PREFACE

The WisDOT Certified Aggregate Technician II course manual was prepared and developed by the Highway Technician Certification Program (HTCP) staff, the HTCP instructors, and other contributors from the Wisconsin Department of Transportation (WisDOT) and the highway industry. The information contained in this course manual is intended to be used to train WisDOT Quality Control/Quality Assurance (QC/QA) Aggregate Technicians - Level II. It is the responsibility of the WisDOT Certified AGGTEC-II to follow all current WisDOT specification parameters and procedures in accordance when conducting work assignments for the Wisconsin Department of Transportation.

The WisDOT Certified AGGTEC-II course manual was developed with these valuable resources:

(1)  *WisDOT Standard Specifications for Highway and Structure Construction*,
(2)  *Supervisors Safety Manual*
(3)  *The Aggregate Handbook*, National Stone, Sand, &n Gravel Association
(4)  *Portland Cement Concrete Materials Manual*, FHWA
(5)  *Hot-Mix Bituminous Paving Manual*, FHWA

ACKNOWLEDGMENTS

The Highway Technician Certification Program Aggregate Technician Manual Committee members have been instrumental contributors to the contents of this course manual. The committee members are:

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# AGGTEC-II

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## APPENDIX

- QMP Award, Corrections Page, Course Evaluation
TOPIC A:  REGISTRATION, INTRODUCTIONS
            COURSE OBJECTIVES, AND COURSE SYLLABUS
PREREQUISITES FOR THIS COURSE

Student candidates must have a minimum of one construction season of field experience in materials testing after becoming a Certified Aggregate Technician - I.

COURSE OBJECTIVES

This course requires 16 hours of classroom attendance. Upon completion of this course the student should understand the applicable parts of the State of Wisconsin Standard Specifications, Special Provisions and the Construction and Materials Manual. The student should be able to interpret field test results, analyze plant operations and process control, and recommend corrective action when the process trend is toward the control limit. The student will become familiar with the following:

1. Origin and types of rock in Wisconsin
2. Aggregate performance and physical properties
   - Particle shape
   - Wear and soundness
   - Stripping potential
   - Absorption
   - Specific gravity
3. Aggregate production process
   - Crushing
   - Screening
   - Materials handling and stockpiling
   - Segregation and degradation
4. Aggregate blending
5. Statistical quality control
6. Process control
   - Equipment problems
   - Material problems
   - Weather problems
   - Testing problems

A text and lecture material will be used to develop a working knowledge of aggregate production and problem analysis. There are no laboratory tests required in this course.
COURSE SYLLABUS

DAY 1

8:00 - 8:15  Registration, Introductions, Course Objectives, and Course Syllabus

8:15 - 8:45  Safety Considerations

8:45 – 9:15  Origin and Types of Rock in Wisconsin
  • General Geology
  • Igneous Rocks
  • Sedimentary Rocks
  • Metamorphic Rocks

9:15 – 11:15 Properties of Aggregate
  • Specific Uses of Aggregate
  • Physical
    o Particle Shape/Texture
    o Absorption
    o Specific Gravity
    o Voids in Aggregate
    o Permeability
  • Chemical
    o Surface Charge
    o Resistance to Attack by Chemical
  • Mechanical
    o Wear Resistance
    o Resistance to Degradation
  • Properties of Aggregate for Specific End-Use Applications
    o Base Courses
    o Asphalt Concrete Mixtures
    o Portland Cement Concrete

11:15 - 12:00 Aggregate Production
  • Quarry and Pit Operations

Noon - 1:00  Lunch

1:00 - 3:15 Aggregate Production (continued)
  • Screening Operations
  • Materials Handling
  • Loadout
  • In-Pit Operations
  • Segregation and Degradation
  • Pit Operations
  • Sampling Aggregate Deposits
3:15 - 5:00  Process Control/Troubleshooting Techniques
- Gradation Variation
- Segregation
- Degradation
- Plant Maintenance
- Overcrushing
- Diminished Product Yield
- Wear of Screens and Noise
- Screen Performance
- Flow Control
- Contamination of Stockpiles
- Crushers Protection
- Dust Control
- Handling Waste Water and Recovery of Fines
- SuperPave

DAY 2
8:00 - 11:00  Aggregate Blending
- Student Problems

11:00 - 12:00  Quality Control Charts

NOON - 1:00  Lunch

1:00 - 5:00  Overview of Wisconsin Specifications
- WisDOT Quality Management Program, CMM 8.30, 8.34
- Quality Management Program, Base Courses, Item 301.010
- WisDOT Standard Specifications, Section 301, 305, 460, and 501

Data Entry
- Atwood Systems

DAY 3
8:00 - 10:30  Review for Written Examination

10:30 - 12:00  Written Examination, Course Evaluation
TOPIC B: SAFETY CONSIDERATIONS
SAFETY FIRST

1. Know your Safety Officer
   a. Emergency phone numbers
   b. Nearest hospital location

2. Safety Equipment
   a. First aid kit
   b. Fire extinguishers
   c. Fireproof gloves
   d. Eye protection
   e. Ear protection
   f. Steel toe shoes
   g. Safety vest
   h. Hard hats
   i. Proper ventilation

3. Equipment Operators
   Always keep eye contact with operators when working close to heavy equipment.

5. Practice Proper Back Maintenance
Safety Considerations

Safety is prime importance while serving your occupational duty on Wisconsin Department of Transportation projects.

About 15% of all accidents are caused by unsafe mechanical or physical conditions. The other 85% of the accidents are caused by absentmindedness, negligence or ignorance. For each accident, 100 near misses occur.
Safety Considerations

C. Crushing Machinery:

- Ample room should be provided for movement around equipment and use of tools.
- Platforms should be provided for service and observation areas should be accessed without climbing on equipment.

- Crushing feed chambers should be shielded to prevent fly-rock injury or accumulation of material on platforms.
- Adjustment tools or hydraulic hoses should be kept off the floor area to prevent tripping of personnel.
Safety Considerations

 Crushing Machinery:

- Properly designed mechanical devices should be provided to permit crusher service and maintenance to use safe procedures.
- Engineered and prefabricated guards for moving parts of machinery should be provided.

Screening Machinery:

- Walkways alongside and parallel to the screen slope should be provided to permit access to the clamping bar bolts and screen frame connections.
- Ample clearance should be provided to permit safe access around drive unit.
Screening Machinery:

- Drive guards should be provided that permit easy access for changing drive parts.
- Safe access to screen decks is very important.

