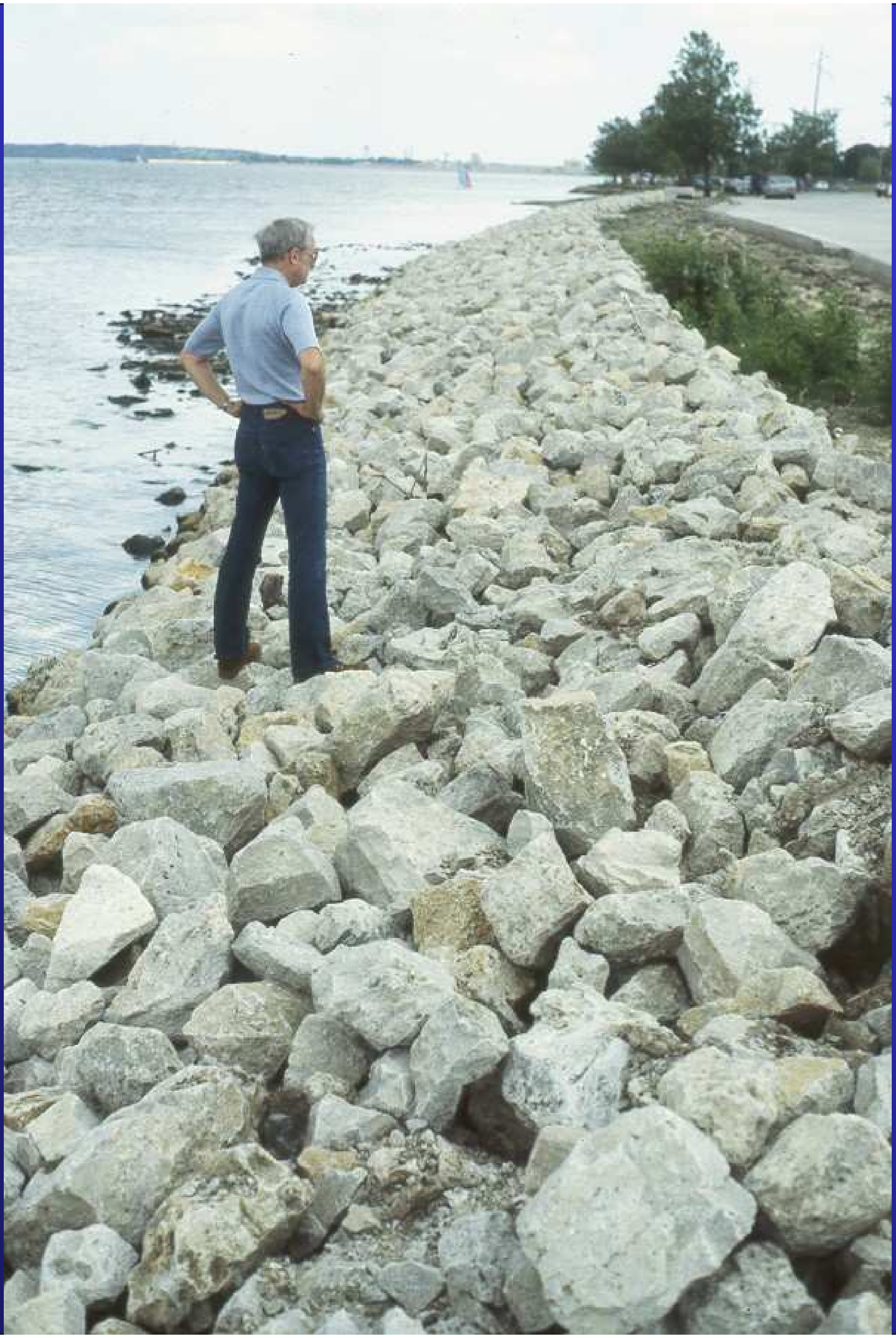

STOP

- Super pave
- Perpetual Pavements

Seal-Cover Coats

Granular Base, Sub Base, Shoulder, Aggregate Surfacing

Rip Rap



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End Use

End use determines the characteristics demanded in the aggregate used

Characteristics

Quality

- Durability
- Concrete Durability
- Toughness
- Deleterious Particles
- Organic Impurities

Physical/Chemical

- Gradation
- Specific Gravity/Absorption
- Unit Weight
- Friction Potential
- Calcium Carbonate Equivalence

Geology of Aggregate

The basic geology of the sand, gravel, or rock being extracted / quarried plays an important part in how an aggregate source would extract the material and produce a quality product with the necessary characteristics for various uses.

AGGREGATE GEOLOGY

- SAND and GRAVEL
- CRUSHED STONE
- Both products are completely different

Sand and Gravel Geology

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Sand and Gravel

Heterogeneous Mixture of Rock Types

* Igneous

* Metamorphic

* Sedimentary

SAND AND GRAVEL

GLACIAL DEPOSITS

- **Valley Glaciers**
- **Piedmont Glaciers**
- **Continental Glaciers**

FLUVIAL (RIVER) DEPOSITS

- **Bar deposits**
- **Over bank/flood-plain deposits**

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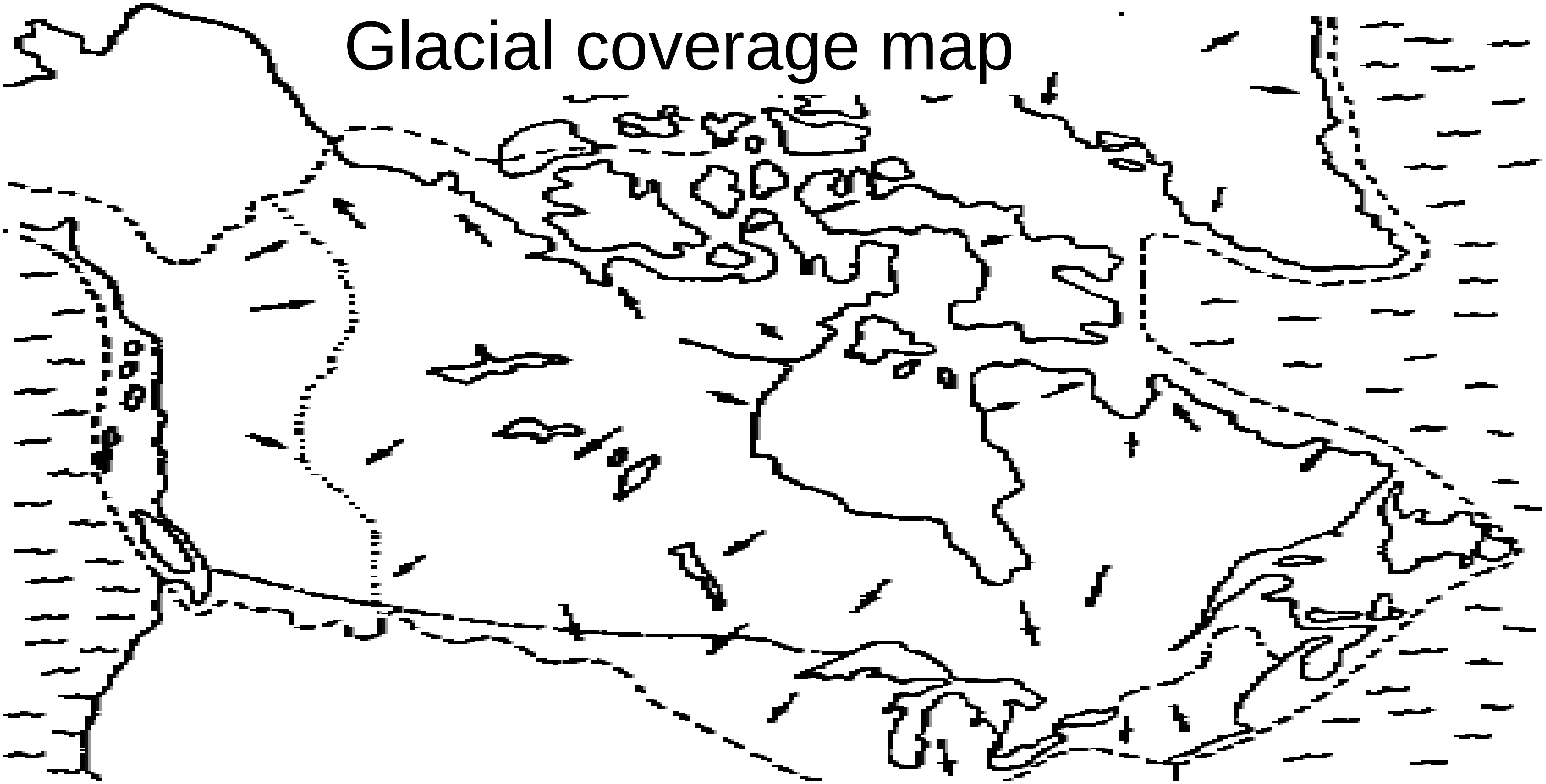
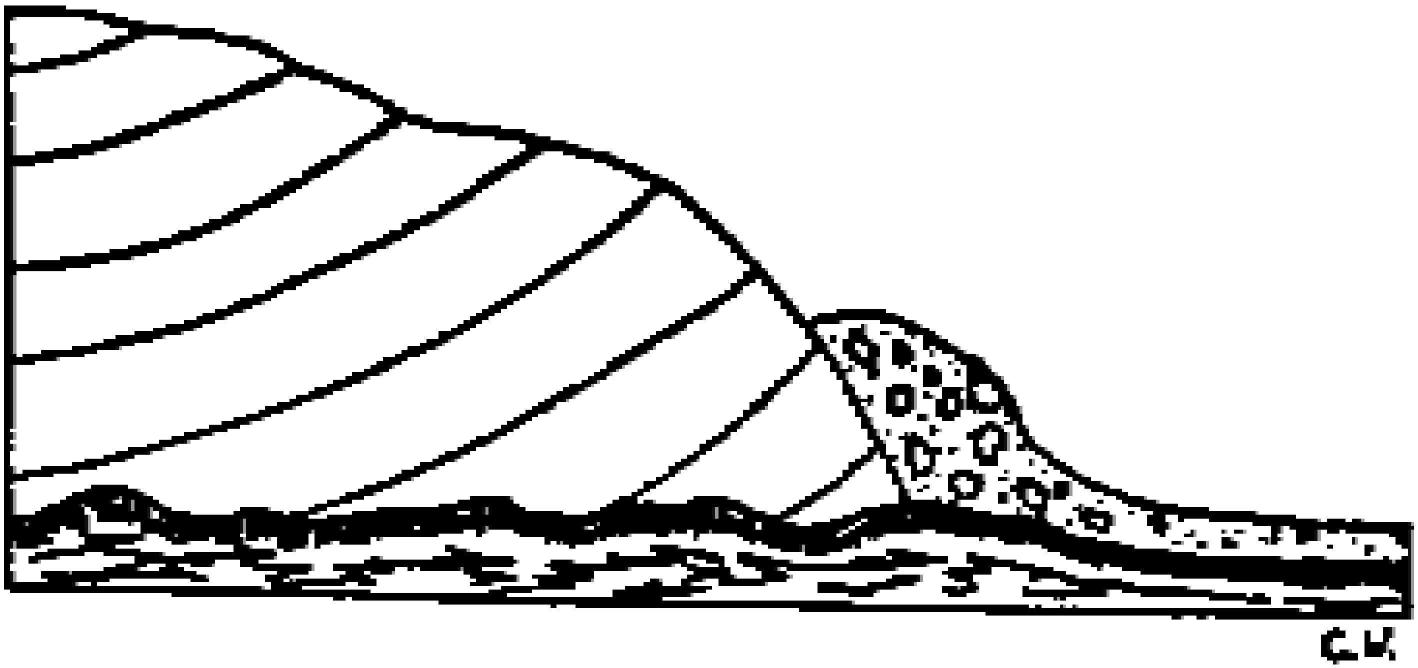
Glacial coverage map



Large sheets of ice, up to 1 mile thick, changed the landscape. They covered hundreds of thousand square miles of land. Chicago was covered by a 3000’ thick glacier 20,000 years ago. They originated in the north-most areas of Canada.



Glacier action - Bulldozer

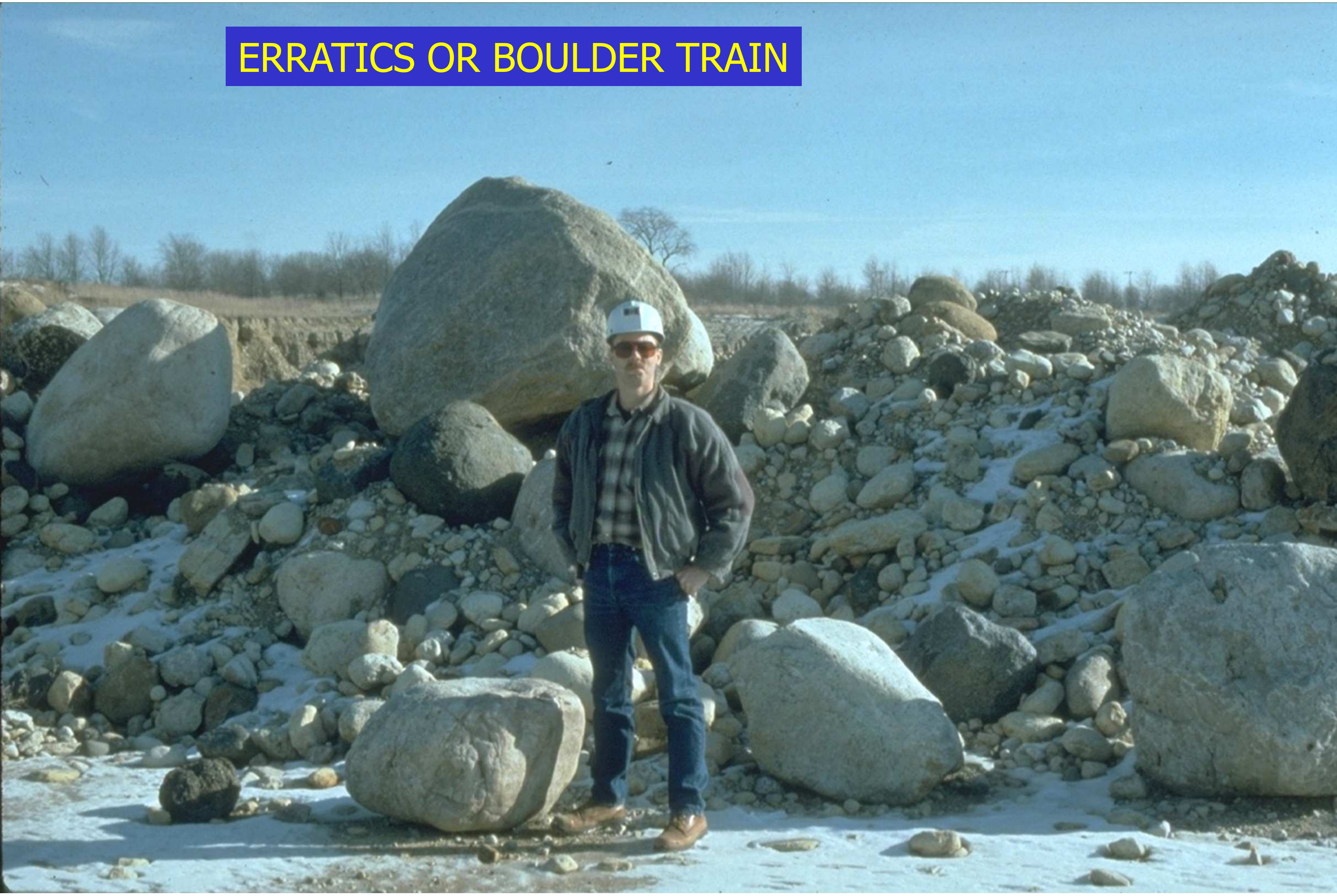
UNSTRATIFIED DRIFT (GLACIAL)

STRATIFIED DRIFT
(Melt waters, water sorted) (classifiers)

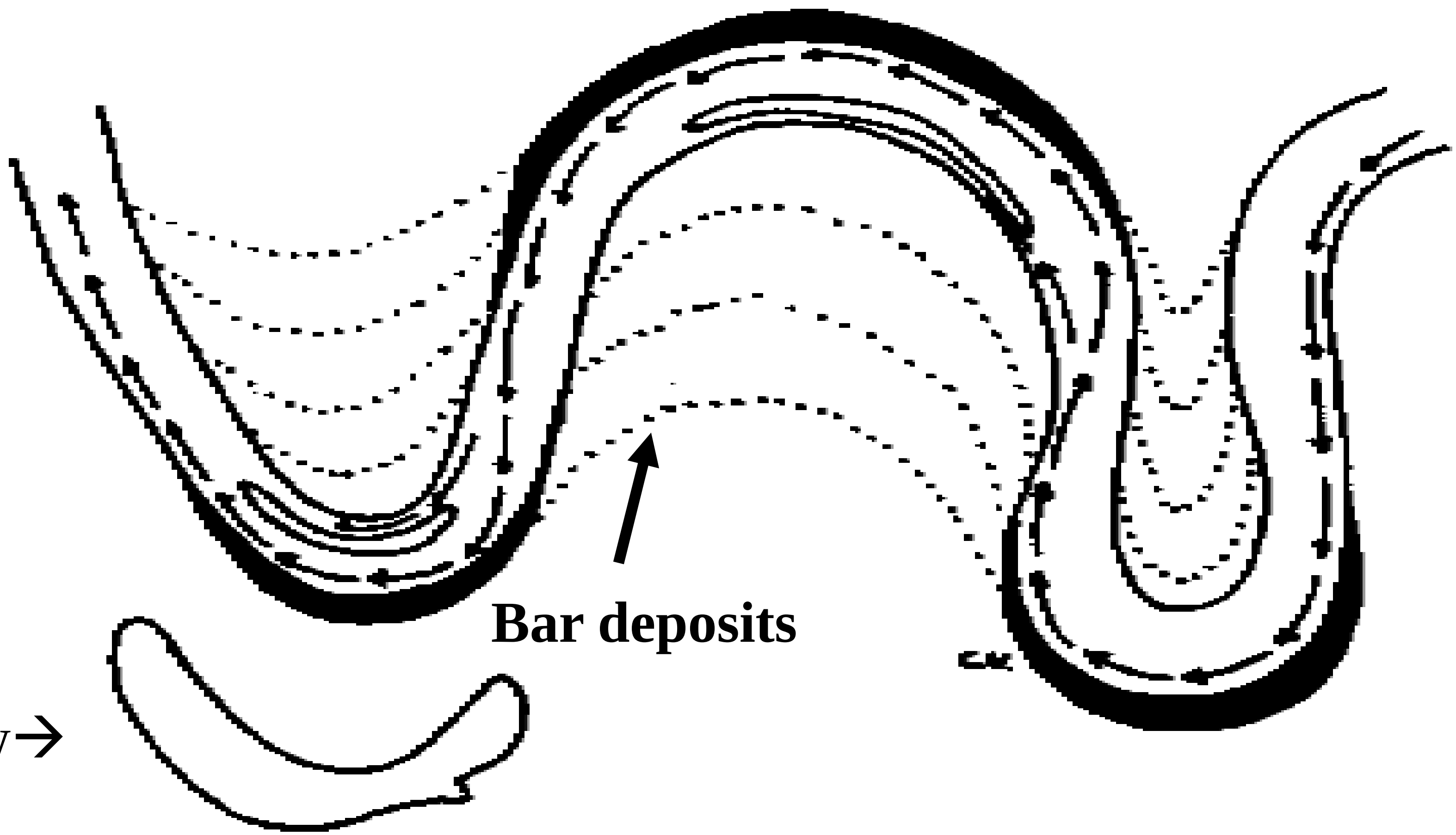
- **For most glacial gravels, 50% of rock originated from beyond 100 miles (Canada) and 50 % within 100 miles**

- **Farther south you go, the finer the gravels tend to be.**

- **Southern Illinois was the furthest south any glaciers came in North America.**


ERRATICS OR BOULDER TRAIN

Fluvial (river) deposits (deposits that have been reworked, resorted, transported and re-deposited downstream)



Oxbow→

Levies have built in the last 50 years to help control rivers

Characteristics of sand and gravel deposits can be broke into 3 areas:

Size Distribution
Sorting
Mineral Composition

Stratified Drift –
Very Little Clay or
Muck

Unstratified Drift - Full of Clay & Muck

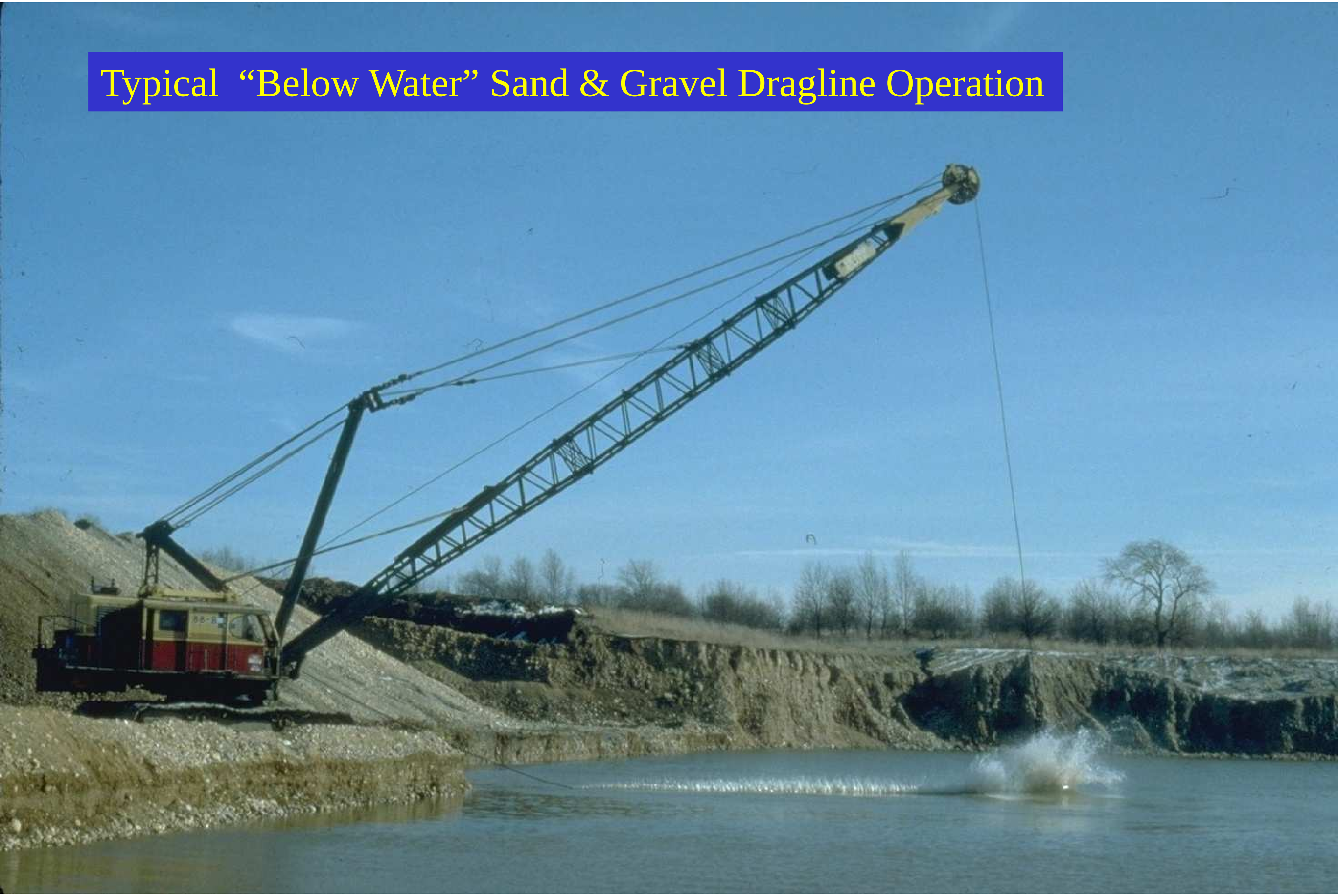
Below or Above Water Deposits

Gravels can be mined from both kinds of deposits which have both good and bad attributes

Below-Water Gravel Deposits

- Mined below-water
  - gray in color
  - exposed to less weathering (oxidation)
  - typically a better quality of material
  - usually cost more to mine
  - draglines or dredges must be used

Typical “Below Water” Sand & Gravel Dragline Operation



A Typical Dredging Operation (“Wet” Operation).

Above-Water (Dry) Gravel Deposits

- **usually brown to reddish brown in color**
- **exposed to more weathering (oxidation)**
- **reduces the quality**
- **contains more deleterious materials**
- **an exception is the larger carbonate gravel deposits**
- **usually has a lower cost to mine**

A major problem with ‘dry’ deposits is that they can have inconsistent qualities - mixing with ‘wet’ deposits is not recommended

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Loading Out Of A Dry Pit With Backhoe And Truck


Dry 'Above
Water' Deposit

Examples of Deleterious Rock Types in Sand and Gravel

- Chert
- Limonite
- Ocher
- Weathered Rock
- Coal
- Lignite
- Shale
- Clay Lumps

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Crushed Stone Geology

Crushed Stone

Homogeneous
Rock Type

* Igneous

* Metamorphic

* Sedimentary

- Igneous rocks (formed by heat)
  - **mafic**
  - **weathered mafic**
  - **coarse felsic**
  - **weathered coarse felsic**
  - **fine felsic**
  - **massive quartz**

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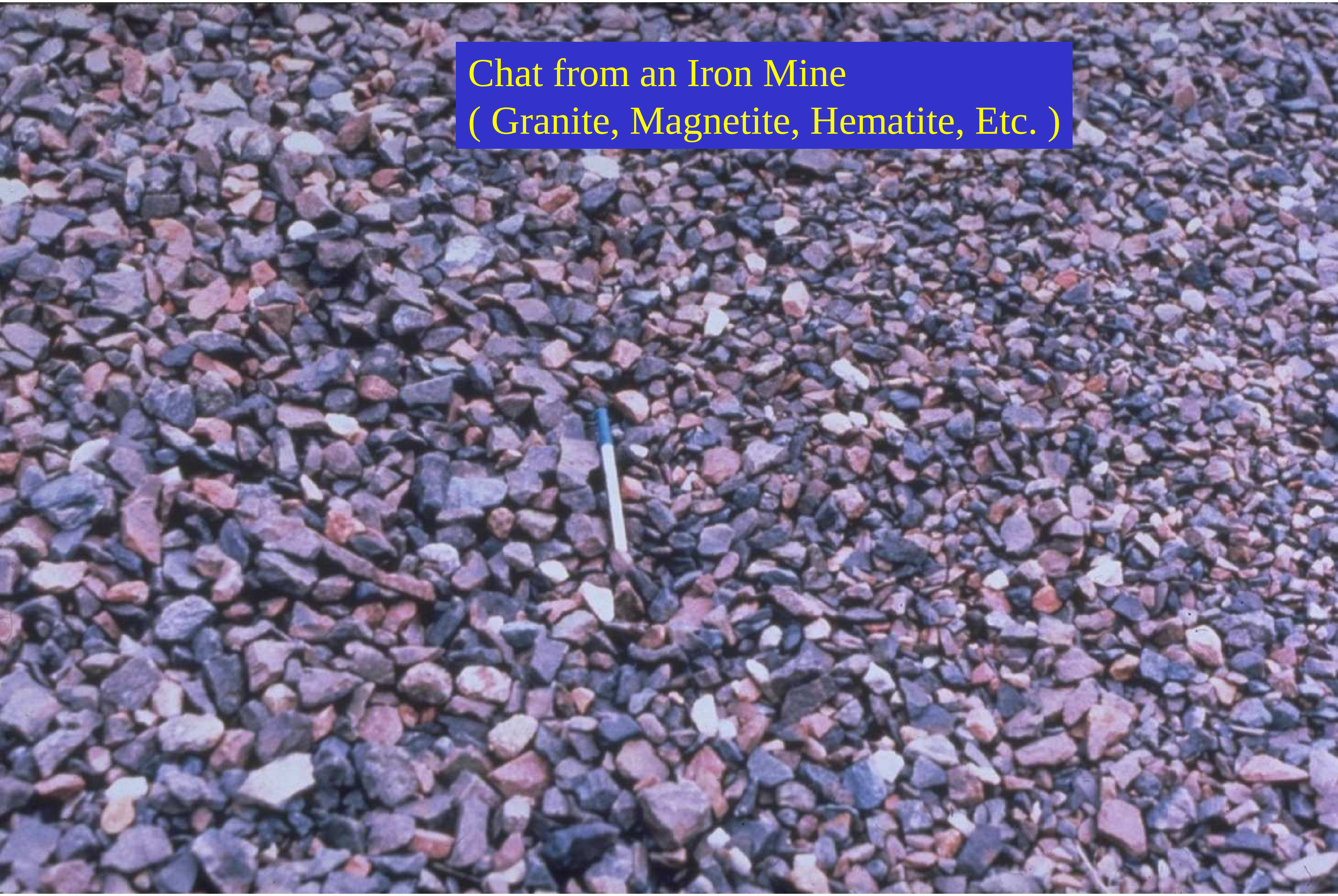
Rhyolite


Chat from an Iron Mine
(Granite, Magnetite, Hematite, Etc.)

