Exploration

- Locate aggregate deposit to supply a given market at a competitive price.

- A geologist typically explores.

- A cost analysis of product is extremely important
  i) Processing
  ii) Hauling
  iii) Sales
  iv) Regulatory expenses
  v) Overall profit

- Aggregate source must meet many physical, mechanical, chemical, and durability properties

- Very few resources are purely homogeneous in aggregates properties

- Gradation is extremely important. Too fine of gradation in sand is not desirable

- Be aware of outcrops: varying mineral sources in a location
  - Granite outcropping, limestone cliffs, sandstone cliffs, case hardening.
Variations in Aggregate Quality

- High variations can create producing and meeting aggregate specifications very difficult and expensive

- Sand & Gravel
  i) Gradation varies widely
  ii) Could be unsound due to shale, silstone, and other minerals

- Crushed Stone
  i) Igneous — porosity and density can vary largely
    - can be highly chemically reactive with alkalis in cement (AAR)
  ii) Metamorphic — can be very flat in shape due to minerals such as slate, schists, & gneiss
    - Low shear strength due to minerals such as slate
  iii) Sedimentary — clay-rich aggregate can retain large amounts of water, which causes expansion
    - Shale may be flat, disintegrate upon wetting/drying, sulfate soundness, and freeze-thaw
MINERAL DEPOSITS AND RESOURCES OF OKLAHOMA
(Exclusive of Oil and Gas) Kenneth S. Johnson, Oklahoma Geological Survey
Investment

1) Magnitude of an investment

2) Anticipated Rate of production

3) End Use of the Resources

4) Complexity of the Resources

5) Permits
Exacting
- removal of a substance
- aggregate exacting is a well-thought out process involving:
  1) Design
  2) Planning
  3) Development
  4) Operating
  5) Reclamation
Extraction of Sand and Gravel

- Typically in a loose state, so no need to blast or drill

- Uses front-end loaders, power shovels, haul trucks, and bull dozers

Two Types

1) Dry or dewatered sources
   - Non-submerged material pulled out with various construction equipment

2) Wet deposit sources
   - Water submerged material is removed with a dredge, dragline, or floating cranes
     - Dredge - using a bucket excavator or large suction pump
     - Dragline - land-based crane that casts buckets into a water
     - Floating crane - grab-type bucket suspended on a cable from a boom to obtain material
Crushed Stone Extraction
- produced from solid rock formations
- exacting involves drilling, blasting, and crushing
- this takes place at a quarry typically

Two Types of Stone Extraction

1) Surface Mining
2) Underground Mining

*Surface mining is the most common and will be talked about most here*

Surface Mining

1) Development of a Quarry
   - remove top soil and weathered rocks
   - construct haul road

2) Drilling and Blasting
   - various drills and explosives are used to break apart rock formations into manageable sizes.
   - sizes and types of drills & explosives are dependent on thickness, rock hardness, chemical composition, climate, geographical restrictions, and local restrictions

3) Loading & Hauling
   - front-end loader or power shovels load aggregate into an off-highway trucks.
   - optimum cycle time is very important
   - loading, hauling, and removing
Mining Process

1. Rock is blasted at the mine face
2. Blasted aggregate is loaded into Euclids
3. The aggregate is trucked to the primary crusher
4. The crusher breaks down the aggregate into pieces small enough to be carried by conveyor
5. The conveyor halls crushed aggregate to the surface
6. At the surface, the aggregate is sorted into different sizes
Designing a Plant

- An experienced plant design engineer must evaluate and formulate a valid design process.
- Very rugged, massive, and expensive construction equipment are used in production.

- Many parameters affect design:
  a) Mineralogy & Material properties
  b) Effects of drilling & blasting on gradation
  c) Potential waste products
  d) Capital Costs
  e) Types of installation - portable, stationary, or skid
  f) Operating costs & criteria
     - Capacity (tons/hr), operating time, percent overtime, electricity (kilo-watt hrs/top)
     and weather
  g) Maintenance
  h) Charging plant - truck, loader, excavator
  i) Method of stockpiling & storage
  j) Method of shipping: truck, railroad, barge
  k) Space Available
  l) Safety
  m) Future Growth
Reclamation

- After extraction is complete, the area needs to be restored.
- Results in creative ideas such as lakes, parks, golf courses, and housing developments.
- Some are turned into landfills.
Fig. 5.53. Flowsheet for a typical crushed rock plant.
Figure 8.15 Typical flow path of a 500 tph plant: surcharges are not shown.
Fig. 5.52. Flowsheet for a typical sand and gravel plant.
Fracture Mechanism of Stone

Stone needs to be fractured by blasting and crushing processes to meet specifications of gradation and shape.