Conveyors:

- Walkways should be provided for service, inspection, and product sampling.
- Pinch points along conveyors need to be protected to prevent inadvertent access to these hazardous areas.
Safety Considerations

Conveyors:

1. Pull cord or inside handrails should be provided at the idler height on conveyors with walkways or personnel access that are not visible to the plant operator.

2. Cages or guards on return idlers must be provided if the area is accessible to personnel.

Conveyors:

1. If conveyor inclination or material size could result in the roll back of materials, buffers need to be provided at sufficient points to eliminate the hazards of falling rock.
Safety Considerations

Stairways:

- All working levels of a plant building need stairway access if at all possible.
- Stairs should have a minimum width of 30 in. and be constructed at a slope of 30° to 35°, with a constant riser height.
- Landings should be provided at appropriate levels.

Ladders:

- Stairs are always preferable to ladders. Vertical stairs should be used at last resort.
- Where ladders are required, rungs should be spaced at 9 in. to 12 in. apart, and be at least 18 in. wide. Safety cages are required for ladders over 7 ft in height and should be designed to applicable regulations.
Safety Considerations

Platforms:

- Hand rails at a 42 in. height with mid-rails are required unless area is enclosed with mesh or plate.

- Toe boards around the edge of the floors should be a minimum of 4 in. high and may be placed 1 in. above the flooring.

Platforms:

- Flooring may be steel checkered plate, expanded metal grating, or a variety of nonskid flooring products.

- Openings in the floor should be guarded by hand rails and toe boards, and the access openings should be protected.
Safety Considerations

Material Storage: ✯ Open hoppers or bins that are in the plant working area should be covered and protected with proper handrails and toe boards.

✠ When internal bin access is required, ladders should be provided as well as life belts or harness suspension facilities.
REFER TO PAGES 8-52 THROUGH 8-56 IN THE AGGREGATE HANDBOOK
TOPIC C: GENERAL GEOLOGY
References


ORIGIN AND ROCK TYPES

Introduction

Rocks are formed by one of the following three processes:

1. By cooling 2 igneous rocks
2. By transportation and resedimentation 2 sedimentary rocks
3. By transformation 2 metamorphic rocks

A brief description of each type of rock is presented in the following paragraphs. Table 1.1 shows the elemental composition of earth crust. Note that oxygen and silicon are the most abundant elements.

Igneous Rocks

“igneous,” from Latin meaning “fire,” are those rocks which have solidified from liquid melts or magmas. Igneous rocks are classified in two ways:

1. chemical composition
2. grain size

Chemical composition of igneous rocks varies considerably and the usual method is by the percentage silica (SiO$_2$) contained. A rock with high silica content is termed Acid and one with lower silica content is known as Basic. The acidity and alkalinity of rocks are graphically illustrated in Figure 1.1. The Acid and Basic terms apply whether the grain size is fine or coarse. Silica content in most common types of igneous rocks is as follows:

<table>
<thead>
<tr>
<th>Coarse-Grained</th>
<th>Fine-Grained</th>
</tr>
</thead>
<tbody>
<tr>
<td>70% approx. SiO$_2$ (Acid)</td>
<td>Rhyolite</td>
</tr>
<tr>
<td>60% approx. SiO$_2$ (Intermediate)</td>
<td>Andesite</td>
</tr>
<tr>
<td>60% approx. SiO$_2$ (Basic)</td>
<td>Basalt</td>
</tr>
</tbody>
</table>

The grain size is largely dependent on the speed at which the rocks have cooled. If the cooling has been very slow, then the individual crystals will be large, the rock will be coarse-grained, and the color is generally light. If the cooling has been fast, then the crystals will be small, even microscopic, the rock will be fine-grained, and the color is dark. For example, molten lava from a volcano will become a fine-grained igneous rock when it has cooled and solidified. Figure 1.2 shows the effect of rate of cooling on crystal size. Fragmented igneous rocks include ash, tuff, and agglomerate. Common crystal forms are shown in Figure 1.3.
### Table 1.1: Elemental Composition of the Earth’s Crust

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Ion</th>
<th>% of Crust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>O</td>
<td>O&lt;sup&gt;2-&lt;/sup&gt;</td>
<td>49.52</td>
</tr>
<tr>
<td>Silicon</td>
<td>Si</td>
<td>Si&lt;sup&gt;4+&lt;/sup&gt;</td>
<td>25.75</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Al</td>
<td>Al&lt;sup&gt;3+&lt;/sup&gt;</td>
<td>7.51</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
<td>Fe&lt;sup&gt;3+&lt;/sup&gt;</td>
<td>4.70</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
<td>Ca&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>3.39</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>Na&lt;sup&gt;-&lt;/sup&gt;</td>
<td>2.64</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
<td>K&lt;sup&gt;-&lt;/sup&gt;</td>
<td>2.40</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
<td>Mg&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>1.94</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>All other elements</td>
<td>2.15</td>
<td></td>
<td>100.00%</td>
</tr>
</tbody>
</table>

**Table 1.1: Elemental Composition of the Earth’s Crust**
Figure 1.1: Acidity and Alkalinity of Rocks
Figure 1.2: Effect of Rate of Cooling on Crystal Size: Slow Cooling (A), Rapid Cooling (B), and Mixed (C)
Figure 1.3: Common Crystal Forms
Sedimentary Rocks

Sedimentary rocks are formed at the earth’s surface and at a normal atmospheric temperature. Two main types are considered:

1. Rocks whose constituent particles have been transported to the place of deposition are known as Clastic rocks.

2. There are also rocks that are formed from nearby, either by aggregation of organic matter or by chemical deposition.

A. Clastic Rocks

Clastic rocks are mostly formed underwater. The sediments compact into rock when the weight of the overlying sediment has caused consolidation, thousands or even million of years later. Marine clastic rocks have uniform grain size.

Classification of clastic rocks is by grain size: coarse-grained rocks are conglomerate, breccia (both consolidated), and gravel (unconsolidated); medium-grained rocks are termed sandstone; and finer-grained rocks are known as siltstone, shale, or mudstone.

B. Rocks Formed In-Site

These rocks fall under four headings, each with a different mode of origin. These are:

1. Limestones, dolostones, and chert
2. Evaporites
3. Coal
4. Oil and natural gas

Only the first will be discussed here. The interested reader in the remaining types may check references on engineering geology.