- Metamorphic rocks (changed by heat/pressure such as slate, etc.)
  - **gneissic**
  - **weathered gneissic**
  - **schistose**
  - **weathered schistose**
  - **metasedimentary**
  - **weathered metasedimentary**
  - **metagraywacke**
  - **tillite**
  - **quartzite**

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- **Sedimentary rocks** **(material that fell out of suspension or crystallized by animal/plant life)**

dolomite	**ironstone**
laminated carbonate	**shale**
silty carbonate	**sandstone-siltstone**
pyitic carbonate	**limestone**
cherty carbonate	**weathered carbonate**


Limestone


Dolomite

Textural Characteristics of Rock

Defined as the kind, size, shape, & arrangement of component particles making up a rock, such as:

Fossils **(skeletons of animals or plants, etc.)**

Oolites **(spheres of quartz surrounded by calcite matrix)**

Crystallinity **(arrangement of mineral grains or crystals)**

Grain Size **(according to grain size diameter)**

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Examples of Deleterious Rock Types for Igneous Rock

Rock with Large Crystals, Poor Crystalline Bond, Weaker Veins Within the Parent Rock, Weathered Rock

These rock types will affect the quality of igneous aggregates for certain uses.

Examples of Deleterious Rock Types for Metamorphic Rock

Rock with Weaker Mica Layers Within the Parent Rock, Weathered Rock, Partially-Metamorphosed Rock

These rock types will affect the quality of metamorphic aggregates for certain uses.

Examples of Deleterious Rock Types for Carbonate Rock

- In many cases, impurities were trapped in carbonate rock as it was formed.

- Chert, Clay, Shale, Pyrite, Weathered Particles, Argillaceous Particles, etc.
- These rock types will affect the quality of carbonate aggregates for certain uses.

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Weathering

- Water / Oxygen / Iron-Rich Minerals
- Wet – Dry Cycles
- Freeze – Thaw Cycles

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3 Rock Types In Order of Use as Aggregate

1. Carbonate
2. Igneous
3. Metamorphic

Carbonate Rock

Carbonate Rock is divided into 2 Major Classes:

- Limestone

- Dolomite

- Limestone ($CaCO_3$)
  - deposited as a lime mud
  - the mud is compacted to create limestone
  - can contain fossils or be all fossils
  - created in shallow seas
  - main material is calcite or calcium carbonate
  - not usually 100% pure due to other impurities

- Dolomite ($CaMg[CO_3]_2$)
  - originally deposited as limestone
  - saturated with magnesium-rich water which replaced some calcium molecules with magnesium
  - similar to a water softener system
  - created from shallow reefs of the limestone seas
  - main material is dolomite
  - usually not 100% due to other impurities

Several State DOTs differentiate Limestone from Dolomite by the amount of magnesium oxide or elemental magnesium it contains:

Illinois	LIMESTONE < 11.0% MgO DOLOMITE $\geq$ 11.0% MgO
Indiana	LIMESTONE < 10.3% Mg DOLOMITE $\geq$ 10.3% Mg

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Limestone

- White to light gray in color but can be dark gray to black depending on clay content or can be tan to brown depending on the iron content
- Sp. Gr. is usually around 2.50 - 2.70
- Hardness equal to a 3 on the Mohs hardness scale or resistance to scratching (1 is soft, talc / 10 is hard, diamond /with quartz (chert) a 7)
- Rapid or violent fizz with hydrochloric acid

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Dolomite

- **White to light gray but can be tan or brown depending on the iron content**
- **Sp. Gr. is usually around 2.70 - 2.80**
- **Hardness equal to a 3 to 4 on the Mohs hardness scale or resistance to scratching (1 is soft, talc and 10 is hard, diamond)**
- **Barely fizz or no fizz with hydrochloric acid**
- **Tends to be more porous appearing**

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Textural Characteristics of Carbonate Rock

Defined as the kind, size, shape, & arrangement of component particles making up a rock, such as:

<u>Fossils</u> **(skeletons of animals or plants, etc.)**

<u>Oolites</u> **(spheres of quartz surrounded by calcite matrix)**

<u>Crystallinity</u> **(arrangement of mineral grains or crystals)**

<u>Grain Size</u> **(according to grain size diameter)**

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Impurities (usually non-carbonate minerals) were trapped/formed in carbonate rock as it was formed

chert, clay, shale, sand particles, pyrite

These impurities affect the quality of the aggregates

Chert

- SiO_2-microcrystalline quartz (similar to glass)
- Found in nodules or layers
- Hardness = 7 (hard to cut, abrasive on equipment)
- Can cause pop-outs in concrete
- Irregular (Specific gravities vary, 2.05 – 2.75)
- Varies (soft, porous, chalky to glassy, angular)
- Can be very colorful

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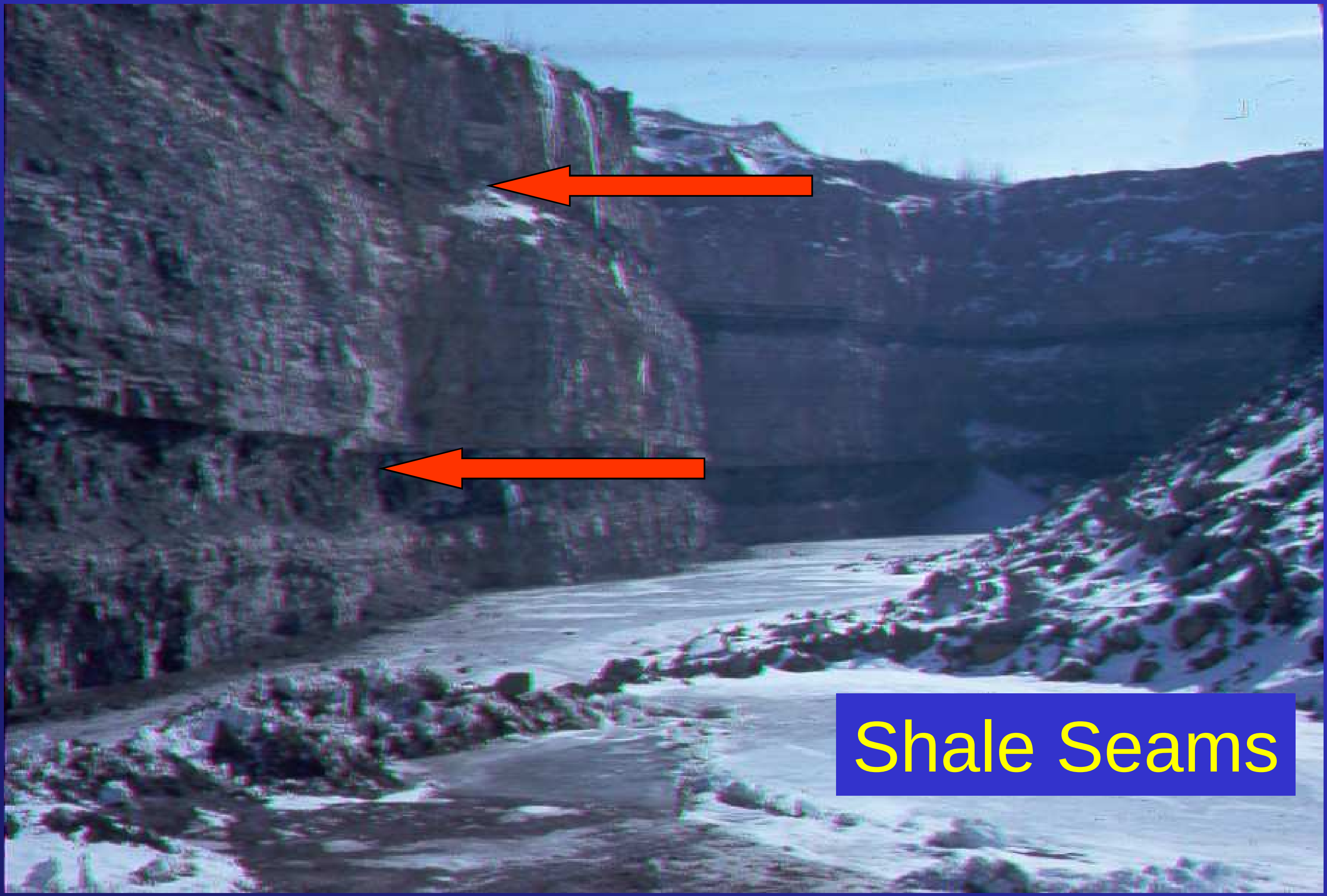
Clay and Shale

- Both are impurities found in Carbonate rock
- Clay occurs as thin partings (layers) or imbedded in the crystalline structure of the carbonate rock(Argillaceous)
- Shale is compacted and hardened clay normally found in layers and can vary in color
- Other impurities can include sand or quartz particles
- Pyrite (fool's gold) and marcasite are also found

Shale Laminations


Shale Seams

Stratigraphy

The branch of geology that studies the sequence in which the rock formations were deposited

- Lithology - rock type (physical characteristics)
- Formation - distinctively different to adjoining material
- Member – a division of a formation due to the Lithology
- Bed - a division in a formation that is a well defined plane
- Lense - a small member within a formation
- Tongue or pinch-out - a member or formation that wedges between a different Lithology
- Lateral variation - horizontal variation in a formation
- Joint - a fracture or crack in rock
- Fault - fracture(s) by movement

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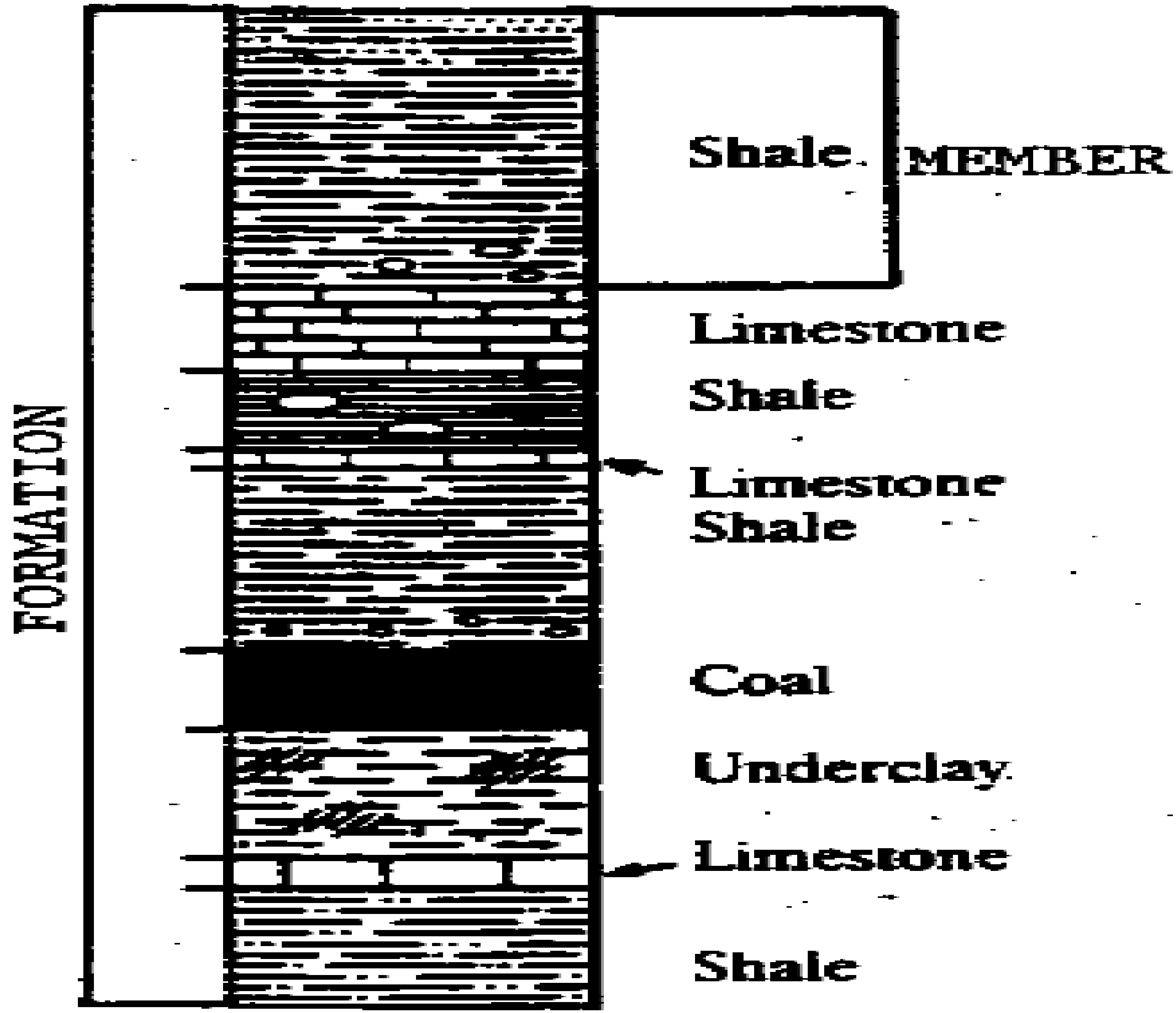
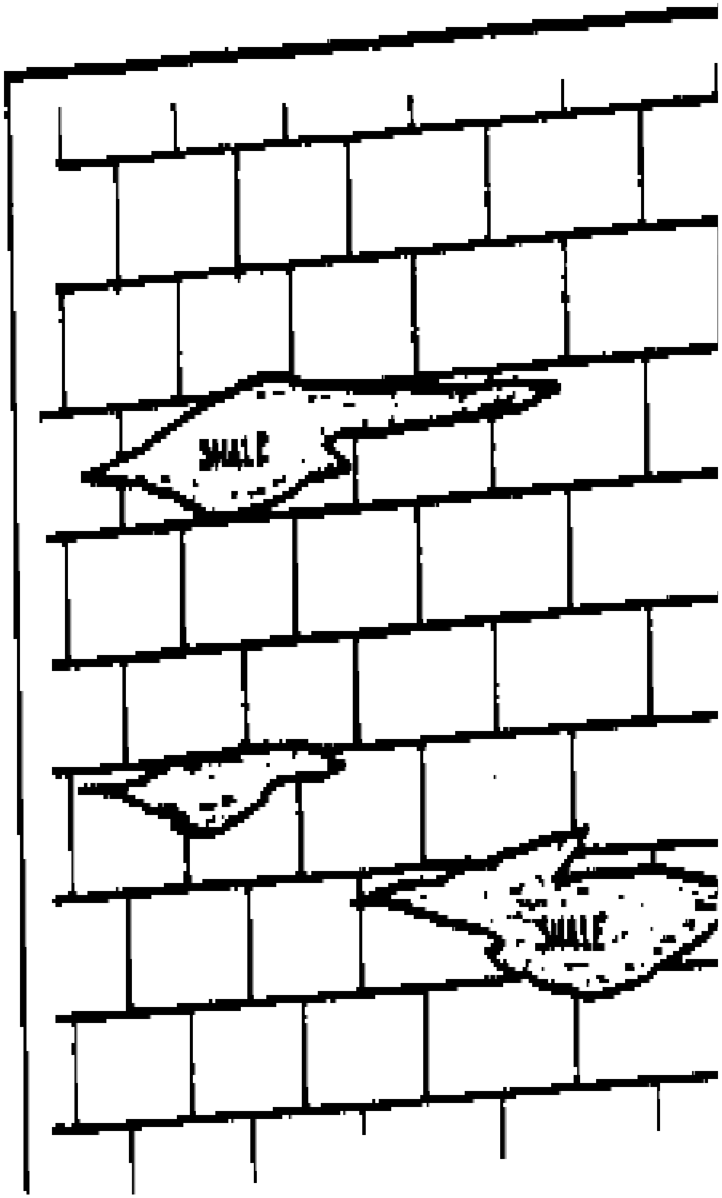
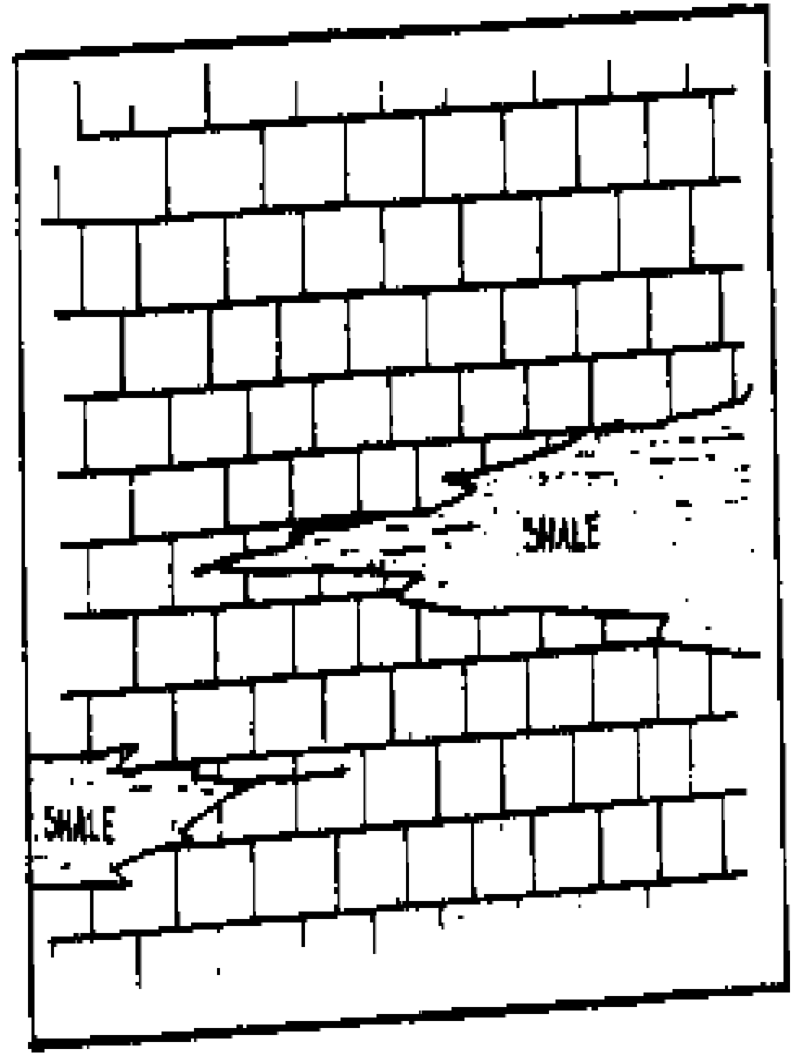

FORMATION
Shale
MEMBER
Limestone
Shale
Limestone
Shale
Coal
Underclay
Limestone
Shale



Pinch-outs



Tongues

Stratigraphy vs. Quality

- Lithology - **changes in the layer can / will affect quality**
- Lenses, tongues - **hard to manage**
- Lateral variation - **a gradual change of Lithology can / will affect quality**
- Joints, Faults - **allows weathering and heat to affect the quality**
- Fault – **beds or layers don’t line up, different quality on each side of the fault**

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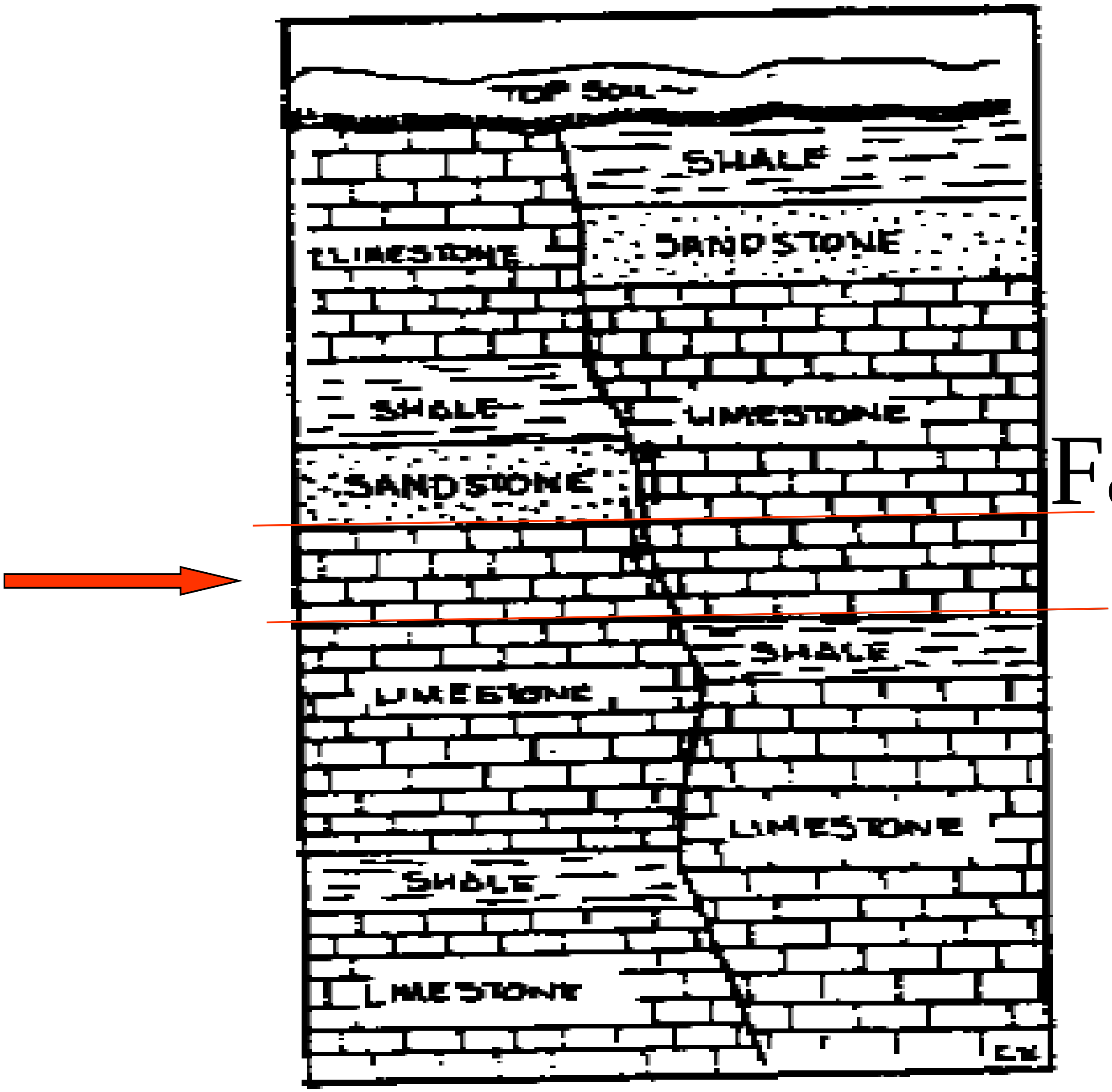

Fault

- Broken Rock
- Altered Rock
- Contaminates

Classification systems

- Rock type – Lithology – grouped by physical characteristics
- Fossils – used to determine the relative age
- Time or age – determined by placement

The following listing is a general age chart, going from youngest to oldest:

		Age (millions of years)
Cenozoic	Quaternary	1 or less
	Tertiary	1 - 63
Mesozoic	Cretaceous	63 - 135
	Jurassic	135 - 181
	Triassic	181 - 230
Paleozoic	Permian	230 - 280
	Pennsylvanian	280 - 310
	Mississippian	310 - 345
	Devonian	345 - 405
	Silurian	405 - 425
	Ordivician	425 - 500
	Cambrian	500 - 600
Pre-Cambrian		more than 600

Rock used as aggregate was formed well before glaciers

Age doesn't have much to do with the quality of the deposit

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- Rock Type vs. Hardness
- Plant/Equipment Wear Rates
  - Granite 6+ Mohs
  - Quartz 7 Mohs
  - Limestone 3 Mohs
  - Dolomite 3.5 Mohs
  - Chert 7 Mohs
  - Steel 5 – 5.5 Mohs

Special Aggregates Used by the Construction Industry

Fly Ash

Slag – Wet Bottom Boiler, Steel, Copper, Air-Cooled Blast Furnace

Recycled Asphalt Pavement
Crushed Concrete
Synthetic Products

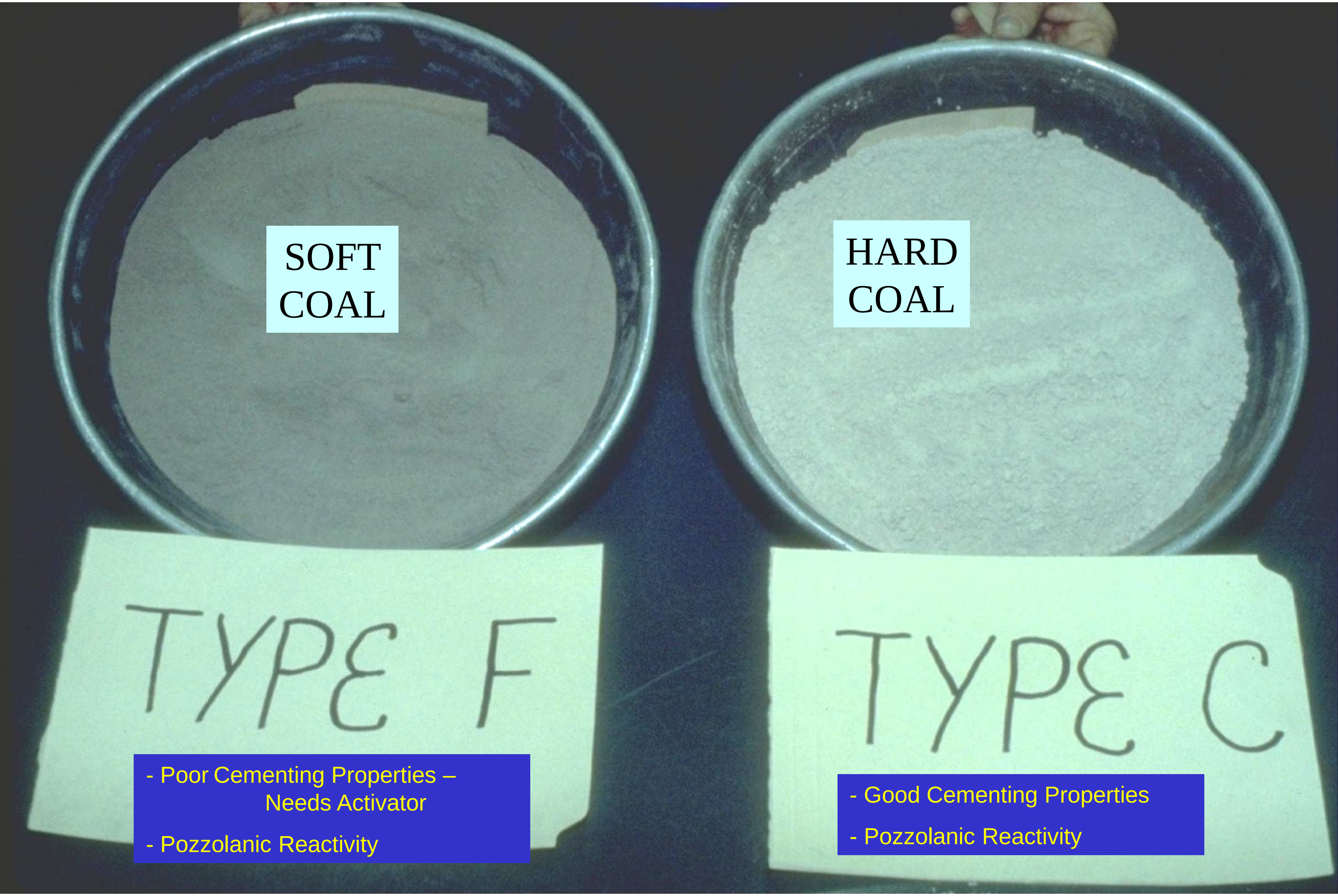
Fly Ash

FLY ASH is a byproduct of burning coal, the minute burnt and un-burnt particles created in the coal burning process

Used in concrete as replacement for cement.

Used in HMA mixes as mineral filler fines.