The keys to fracturing stone
1) Force
2) Distribution of force
3) Aggregate Characteristics

A small hammer and chisel can be very effective at reducing the stone size and creating a well shape. However, a sledge hammer will reduce the size but create more fines and poorer shapes.

3 Mechanisms of Stone Breakage

a) Abrasion - Not enough energy
b) Clevage - Sufficient energy
c) Shatter - Too much energy
Abrasion fracture, Figure 8.6(a), occurs when the applied energy is not sufficient to cause significant fracture of the entire particle. Localized stressing occurs and a small area is pulverised to give a distribution of very fine particles.

Cleavage fracture, Figure 8.6(b), occurs when the energy applied is just sufficient to load comparatively few regions of the particle to the fracture point and only a few particles result. Typically this situation occurs under conditions of slow compression where the fracture immediately relieves the loading on the particle.

Fracture by shatter, Figure 8.6(c), occurs when the applied energy is well in excess of that required for cleavage fracture. Under these conditions many areas in the particle are overloaded and the result is a comparatively large number of particles with a wide spectrum of sizes.
Figure 8.7 Representation of the mechanisms of particle fracture and the resulting product size distributions.³
Blasting

- A well-executed blast transforms a solid rock formation into fragments small enough to be accepted by a crusher without excessive fines.

- Too much concentrated force will produce too small of sizes.

- Too little concentration of force will result in too large of particle sizes to be crushed.

- Very dangerous

- Many safety guidelines have been created.

ROCK BLASTING STEPS

1. Face survey
2. Drilling the shot holes
3. Checking the holes
4. Charging with explosives & stemming top
5. Detonating the explosives
6. Shotpile ready for loading
Crushing

- Stone is broken into the desired gradation and shape through a series of crushing processes and screens.
- Again, the 3 keys to fracturing are still important to achieve desired gradation and shape, but even more details go into the crushing process.

3. Crushing Factors

1. Resistance of the material to crushing.
2. Reduction ratio of the crusher

\[
\text{Reduction ratio} = \frac{\text{Size Feed into crusher}}{\text{Size Product Out of Crusher}}
\]

*Note Size is 80% passing a sieve size

3. Quantity of feed (tons/hr)

3 Stages of Crushing

1. Primary Crushing
   - reduces large boulders to manageable sizes
   - Typically, a jaw or gyratory crusher

2. Secondary Crushing
   - reduces sizes to commercial uses
   - Typically, a cone or impact crusher

3. Tertiary Crushing
   - Sometimes used when secondary crusher doesn't achieve desired size and shape
3 Types of Crushing Equipment

a) Impact Crushers
   - Exerts high speed blows causing high degree of shatter

b) Jaw and Gyratory Crushers
   - Exerts low amounts of energy causing more abrasion and cleavage

c) Cone Crushers
   - Exerts moderate amounts of energy creating cleavage and shatter

Crusher Equipment Manufacturers

- They are selling a product
- However, they can provide charts for predicting the capacity and gradation using their equipment
- Chart can't take into account the ability of the aggregate type to crusher.