Limestones, dolostones, and chert:

The first two rocks are mainly composed of the carbonate minerals calcite (CaCO$_3$) and dolomite CaMg (CO$_3$)$_2$ respectively. These rocks are largely made up of the remains of fossil animals and plants, and some are inorganic. Chalk is another type of limestone formed by immense numbers of algal skeletons (about 10 microns diameter).

The grains in limestone are not usually seen. Limestone is a compact rock which breaks with angular fractures. Color varies considerably but is chiefly white. Chalk is a less-consolidated variety of limestone. Dolostone is like limestone but often light brown in color. It will not effervesce with dilute hydrochloric acid (HCl) as does the limestone.
Chert, including its variety flint, consists of amorphous silica (SiO$_2$) often occurring as bands or nodules within limestone sequences. The silica is deposited originally under sea water and concentrated into the bands and nodules during the rock-forming period subsequent to deposition. Chert is very hard non-granular rock. Its color varies but is usually brown or black.

**Metamorphic Rocks**

When rocks of all types are subjected to very high temperature and pressure, they will melt and remobilize to form igneous magma. Some constituents will recrystallize before others. Rocks which still reflect some traces of their original bedding and structure are termed metamorphic rocks. The four principle types of metamorphic rock are:

- **Slate:** Metamorphosed shale is hard and brittle and split along directions unrelated to original bedding planes 2 cleavage
- **Schist:** Completely recrystallized fine-grained rocks
- **Gneiss:** Coarsely recrystallized rock; distinguished from granite by banding
- **Marble:** Recrystallized limestone
- **Quartzite:** A metamorphosed sandstone

The following is a table of the mechanically and chemically deposited sedimentary rocks:

<table>
<thead>
<tr>
<th>Mechanically Deposited</th>
<th>Chemically Deposited</th>
</tr>
</thead>
<tbody>
<tr>
<td>(consolidated)</td>
<td>(calcareous)</td>
</tr>
<tr>
<td>shale</td>
<td>limestone</td>
</tr>
<tr>
<td>siltstone</td>
<td>dolomite</td>
</tr>
<tr>
<td>sandstone</td>
<td>(siliceous)</td>
</tr>
<tr>
<td>conglomerate</td>
<td>chert</td>
</tr>
</tbody>
</table>

All three classes of rock have been used successfully in Wisconsin as road aggregate either from a quarry or from a natural aggregate deposit. Whatever the source of aggregate, the suitability of aggregate from a given source must be estimated from a combination of tests, supplemented by mineralogical examination. The best possible index of aggregate suitability is its known performance in earlier service of the type contemplated.
Definitions:

Following are some of the most frequently encountered terms in highway materials.

**Igneous Rocks:**
Rocks formed directly by crystallization or super-cooling of a natural melt

**Sedimentary Rocks:**
Consolidated sediments, usually conspicuously bedded or layered

**Metamorphic Rocks:**
Rocks formed by heat and/or pressure acting beyond consolidation diagenesis

**Acid Rocks:**
Igneous rocks with relatively high silica and high potassium and sodium content

**Basic Rocks:**
Igneous rocks with relatively low silica and low potassium and sodium content

**Calcareous:**
Containing calcium carbonate

**Chert:**
A sedimentary rock composed chiefly of crypto-crystalline silica

**Cleavage:**
The splitting of a mineral along its natural fracture planes or of a rock along closed-spaced planes, other than the original bedding planes or joints

**Dolomite:**
A mineral form of magnesium/calcium carbonate

**Glacial Deposit:**
Sediments deposited by ice sheets, glaciers, and melt streams

**Lacustrine Sediments:**
Sediments deposited or formed in a lake

**Limestone:**
A sedimentary rock composed chiefly of calcium carbonate

**Moraine:**
Glacial deposits of unsorted rock fragments relatable to the position of a former ice sheet
Siliceous:
Referring to rocks principally composed of silicate or silica minerals

Talus:
Loose and incoherent deposits, usually at the foot of a slope or cliff

Till:
Universal term for any sedimentary deposit resulting directly from the melting of an ice sheet
CHERT CONTAMINATION POTENTIAL

VERY LOW

MEDIUM

HIGH

LOW

LOW-MEDIUM
PLASTICITY PROBLEM POTENTIAL
REFER TO PAGES 4-2 THROUGH 4-19 IN THE
AGGREGATE HANDBOOK
Aggregate Properties

- Physical
- Chemical
- Mechanical

Physical Properties

- Particle Shape
- Particle Surface Texture
- Pore Structure (Porosity, Permeability and Absorption)
- Specific Gravity
- Particle Grading
- Others
Chemical Properties

- Surface Charge
- Resistant to Attack by Chemicals
- Chemical Compound Reactivity

Surface Charge

Aggregate Cross Section

Water Molecule

Aggregate Cross Section
Mechanical Properties

- Particle Strength
- Mass Stability
- Wear Resistance
- Resistance to Degradation

Aggregate for Base Courses

Particle Grading
- Dense graded for mass stability
- Open graded for drainage
- Optimum fines dense graded
- Compactible and Uniformity

Particle Shape and Texture
- Angular/Cubical
- Rough
- Thin and Elongated
  - Loss of Strength, Segregate
Aggregate for Base Courses

Degradation
- Excessive fines generation may result in loss of stability
- Later fines generation can influence permeability of open graded bases

Aggregate for HMA Mixtures
- Particle Grading - consistent uniform
- Particle Strength
- Particle Shape - Angular/Cubical – Limit thin/elongated
- Porosity and Absorption
- Surface Texture – Rough; binder adhesion & stability
- Surface Charge – hydrophylic/hydrophobic
Aggregate for PCC Mixtures

- Size and Grading - Workability of fresh concrete, economy, strength
- Cleanliness – Aggregate (paste bond)
- Hardness/Toughness – resistance to abrasion
- Porosity, Permeability and Absorption – Resistance to freeze thawing, durability, mix proportions
- Particle Shape and Surface Texture – Workability of concrete, strength, appearance when exposed

Aggregate for PCC Mixtures

- Volume Stability – Drying shrinkage
- Particle Strength and Elasticity – Resistance to abrasion, creep and shrinkage
- Thermal Properties – Durability
- Specific Gravity and Bulk Unit Weight – Mix proportioning calculations and concrete density
- Chemical Stability – Resistance to chemical attack, strength and durability
### Aggregate Properties