Fly Ash


SOFT
COAL
HARD
COAL
TYPE F
TYPE C
- Poor Cementing Properties –
Needs Activator
- Pozzolanic Reactivity
- Good Cementing Properties
- Pozzolanic Reactivity

ACBF & Steel Slag Materials

2 Processes used :

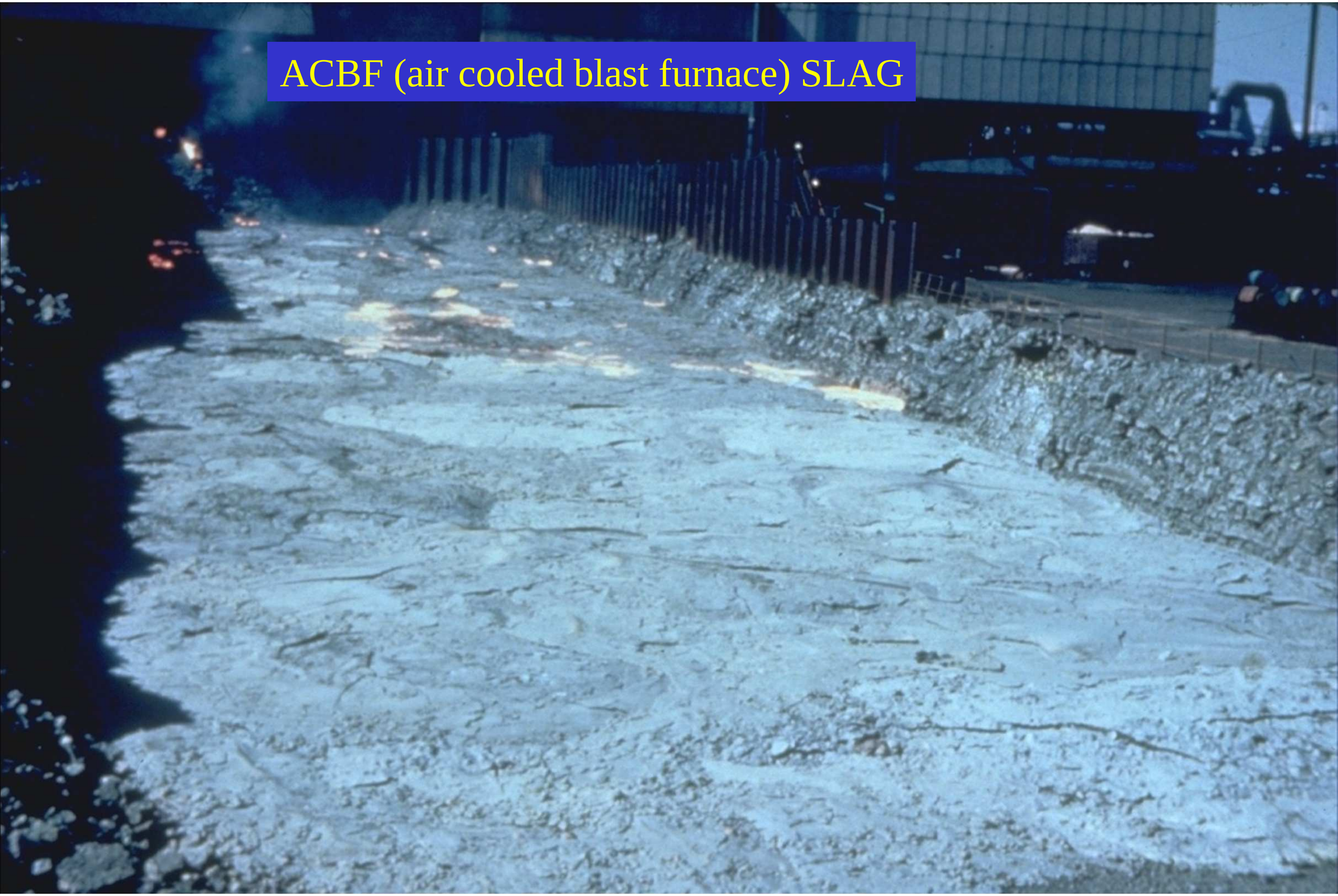
- Impurities removed from iron-making process

- Impurities removed from steel-making process

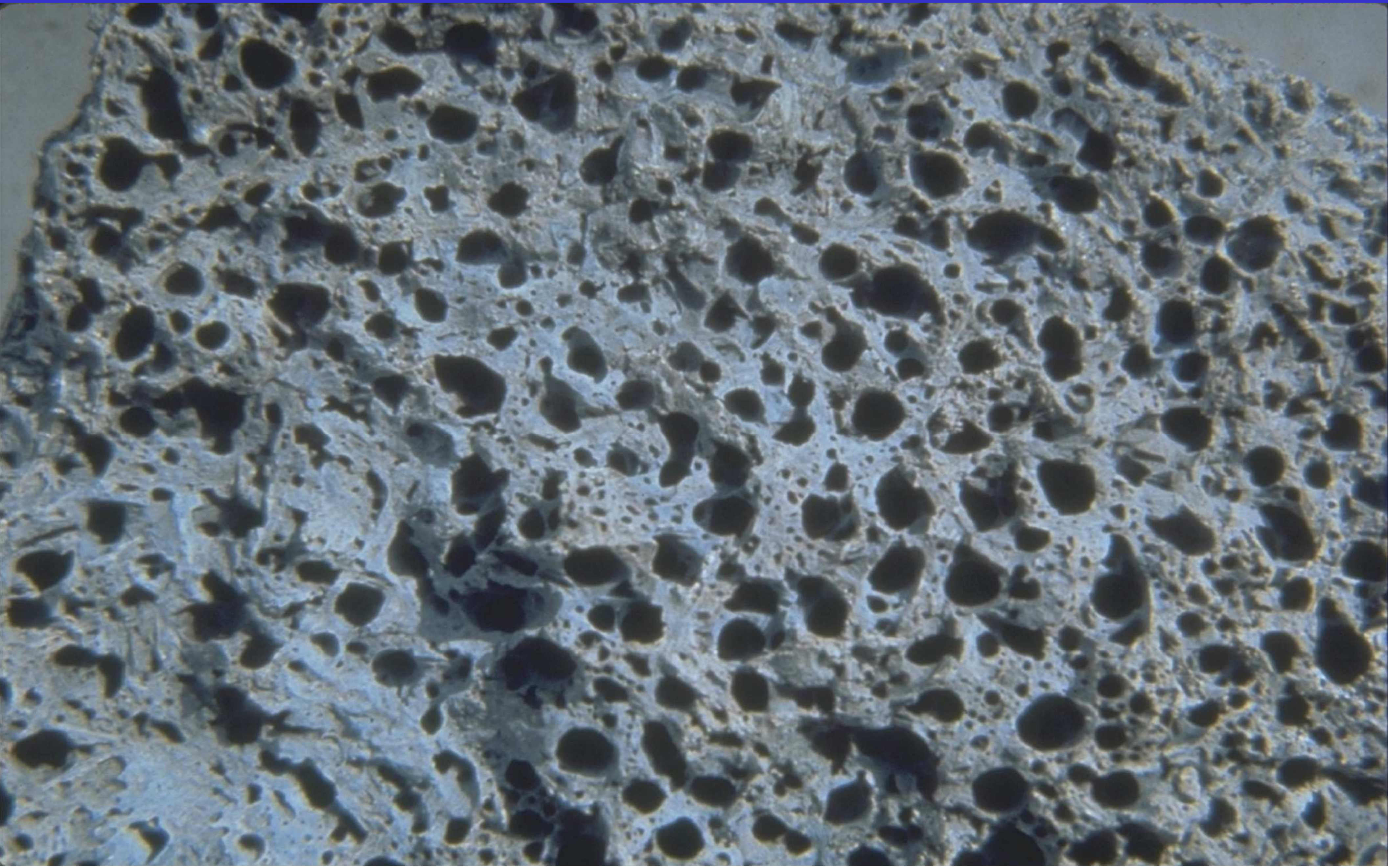
Air-Cooled Blast Furnace Slag (ACBF)

- Produced in the iron making process- Has high friction and high absorption due to the vesicular nature of the particles
- Can be used in both concrete or asphalt
- Specific Gravity/Absorption may vary widely from production batch to production batch

ACBF (air cooled blast furnace) SLAG



Air-Cooled Blast Furnace (ACBF) SLAG



Steel Slag

- Produced in the steel-making process
- Heavy Gravity- Exhibits high friction due to vesicular nature
- Steel Slag may exhibit expansive properties when placed in a confined space
- Specific Gravity/Absorption may vary from production batch to production batch

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STEEL SLAG

Wet-Bottom Boiler Slag / Dry Bottom Ash

Coarse, angular product from coal combustion used in blotter, ice control, fill


Wet-Bottom Boiler Slag / Dry Bottom Ash

Recycled Concrete Pavement (RCP)

- Commonly used as base material which can cause a conflict with aggregate producers that make base products
- Not used in most asphalt mixes due to high absorption
- EPA tightened restrictions on disposal so more is being recycled, even in the rural areas.
- Pavement rubblization is being used so the concrete can be left in place


Recycled Concrete Pavement

Recycled Asphalt Pavement (RAP)

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CONGLOMERATE
RAP
RAP STOCKPILE

AGGREGATE PRODUCTION

- Basics of how aggregates are produced
- The method of production helps determine the aggregate’s physical / quality characteristics

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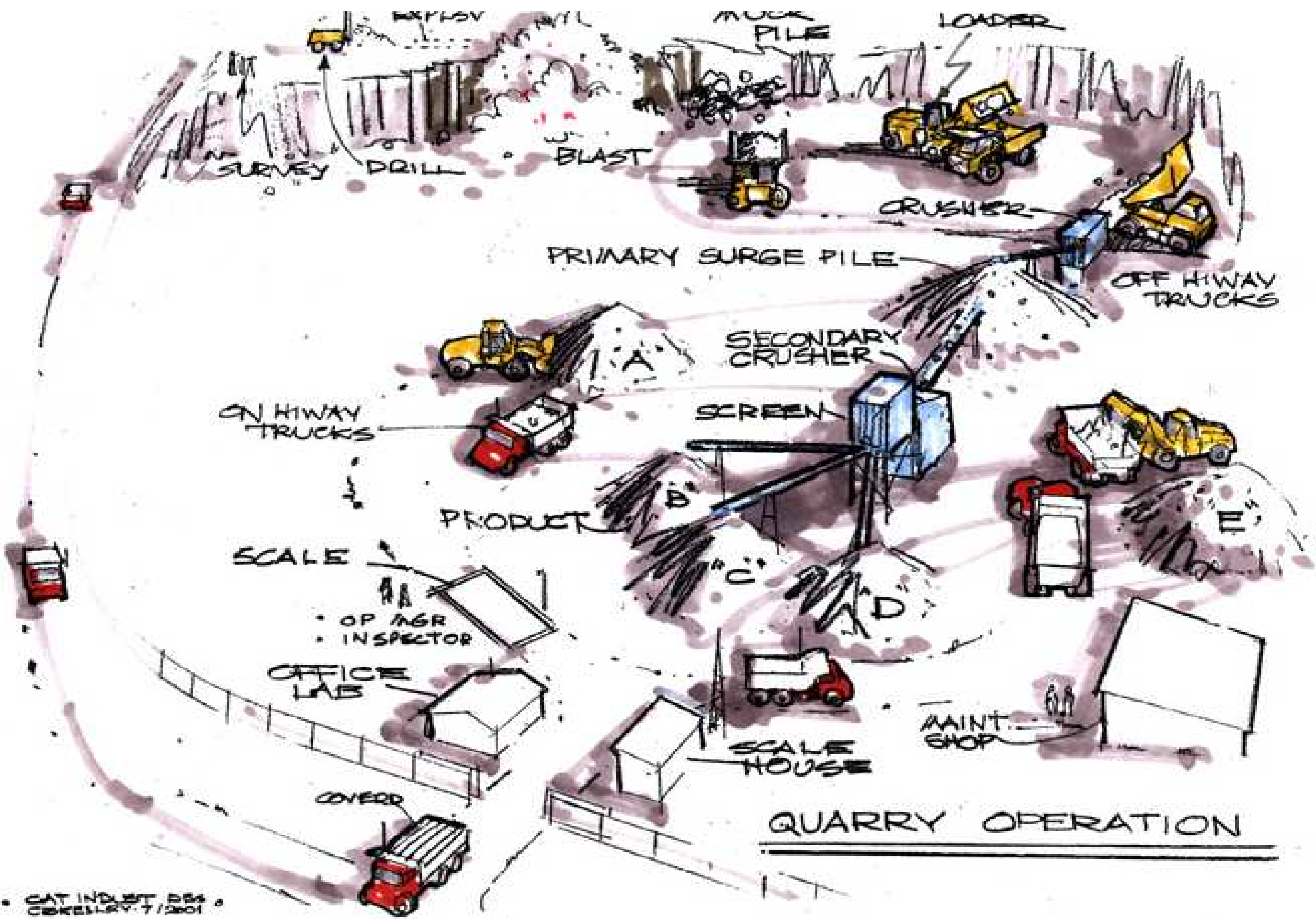
Operations

- stripping
- drilling
- blasting
- loading and hauling
- scalping
- crushers
- beneficiation processes
- screening
- sand production
- stockpiling and handling


PILE
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"D"
• OP MGR
• INSPECTOR
OFFICE LAB
SCALE HOUSE
MAINT. SHOP
COVERED
QUARRY OPERATION
CAT INDUST DSG
CBKELLEY 7/2001

Stripping

- Can affect the quality and gradation by introducing contamination into the raw feed material.
- Depending on the quarry location depends on the amount of overburden that needs to be removed.
- Economics and availability of the product will determine the cost effectiveness of how much overburden can be removed.
- Can be done by a variety of methods.
- Contracting this out is common.

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Stripping is a basic operation in a sand & gravel pit or rock quarry.

Drilling

- Production ledges are maintained by proper drilling methods

- Location, depth, and dip of ledges need to be known to be able to mine the right material and not mix different qualities of materials


Drilling the ledges of rock

Blasting

- Reduces the material to the proper size for the raw feed
- Helps to improve the product by blasting finer to disintegrate the weaker material
- Can be different for different ledges of material due to the physical characteristics of the rock
- Can be adjusted to make certain products (Rip Rap, etc.)
- Can be limited due to environmental issues

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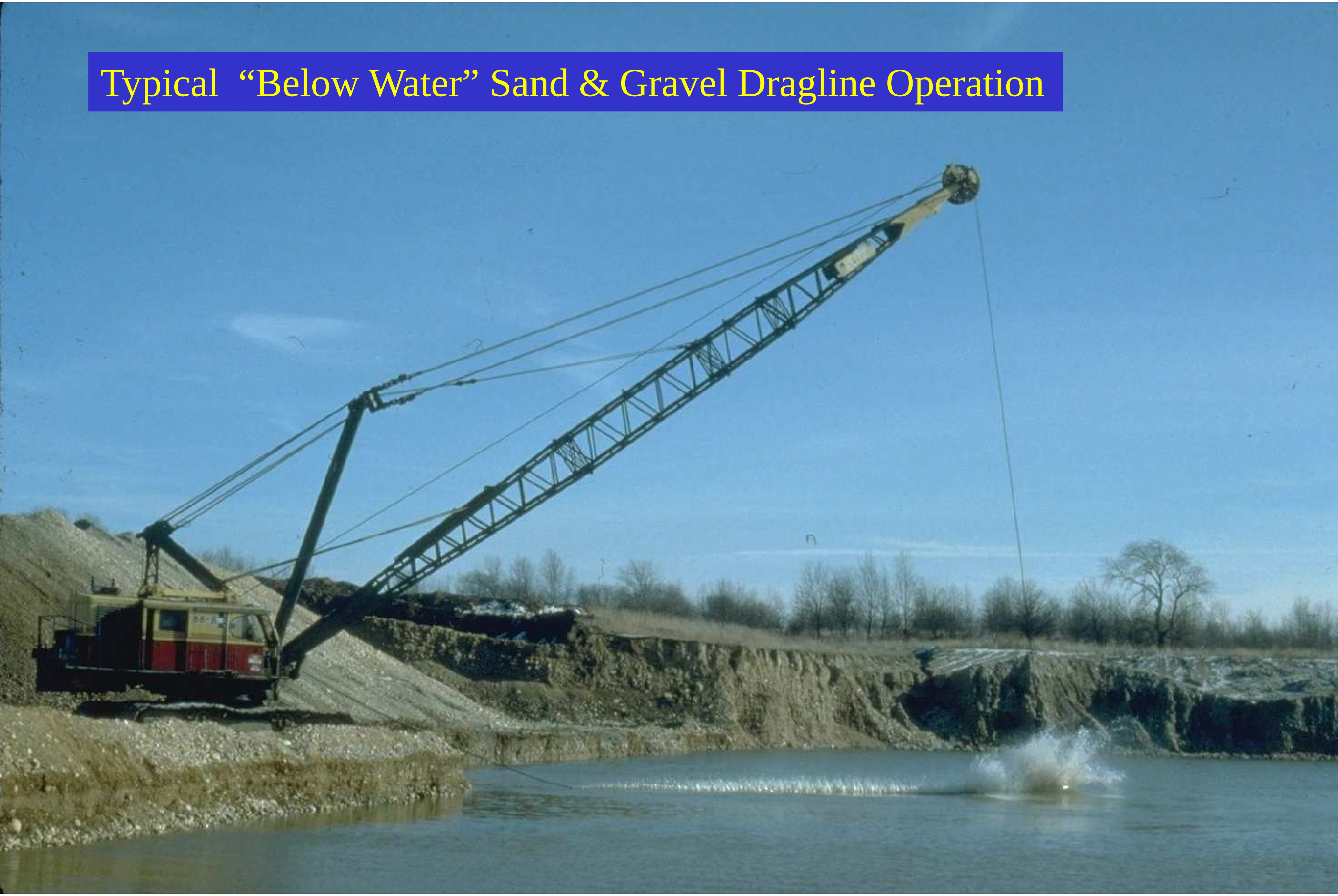
Blasting to produce the raw feed material

Loading & Hauling

Loading can be done "wet" or "dry"

- **"Wet" operation uses a dragline or dredge**
- **"Dry" operation uses end loaders or larger quarries may use an electric shovel**
- **Hauling is done by large trucks, conveyor belts systems, but portable crushers can be set up at the site and use end loaders**

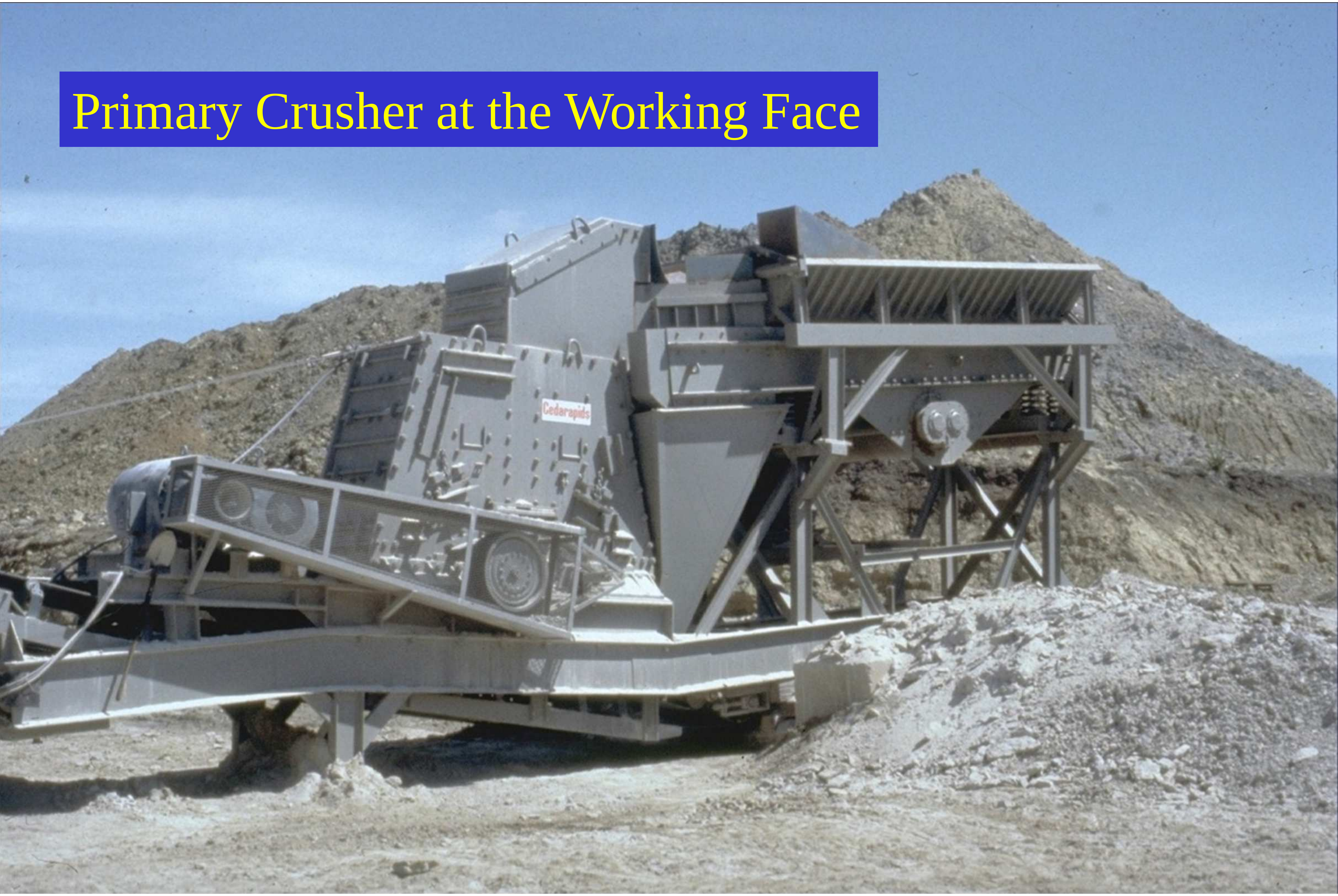

Typical "Below Water" Sand & Gravel Dragline Operation

A Typical Dredging Operation ("Wet" Operation).


‘ Dry ‘ Sand and Gravel Operation


End Loader and Large Truck Haulage System

Primary Crusher at the Working Face

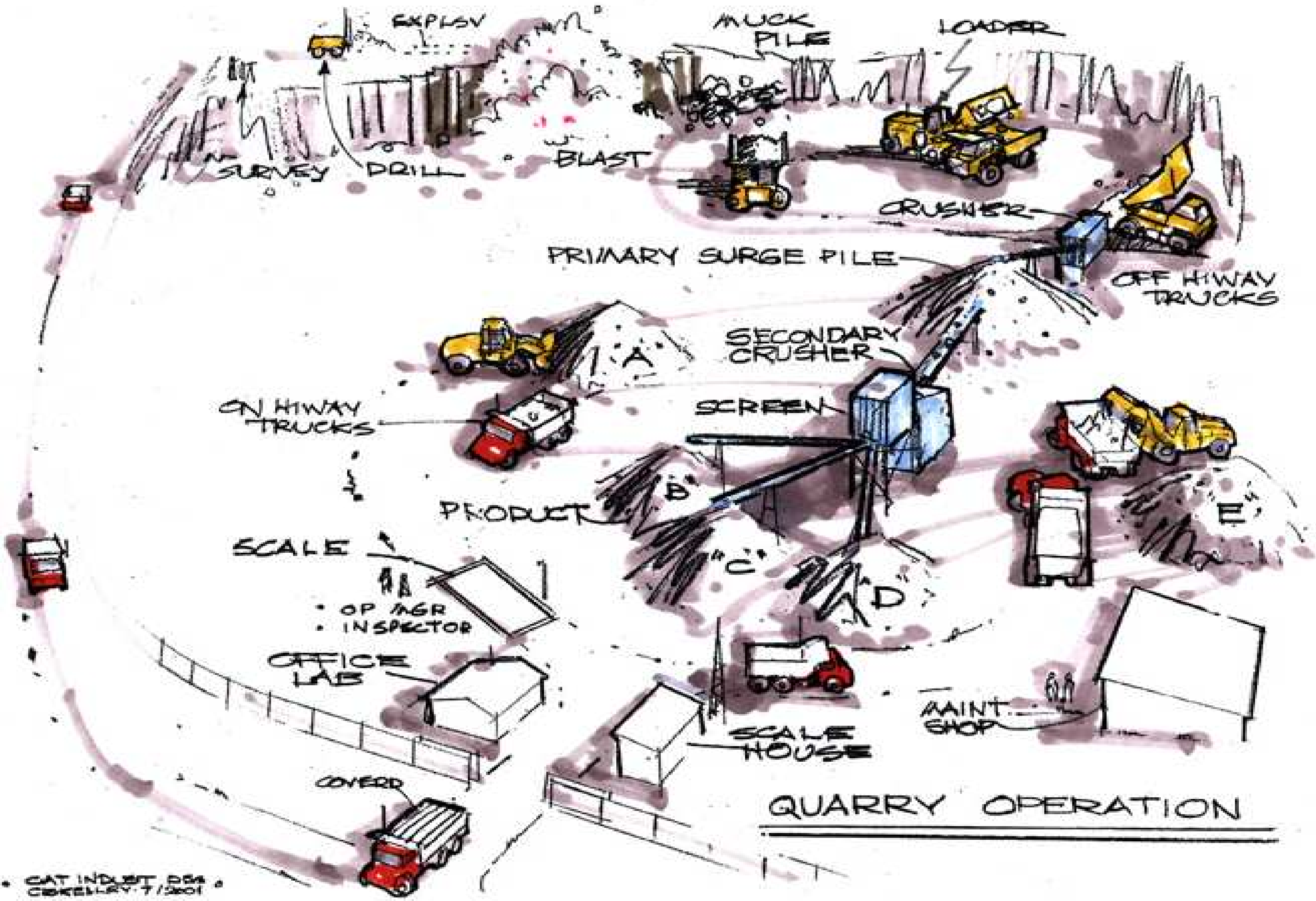


Scalping

- Separates oversize material from smaller material
- Oversize tends to be better quality since it held together during the blasting or crushing
- Allows the worst material to be removed benefiting the product
- Can be done at the Primary Crusher or at screen decks further down the process
- Rip Rap can be made using a scalper

Primary Scalping

Surge Pile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COVERD
QUARRY OPERATION

Surge piles are used to help even out the flow of raw material and maintain a constant feed of material thru the plant. It is also a temporary pile to be used later.

Crushers

- Very important part of the production of aggregates
- Crushers upgrade the quality of the materials being produced by reducing the bad material to fines
- Crushing determines the quality upgrading dependant upon the physical characteristics of the rock and type of crusher used
- Crusher selection is very important to the product and the economics of the quarry

Crushers

Compression

- gyratory* (larger capacity)
- jaw* (single or double jaw)
- cone (smaller, higher rpm, less dust, elongated particles, used as a secondary)
- Roll (secondary)

- Advantages
  - less dust produced
  - lower cost
- Disadvantages
  - particle shape (elongated)
  - deposits will crush differently
  - very large in size (10'- 20')

* Usually used as a primary crusher

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Crushers (cont.)