Optimal Feed

- Crushing equipment, especially compression and impact crushers require interparticle energy transfer to achieve efficient performance
<table>
<thead>
<tr>
<th>Type</th>
<th>Illustration</th>
<th>Reduction Ratio</th>
<th>Characteristics &amp; Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact Crushers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal Shaft Primary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Rotor</td>
<td></td>
<td>to 15:1</td>
<td>Breaks mostly by impact, giving a high reduction ratio and a cubical product. Reduction ratio can be increased with higher speeds and/or closer clearances but at the cost of greater wear. Economical use is limited to low abrasion feeds. Suitable for damp and/or, moderately sticky feeds.</td>
</tr>
<tr>
<td>Double Rotor</td>
<td></td>
<td>to 15:1</td>
<td></td>
</tr>
<tr>
<td>Andreas</td>
<td></td>
<td>to 15:1</td>
<td>The geometry of the impact apron gives a high proportion of impact crushing, which results in lower wear costs for a given feed compared to other impact crushers. The gap settings of the apron are easier to change than other impact crushers, which allows better control of the reduction ratio.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact Crushers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact-Shaft—Secondary and Tertiary</td>
<td></td>
<td>to 15:1</td>
<td>Given high reduction ratio and a cubical product, similar to other impactors. Manganese hammers increase maintenance costs on higher abrasive feeds.</td>
</tr>
<tr>
<td>Hammer Mill</td>
<td></td>
<td>to 20:1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Crushing by attrition as well as impact. Produces a cubical product with a high proportion of fines. Economical use is limited to low abrasive feed. Cannot tolerate wet or sticky feed which would clog the grate openings.</td>
</tr>
<tr>
<td>Horizontal Shaft</td>
<td></td>
<td>8:1 to 20:1</td>
<td>May have 1, 2, 4 or 6 cages with alternate rows of pins turning the opposite direction. Feed enters at the center and is thrown outward into successively taller spinning rows of pins. Most suitable for low abrasive, dry feed.</td>
</tr>
<tr>
<td>Cage Mill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Illustration</td>
<td>Reduction Ratio</td>
<td>Characteristics &amp; Applications</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------</td>
<td>-----------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>True</td>
<td></td>
<td>Average 8:1</td>
<td>Primary: Characterized by diverging conical crushing surfaces formed by a gyrating mantle within a deep bowl. It provides continuous crushing action for high capacity primary or secondary crushing of hard tough abrasive rock. Trucks may dump directly into the cavity. Is able to handle sludgy feeds better than jaw crushers and produce a more cubical product through the annular discharge opening. Capacity is usually rated at open-side setting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Range 3:1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10:1</td>
<td></td>
</tr>
<tr>
<td>True</td>
<td></td>
<td>Average 4:1</td>
<td>Secondary: Used to reduce 8-in. to 12-in. material down to 3-in. to 4-in. The feed is normally scalped ahead.</td>
</tr>
<tr>
<td>Primary &amp; Secondary</td>
<td></td>
<td>4:1 to 6:1</td>
<td>Cone gyratories operate at about twice the speed and with a much larger head movement than true gyratories. A relatively flat gyrating head forms a crushing chamber within an inverted bowl. The large head throw and speed creates an impact like crushing action. “Standard” versions are made with larger feed openings for secondary applications making products in the 1-in. to 4-in. range. “Shorthead” versions have smaller feed openings and a shorter, steeper, more parallel crushing chamber suitable for products ranging from ½-in. to 1-in. Both crushers are suitable for hard, tough abrasive crushing applications. Capacity is usually rated at closed-side setting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2:1 to 5:1</td>
<td>For production of fine sizes (¼-in. top size or less). Shallow cone angle of 28° to the horizontal and multilayer impact plus attrition results in a cubical product with relatively low liner wear. A controlled choke feed is mandatory. The finer the product, the higher the recirculating load. Not suitable for sticky feeds. Usually mounted in a closed circuit system. Finelined product capacity may not be related to the closed-side crusher setting.</td>
</tr>
</tbody>
</table>

---

Table 8.2 Selected Major Types of Crushers² (continued)
Screening

- Screening is the process of separating aggregate particles into various sizes.

- Various types and layers of screens can be used to efficiently separate particles.

- Screen capacity, efficiency, and screen bed depth all impact production rate. Formulas can be found in the Aggregates Handbook.

- Aggregate height on screen should not exceed 4 times the screen size opening.

- A grizzly is a type of screen for initially separating the muck pile before it enters the primary crusher.

- Moisture can also reduce the efficiency of screening.

Figure 8.11 The three major regions occurring along a screening surface.
Inclined screening

a) Sizing by selection
b) Sizing by rejection
c) Splitter screening

Fig. 5.26. Arrangements of inclined vibrating screens: (a) sizing by selection; (b) sizing by rejection; (c) use of splitter screen.

Pictures of Grizzly

(a) Bar grizzly screen

(b) Roll grizzly screen

Inclined Screen
**PLATE: Apertures (Flow directions indicated)**

- **Round, staggered**
- **Hexagonal, staggered**
- **Square, straight**
- **Square, staggered**
- **Slot, end staggered**
- **Slot, side staggered**
- **Slot, straight**

**MESH: Apertures (Usual flow direction indicated)**

- **Square**
  - Most widely used mesh.
  - Gives most accurate sizing of all meshes.
  - Regular shape particles most suitable.
- **Rectangular**
  - Allows increased throughout because of increased % open area, or heavier wire for given % open area. Decreased accuracy, reduced blinding.
- **Triple shute elongated**
  - Maximum open area, reduced accuracy. (Accuracy can be increased by running slots at right angles to flow.) Minimum blinding because of slot length and wire vibration.