<table>
<thead>
<tr>
<th>Function</th>
<th>Aggregate Property</th>
<th>B says: importance of Property</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>FOC</td>
</tr>
<tr>
<td>6. Retention of a surface that will assure acceptable standards of permanence. To have the characteristic, consider the characteristics of the surfaces.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Shaped resistance</td>
<td>1. Particle shape</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>2. Particle surface texture</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>3. Maximum</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>4. Particle strength</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>5. Near resistance</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>6. Particle shape of absorbed binder</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>7. Porosity</td>
<td>I</td>
</tr>
<tr>
<td>b. Surface roughness</td>
<td>1. Maximum</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>2. Grading</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>3. Gloss</td>
<td>I</td>
</tr>
<tr>
<td>c. Colour and light reflection</td>
<td>1. Reflection</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>2. Colour</td>
<td>I</td>
</tr>
<tr>
<td>d. Loose material</td>
<td>1. Volume by degradation</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>2. Solidity</td>
<td>N</td>
</tr>
<tr>
<td>e. Tire wear</td>
<td>1. Particle shape</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>2. Particle surface texture</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>3. Maximum particle size</td>
<td>I</td>
</tr>
<tr>
<td>f. Rolling resistance</td>
<td>1. Maximum</td>
<td>U</td>
</tr>
<tr>
<td></td>
<td>2. Particle shape</td>
<td>I</td>
</tr>
<tr>
<td>g. Noise level</td>
<td>1. Maximum</td>
<td>U</td>
</tr>
<tr>
<td></td>
<td>2. Particle size</td>
<td>U</td>
</tr>
<tr>
<td>h. Electrostatic properties</td>
<td>1. Electrical conductivity</td>
<td>U</td>
</tr>
<tr>
<td>i. Appearance</td>
<td>1. Particle shape</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>2. Particle size</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>3. Porosity</td>
<td>N</td>
</tr>
<tr>
<td>j. Resistance of prop. during the separation of different components of the system</td>
<td>I</td>
<td>N</td>
</tr>
<tr>
<td>k. Effect on the strength of the system</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>l. Effect of the aggregate on the system</td>
<td>I</td>
<td>I</td>
</tr>
</tbody>
</table>

Note: I = Important; N = Not important; U = Importance unknown; NA = Not Applicable; FOC = Portland cement concrete; Asph. Conc. = Bituminous or asphalt mixture; Base = Unbound aggregate base.

**Note:** Properties of Aggregates
REFER TO PAGES 3-2 THROUGH 3-35
IN THE AGGREGATE HANDBOOK
TOPIC E:  AGGREGATE PRODUCTION
Principles of crushing - Introduction

- How does a rock break
- Definition of particle size
- Distribution - "Curves"
- Description of curves, F_{80}, P_{80}
- Definition of reduction
- Reduction for different crusher types
- Quick ”Rule of thumbs” for plant evaluation

Breakage by Blasting

- Energy shock
- Break in weakest direction
Rock Breakage

**COMPRESSION**

**IMPACT**

**INTER-PARTICLE**

**ROCK ON ROCK**

**BREAKAGE BY COMPRESSION**

Rock against metal
Crushing

Pressure

Impact

Jaw crushers
Gyratory crushers
Cone crushers
Roller crushers

Impact breakers
Hammer mills
Ball mills
Rod mills

BREAKAGE
Crushing Inter-particle
BREAKAGE BY IMPACT
Rock against metal

Crushing
- Pressure (compression)
- Impact

Jaw crushers
Gyratory crushers
Cone crushers
Roller crushers
Impact breakers
Hammer mills
Ball mills
Rod mills
**Mechanical Crushing Actions**

- **Impact**
- **Compression**
- **Inter-particle**
- **Abrasion**

**Energy**
- Higher
- Lower

**Rock Breakage Mechanisms**

- **Shatter**
- **Cleavage**
- **Inter-particle**
- **Abrasion**

**Energy**
- Higher
- Lower
Rock Breakage Mechanisms

Crusher type emphasis

Impact Crushers - Shatter

Jaw and Gyratory - Abrasion and cleavage

Cone and Compression(roll) - Cleavage and shatter

TOTAL ECONOMY

Cost

Impact Breaker

Compression crushers

Break-even point

Accumulated production
Reduction Ratio - Rule of thumb

Typical RR for compression crusher
4:1 HIGH
3:1 AVERAGE
2:1 LOW

Typical RR for Impact breaker
10:1 HIGH
8:1 AVERAGE
6:1 LOW

Reduction Ratio

Reduction ratio = \( \frac{F_{80}}{P_{80}} \)

Example: RR = 18 / 6 = 3
Reduction Ratio and plant design

Given: Topsize 32 inch, product -1.0 inch
Can this be done by a jaw and a cone?

RR is approx 32/1 = 32
3 x 3 = 9  No, not enough!

How about adding a cone?
3 x 3 x 3 = 27  Yes, now we’re almost there!
Principles of crushing - Summary

- Crushing by impact
- By compression
- Separation into size classes on test sieves
- Distribution curves
- Feed and product, F_{80} and P_{80}
- Reduction ratio, RR
- Multiply RR for units to get circuit RR
Typical Aggregate Circuit

Selection based on:

- What size in?
- What product desired?
- What capacity?
- Material characteristics
PRIMARY GYRATORY CRUSHERS

- Large feed opening
- Primary application
- Hard abrasive material
- High capacity

Primary Impactor

- High reduction ratio
- Typical feed arrangement w/ grizzly feeder
- Typically 1-2 H.P. per ton of material crushed
JAW CRUSHER

• High reduction ratio
• Primary duty - Large feed opening
• Typically fed with grizzly feeder

Feed Size

For best optimization, maximum feed size should not exceed 80% of feed opening
Capacity is dependent on size distribution in feed

IMPACTMASTER SECONDARY CRUSHERS
IMPACTMASTER II

- High reduction ratio
- Large feed opening
- Typically a secondary crusher
- Excellent product shape

THOUSAND SERIES
SUPERIOR CRUSHERS

- High reduction ratio
- Typically secondary crusher
- Hard abrasive materials

For best use, maximum feed size should not exceed 80% of feed opening
THOUSAND SERIES HYDROCONE

- Typically 2nd, 3rd, 4th stage crushing
- Hard abrasive materials
- Typical reduction ratio for concrete & asphalt rock