- Impact
  - Horizontal
    - high speed impellor breakage
    - Also breakage on steel plates / bars
    - some rock on rock breakage
  - Vertical shaft
    - High speed feed plate
    - Can be rock on rock breakage
  - Hammer-mill
    - uses impacting, shearing, and attrition
  - Cage mill
    - creates lots of dust

- Advantages
  - beneficiates material
  - better particle shape
- Disadvantages
  - creates dust and has higher cost

Most impact crushers can be used as a primary, secondary, tertiary, or quaternary crushers

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Compression crushers

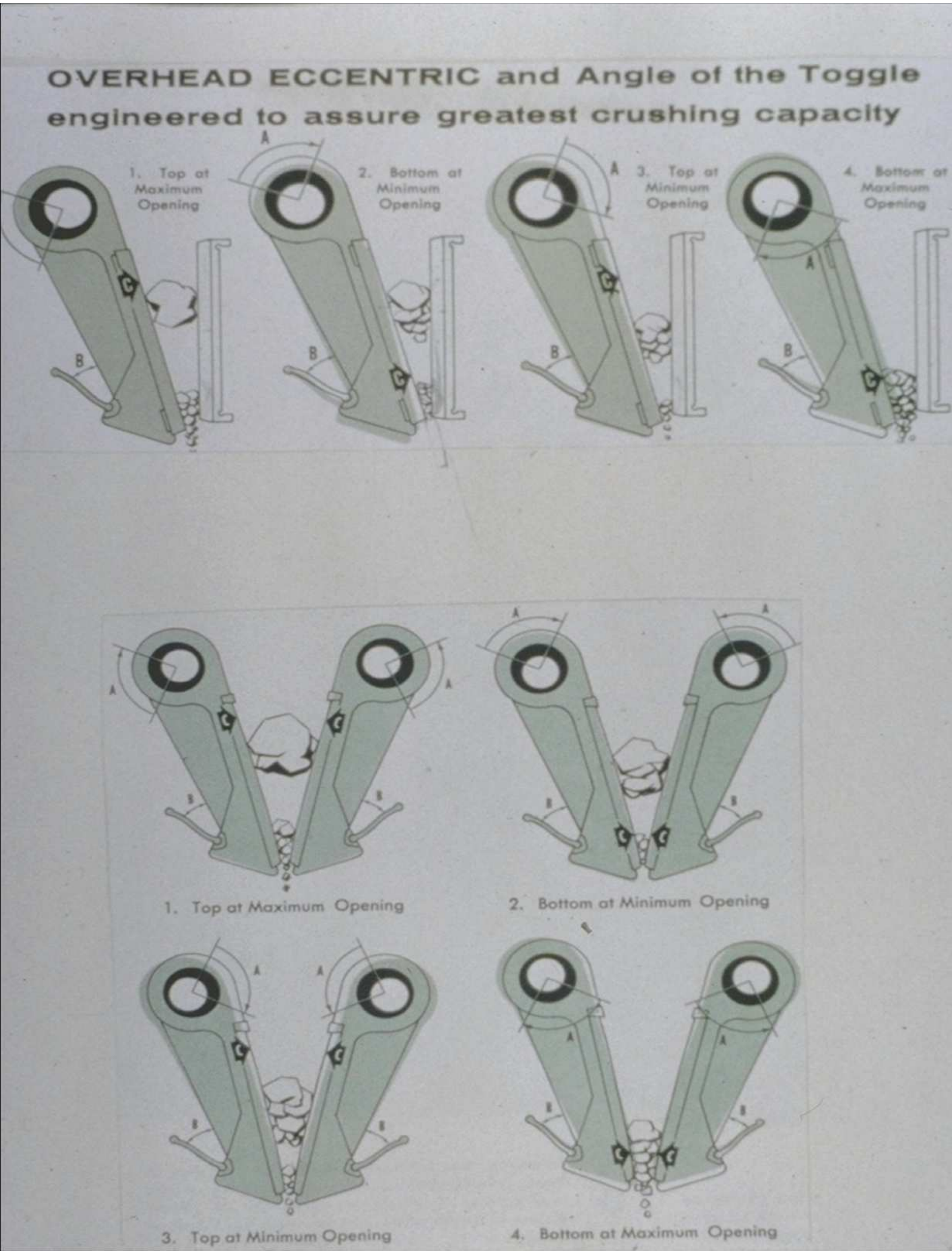
Gyratory Crusher

2000-3500 tons per hour

Used at larger quarries

Normally a primary crusher

Opening 6" – 10"

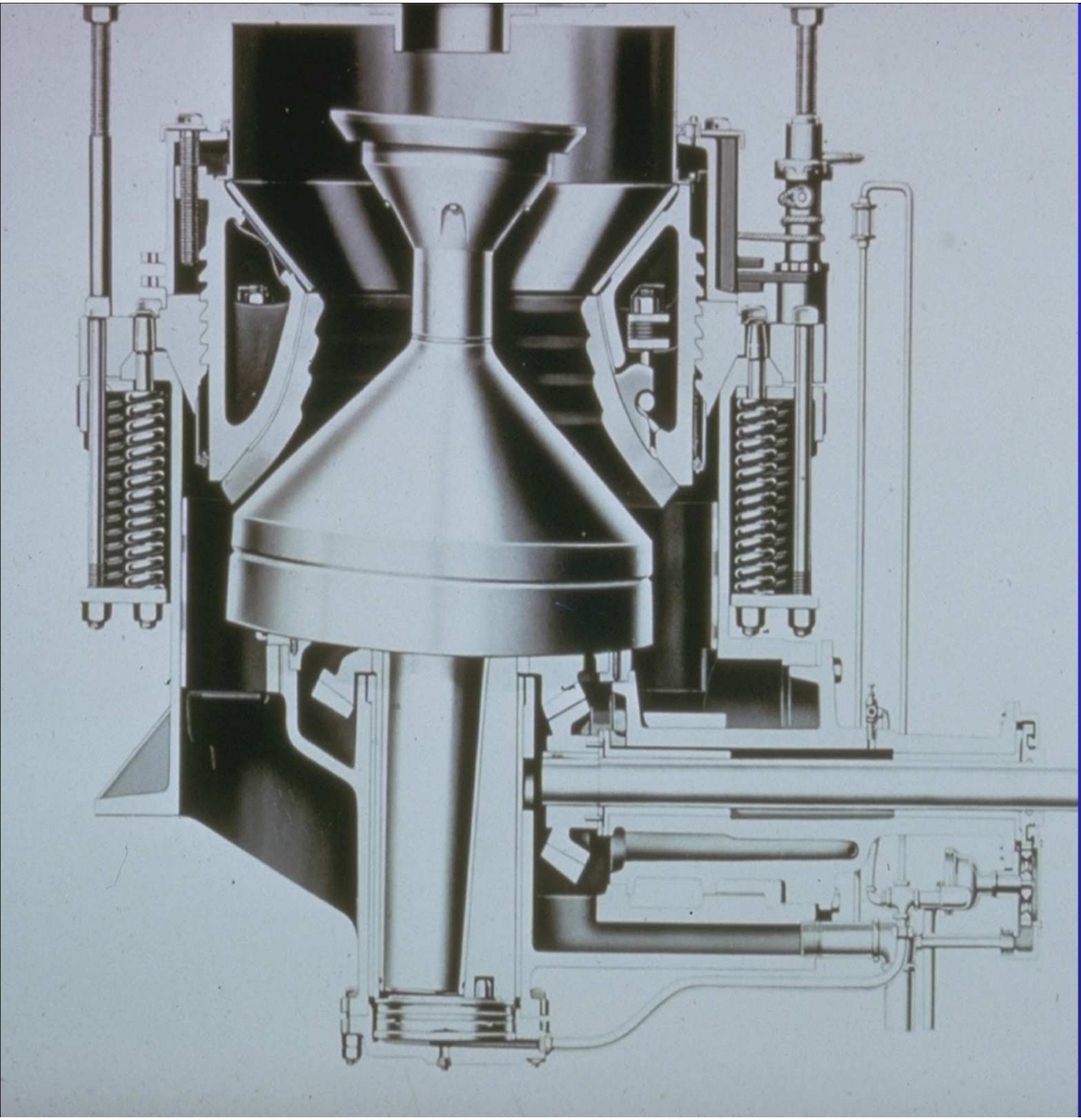


Jaw crushers

Portable

Single or double jaws

Primary or secondary crushers



Cone crusher

High speed

Less dust

Elongated particles-
If choke-fed,
elongated particles
may be reduced

Normally used as a
secondary,
tertiary or
quaternary crusher

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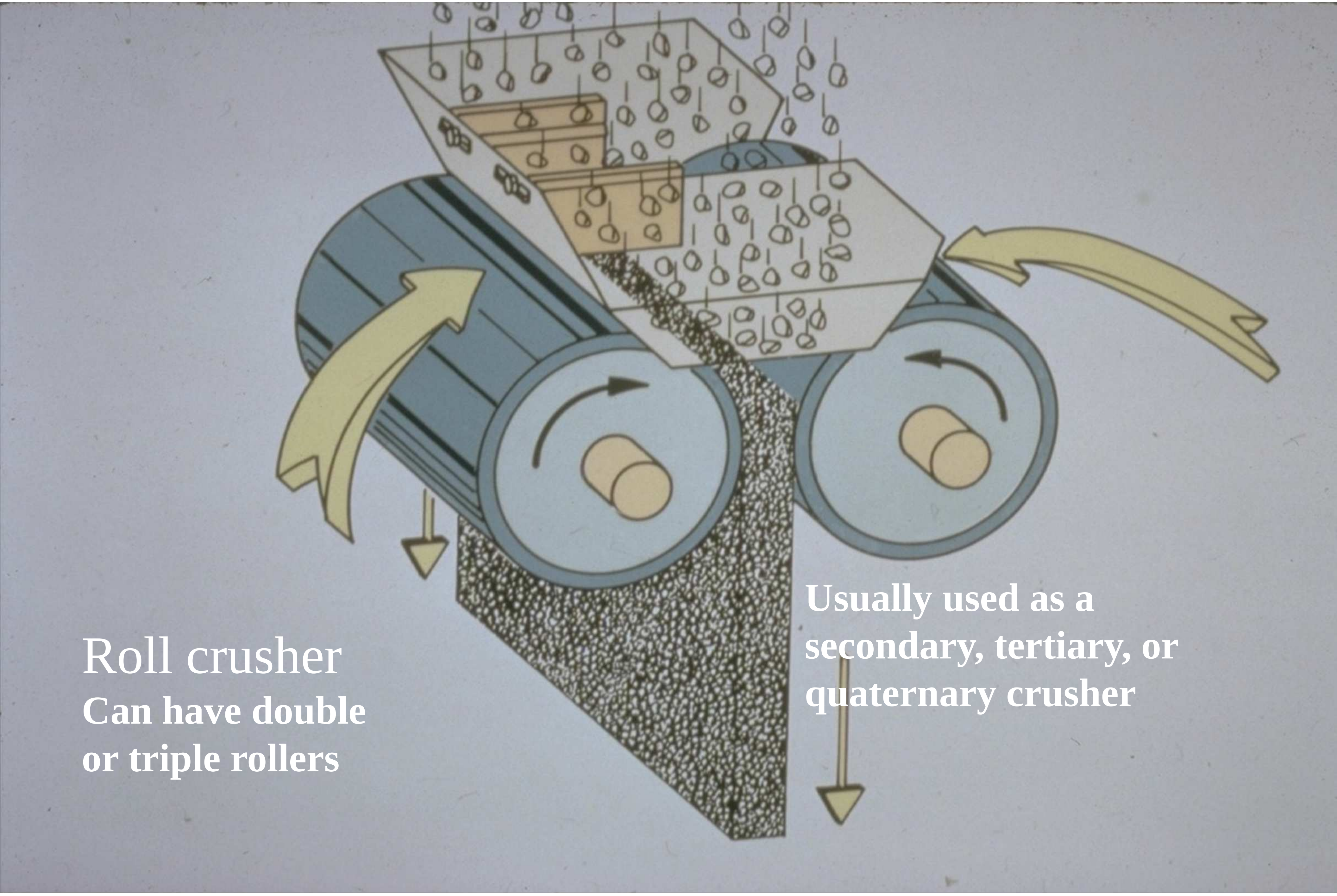
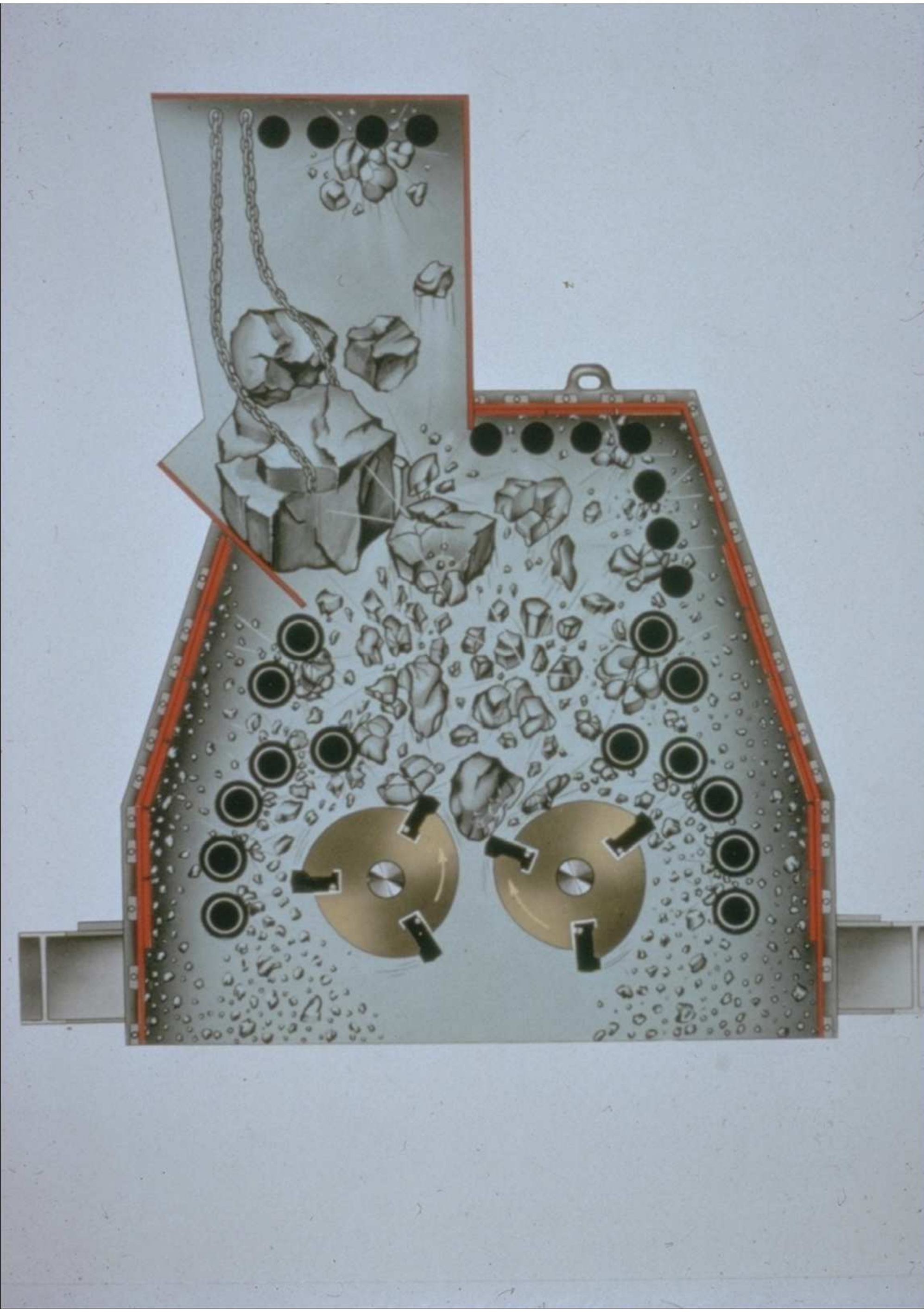

Usually used as a secondary, tertiary, or quaternary crusher
Roll crusher
Can have double or triple rollers


Impact Crusher
Cedarapids



Horizontal Impactor Crusher

High speed

Can be rock on rock breakage

Used as a primary, secondary, tertiary, quaternary crusher

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Vertical Shaft Impactor

Throws rock at high speed

Some rock on rock only crushers

Used as a secondary, tertiary, quaternary crusher

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Vertical Shaft Impactor

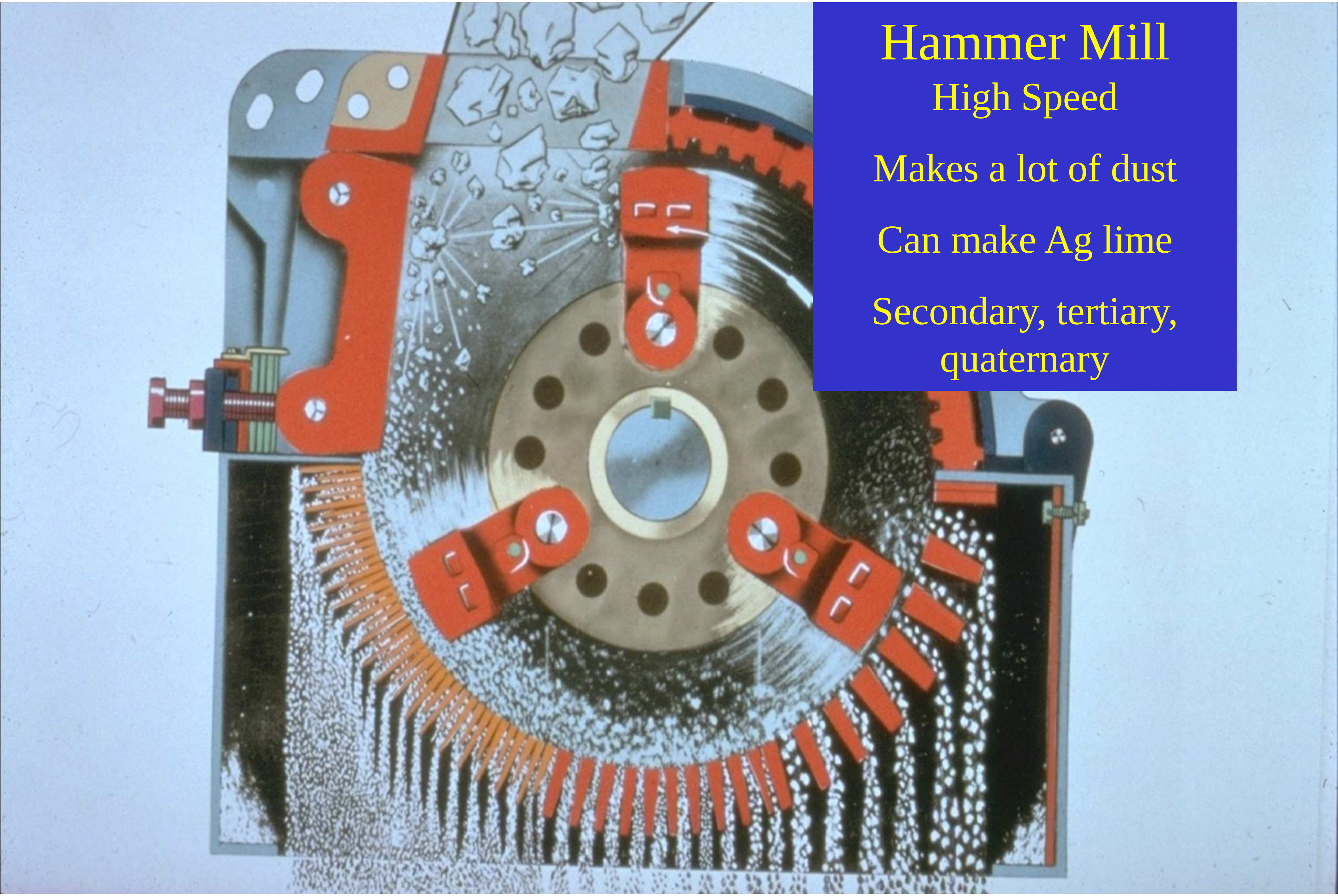
Hammer Mill

High Speed

Makes a lot of dust

Can make Ag lime

Secondary, tertiary, quaternary



Cage mill

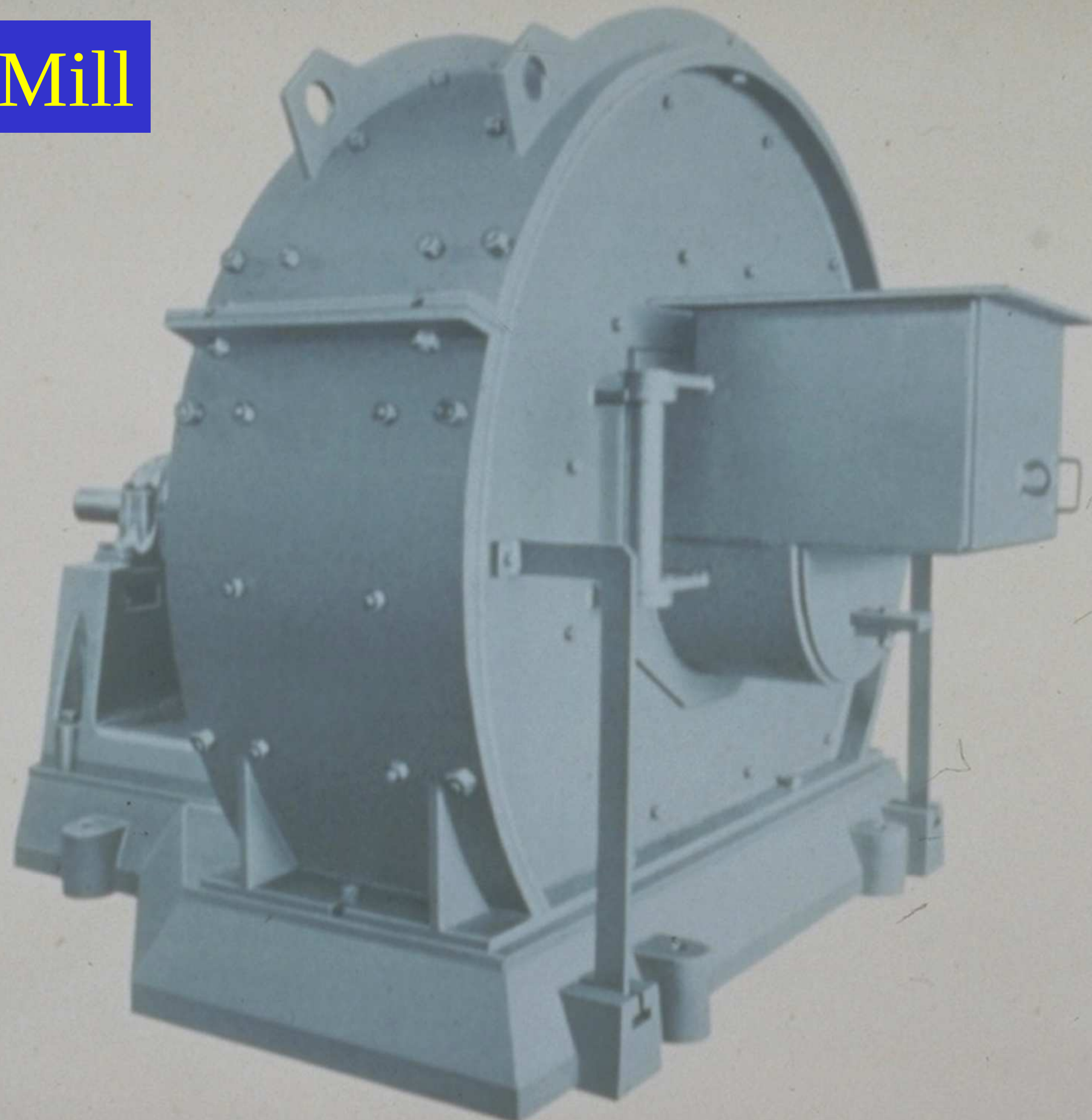
High Speed

Creates lots of dust

Not very common

Used as a secondary, tertiary, quaternary

Cage Mill



Some quarries/materials have flat and elongated problems

Physical characteristics of the rock can make it prone to flat and elongated shapes

Compression crushers tend to create flat and elongated particles

Flat and elongated particles are prone to severe segregation

What would be the ideal particle shape?

Cube Shaped

Tends to have stronger properties and characteristics

Tends to produce better stability in products and uses

Beneficiation processes

The process used to improve the material being produced:

Heavy media, logwasher, attrition mill, magnet, screening, classifiers

Heavy media

Uses a slurry of water and iron-based particles (2.55 Sp.Gr.)

Lighter or deleterious material floats and good material drawn off the bottom

Costly & slow

Not popular

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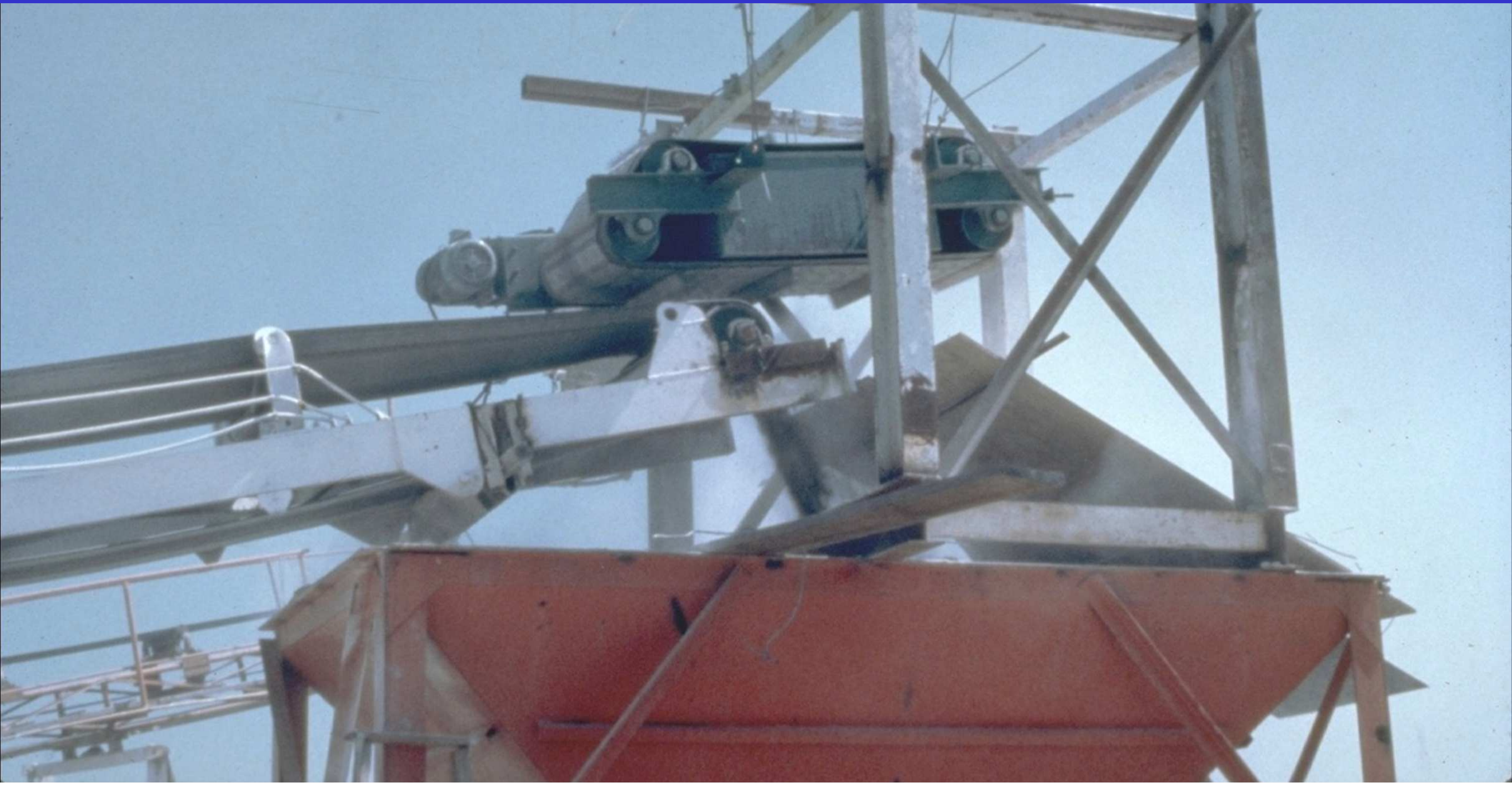
Washing off the heavy media

Logwasher washes off dust & washes out deleterious material

Magnet pulls off tramp iron & metals
that can damage the plant,
definitely used when recycling concrete

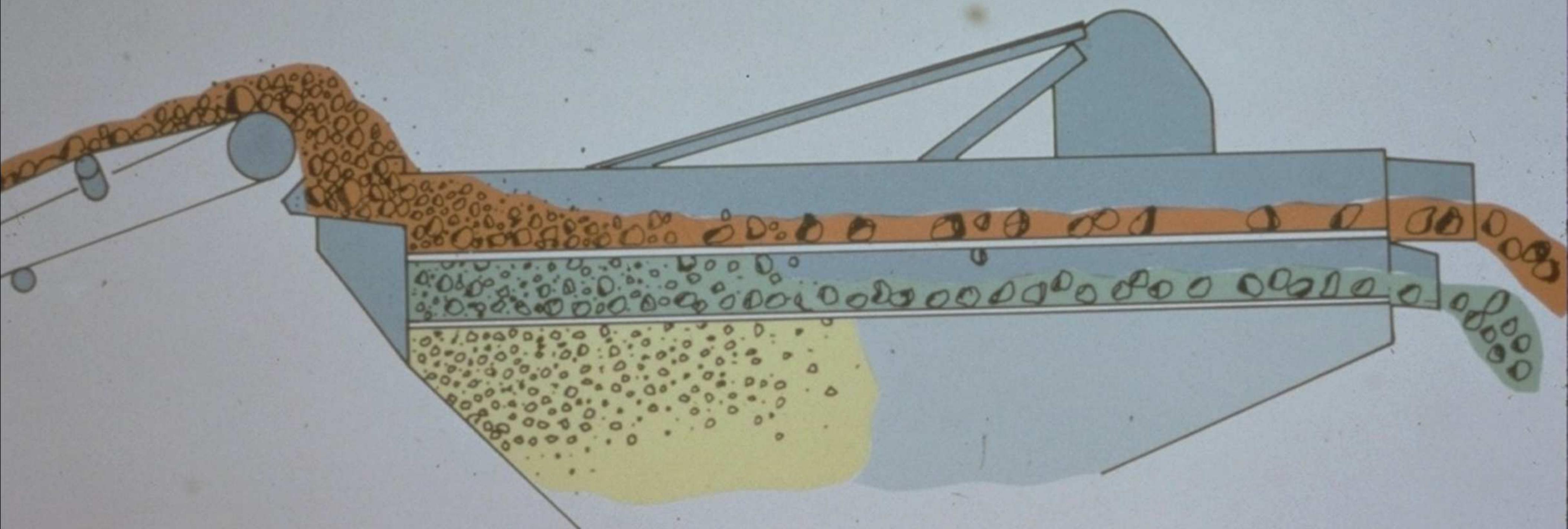


Screening

- Material from the crushing process is screened to produce different graded products or oversize to process further down the production process

- Can be used to fractionalize material to be blended together later

Screening



Sand Production

- A sand screw can be used to float out fines / deleterious materials or de-water the sand

- While water is a good classifier in a sand screw for the fines, a mechanical classifier using rising currents of water might need to be used to produce a graded product

- Sand Classifiers can be used to make more than one material

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Sand Screw


Sand
Classifier

Sand Classifier

Testing

Aggregate Characteristics

- Quality
- Physical/Chemical

QUALITY USE CLASS

A. P.C. CONCRETE
B. CLASS I HMA SURFACE
C. SEALCOAT, CLASS I BINDER, MIX B
D. BASE COURSE, SUBBASE, SHOULDER

Quality Parameters

- Durability
- Concrete Durability
- Toughness
- Deleterious Particles

Characteristic Parameters

- Gradation
- Specific Gravity / Water Absorption
- Organic Content
- Chemistry
- Friction Potential

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Quality Tests

Durability

- Sodium/Magnesium Sulfate Soundness Test
- Unconfined Freeze-Thaw
  - Water
  - Water-Alcohol

NA / MG SULFATE SOUNDNESS

- Used to Measure the aggregate resistance to weathering
- Run on both coarse & fine aggregates
- Material is soaked in a saturated sulfate solution, then dried. Subsequent soaking hydrates the sulfate crystals in the pore system, causing large forces, which causes the weaker particles to break