**MESH: Crimps**

- **Flat Top**
- **Double Crimp**
  - Most commonly used. Rigid construction. Uneven surface breaks up material being screened and increases throughout. Gives good sizing with small apertures, or small % open area.
- **Locked Crimp**
  - Firmer mesh for larger % open area, especially on vibrating screens. Suitable for scalping operations.
- **Corrugated Crimp**
  - Wires in every third or fifth crimp to give rigid mesh with large % open area. Not suitable for heavy duty.

Figure 8.10 Screen surfaces.
Other Products Produced Indirectly From Crushing

Riprap
- As a muckpile is loaded into a gizzly screen, large stones are rejected from being crushed due to the size. The rejected stones are used for Riprap.
- These sizes range from 6 to 30 inches.
- They can be used to help protect structures against erosion and scouring.

Manufactured Sand
- This is a by-product from the crushing process.
- Sizes can vary from 3/8" to very fine dust.
- Screenings is the unwashed by-product that comes directly after the screening (sizing) process. This is many times called unwashed manufactured sand. It is used to help fine grade many aggregate base surfaces.

- Manufactured sand is usually a coarser gradation than many natural sands. This has typically been washed to remove the dust particles.

- A fine manufactured sand has been re-crushed to finer gradations and the dust removed. The gradation will not be as well-distributed as natural sand.

- Depending on the market in the area, cost of production, cost of disposal, and revenue of it, all are variables that go into the decision of producing any of the manufactured sand types.
Handling of Material into a Gradation

- To move material in an efficient and timely manner during the crushing process, chutes, conveyors, elevators, and hoppers can be used.
- Feeders and gates can help monitor the flow.

- After material is crushed and screened into the desired size, it is typically placed into separate bins. This process is called fractionating.
- To meet a gradation requirement, the aggregate sizes are blended together on a stockpile or truck loadout bins.
- Aggregate may need to be washed to remove excessive fine. Many techniques can be used to accomplish it.

Gradation Variation due to Plant Preformance

- Maintaining screens
- Setting on crushers
- Production rate
- Gradation into and out of crusher
Load out

- This is a term describing the process of transporting the finished product to the customer.
- The product is weighed during loading processes and sold by the ton.
- Then, the finished product is discharged into a dump truck, rail car, or a barge.

Segregation of gradation

- Defined as the separation of a particle size from the overall mass.
- This can be caused by handling, transporting, poor storage, and large range of gradation.
- Producers want a close gradation range to reduce problems with segregation.

Figure 18.6 Sampling from a Stockpile Formed with a Fixed Conveyor

Zones of segregation:

Coarse Areas:
- A: Side of stockpile farthest from stacker (in this case left side).
- B: Bottom of pile.
- C: Exterior surface of pile.

Fine Areas:
- D: Inverted cone within center of pile.
Loadout Examples

One of the simplest loadout systems uses a front-end loader to move the finished product from the stockpile directly to the truck or rail car, as shown in Figure 8.12. One of the more elaborate loadout systems employs a reclaim tunnel passing beneath stockpiles of either fractionated sizes or finished products, as illustrated in Figure 8.13. A conveyor in the tunnel is fed from the stockpiles by gates or feeders that proportion the flow to meet the required specification.

**Rinsing:** The blended material may then be delivered to a cleaning screen which removes the fines from the product by rinsing it with water. The removed fines then require some form of processing in settling cells, sand plants or other dewatering systems before being sold as a product. A cleaning screen can be operated dry with the fines being collected in a bin for stockpiling or disposal. The collected fines can be wetted after screening and handled as slurry, as discussed above.

![Diagram](image-url)

**Figure 8.12** Sample truck and rail loadout.

![Diagram](image-url)

**Figure 8.13** Reclaim tunnel/bin loadout.
Storage in a Drum or Central Batch Plant

- Many different methods can be used to store and transport aggregates in an Drum or Central Batch Plant for Asphalt or Concrete.

- The more aggregates are moved, the more prone the aggregates will be to segregate.

- Conveyors drastically reduce segregation compared to front-end loaders.

- The most preferred method to prevent segregation and increase production is to use conveyor belts that place aggregate into storage bins.