For best product shape and optimum gradation, chambers should be choke fed

FEED SEGREGATION

CONVEYOR BELT FEED
BIN & CHUTE FEED
PROPER FEED INSTALLATION PRACTICES

How it Works

- Typically 3rd, 4th stage of crushing
- Hard abrasive material's
- Excellent product shape
Barmac VSI Crushing Action

The principle crushing action is impact reduction

Product Specification

- Increased rotor speed produces a finer product.
- Increase in the cascade flow produces a coarser product.
TYPICAL CLOSED CIRCUIT
SCREENING PROCESS

FEED - Material presented for processing

Screening Surface

OVERS - Material (product) that passes over screening surface

THROUGHS - Material (product) that passes through screening surfaces

STRATIFICATION & SEPARATION ON SCREEN
STRATIFICATION & SEPARATION ON SCREEN

- a - b: Feed enters on the feed end and the vibration causes the material to stratify
- Maximum stratification occurs at point b
- b - c: Maximum particle removal occurs due to high percentage of fine particles
- c - d: The relation of particle size to opening is close, therefore, separation occurs by repeated trials

SCREEN PRODUCT LINE USA

Circular Throw
- ST Ripl-Flo
- SH Ripl-Flo
- XH Ripl-Flo
- XXH Ripl-Flo

Elliptical Throw
- TRI-Series

Straight Line Throw
- Levil-Flo
- Low Head
- Multi-Flo
- Dewatering
- Feeders

Total Product Line 284
Standard Units Available
SCREEN STROKE CHART

<table>
<thead>
<tr>
<th>INCLINED</th>
<th>HORIZONTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opening</td>
<td>Stroke</td>
</tr>
<tr>
<td>&lt; 6”</td>
<td>½”</td>
</tr>
<tr>
<td>4 - 6”</td>
<td>7/16”</td>
</tr>
<tr>
<td>2 – 4”</td>
<td>3/8”</td>
</tr>
<tr>
<td>½ - 2”</td>
<td>5/16”</td>
</tr>
<tr>
<td>12M – ½”</td>
<td>5/16”</td>
</tr>
</tbody>
</table>

MECHANISM TYPES

Circular Motion
- Ripl-Flo
- Universal V-Mechanism
- Unbalanced Electric Motors

Linear Motion
- Levl-Flo
- Low-Head
- Unbalanced Electric Motors

Elliptical Motion
- Tri-Series Mechanism
**SH RIPL-FLO SCREEN**

**Standard Heavy Duty Screen**
- Standard RIPL-Flo mechanism
- Standard throw = 3/8”, standard speed = 800 RPM
- Bolt in 18” feedbox and 8” discharge spout
- 3/8” thick parallelogram shaped sideplates
- Rectangular tubeross members

**RIPL-FLO MECHANISM**
- Double seal arrangement...
- Slip-on bearings...
- High strength bolts...
- Adjustabe throw with changeable counterweights
- Adjustable throw with changeable counterweights
- Quick-Check oil level indicator (5 and 6 mechanisms)
TRI-SERIES SCREEN

Triple shaft arrangement with keyless locking device

Continuous splash lubrication

(6) 160 mm self-aligning dual spherical roller bearings

Hardened steel gears, adjustable counterweights, variable throw angles

Open rotor design simplifies maintenance

Deep groove sheave provides better drive performance. No belt jump-out.

High misalignment kevlar seal

Continuous splash lubrication
LOW-HEAD GRIZZLY FEEDER

- Standard Low-Head mechanism
- 1/2 inch thick sideplates with welded bottom and top flanges
- Fabricated steel tapered grizzly bars in either 4 or 6 foot lengths
- Pan thickness = 1 to 1 1/2 inches
- Egg crating
- Fixed or adjustable grizzly bars
- Flat or stepped grizzly bars
- Standard slope = 0 degree, up to 10 degrees available
- Standard throw = 7/16 inch, average speed = 900 RPM

LOW-HEAD HORIZONTAL SCREEN
LOW-HEAD MECHANISM

- Deep groove sheave provides better drive performance. No bolt jump out.
- Oil-tight mechanism is sealed to prevent oil contamination.
- Precision high capacity, cylindrical roller bearings.
- Short bearing centers minimize shaft deflection and extend bearing life.
- Double ended shaft provides choice of left or right hand drive.
- Hardened steel gears.
- Continuous splash lubrication.

LEVL-FLO MECHANISM

- Hardened steel gears for long life operation.
- Gear drive assures uniform angle of motion.
- Oil sight gauge simplifies maintenance check.
- Inspection cover for counterweight adjustment.
- Combination labyrinth and rubber lip seals.
- Continuous splash lubrication reduces drag on bearings.
- Adjustable counterweights permit adjustment throw.
- Slip-on anti-friction bearings easily removed and replaced.
References


QUARRY AND PIT OPERATIONS

Introduction

This chapter presents an overview of the quarry and pit operations. A basic understanding of these operations will increase the diagnostic abilities of the Aggregate Technician II who has to investigate the production process when the process control appears to be in trouble. The materials presented in this chapter are for natural aggregates such as crushed stone, sand, and gravel.

Aggregate plants are as varied as the material handled and the products produced. Plant design is a function of experience.

The following major categories are normally considered in the design and operation of a production facility. These are:

1. Process Parameters:
   These include pit variation, materials property, and potential waste products.

2. Project Development:
   This is a function of marker forecast. The market forecast typically covers a minimum of 10 years. The obtained annual volumes and product mix are the primary considerations for developing a preliminary flow sheet and plant layout.

3. Quality Control:
   This encompasses the processing plant design and the techniques implemented in processing, materials handling, stockpiling, and load-out. Quality control requires initiation of in-plant testing to monitor and then control the variables in the processing plant.

In addition, the design consideration includes proper drainage and accessibility of each part of the plant for maintenance. The crushing stations must have adequate overhead clearance. Safety is a very important consideration. Stairs, rather than ladders, should be designed to access platforms. Screening stations should have access doors for hoppers and chutes to permit monitoring wear and making repairs. The chutes should be designed to avoid plugging and wear rates.

In summary, the overall appearance of a plant generally reflects its state of maintenance. A clean, well-kept plant is usually one that is in a high state of operating readiness. This high state of readiness does not just happen by itself.
Crushing Operation

Energy Application

A rock is broken or crushed when a force is applied with sufficient energy to disrupt internal bonds or planes of weakness, which exist within the rock. Crushing rocks is an energy-intensive action. The ability of the crushed stone operator to influence and control the product lies within the application and control of this energy.