The test is run as a 5-cycle or 10-cycle test

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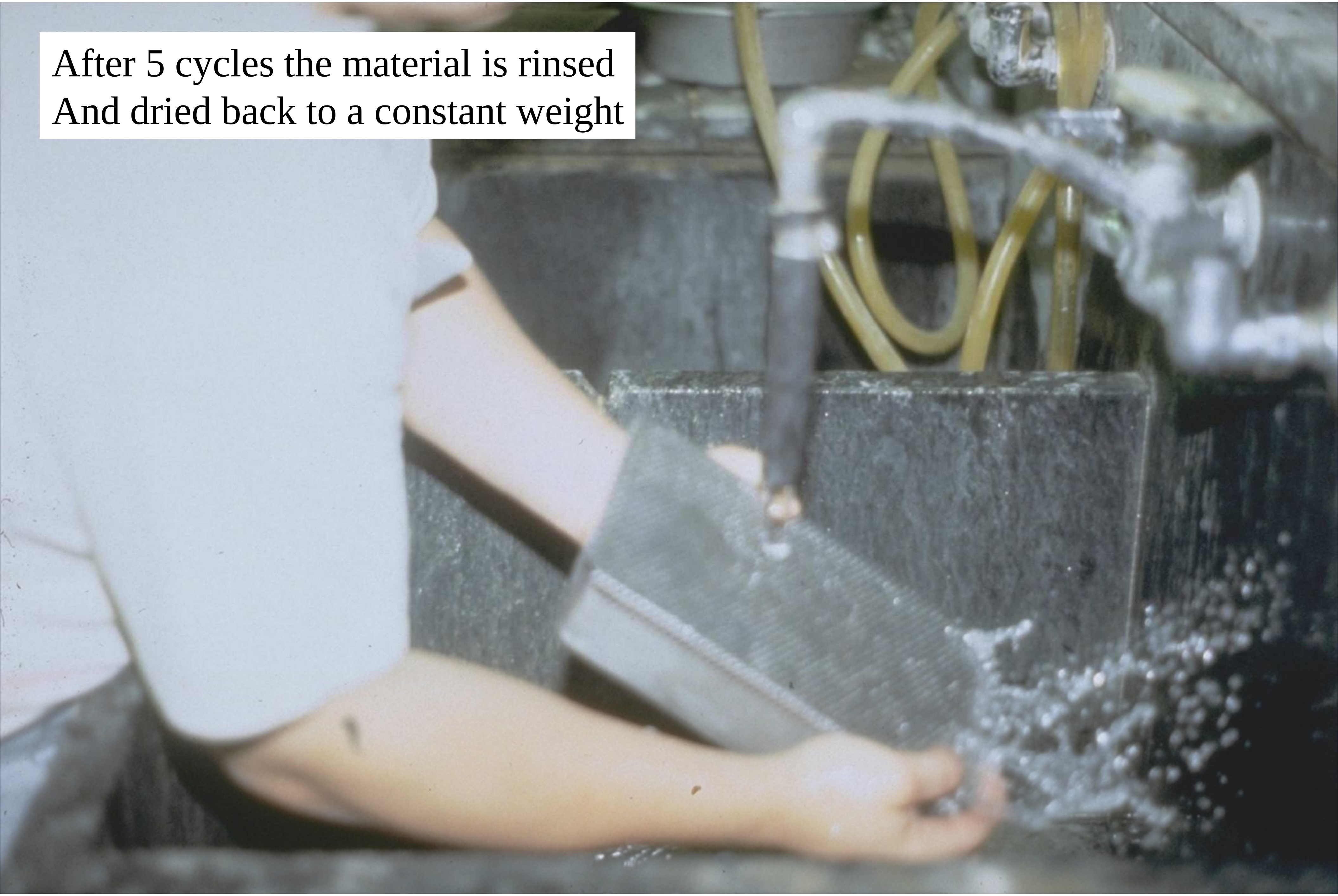
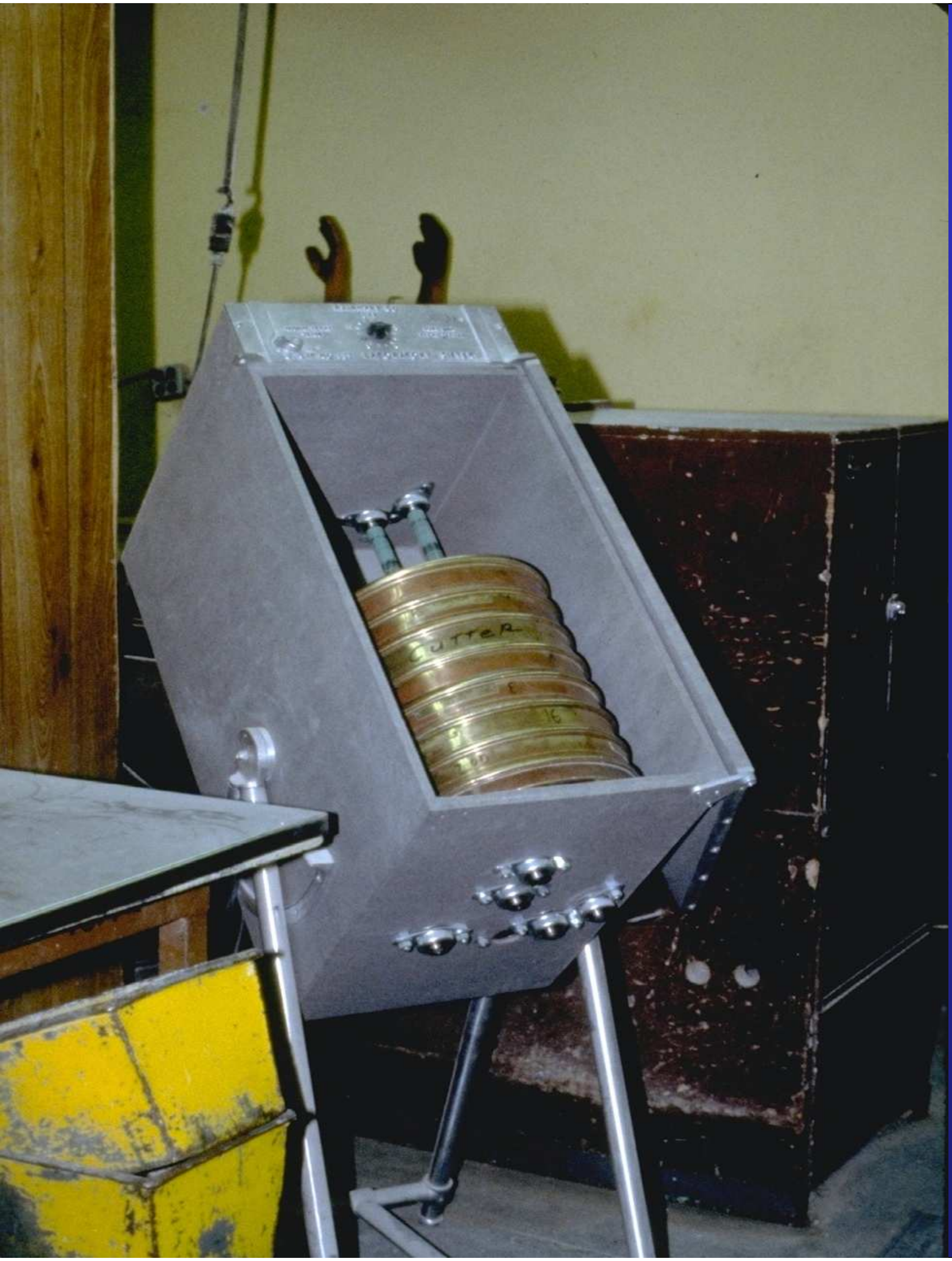
1000g 1/2"
1000g #4

Soak 16-18 hours at 70° ± 1°F

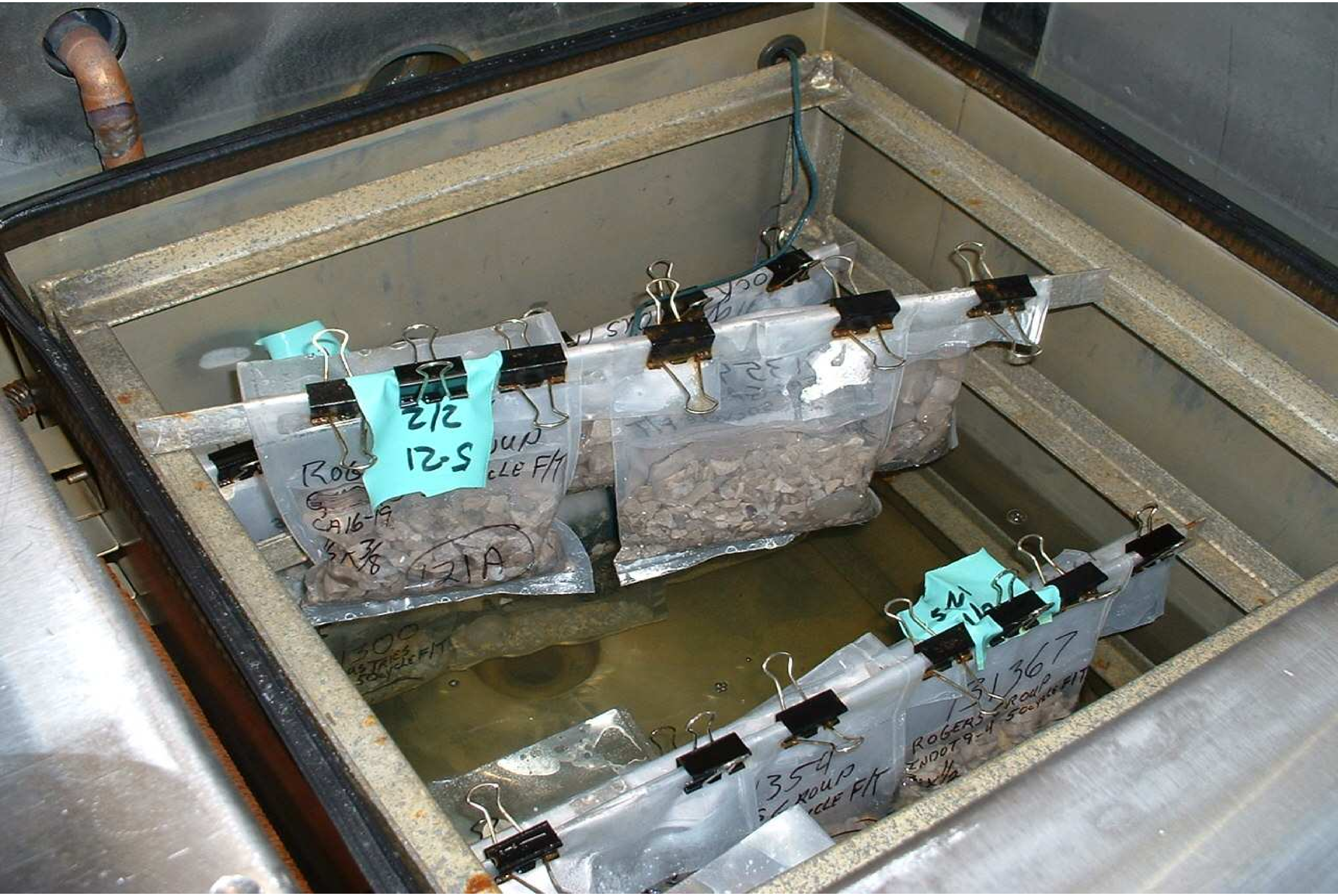
The solution is poured off and the material is dried back at 230°±9°F to a constant weight


After 5 cycles the material is rinsed
And dried back to a constant weight



The material is sieved and then the percent loss is figured for the sample

Unconfined Freeze-Thaw


2/2
12-S
CA16-19
121A
131367

Toughness

- Los Angeles Abrasion and Impact Test
- Micro Deval

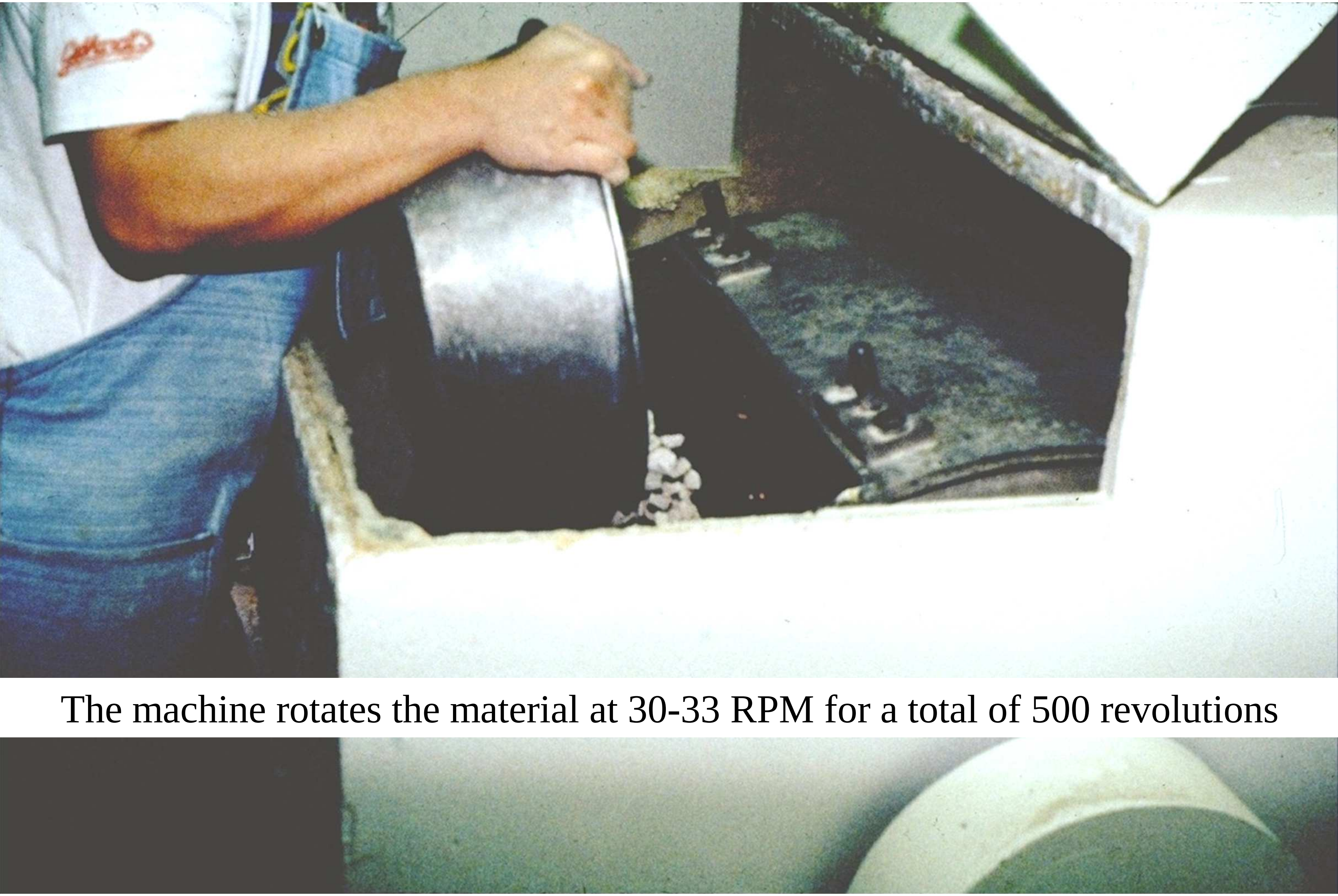
LOS ANGELES ABRASION

- Measures the aggregates ability to resist wear and potential for degradation
- More of an impact test than abrasion

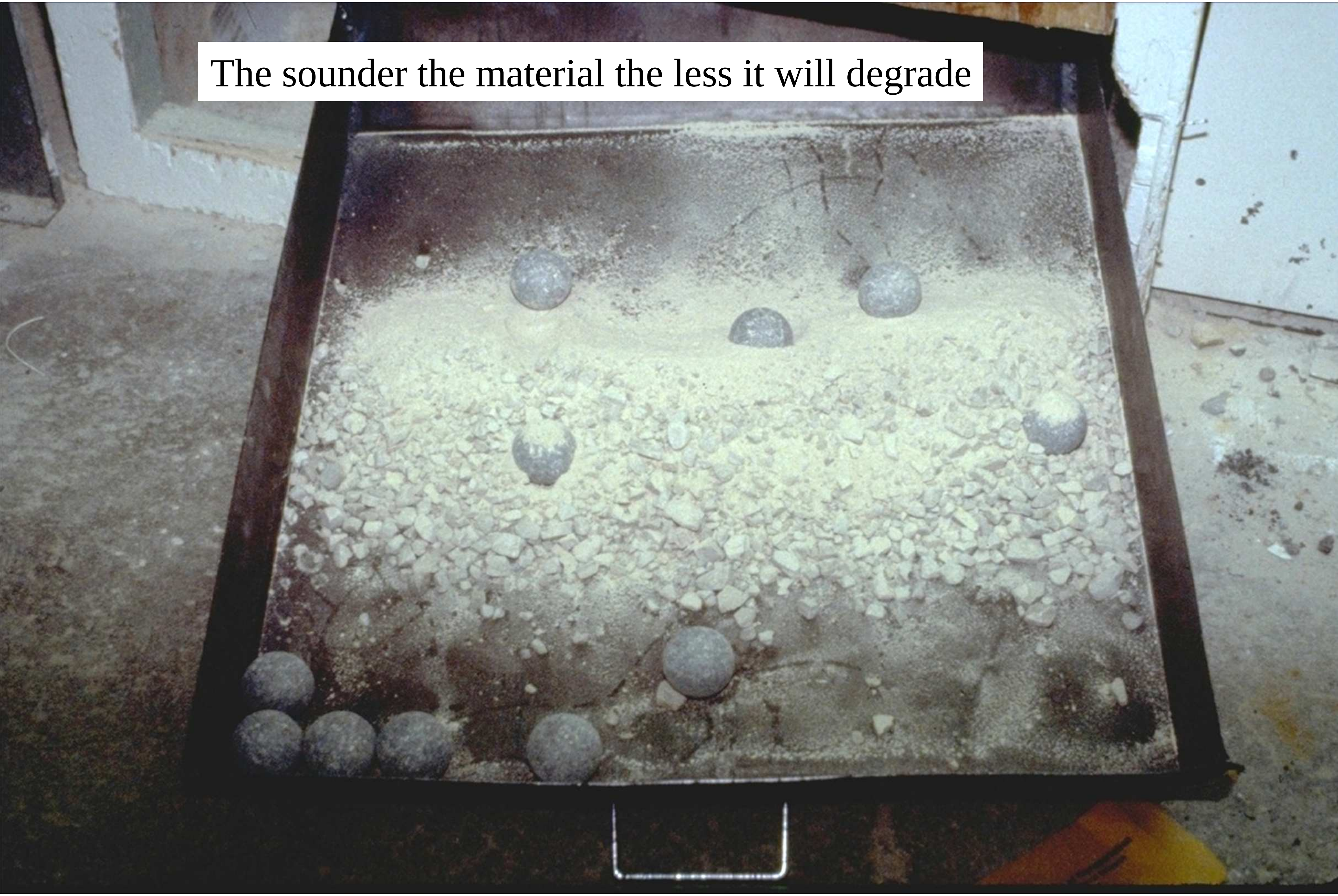

2500g 1/2"
2500g 3/8"

Size level of the aggregate will determine the number of steel balls used:

For	1 Inch	12 steel balls
	3/4 Inch	11 steel balls
	1/2 Inch	8 steel balls



The machine rotates the material at 30-33 RPM for a total of 500 revolutions


The sounder the material the less it will degrade

Micro Deval


START
EMERGENCY OVERRIDE
JAR LID TO LEFT
IMPORTANT
TO SET COUNTER

Deleterious Particles

DELETERIOUS COUNT

- **Used to determine deleterious material not suitable for various highway construction uses**
- **In coarse aggregate**
- **In fine aggregate (normally natural sand only)**
- **Repeatability is main problem for this test**
- **Each state or agency may have its own definitions for various deleterious materials in aggregate**
- **Aggregates are at the mercy of their origin**

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Each piece has to be hand examined


X-191
3208
X-191
7
11

Concrete Quality Coarse Aggregate Deleterious Count

	Maximum %
Shale	1.0
Clay lumps	0.25
Coal and lignite	0.25
Soft and unsound	4.0
Other deleterious (includes deleterious chert)	4.0
Total deleterious	5.0

Chert test

The specific gravities of the chert is checked to determine quality
Non-Deleterious chert has a specific gravity of >2.35, >2.40, or >2.55
Depending on whose test procedure or specification is used

Other counts for information only: **Carbonate (gravel)**
Siliceous (chert gravel)
Crushed Particle
Flat & Elongated


Fine aggregate deleterious count test

Fine Aggregate Deleterious Count

	Concrete Quality % Max.	HMA Quality % Max.
Shale	3.0	3.0
Clay lumps	1.0	3.0
Coal, lignite & shells	1.0	1.0
Conglomerate	3.0	3.0
Other deleterious	3.0	3.0
Total deleterious	3.0	5.0

Concrete Durability

- D-Cracking
  - ASTM C 666
- Alkali Silica Reaction
  - ASTM C 1260
  - ASTM C 1293
  - Other Tests

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Freeze-Thaw Expansion Test

- “The disintegration cracking of PCC due to freeze-thaw failures of its aggregate particles and surrounding mortar”
- Test is used to identify aggregate susceptible to D-cracking
- D-cracking starts at the lower levels of pavements/joints and works upward and outward destroying the concrete pavement
- Carbonate aggregates are susceptible

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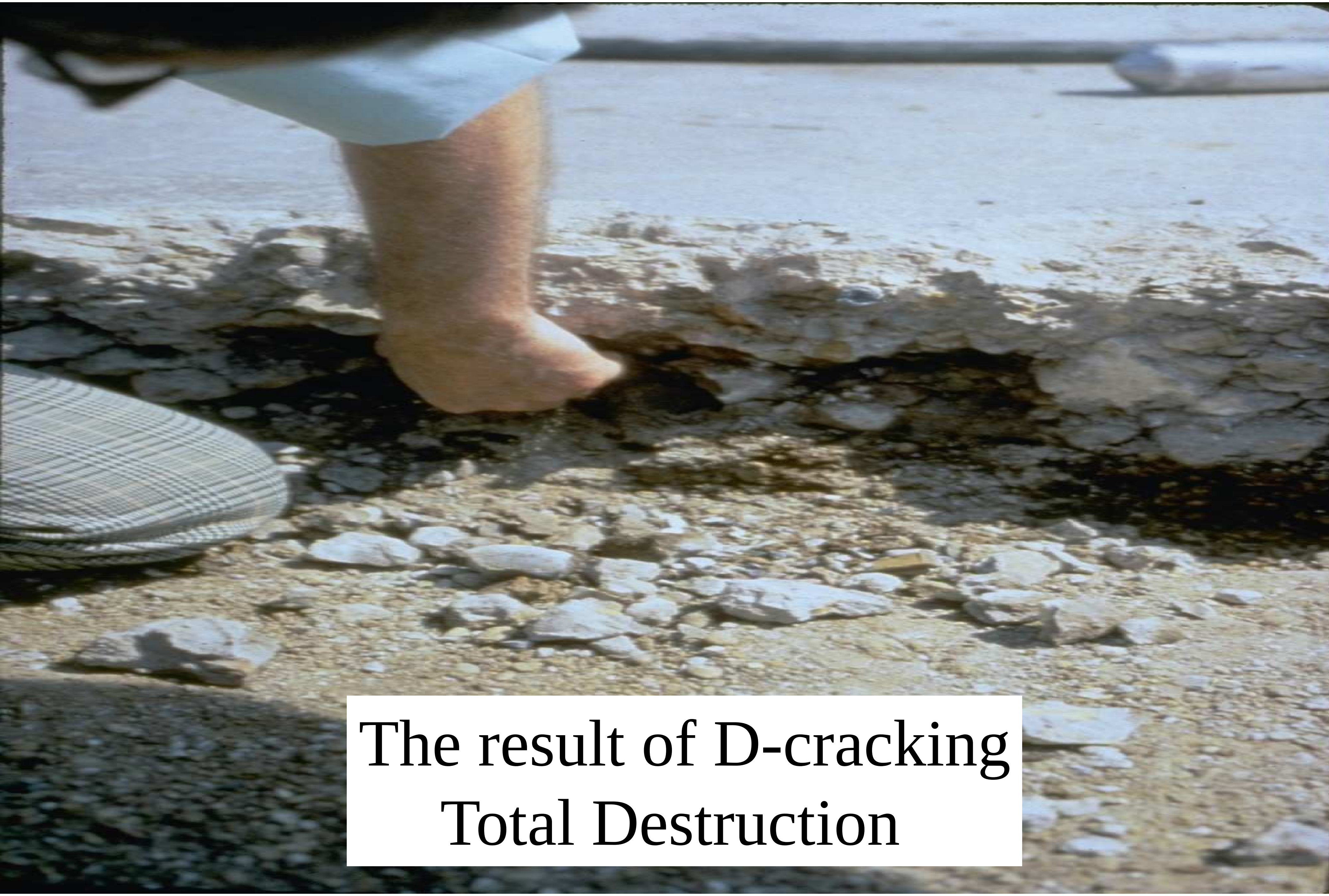
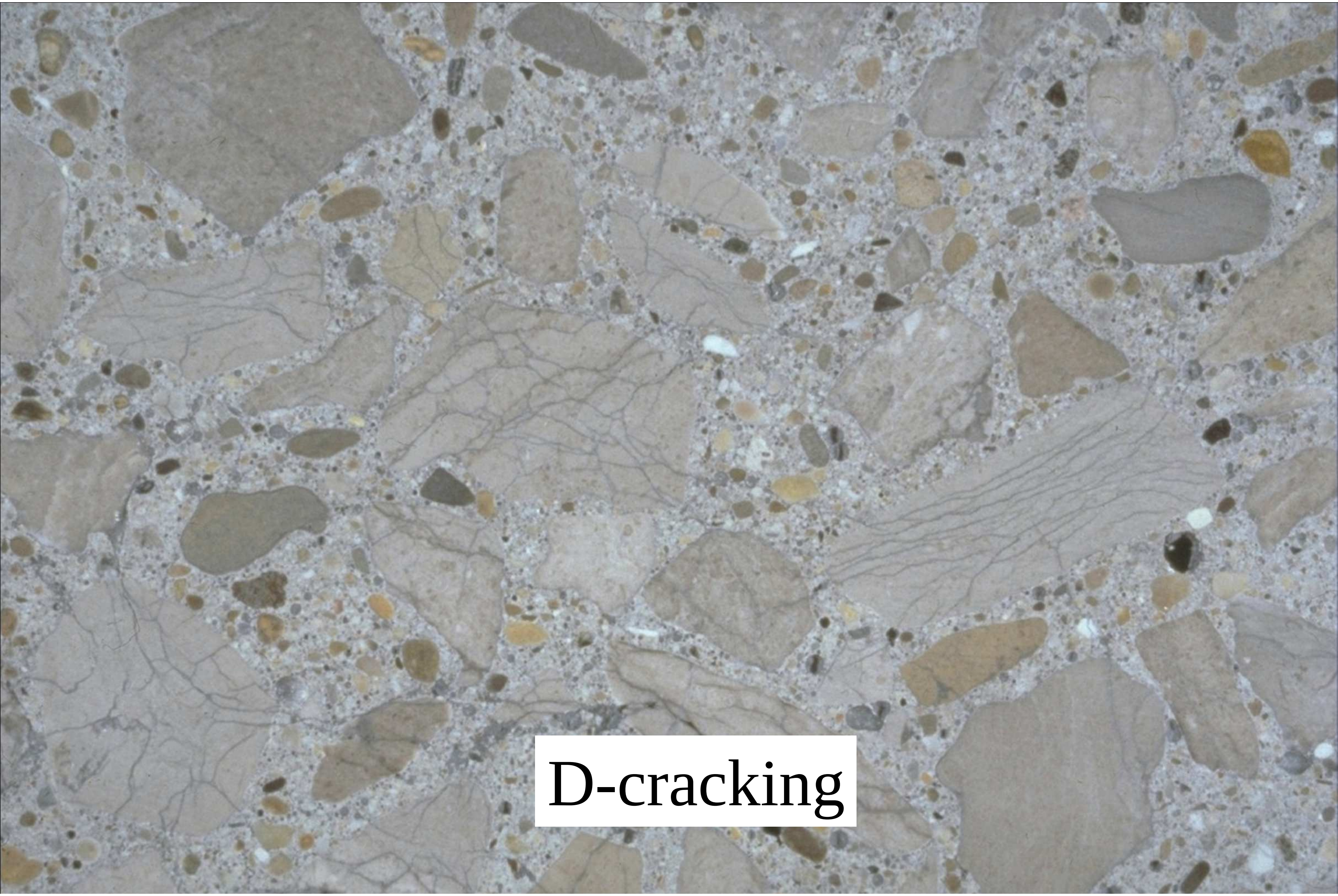
- Freeze-Thaw Environment
  Can’t be controlled
- Water
- Susceptible Aggregate
  The best approach to fix the problem