- However, many ready-mix plants and temporary asphalt plants will use stockpiles to store aggregate and use a front-end loader to load them.

- Many different bins can be used to meet a gradation.

- It is not unrealistic for an Asphalt pavement to use 6 different gradation bins to meet a combined gradation.

- A Ready-mix plant may only have a single sand bin and a single coarse aggregate bin.

Types of Bin Techniques

1. By Sieve-Size - For a more precise way of combined gradation, aggregates are sieved before being placed into bin.

2. Two-Bin System - Using only a rock bin and a sand bin to meet a combined gradation.

3. Multiple Bins - For more aggregate gradations are used. For example: #57, 3/8" chip, and sand bin.
Sampling Methods for Gradation Quality

- Not only is gradation important but the consistency of the gradation might actually be more important.

- Samples are taken and sieved to ensure the gradation quality.

- Samples should be randomly taken at different times and locations.

- The different locations should encompass the whole cross-section.

- Should follow: ASTM D 3665 - Random Sampling
  ASTM D 75 - Sampling Aggregates

- At a quarry, samples should be taken at the conveyor belt.
Sampling Method

Product testing must be performed on samples of aggregates that are representative of the material being produced. Methods for securing representative samples are as follows:

- **Conveyor Belt Samples.** At least three increments should be taken from the belt and combined into one field sample. The sample should be obtained in the following manner:

  1. Use a sweep type belt sampler, if available;
  2. If a sweep type sampler is not available, stop the conveyor belt prior to taking the sample and lock out the conveyor until completion of the sampling procedure;
  3. With a shovel or scoop separate an area on the belt large enough to provide the proper size sample as discussed later in this chapter. Clear the material ahead of and behind the sample for a distance of at least six inches and
  4. Carefully scoop all material between the cleared areas into a sample bag, collect the fines on the belt with a brush and add to the sample.

- **Bin Samples.** Bin samples should be taken at random intervals from the bin. The increments are combined to make a single sample. Sampling collection is facilitated by discharging the bin into the bucket of a front-end loader and then placing each increment onto a hard, flat surface on the ground. The sample should be taken in the following manner:

  1. The sample should be obtained during the discharge of material from a full or nearly full bin to minimize segregation. In the case of a belt discharge, the conveyor should be operating at normal capacity during normal plant operations.
  2. The sampling device, either a bag or pan, is passed through the entire cross section of the discharge to obtain a representative sample. The speed of the pass is determined by the material being sampled, the size of the sample desired, and the discharge rate.
  3. The sample should not include the initial discharge from a conveyor or newly filled bin.

- **Stockpile Samples.** When a sample must be obtained from a stockpile, the following techniques should be used. Samples should be obtained using a front-end loader as previously described in Section 18.11. When power equipment is not available:

  1. Select the area to be sampled; it should be a minimum distance above the ground of one-third the total height of the material stockpile.
  2. Place a sheet of plywood or a sheet of thin metal, approximately 2 feet by 2 feet, corner first and horizontally into the material directly above the area to be sampled to a depth of at least 1 foot. The sample is obtained from the stockpile directly below the sheet of plywood or metal.
  3. Discard material to a depth of approximately 6 inches by removing it with a shovel. Sample the material until a sufficient amount is obtained as discussed later in this chapter.

- **Truck/Rail Car/Barge Samples.** General principles for sampling aggregates from stockpiles are applicable to sampling from trucks, rail cars, barges or other transportation units.

- **Roadway Samples.** Samples obtained from the roadway should be selected by a random method such as that set forth in ASTM D3665, Standard Practice for Random Sampling of Construction Materials. A minimum of three equal increments, selected at random, should be taken and combined to form the required field sample. All increments should be taken for the full depth of the material, and care should be exercised to exclude any underlying material from becoming part of the sample.

Size of Sample

Sufficient material must be obtained and submitted to the testing laboratory to permit proper execution of all desired tests. The quantities given in Table 18.8 generally provide adequate material for routine grading and quality analysis. A rule of thumb for sample size is to obtain a 50-pound sample for each inch of diameter of the nearest particle. A sample which is too large can be reduced in the laboratory, but a sample which is too small is of no value and represents wasted effort.
Lightweight Aggregate (LWA)

- Used in high rise building and architecture features for reducing the dead load of the overall structure

- Unit weight of LWA is less than 70 lbs/CF

- In the early years, Romans used the LWA produced around erupting volcanoes

- Now, LWA is quarried, put through a kiln, and crushed and screened into the gradation required

- LWA quarried material is normally shale, clay, slate, perlite, pumice, or vermiculite.