The first application of energy to rock is in blasting. A well-executed blast transforms a solid rock formation into fragments small enough to be accepted by a processing plant. A low energy or poorly executed blast results in many oversize pieces, which require extensive secondary breakage.

The quantity of energy applied to a unit of stone relates directly to the amount of size reduction accomplished. The required amount of energy is a function of: 1) materials resistance, 2) size-reduction ratio, and 3) quantity of material undergoing the crushing such as tons per hour.

Controlling the degree of breakage and the excessive generation of fines requires reduction over three or more stages of crushing and screening sequences.

Breakage Mechanism

Particles break from three major causes: abrasion, cleavage, and shatter. An abrasion fracture occurs when the applied energy is not sufficient to cause significant fracture of the entire particle. Localized stressing occurs and a small area is pulverized to give a distribution of very fine particles. A cleavage fracture 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 condition occurs under conditions of slow compression. A fracture by shatter 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. A probable size distribution from each fracture mechanism is shown in Figure 2.1.

Crushing Equipment

Crushing equipment may be grouped into two classifications:

1. Compression-type machines
2. Impact-type machines
Figure 2.1: Mechanisms of Rock Breakage

- **Abrasion** (Localised Stressing)
- **Cleavage** (Compression)
- **Shatter** (Impact)
Compressive-type machines include: jaw (Figure 2.2), gyratory (Figure 2.3), cone, and roll (Figure 2.4) crushers. Compression machines are suitable for different applications. A common characteristic of compression type machines is that the product must pass through a fixed but adjustable opening before being discharged. Power demand, volume of stone processed, and product control are all influenced by the discharge opening.

Impact crushers (Figures 2.5 and 2.6) apply a high speed impact force to the feed rock. Some impact machines use close-fitting discharge bars or grates to further shear or compress particles between the rotating and stationary ports. A common characteristic of impact-type crushers is that the energy available for impact varies as the square of rotational speed,

\[
\text{Energy} = \frac{1}{C} \frac{mv^2}{2}
\]

where \( m \) is the mass of the stone, and \( v \) is its velocity. Large particles break more readily from impact than small particles.

Crusher manufacturers provide capacity and gradation charts allowing rough selection of the equipment sizes. The feed-size, which is rarely considered in the product charts, influences the capacity.

The optimum feed to the crusher utilizes the interaction of particles in the crushing chamber. An underfed compression machine allows passage of oversize particles that would normally be retained in the crusher by other particles being processed and as a result be crushed to the size desired.

Factors Influencing Product Characteristics

Crushing objectives are: 1) size reduction to a specified size range and 2) minimum production of unwanted fines.

Among the factors influencing the product characteristics are the following:

- Generation of fines
- Diminished product yield
- Tuning impact crushers
- Particle shape

1. Generation of fines:

Fines generation is directly related to the size reduction ratio. Crushers operating at high reduction ratio will produce more fines than a crusher operating at a lower reduction ratio.
Figure 2.2: Jaw Crushers, Average Reduction 7:1
a. True Gyratory

b.1 Standard Gyratory  b.2 Shorthead Gyratory

c. Cone Gyratory

Figure 2.3: Gyratory Crushers
a. Single Roll Compression

b. Double Roll Compression

c. Double Shaft Shear

Figure 2.4: Roll Crushers
Figure 2.5: Primary Impact Crushers with Horizontal Shaft

- a. Single Rotor
- b. Double Rotor
- c. Andreas

REDUCTION RATIO
to 15:1
a. Secondary

b. Hammer Mill

c. Cage Mill

REDUCTION RATIO

to 15:1

REDUCTION RATIO

to 20:1

REDUCTION RATIO

8:1 to 20:1
Impact type crushers usually produce a higher percentage of minus No. 4 sieve than compression type machines when both have the same setting. In size, the fines produced by compression machines are finer than those produced by impact.

2. Tuning Impact Crushers

Usually, impact crushers can be tuned by speed, impact bar spacing, and/or grate spacing to emphasize certain sizes. The impact process by nature is less discriminate than a controlled stroke process.

3. Particle Shape:

Among the most important factors affecting the particle shape are the reduction ratio and the re-crushing which occurs in the lower part of the crusher cavity.

Screening Operations

Definition:

Screening is defined as the separation of aggregate particles into various sizes.

Screen Types:

Screens used to separate aggregate include the following:

- Vibrating inclined screens
- Stationary inclined screens
- Vibrating grizzly screens
- Vibrating horizontal screens
- Rotary screens

The most popular and reliable is the vibrating inclined screen. The major regions which are generated by the screening are shown in Figure 2.7. The majority of aggregate producers utilize a two or three deck inclined vibrating screen. The inclined vibrating screen can be easily adjusted to improve efficiency.

Screen Media:

The screen surface must be strong enough to support the weight of the material, flexible enough to withstand the vibration and provide enough area to allow the desired throughput of aggregates.
Figure 2.7: Major Regions Along a Screening Surface
There are a variety of available screen surface sizes, shapes, types and materials. Screen types include the following:

1. **Wire Cloth:**

   This is the most commonly used and is the most versatile screen type. Open area is typically 20-80 percent of total screen area. Configurations include square and rectangular openings.

2. **Other Types:**

   Other types include the following: rubber, polyurethane, perforated plate, rubber-clad perforated plate and grizzly bars. Rubber and polyurethane fabrics reduce noise and increase service life. The grizzly bars and perforated plate are rugged and can withstand great abuse.

   An illustration of screen surfaces is shown in Figure 2.8.

**Screen Performance**

Screen performance is governed by screen capacity and efficiency. Screen capacity is defined as the number of tons per hour of aggregate being fed to the screen. Capacity is almost directly proportional to the screen width. Increasing screen capacity usually decreases efficiency. Also, increasing the length of a screen increases efficiency but results in little capacity increase. Normally, an aggregate screen has a length of two to three times its width.

**Screen Efficiency:**

Screening efficiency is defined as the percent of undersize aggregate that actually passes a screening deck. A screen efficiency between 90-95% is typical for sizing in the aggregate industry. A scalping and crusher efficiency between 70-85% is generally accepted.

Efficiency of multiple deck screens is controlled by each deck. The efficiency is usually determined by tons per hour passing the bottom deck. Multiple decks are more economical since they use one drive assembly, conserve space, and reduce installation costs while making multiple operations.