The result of D-cracking
Total Destruction


D-cracking

D-cracking of Jointed Pavement

Freeze-Thaw Expansion Test

ASTM C 666
Method B

Freeze in Air - Thaw in Water

Many state DOTs use his test but in a modified form

Freeze-Thaw Expansion Test

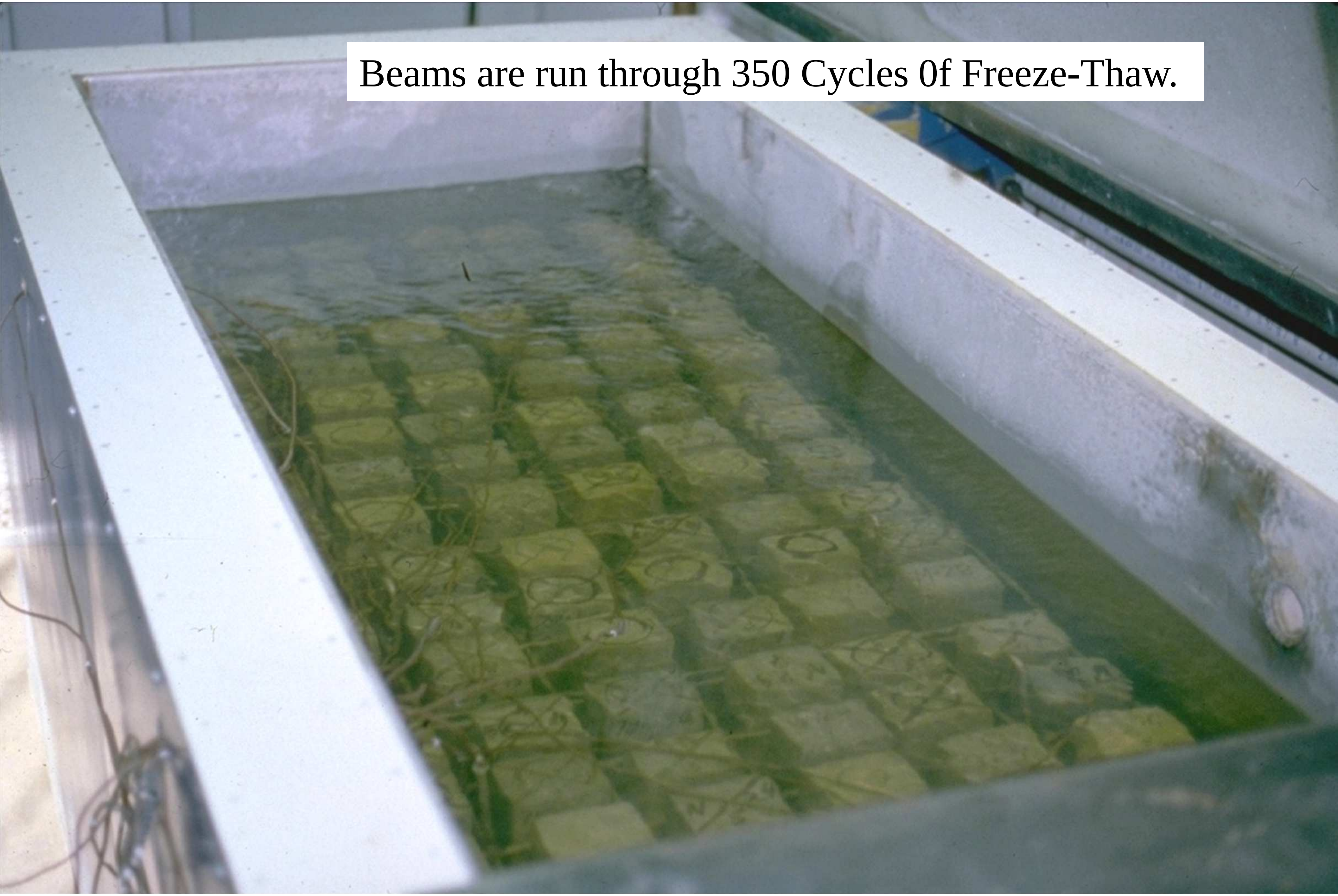
ASTM C 666
Method B

Freeze in Air - Thaw in Water

Illinois DOT Version

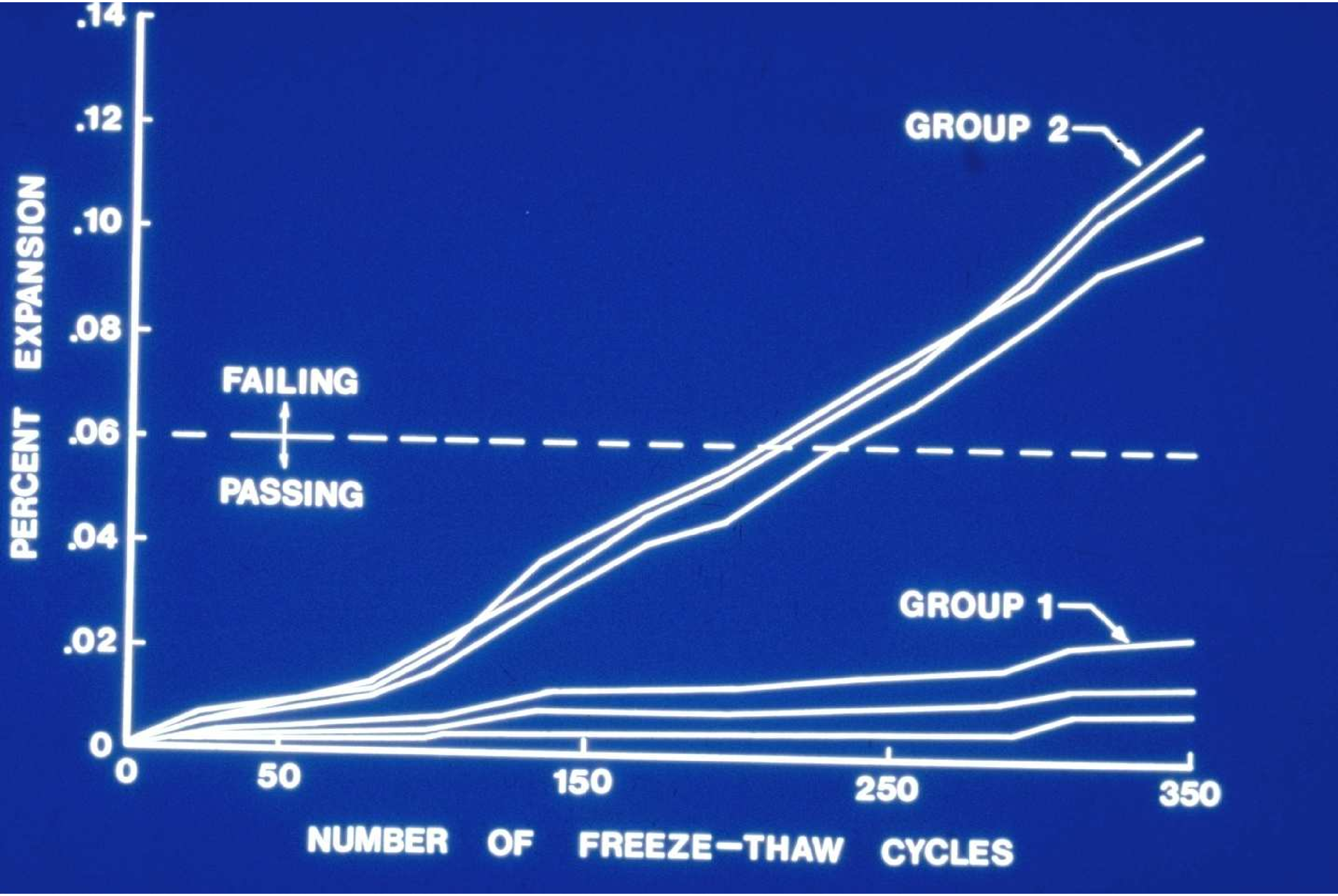
Coarse aggregate is collected and fractionalized and re-combined to a standard gradation


Beams are made and cured for 14 days
Bolt→
←Bolt


Beams are run through 350 Cycles 0f Freeze-Thaw.

Beams are measured once per week or approx. every 25 – 50 cycles

Length changes are plotted on a graph


PERCENT EXPANSION
.14
.12
.10
.08
.06
.04
.02
0
0
50
150
250
350
NUMBER OF FREEZE–THAW CYCLES
FAILING
PASSING
GROUP 2
GROUP 1

Alkali Silica Reaction

ASR Aggregate Tests

ASTM C 1260
Accelerated Mortar Bar Test

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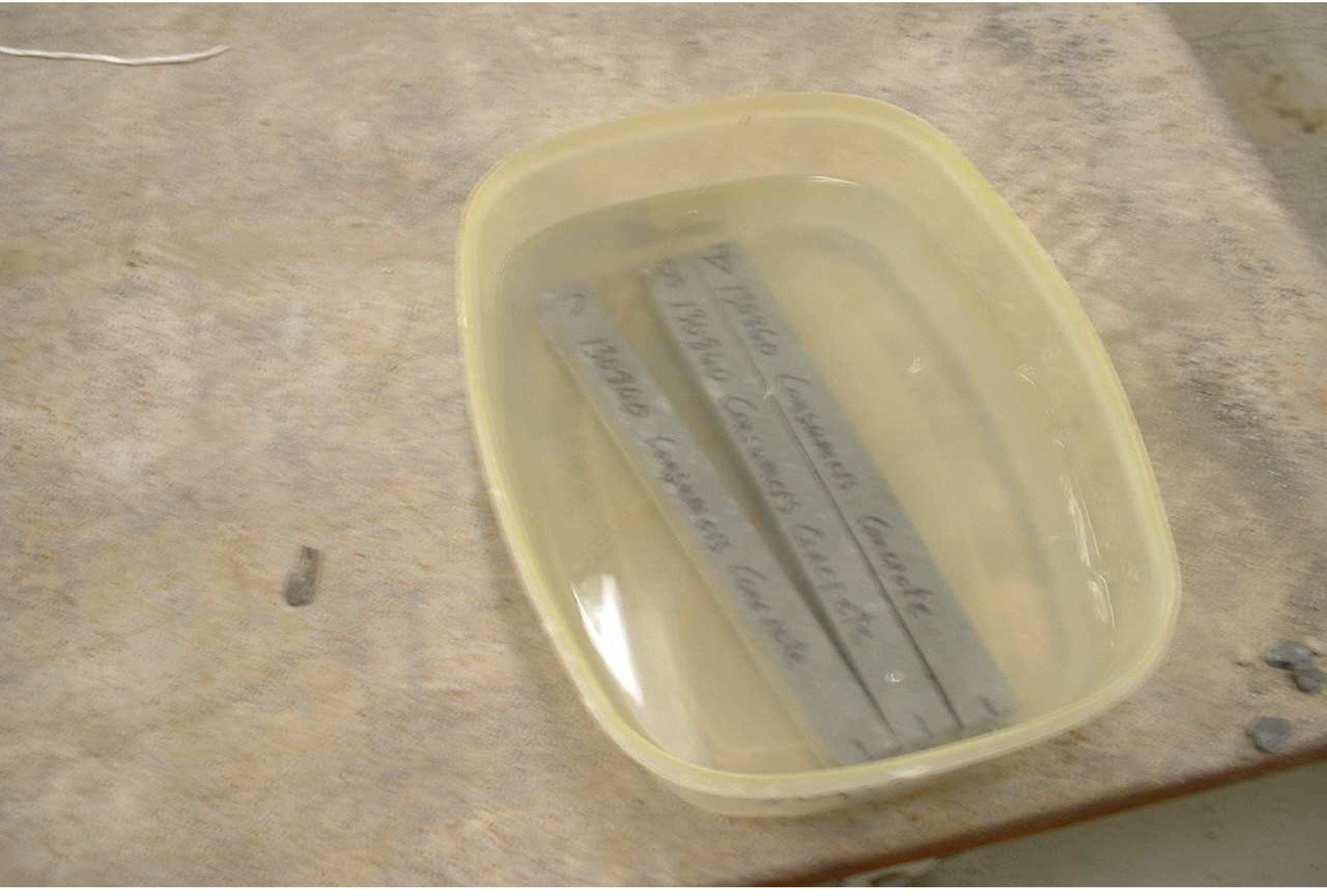

Valid Results ?

Test can show erroneous failing results

ASTM C1293

- Concrete Prisms
- Add Sodium Hydroxide to mixture water
- One year test
- Length-change measurements

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Beams are made and cured for 14 days
Bolt→
←Bolt

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BOWSER MORNER®

BOWSER MORNER®

Beams are measured once per week or approx. every 25 – 50 cycles

Length changes are plotted on a graph

Physical / Chemical Characteristic Tests

- Hydrometer Test
- Colorimetric Test
- Dolomite Determination/CCE
- Friction Determination
- Specific Gravity/Absorption Test
- Gradation Test

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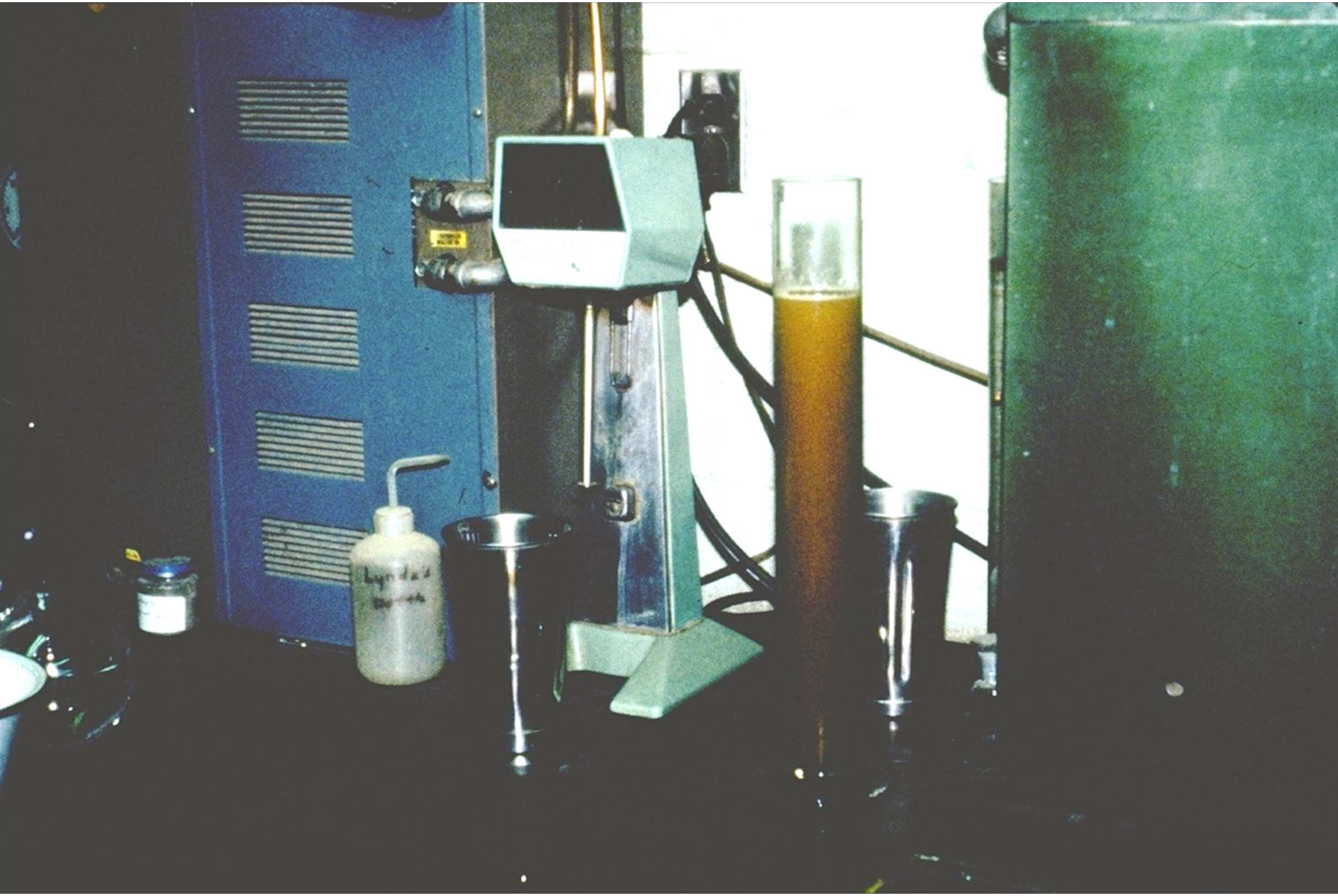
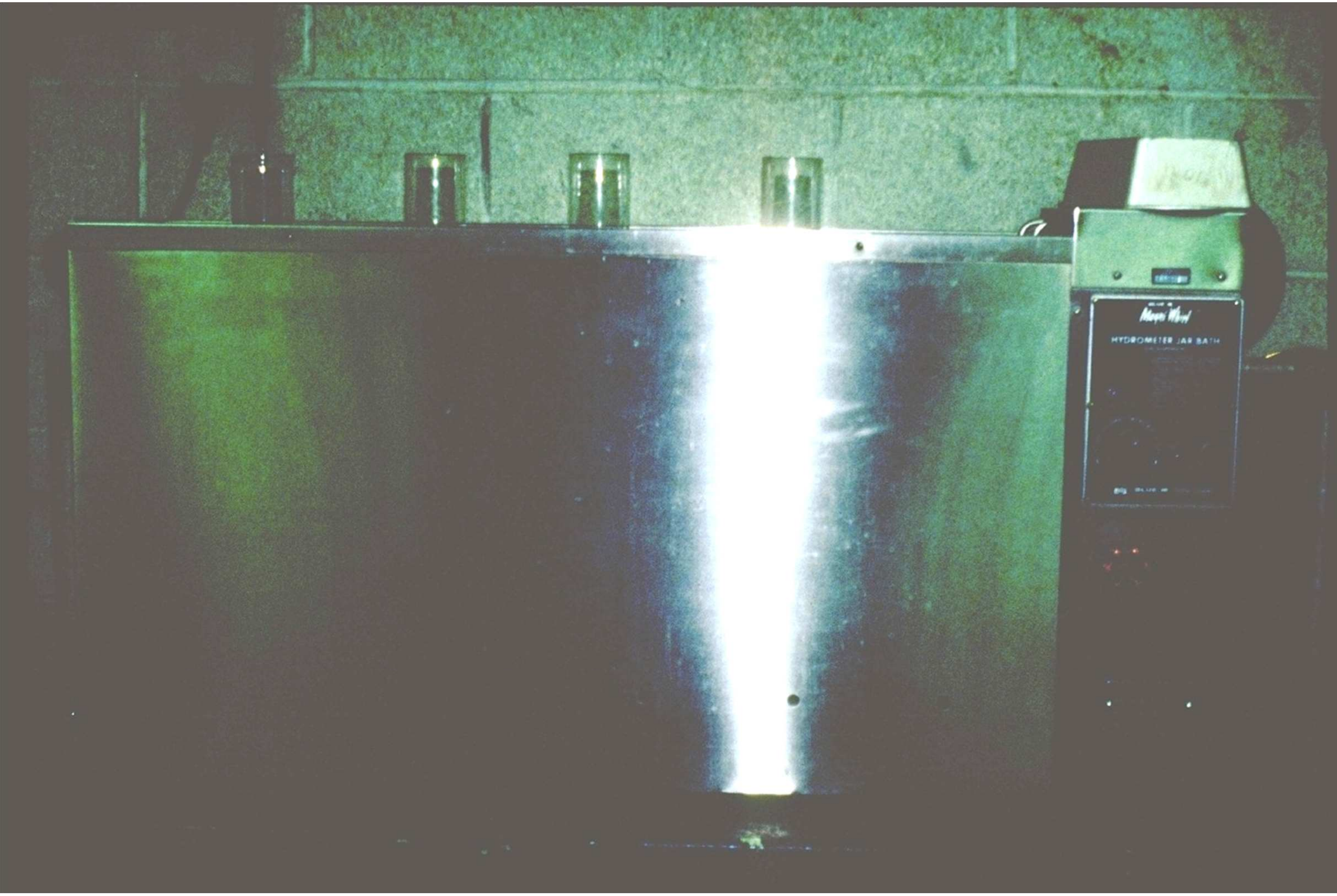
Hydrometer Test

- **A test used to determine the percentage of clay-sized particles**
- **Clay can be detrimental to both HMA & PCC**




HYDROMETER JAR BATH

COLORIMETRIC

Used to determine the organic content in Concrete quality sands which can reduce concrete strengths

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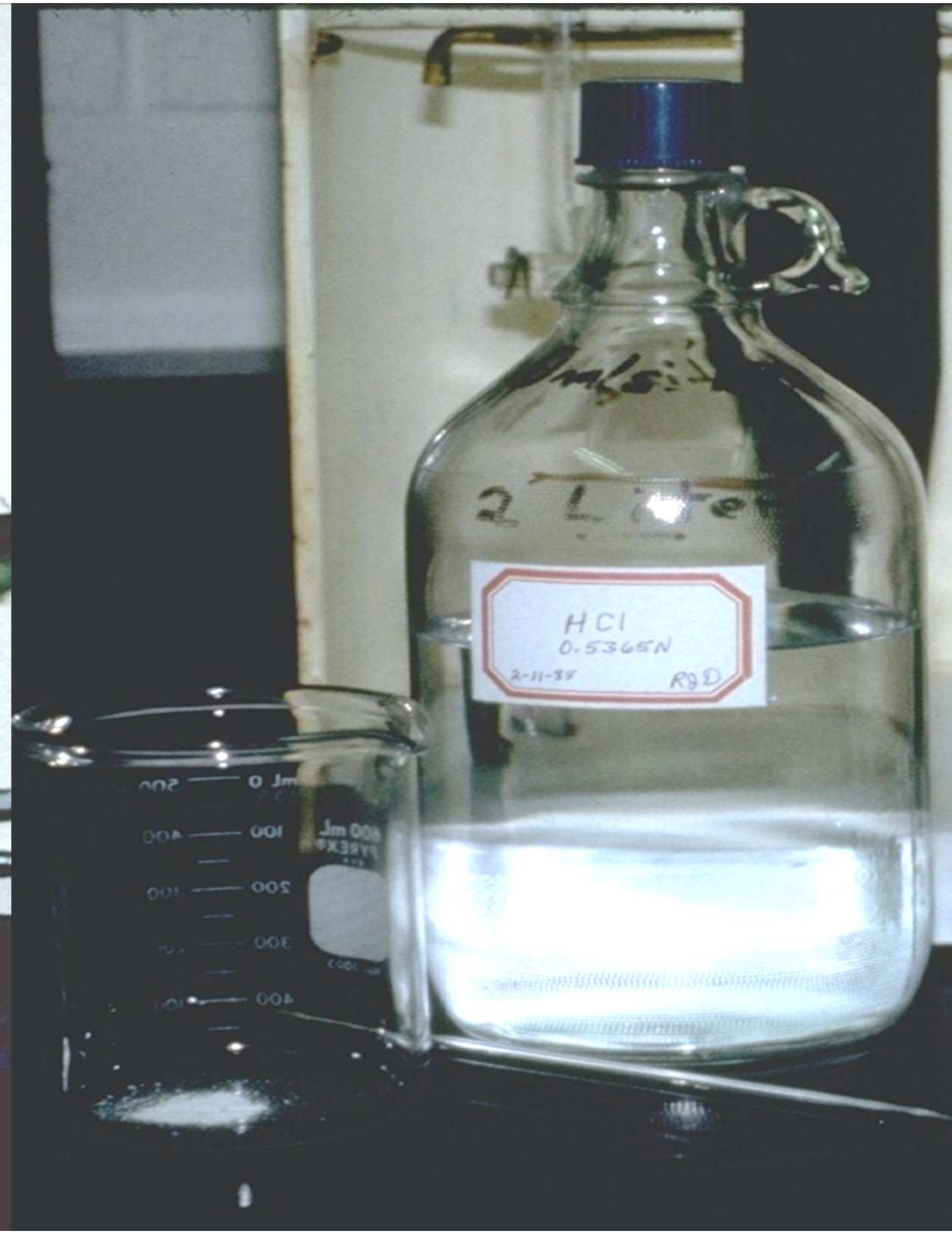
131219
P.M. INGLESIDE
MFC SAND
ORGANIC IMPUR
05/24/09
9:12 AM
1
2
3
4
5

DOLOMITE DETERMINATION
&
C.C.E. (Calcium Carbonate Equivalent)


HCl
0.5365N

Friction Potential

Class — I & Superpave

Mixture — D Surface

Aggregates Allowed

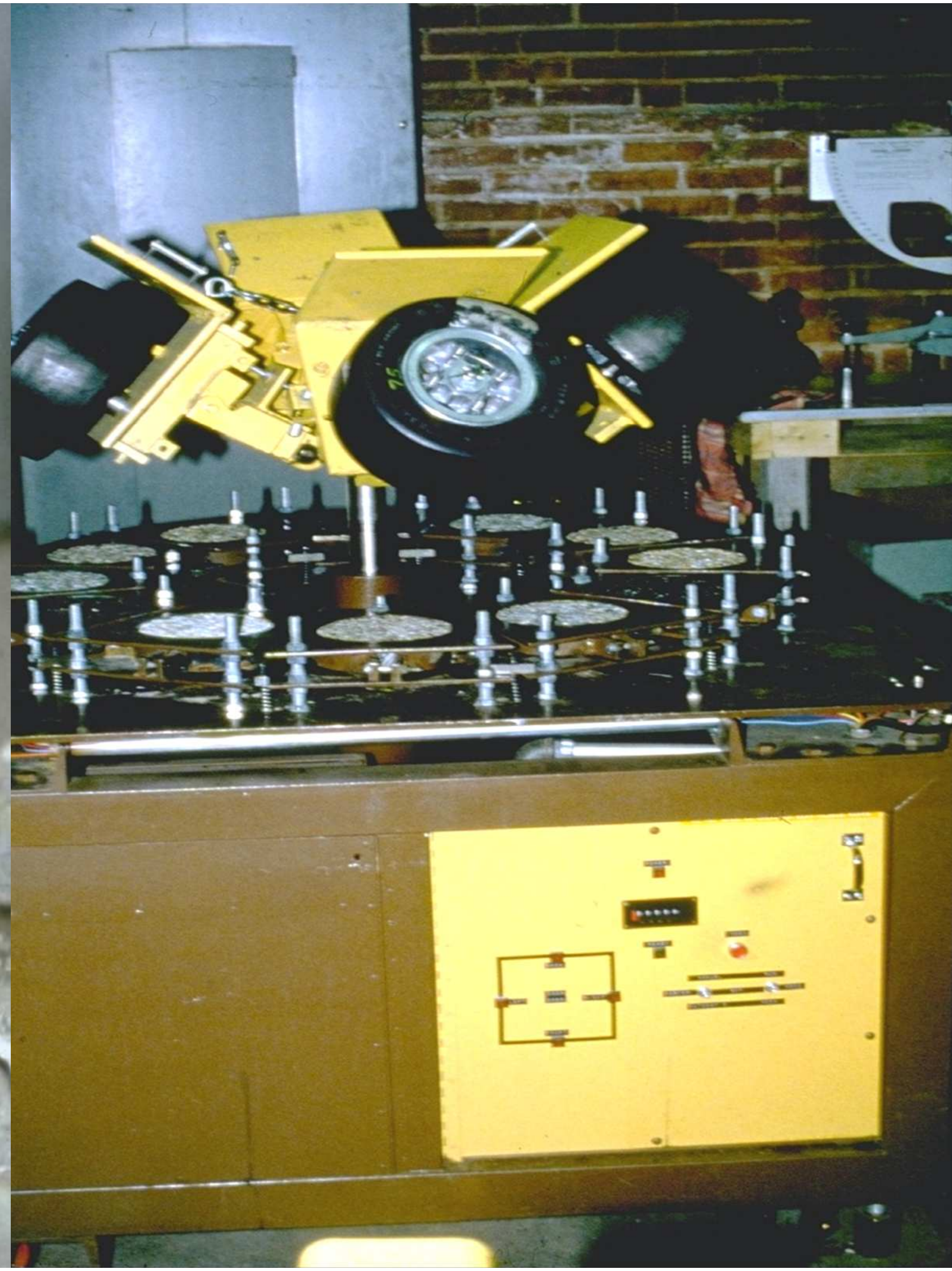
Crushed Gravel
Crushed Sandstone
Crushed Steel Slag
Crushed Stone (other than limestone)
Crushed Slag (ACBF)

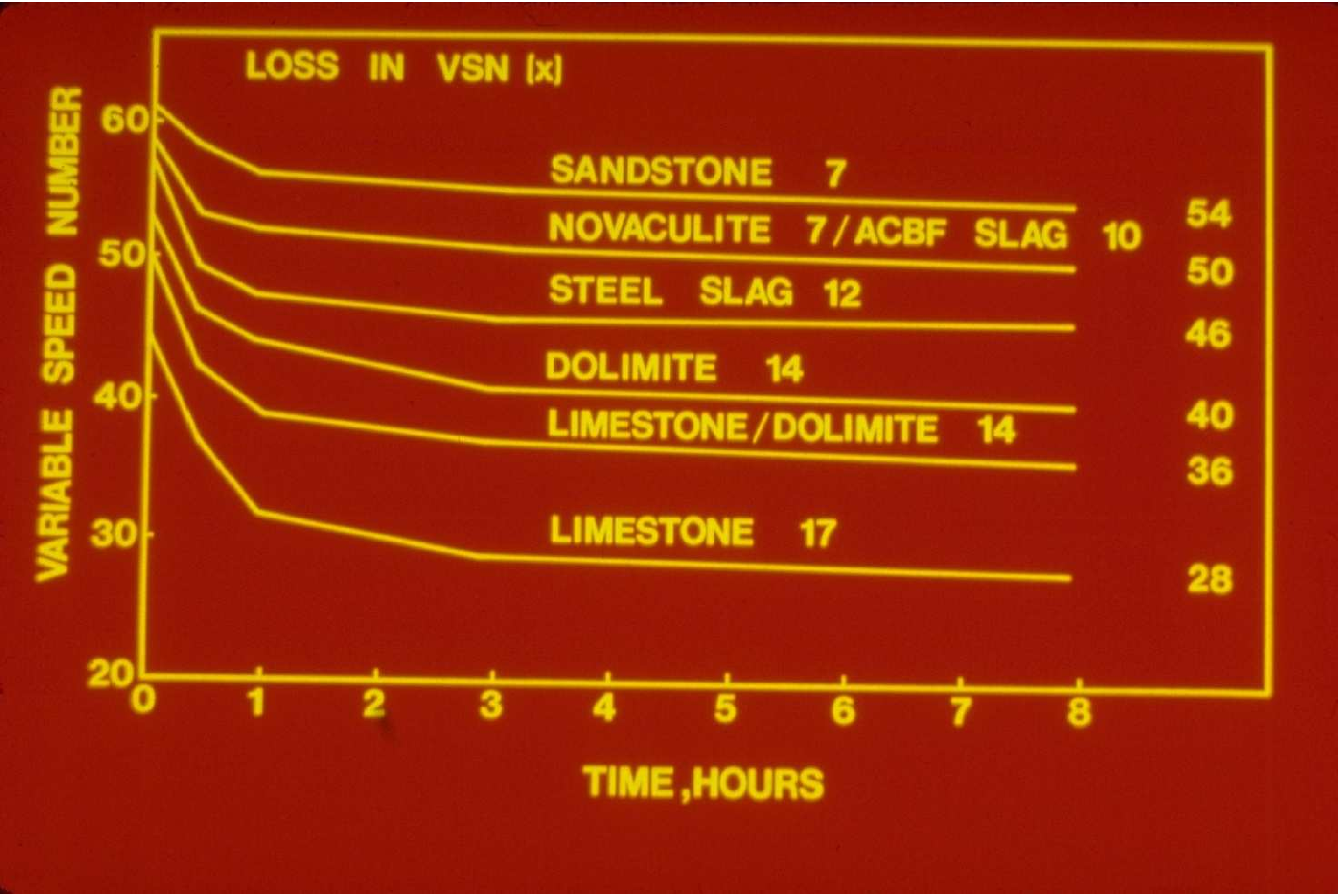
Limestone may be used in Mix. D if blended by volume in the following coarse aggregate %s:

- Up to 25% with at least 75% Dolomite
- Up to 50% limestone with at least 50% any aggregate listed for Mix. D except Dolomite
- Up to 75% limestone with at least 25% Crushed Slag (ACBF) or Crushed Sandstone

Typically for Rural Interstates


Friction Trailer




LOSS IN VSN (x)
VARIABLE SPEED NUMBER
60
50
40
30
20
SANDSTONE 7
NOVACULITE 7/ACBF SLAG 10
STEEL SLAG 12
DOLIMITE 14
LIMESTONE/DOLIMITE 14
LIMESTONE 17
54
50
46
40
36
28
0
1
2
3
4
5
6
7
8
TIME, HOURS

British Wheel

British Portable Friction Tester

Test coupons ready to place on wheel

Metal wheel upon which the test coupons are placed.