- However, some LWA are produced through the by products of glass, fly ash, or slag.

Aggregates for Concrete

Lightweight aggregate spectrum
Production of LWA through Volcanos

1) Volcano erupts, magma comes out, and cools into a harden mass on the surface.

2) The harden mass forms in layers with different properties
   - The spongy porous layer is used in LWA
   - The glassy layer is used as cement

3) The spongy porous layer is crushed, sieved, and combined to meet specifications.

Production of LWA (Today)

1) Quarry material - such as shale & slate
2) Crush and screen
3) Kiln - 45 minutes of heat and then cooled

4) This newly formed clinker is crushed and screened into the required gradation.

Common LWA Companies

- Livlite - clay-based material
- Norlite - a shale-based material
- Sta lite - a slate-based material
Clay Brick

-used largely in exterior walls of buildings and house.

- components
  Clay Brick = clay + sand + water
  - a physical hardening process using a Kiln

steps:
1) Exact material - clay & sand
2) Using the design batch weights, mix components together
3) Place and mold fresh clay
4) Depending on plant process, drying maybe required
5) Heat Brick through a Kiln

### Major Chemical Compounds of Clay Brick

<table>
<thead>
<tr>
<th>Name</th>
<th>Compound</th>
<th>Amount</th>
<th>Function</th>
<th>Excessive Amounts Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumina</td>
<td>Al₂O₃</td>
<td>20-30%</td>
<td>When wet, it creates an easy way to be molded. Also, when heated, it fuses components together (Found in Clay)</td>
<td>Shrinkage, cracking, &amp; warping</td>
</tr>
<tr>
<td>Silica</td>
<td>SiO₂</td>
<td>50-60%</td>
<td>Prevents cracking, shrinking, and warping of raw brick (Usually found in sand)</td>
<td>Britteness issue</td>
</tr>
<tr>
<td>Lime</td>
<td>CaCO₃</td>
<td>2-5%</td>
<td>Reduces shrinkage and acts as a flux with the silica during the heating process</td>
<td>Lime Pops (discoloration)</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe₂O₃</td>
<td>5-6%</td>
<td>Influences the bricks color and reduces permeability.</td>
<td>Change of Color</td>
</tr>
<tr>
<td>Magnesia</td>
<td>MgCO₂</td>
<td>&lt;1%</td>
<td>Decreases Shrinkage and influences yellow tinge</td>
<td>Brick decay</td>
</tr>
</tbody>
</table>
Concrete Masonry Units (CMU)

- Used largely in interior walls of building and basements.
- Components
  CMU = Intermediate rock + Sand + Cement + Water
- Basic Production Steps of CMU

Step 1:

The weigh batcher is used to measure the proper amount of each material.

Step 2:

The concrete comes off a conveyor and is forced into molds. The rotating brushes remove loose material.

CMU are harden through the chemical process of Cement hydration.
Production Cement

- Used in concrete, mortar, grout, CMU, and soil stabilization
- Created from crushed limestone that is heated and crushed into fine particles

Production Steps
1) Exact Limestone
2) Using a kiln, Limestone is transformed into clinker
3) Clinker is ground into small particles (~10 microns)

Other materials can be added through the production

- When cement is added with water, it creates the chemical reaction of hydration and evenly hardness within hours
- The hydrated cement contains many chemical compound to help in the whole hydration process.

<table>
<thead>
<tr>
<th>General Name</th>
<th>Compound</th>
<th>Amount</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSH</td>
<td>CaO SiO₂ H₂O</td>
<td>50-60%</td>
<td>Provides the strength and creates pores</td>
</tr>
<tr>
<td>CH</td>
<td>CaO H₂O</td>
<td>15-25%</td>
<td>Creates a 12.5-13 pH in pores</td>
</tr>
<tr>
<td>Ettringite</td>
<td>6CaO Al₂O₃ 3SiO₂ 2H₂O</td>
<td>varies</td>
<td>Causes initial set and reduces size of pores</td>
</tr>
<tr>
<td>AFm</td>
<td>4CaO Al₂O₃ SO₃ 12H₂O</td>
<td>varies</td>
<td>Helps with sulfate attack and reduces size of pores</td>
</tr>
</tbody>
</table>