Aggregate near the size of the screen are most difficult to screen. Damp fine aggregate or flat and elongated aggregate are also deterrents towards obtaining efficient aggregate separation.
Figure 2.8: Types of Screen Surfaces
Materials Handling

Materials handling is a functional unit which is totally woven into the processing system (crushers and screens). Materials handling equipment permits flexibility and multiple arrangements of material storage and flexibility.

Materials handling equipment includes the following:

- Flow control
- Feeders (both primary and secondary)
- Conveyors
- Elevators
- Screw conveyors
- Chutes and hoppers
- Storage bins
- Stockpiling after crushing

1. Flow Control:

Two basic methods are available for controlling the flow of bulk material. The first is a gate that gives an effective control only when material size is small enough and moisture content is such that bridging or plugging does not occur. The second is a feeder. A feeder is a mechanical device that provides a greater accuracy of control and allows handling of material which does not readily flow through a gate or down a chute.

2. Feeders:

These provide flexible material handling links for controlling the flow of solids among storage, handling, and processing equipment.

Primary feeders include the vibrating grizzly, considered a popular choice in handling large range of material sizes; other primary feeders are the stepdeck grizzly, apron feeder, reciprocating plate feeder, and wobbler feeder.

Secondary feeders include the vibrating pan feeders, reciprocating plate feeders, and conveyor belt feeders. A typical layout for crusher feed control is shown in Figure 2.9.

3. Conveyors:

Belt conveyors are considered the arteries which keep material flowing through the typical aggregate plant. Conveyor belt selection involves:
Figure 2.9: Typical Crusher Feed Control

NOTES:
1. Belt scale to monitor plant production rate and accumulated totals.
2. Level control for surge bin to control rate of feed from reclaim feeders from surge pile.
3. Variable speed belt feeder to control feed to crusher.
4. On cone crushers use level and power control to monitor and control rate of feed to crushers. On impact crushers use power control to monitor and control rate of feed to crusher.
• Capacity
• Length and lift
• Material weight and size

Normal belt speed range is between 300 to 600 fpm. Higher speeds have been used. Belt width is influenced by capacity, material gradation, and maximum particle size. The belt is supported by three idlers. The two outer idlers are positioned at inclinations of 20°, 35°, or 45°. The 35° setting is most prevalent. A typical roller layout with skirtboards for retaining and shaping the material is shown in Figure 2.10.

Conveyors are usually installed at inclinations up to 18° but can be increased to about 20° inclination if necessary.

4. Elevators:

These are used for small free-flowing materials; bucket elevators utilize minimum horizontal space.

5. Screw Conveyors:

Screw conveyors have pitched auger flights on a rotating shaft and are enclosed within a tubular or U-shaped housing. Screw conveyors are used to handle fine free-flowing materials.

6. Chutes and Hoppers:

The hopper bottom plate is sloped so as to avoid segregation and for achieving predictable and reliable flow in bins, chutes, and hoppers. The proper slopes for chutes vary from 30° for large rock with high initial velocity to almost 90° for materials with very sticky fines with no initial velocity.

7. Storage Bins:

Aggregate bins are used to regulate aggregate volumes during in-plant crushing, minimizing intermediate processing surges, and providing large capacity product shipping storage units.

8. Stockpiling after Crushing:

Finished aggregate sizes are normally stockpiled by belt conveyor or by mobile equipment. Most plants employ a combination of both, such as trucks, dozers, or front-end loaders.
Figure 2.10: Typical Roller Layout with Skirtboards for Retaining and Shaping the Materials on the Conveyor
In a fractionated plant, the individual aggregate sizes are stockpiled by conveyor, then blended into truck load-out bins or onto finished product stockpiles.

Stockpiling in layers use trucks to reduce segregation. It may however cause degradation. This type of stockpiling requires a large amount of space.

Stockpiled materials should be kept free of contamination from other size aggregate or foreign material.

Load-out

Load-out procedures are of important concerns in quality control. The bottom line is avoid segregation. Load-out can take many forms and involve tunnels, feeders, conveyors, bins, and scales. It can be as basic as a front-end loader loading a customer truck from a stockpile. Several load-out layouts are shown in Figure 2.11.

The flow characteristics of a product may determine the stockpiling methods. Large aggregates, for example, rip-rap, is usually stored in stockpiles. Base materials, because of the presence of fines and moisture as they tend to compact, are generally stockpiled on the ground and loaded with a front-end loader because of its poor flow characteristics.

Typical plant layouts for a 500 tph production are shown in Figures 2.12, 2.13, and 2.14.

Other Processing Equipment

Special and unique process functions employ additional processing equipment. Such equipment becomes an integral part of the process flow. Conditions requiring such equipment include production of special products, uniform blending of materials, protection of the crusher, or environmental regulations.

The following is a summary of some of the special processing equipment:

1. **Rock Breaker:**

   This is used to fracture oversize pieces or to prevent bridging of near-size pieces in the feed to the primary crusher.
(a) Truck Loadout

(b) Rail Loadout

(c) Reclaim Tunnel/Bin Loadout

(d) Barge Loadout
Figure 2:12: Typical Flow Path of a 500 TPH Plant: Surges are not shown.
Conditions:
- Screen efficiency 90%
- 500 tph feed to screen conditions 217 tph of .3 in. and 93 tph of .1 in.
- Efficiency adjustments are rounded to whole numbers.

![Diagram of Primary and Secondary Flow Path for a 500 TPH Capacity](image)

Screen products a, b + c (in. tph) are determined from screen feed gradation:
- Plus 3 in. size = 283 tph
- Minus 3 in. size = 217 tph
- Minus 1 in. size = 93 tph

And adjusted for 90% screen throughput efficiency as follows:
- 10% of minus 3 in. (217 tph) = 21.7 tph will not pass 3 in. screen size
- 10% of minus 1 in. (93 tph) = 9.3 tph will not pass 1 in. screen size

Therefore,
- Product \( a = 283 \text{ tph} + 22 \text{ tph} = 305 \text{ tph} \)
- Product \( b = 217 \text{ tph} - 22 \text{ tph} - 93 \text{ tph} + 9 \text{ tph} = 111 \text{ tph} \)
- Product \( c = 93 \text{ tph} - 9 \text{ tph} = 84 \text{ tph} \)
Figure 2.14: Typical 500 TPH Plant with Primary Surge Pile and Surge Bins Preceding Secondary and Tertiary Crushers
2. **Removal of Metal:**

Removal of metals employs magnets and metal detectors. Powerful permanent or electromagnetic magnets are positioned strategically over the aggregate flow to remove ferrous metals without stopping the conveyor belt.