The British Wheel Test Machine - Test wheel is placed on axle.

British Portable Pendulum Friction Tester

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Specific Gravity / Absorption Tests

- Not used for acceptance but critical in designing both HMA & PCC mixtures

- Can be indicators of quality & durability

- A 'general rule' is:

	Specific Gravities	Absorption
Good	2.60 or higher	2.0% or lower
Borderline	2.54 – 2.60	2.0% – 3.0%
Bad	2.53 or lower	3.0% or higher

- Slag materials and shale-laminated stone are an exception to this rule

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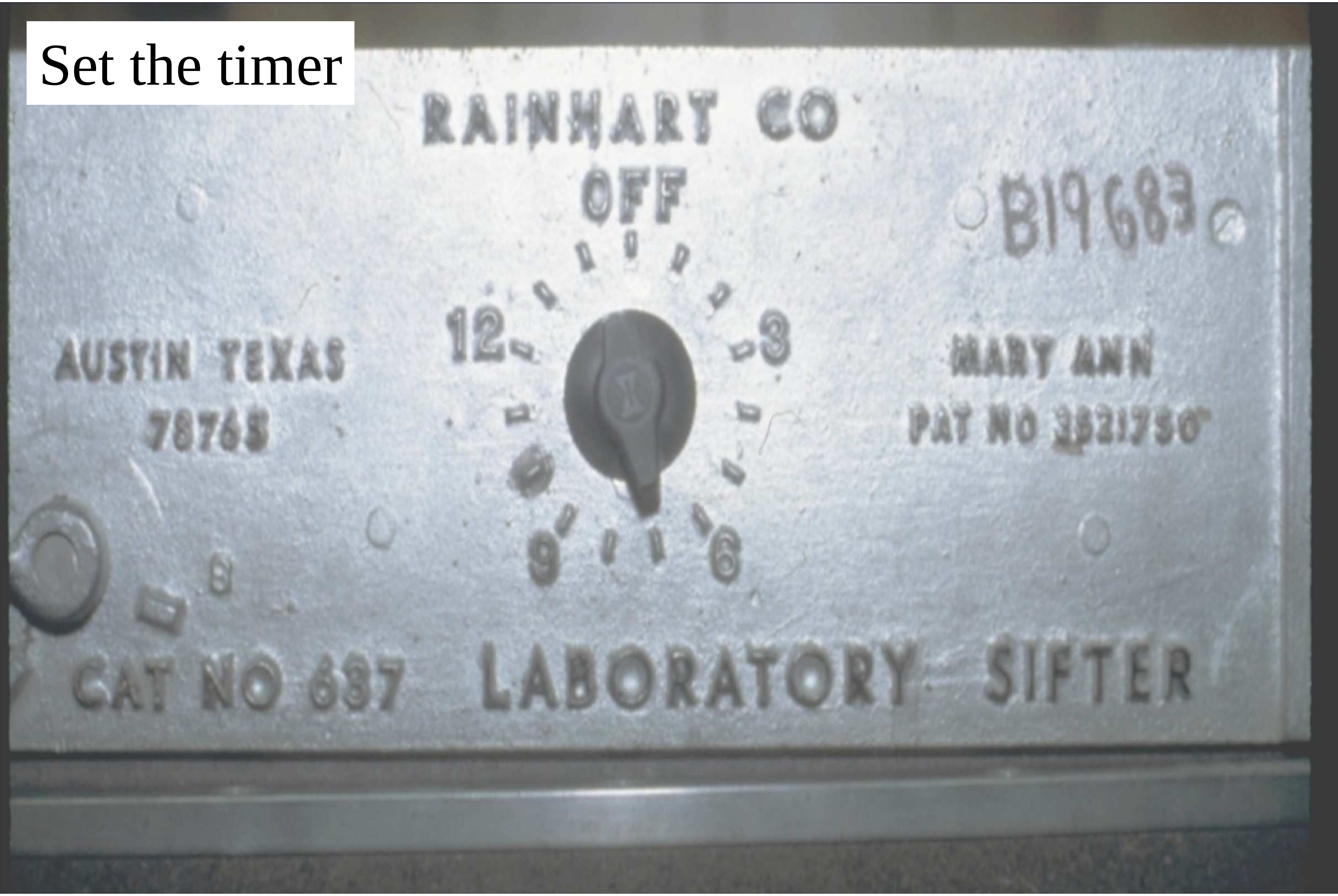
ASTM Procedures and Specifications
Explorer

Gradation Testing

Place the stack into the sieve shaker

Set the timer



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Weigh the retained material

The end …

Stockpiling
Handling
Load-out

- **Stockpiling, handling, and load-out are three of the most important aspects of aggregate production**

- Material produced in-specification can easily become out of specification

- Three main factors contribute to this problem
  - Segregation
  - Degradation
  - Contamination

SEGREGATION

- **Defined as "the separation of a well graded production aggregate into individual sizes due to gravity".**

- Larger size particles will roll down a side of an inclined pile

- Smaller size particles tend to congregate in the middle and back sides of an inclined pile

- Care needs to be taken to re-blend the material during load out

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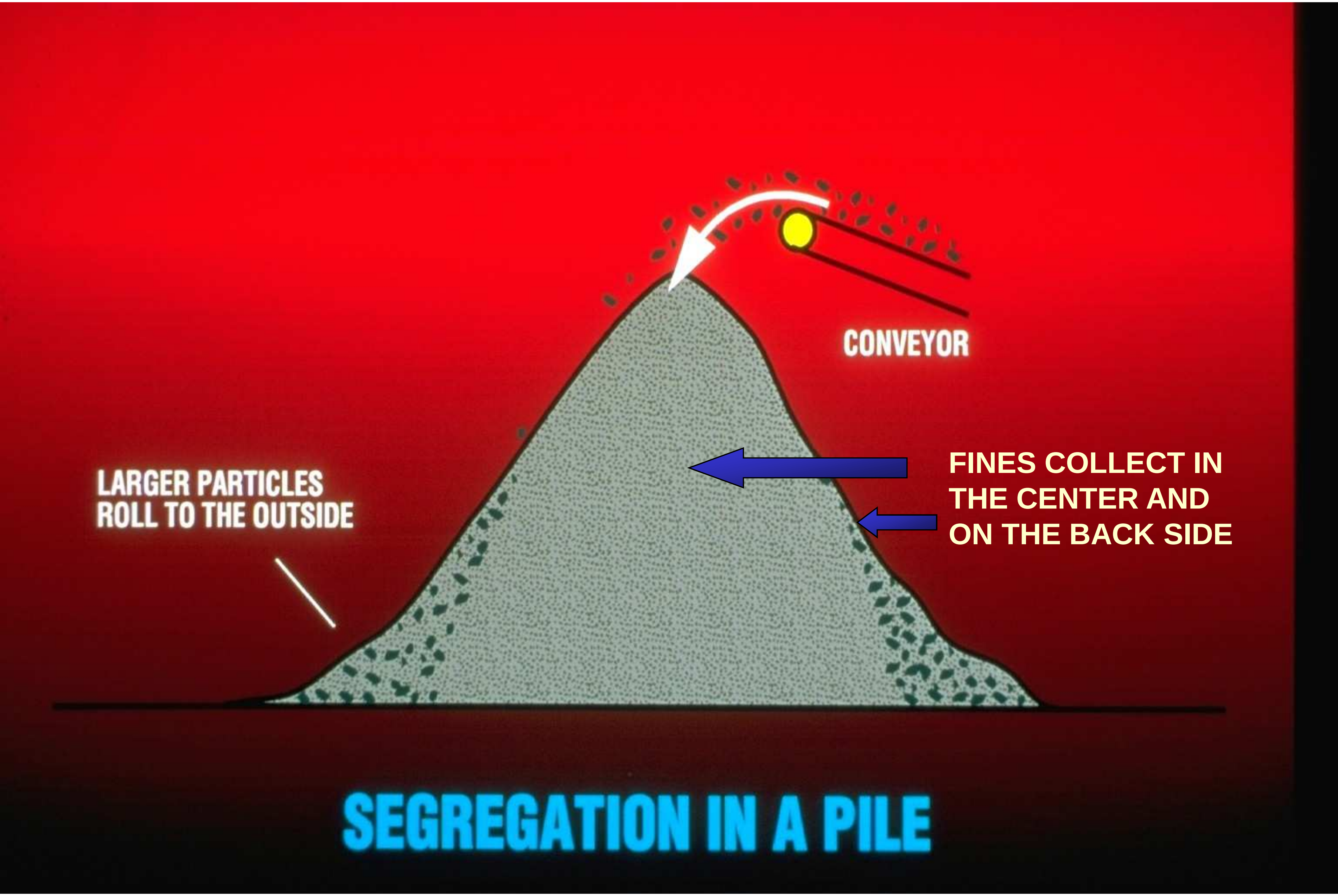
Segregation is one of the main causes of pavement destruction and needs to be addressed

Segregation can reduce pavement life by 3-5 years or more


CONVEYOR
LARGER PARTICLES ROLL TO THE OUTSIDE
FINES COLLECT IN THE CENTER AND ON THE BACK SIDE
SEGREGATION IN A PILE

Segregation Problems at HMA Plants
Batch Plants

- Segregation will cause bin overload or bin starvation
  - Affects production
  - Changes mix properties
  - Problems seen at plant and road
  - Wastes material, increases costs

Segregation Problems at HMA Plants
Drier-Drum Plants

Segregation is not necessarily seen at the plants

- Material is conveyed directly from cold feeders to the drum mixer across a weigh-belt
- Still affects mix properties
- Problems seen at the road:

Rutting, Unraveling, Density, Movement, etc.

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Segregation at Concrete Plants

- **Plant does not correct, problems are seen on the jobsite and in the final products**

- Too much large aggregate will cause:
  - Harsh mixes
  - Poor workability
  - Increased material costs, wasted material

- Too many fines:
  - Strength goes down

Segregation at

<u>any type of plant</u>

will reduce

the pavement's life

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DEGRADATION

- **Degradation is defined as "The actual breakdown of individual aggregate particles due to abrasion and attrition during stockpiling and handling"**

- Can be detrimental to the final product due to the increased minus #200 material (fines)

- Increased fines cause performance problems in the final products

Edges Break Off Due to Attrition , Abrasion – Increased Dust

Degradation in Concrete Plants

- **Excessive fines:**
  - **Changes the properties & characteristics of mixes**
  - **Increases water demand**
  - **Produces low strength**
  - **Reduces pavement life**

Degradation in HMA Plants

- Excessive fines:
  - **Changes the properties & characteristics of mixes**
  - Can overload the dust collection systems
  - Waste material that has to be disposed of
  - Causes tender mixes
  - Causes rutting in mixes
  - Increases overall product costs

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Contamination

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The introduction of extraneous material (normally deleterious) into a finished aggregate

Contamination by Digging into Stockpile Pad or Dumping Clean-up on Side of Pile

Contamination by Tracking Mud and Clay on to Pile

CONVEYOR STOCKPILES

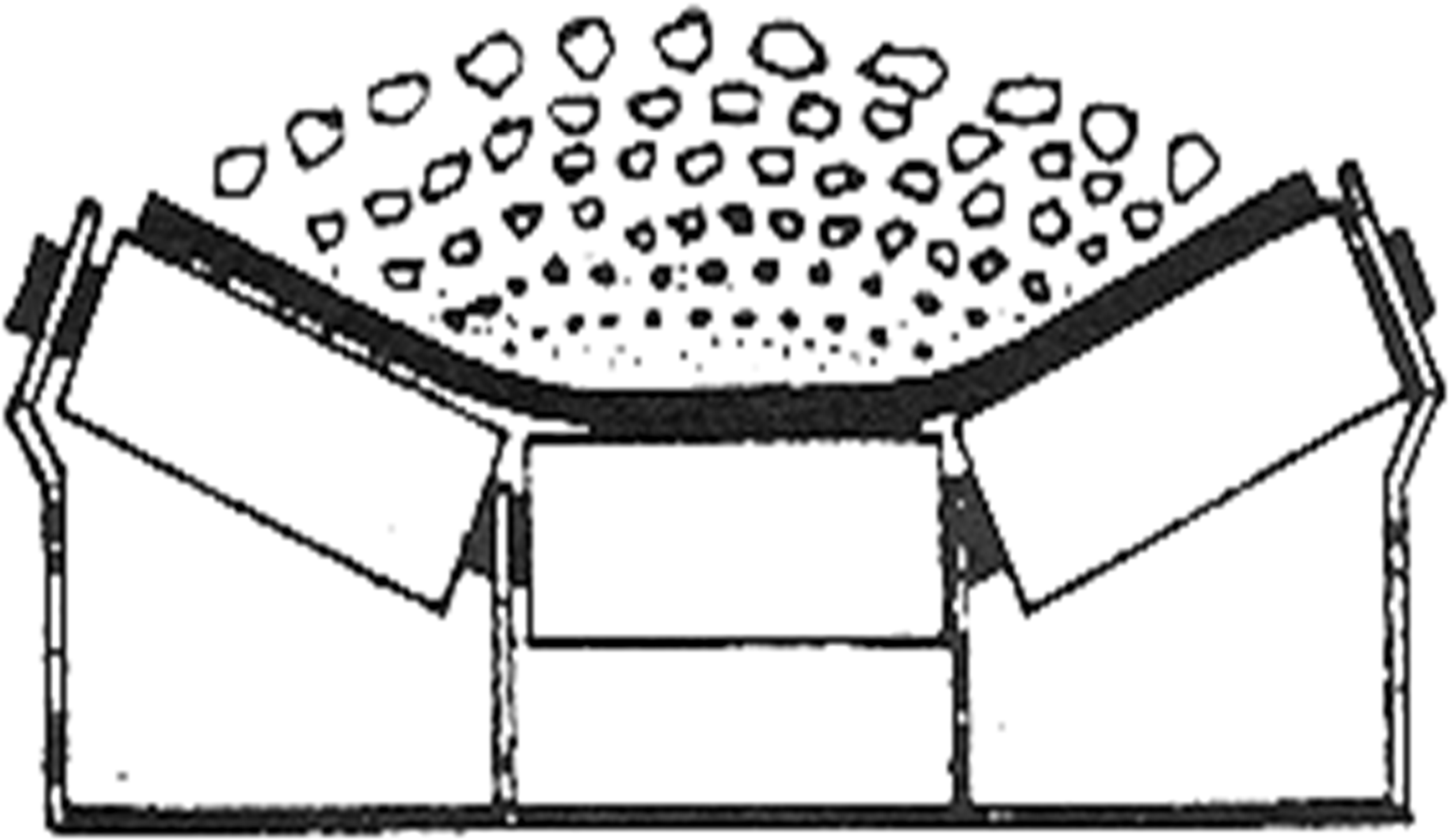
Two kinds:

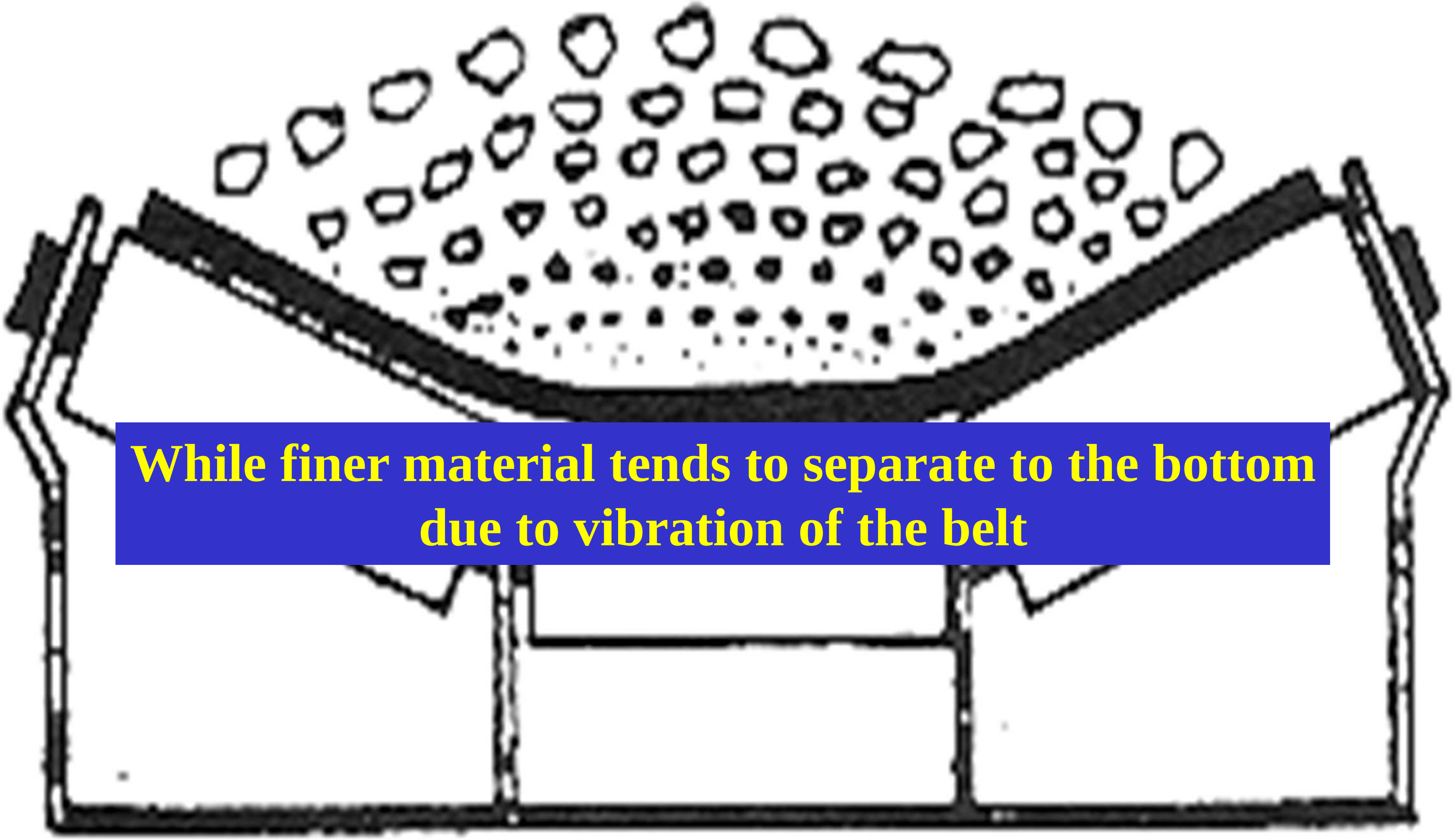
Cone – fixed or adjustable

Elongated – radial or movable

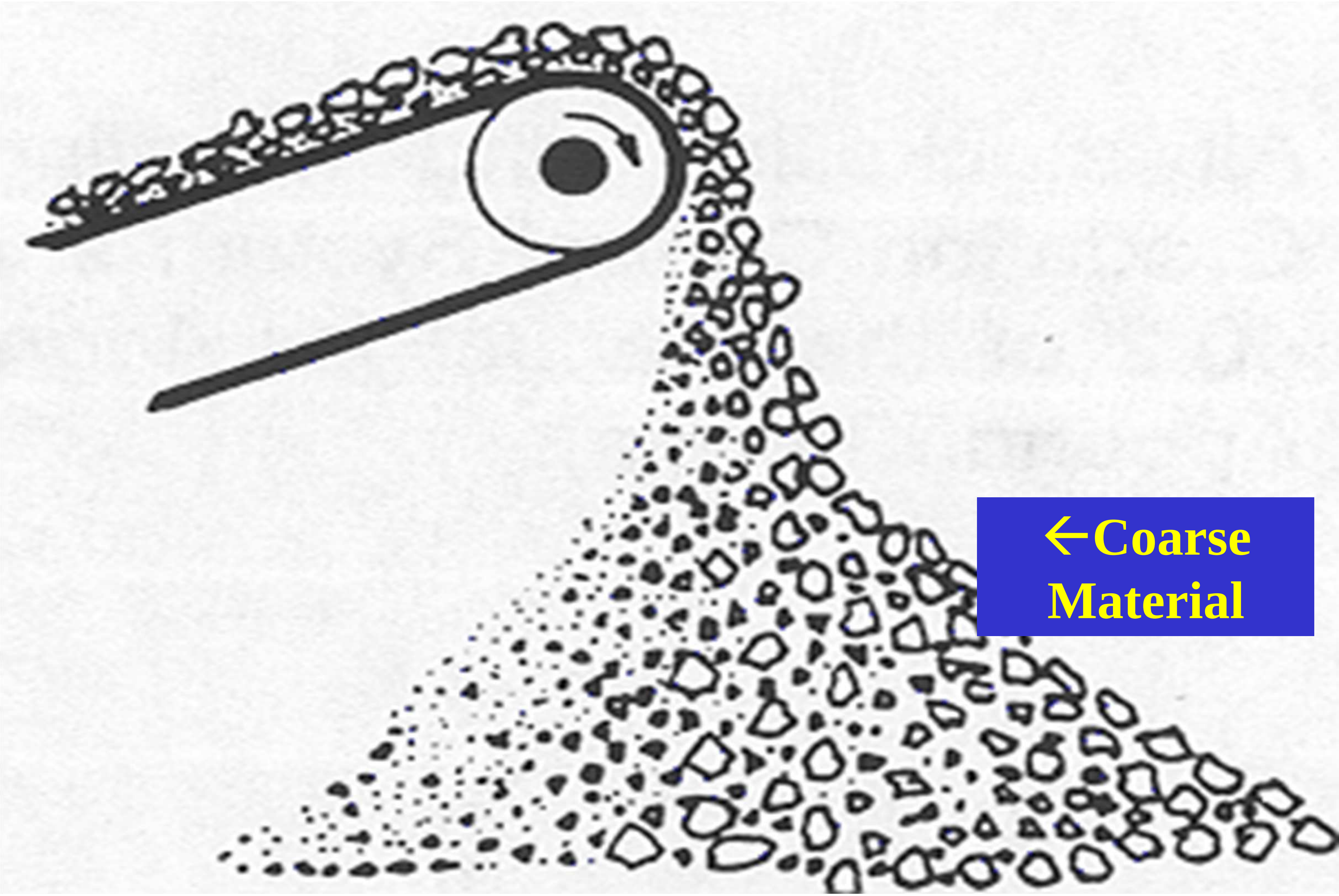
Segregation tends to be a major problem with this method but not degradation

Coarse material tends to 'float' to the top

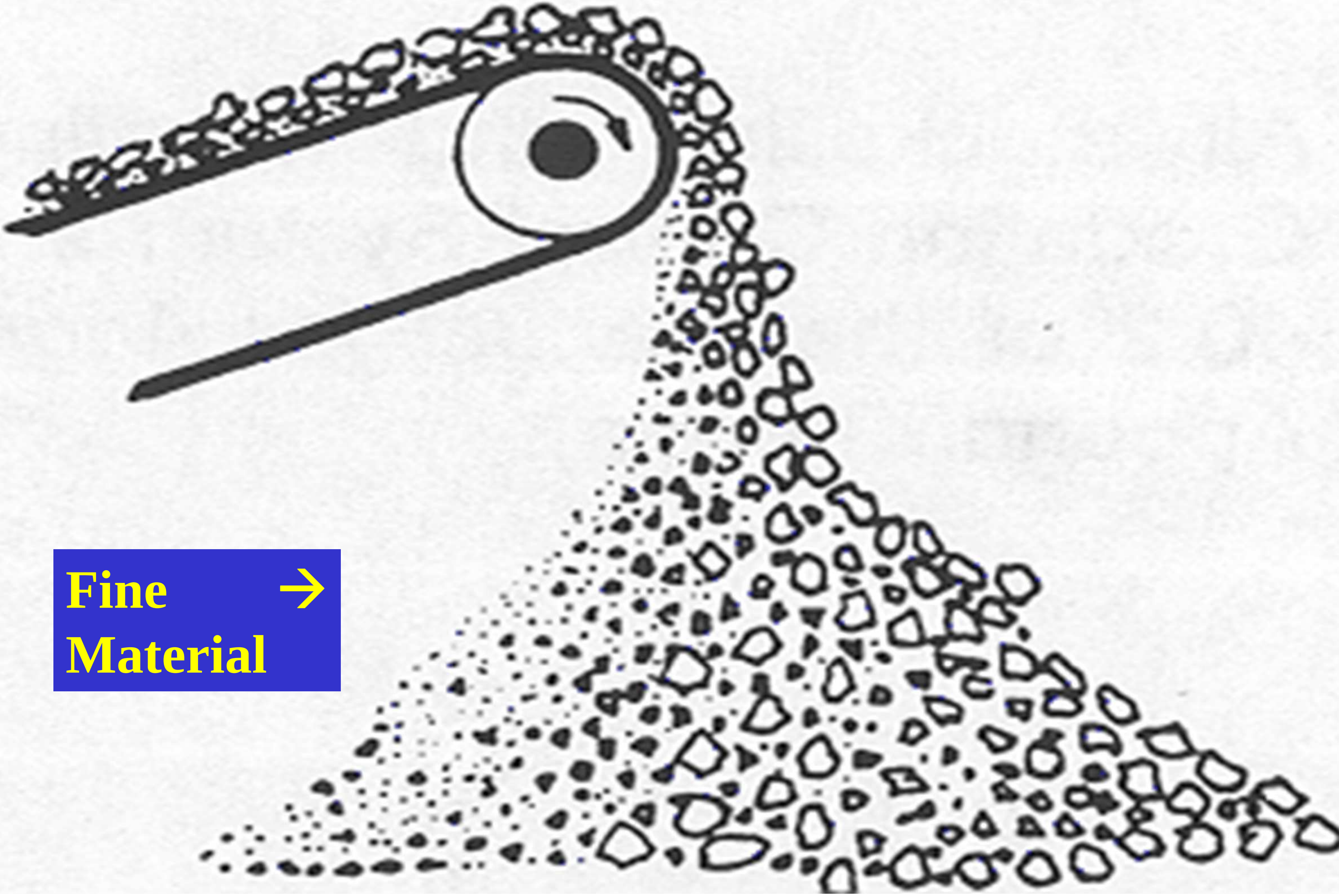




While finer material tends to separate to the bottom due to vibration of the belt



←Coarse Material


Fine Material →

5 Factors that will influence the amount of segregation in cone stockpiles:

1. Distance of fall from the conveyor
   (normally should limit to a maximum of 15’)
2. Amount of moisture in the aggregate
3. Wind conditions (this will affect the –200 material)
4. Height of the pile
5. Speed of the conveyor belt

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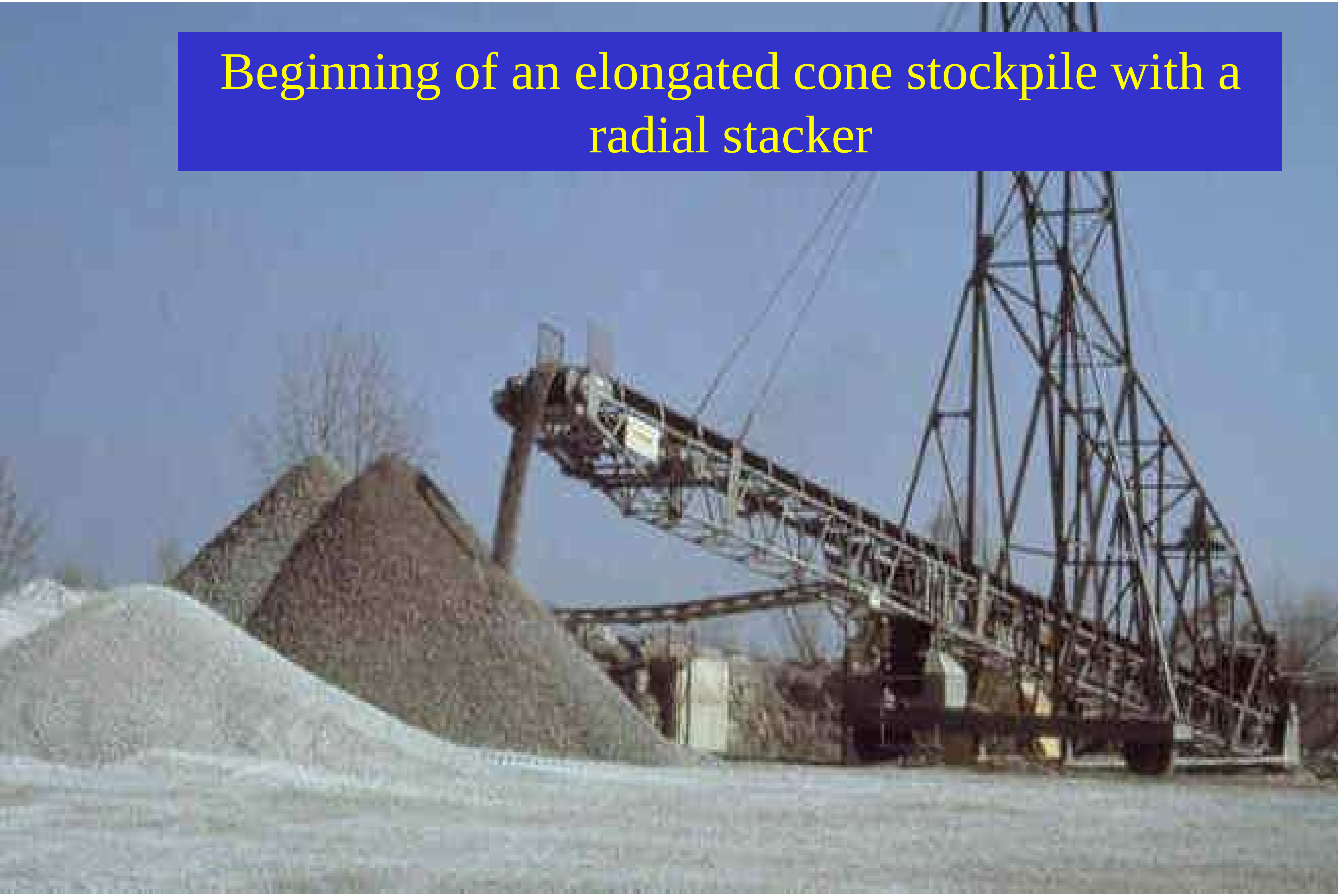
Cone stockpile

An adjustable radial stacker moves horizontally and vertically as the material is produced

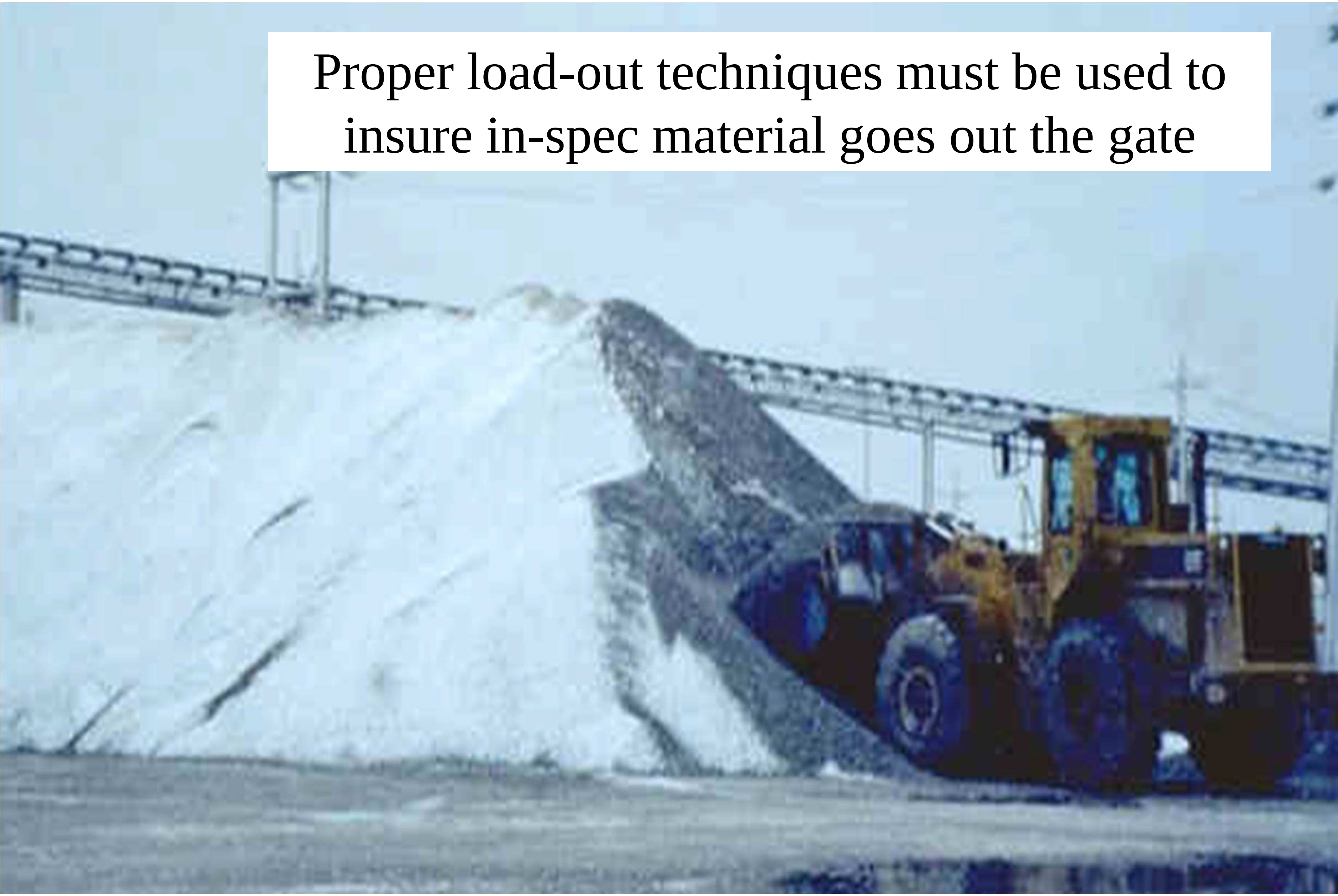
Beginning of an elongated cone stockpile with a radial stacker



Segregation can still be a problem

Telescoping Radial Stacker

Proper load-out techniques must be used to insure in-spec material goes out the gate



An endloader is very important in stockpiling and load-out

- The loader must load-out perpendicular to the material flow from the belt

- Material must be re-mixed during the load-out process

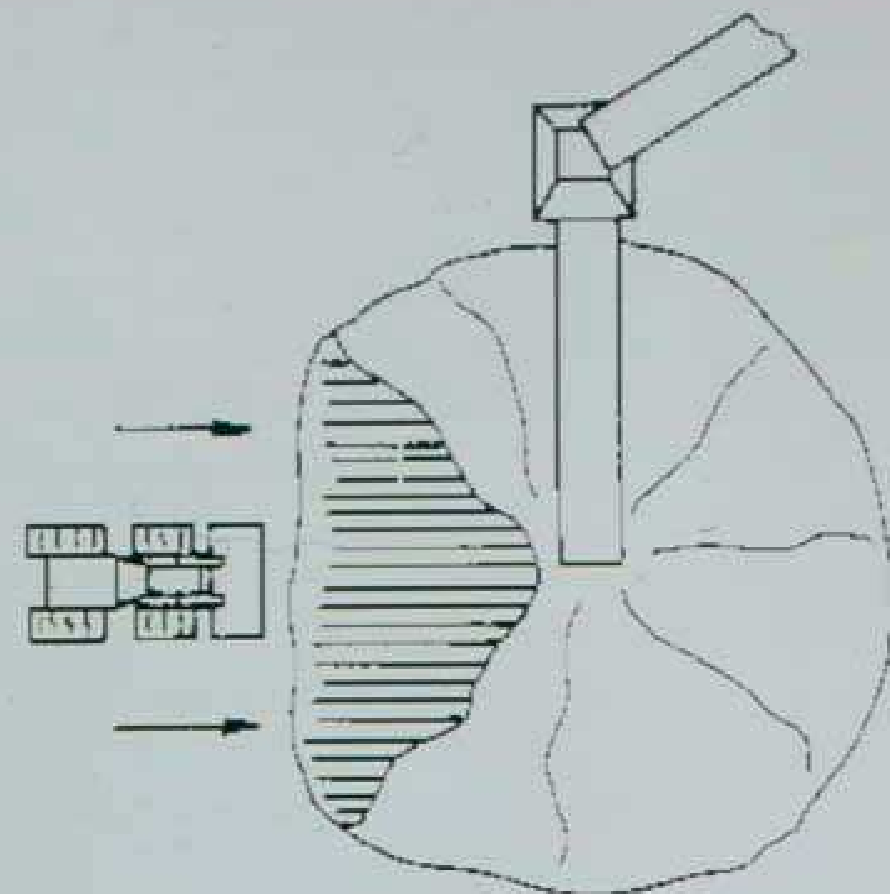
- The loader should work the entire face to incorporate both fine and coarse materials during the load-out

-The end loader is one of the most important jobs in stockpiling and load-out

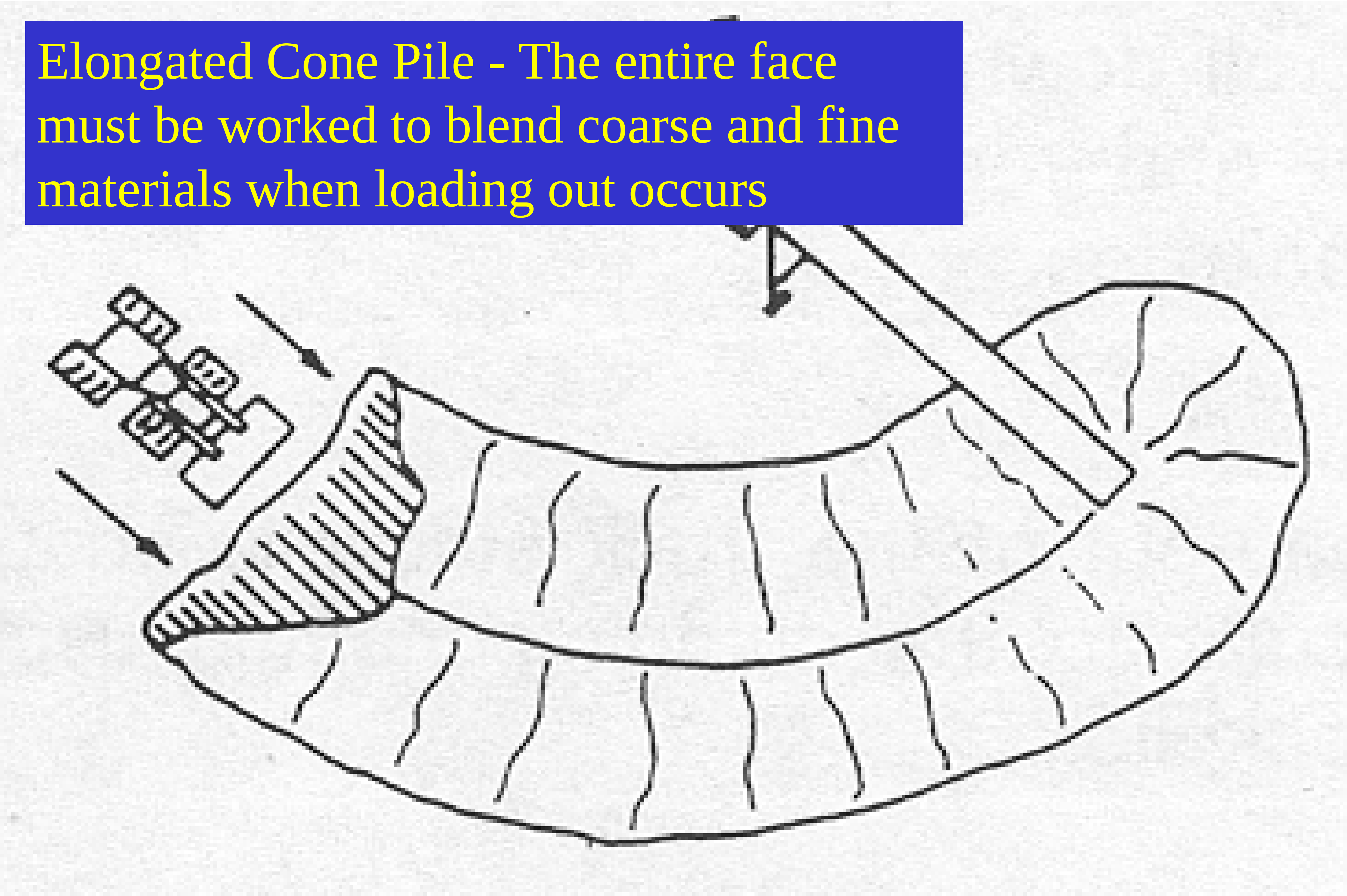
- The loader operator can make or break the shipment of In-Spec material out the gate

TYPES OF STOCKPILES

- CONE



Elongated Cone Pile - The entire face must be worked to blend coarse and fine materials when loading out occurs



Truck Stockpiles

- 2^{nd} most common method used for stockpiling
- Large Trucks or end loaders are used to transport and build the piles
- The piles can be built as single layer or multi-layer
- A layer can be pushed up by loaders
- Material should not be placed closer than 2’ – 4’ to the layer’s edge

Truck Stockpiles

- Degradation is a major problem with these piles
- Aggregates prone to degradation should not be driven on
- Conveyors are not used with this method
- Load-out should be perpendicular to the direction of the dumps


Multi-Layer Truck-Built Stockpile
Single Layer Truck-Built Stockpile

Multi-Layer Stockpile Built by End Loader


Don't Dump Over Side - SEGREGATION

Multi-Layer Stockpile


High Minus No. 200 From Degradation

Clam Shell Stockpile

- Not a common method being used

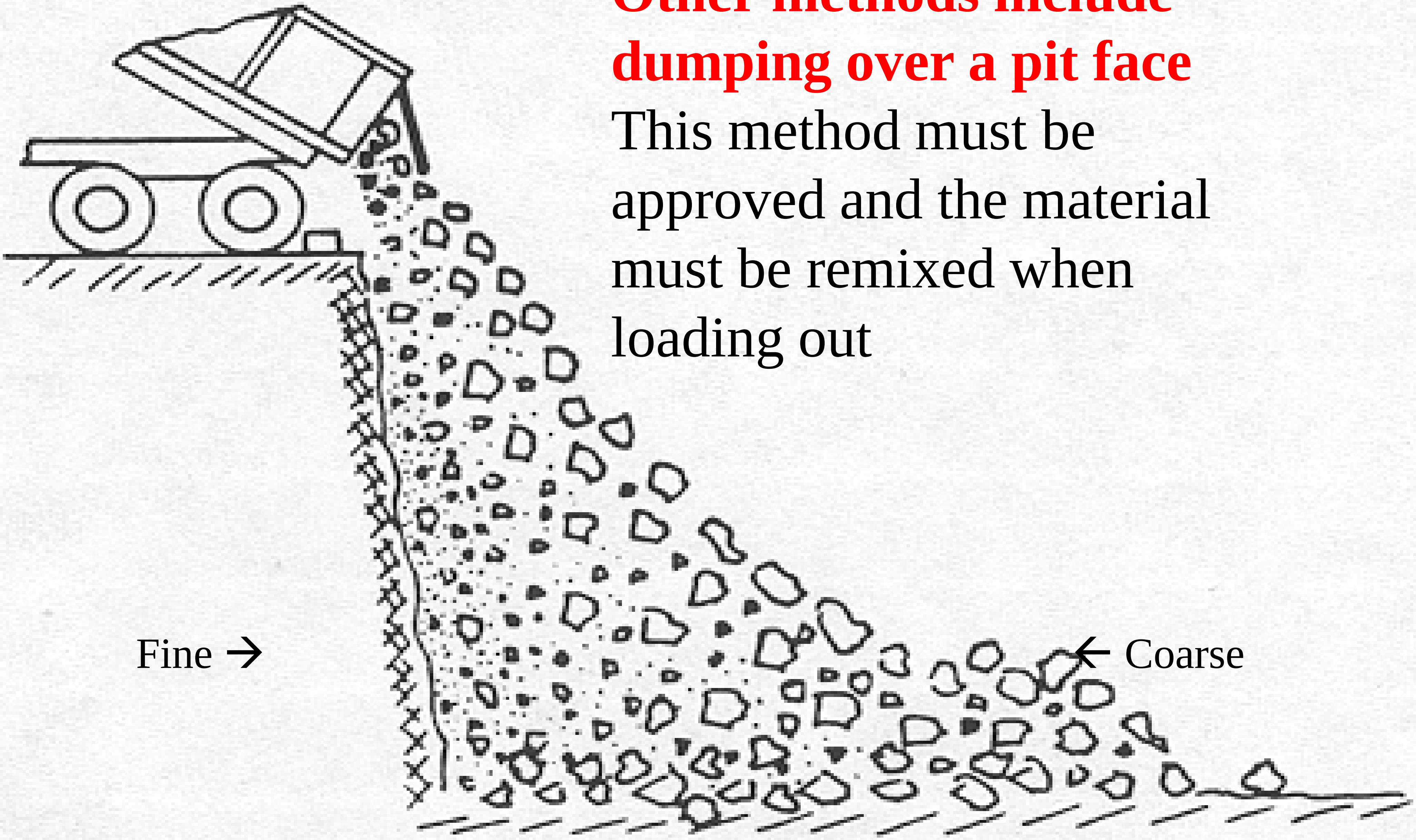
- Normally used to unload material from barges

- Segregation and degradation not a problem if done correctly

- High cost and slow process

Other methods include dumping over a pit face

This method must be approved and the material must be remixed when loading out



COARSE AGGREGATE GRADATIONS[1] (ENGLISH)

Sieve Size — Percent Passing

Grad No.	3 in.	2 1/2 in.	2 in.	1 1/2 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	No. 4	No. 16	No. 50	No. 200[2]
CA 1	100	95±5	60±15	15±15	3±3							8±4
CA 2		100	95±5		75±15		50±15		30±10	20±15		
CA 3		100	93±7	55±20	8±8		3±3					
CA 4			100	95±5	85±10		60±15		40±10	20±15		8±4
CA 5				97±3[3]	40±25		5±5		3±3			
CA 6				100	95±5		75±15		43±13	25±15		8±4
CA 7				100	95±5		45±15[4]		5±5			
CA 8				100	97±3	85±10	55±10		10±5	3±3[5]		
CA 9				100	97±3		60±15		30±15	10±10		6±6
CA 10					100	95±5	80±15		50±10	30±15		9±4
CA 11					100	92±8	45±15[6]		6±6	3±3[5,7]		
CA 12						100	95±5	85±10	60±10	35±10		
CA 13						100	97±3	80±10	30±15	3±3[5]		
CA 14							90±10[6]	45±20	3±3			
CA 15							100	75±15	7±7	2±2		
CA 16							100	97±3	30±15	2±2[5]		
CA 17	100								65±20	45±20	20±10	10±5
CA 18	100				95±5				75±25	55±25	10±10	2±2
CA 19	100				95±5				60±15	40±15	20±10	10±5

(d) COARSE AGGREGATE GRADATION TABLE.

TABLE OF ALDOT COARSE AGGREGATE SIZES *

Size No.	100 mm	90 mm	75 mm	63 mm	50 mm	37.5 mm	25.0 mm	19.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	300 µm	150 µm	75 µm
	PERCENT PASSING BY MASS, EACH LABORATORY SIEVE (U.S.A. STANDARD SERIES)															
1	100	90-100		25-60		0-15		0-5								
2			100	90-100	35-70	0-15		0-5								
24			100	90-100		25-60		0-10	0-5							
3				100	90-100	35-70	0-15		0-5							
357				100	95-100		35-70		10-30		0-5					
4					100	90-100	20-55	0-15		0-5						
467					100	95-100		35-70		10-30	0-5					
410					100	85-100	60-85		30-60		18-30	11-20	8-15	5-9		2-6
5						100	90-100	20-55	0-10	0-5						
56						100	90-100	40-85	10-40	0-15	0-5					
57						100	95-100		25-60		0-10	0-5				
6							100	90-100	20-55	0-15	0-5					
67							100	90-100		20-55	0-10	0-5				
68							100	90-100		30-65	5-25	0-10	0-5			
610							100	90-100		25-60		7-30		0-15		
7								100	90-100	40-70	0-15	0-5				
78								100	90-100	40-75	5-25	0-10	0-5			
710								100	90-100	50-85		12-35		0-15		
8									100	85-100	10-30	0-10	0-5			
89									100	90-100	20-55	5-30	0-10	0-5		
810									100		70-90	50-74	38-62	20-42		9-24
8910									100	90-100	60-85	40-70		10-25		1-5
9										100	85-100	10-40	0-10	0-5		
10										100	85-100				10-30	

Wade Sand & Gravel Co., Inc.

Product	Nominal Size
Pit Run Stone	
Class II Rip-Rap………………	10lb – 200lb
Class III Rip-Rap……………..	25lb – 500lb
8” x 3” Rip-Rap………………..	8” x 3”
#1 Stone………………………	4” x 1.1/2”
#2 Stone………………………	2.1/2” x 1.1/2”
#24 Stone……………………..	2.1/2” x 3/4”
#4 Stone………………………	1.1/2” x 3/4”
#410 Stone……………………	1.1/2” x 0”
#467 Stone……………………	1.1/2” x .1/4”
#57 Stone……………………..	1” x 3/16”
#67 Stone……………………..	¾” x 3/16”
#610 Stone……………………	1” x 0”
#7/78 Stone…………………..	5/8” x 1/8”
#89 Stone……………………..	3/8” x 1/8”
#810 Stone……………………	¼” x 0”
#8910 Stone……………………	3/8” x 0”
Dense Grade Base……………	2” x 0”
Stone Sand	
Mixed Stone Scrap	
Pea Gravel ……………………	5/8” x 1/8”

Washed Gradation Test

- Gradation Control
  - Trained Technician
  - Frequency of Test
  - Inspected Laboratory Equipment
  - Control Charts
  - Incoming Aggregate Samples
  - Stockpile Load out Samples

BOWSER MORNER

Producer Goals

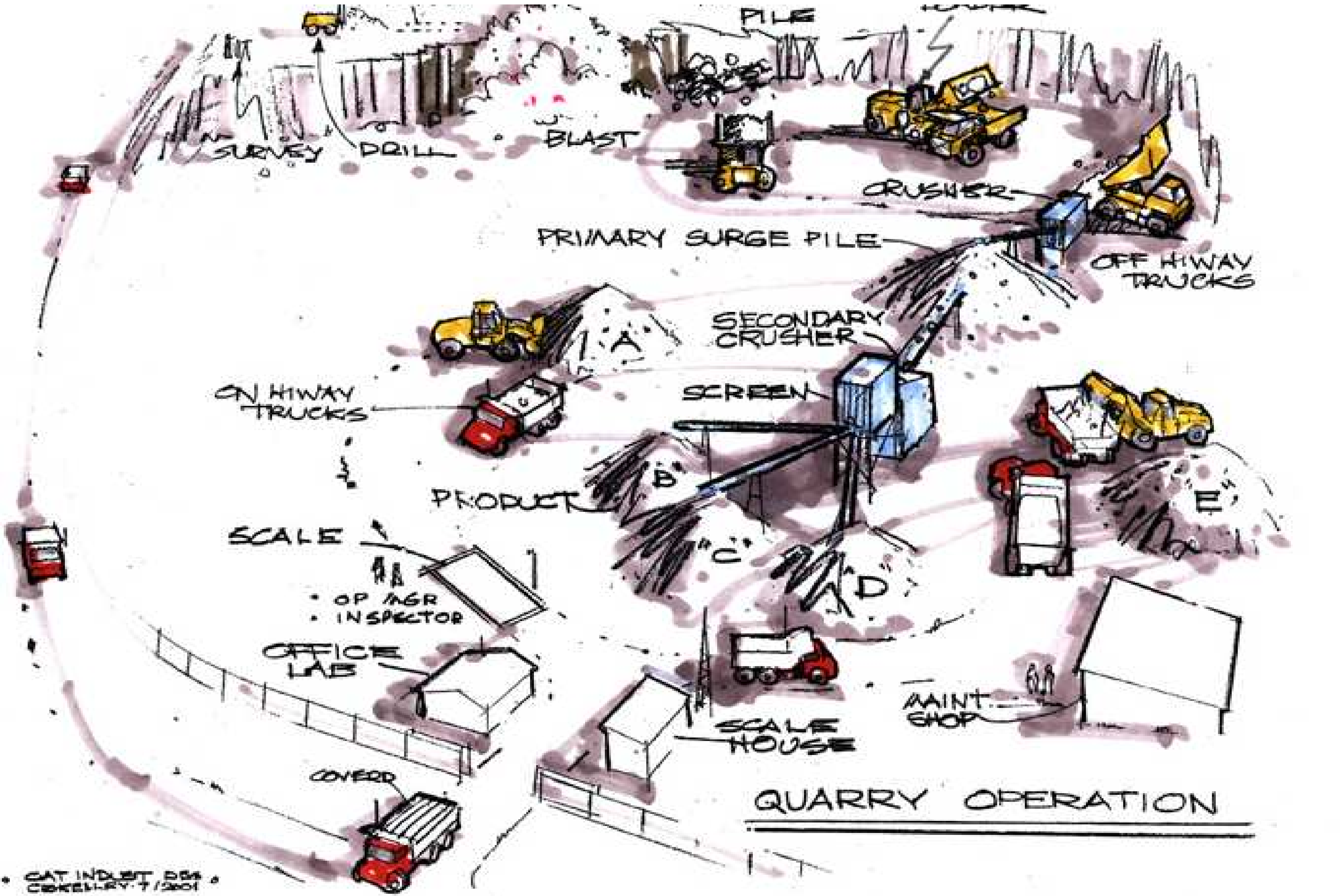
- In-specification Aggregate
- Uniform/Consistent Aggregate

PCC Problems Caused By Gradation Changes

- Changes in Water Demand
- Low Strength
- Excessive Cracking
- Decreased Life of Pavement or Other Structure

Gradation Problems at HMA Plants

- Affects production
- Changes mix properties
- Problems seen at plant and road
- Wastes material, increases costs


PILE
SURVEY
DRILL
BLAST
CRUSHER
PRIMARY SURGE PILE
OFF HIWAY TRUCKS
SECONDARY CRUSHER
"A"
ON HIWAY TRUCKS
SCREEN
"B"
PRODUCT
"C"
"D"
"E"
SCALE
• OP MGR
• INSPECTOR
OFFICE LAB
SCALE HOUSE
MAINT. SHOP
COVERED
QUARRY OPERATION

BOWSER MORNER