Metal detectors utilize a high frequency electromagnetic field to detect the presence of metallic particles. Once the metal is detected, the conveyor belt is stopped and the metal is removed.

3. **Pugmills:**

A pugmill consists of twin counters rotating shafts with interlocking mixing paddles inside a metal hopper. A pugmill is used when a specific moisture content and a uniform blend of base materials is required.

4. **Washing Equipment:**

Most coarse aggregate is washed adequately over a vibrating inclined screen utilizing high pressure spray nozzles. Additional washing equipment includes the following:

- **Screw Washer:** A screw washer is used to remove dirt, clay, and crusher dust particles. If the specific gravity of the deleterious material is close to that of the aggregate, a heavy media is used to provide a split.

- **Log Washer:** A log washer is used for tougher plastic clays, cemented particles, and certain conglomerates. Log washers provide rigorous agitation.

- **Rotary Scrubber:** A rotary scrubber is a heavy duty, high capacity washer. It is capable of removing high contents of soluble waste, such as dirt, soft rock, and clay from good aggregates.

**In-Pit Operations**

In-pit haulage costs escalate with increased distance and elevation change from working face to the primary crusher. Alternate systems include use of a conveyor belt. Belt conveyors enjoy advantages of personnel, maintenance, energy, and capital replacement over trucks. The in-pit haulage costs are reduced when the primary station is located in the pit. A primary crusher precedes the conveying system to control the lump size. Figure 2.15 shows a typical layout for a mobile primary crusher.
Mobile crushers are used for crushing limestone or granite and have a theoretical output of 500 to 1500 tph. Larger output units of 2000 to 5000 tph are also available.

**Segregation and Degradation**

**Definition:**

Segregation is defined as the separation of one size of particles from a mass of particles of different sizes.

**Causes:**

Segregation can be caused from early stages of aggregate production (blasting, crushing, screening) or can be caused by methods used to mix, transport, handle, or store the aggregate in the plant under conditions favoring non-random distribution of the aggregate sizes.

**Occurrence of Segregation:**

Segregation starts with the blasting process in the quarry as a result of blasting energy and size distribution of the shot rock in the formation of the muck pile. A wide variety of gradation exists in the quarry run material to be dumped in the primary crusher. Figure 2.16 schematically illustrates occurrences of segregations in stockpiles.

**Cone Stockpile:**

The trend in aggregate plants today is to stockpile with conveyors rather than dozers or front-end loaders so as to minimize the cost of handling aggregate. Tests show that the highest degree of variation exists in a cone stockpile. As the height of the cone of the surge pile increases, the coarser particles tend to roll and slide to the parameter of the pile.

**Moving Aggregates:**

Segregation begins with the movement and vibration as is the case when transporting material on the primary conveyor belt as the finer material moves downward to the belt surface.
Figure 2.15: Typical Mobile Primary Crusher
Figure 2.16: Occurrences of Segregation in Stockpiles
Surge Pile:

Segregation in the intermediate surge pile and finished product stockpile is less than in the primary surge pile because the maximum size has been reduced and the ratio of larger to smaller sizes has been also decreased.

Minimizing Segregation:

A fractionated plant is considered one of the better processing alternatives for controlling segregation. Blending the various sized aggregate together at the load-out point in the asphalt plant or at the ready-mix plant minimizes the effect of segregation and helps to achieve the desired product specifications. A typical blending system is shown in Figure 2.17.

Degradation:

Degradation is defined as the breakdown of an aggregate into smaller particles. Degradation can also result in dust formation. Dozers pushing on coarse aggregate stockpiles and multiple handling of the aggregate both cause degradation. Degradation is a stronger concern in quarries having softer and more friable aggregate.

Degradation of aggregate particles can also occur when the aggregate falls a great distance from the conveyor to the stockpile.

One solution for degradation is to compensate for degradation by producing the aggregate slightly on the coarse side of the specification. Minimizing degradation due to falls may be done by keeping the stockpile at a high level or by the use of luffing boom stackers which can be adjusted vertically to control the height of fall.

Pit Operations

Introduction

The term pit operations means the prospecting, recovery, and testing of natural aggregates for different uses in highway and related construction areas. Individual state maps and records showing locations of sources are available. Figure 2.18 shows gravel and sand distribution zones for the state of Wisconsin. Aerial photographs are commonly used as the basis for topographic mapping of aggregate sources. The U.S. Geologic survey should be contacted for information on the availability of maps.

Geological and Related Characteristics of Aggregates and Aggregate Deposits:

Most factors pertaining to suitability of aggregate deposits are related to the geological history of the region and processes in which a deposit was formed or by which it was subsequently
Figure 2.17: Typical Blending System
Figure 2.18: Gravel and Sand Distribution Zones for the State of Wisconsin
modified are responsible for many of the characteristics that may influence a decision as to utilization. Among these are size, shape, and location of the deposit.

Stream deposits are the most common and most desirable in particular for PCC. Stream deposits are rounded, reasonably graded, and free of weaker particles due to abrasion caused by stream transportation.

Glacial deposits, such as those in Wisconsin, are of two types: true glacial and fluvial glacial. True glacial deposits have been transported by glacial ice and have not been subjected to the abrasive or sorting actions of river transportation. Therefore, while such deposits will usually contain material having heterogeneous shapes and sizes and ranging widely in quality, the weaker constituents have not experienced the abrasive disintegration associated with stream action. Fluvial glacial deposits consist of glacial materials that have been subjected. True glacial deposits usually occur as hummocky hills and ridges (moraines) while fluvial glacial deposits occur mainly in stream channels or on outwash plains downstream from moraines.

**Prospecting:**

When searching for suitable aggregate, it is important to bear in mind that ideal materials are seldom found. Deficiencies or excesses of one or more sizes are very common; objectionable rock types, coated and cemented particles, or particles of flat or slabby shape may occur in excessive amounts; clay, silt, or organic matter may contaminate the deposit or weathering may have seriously reduced the strength of the particles.

The size and shape of the aggregates are influenced by the flow and the depositional environment. Figures 2.19 through 2.24 illustrate the type of material encountered for different depositional environments. Figure 2.25 illustrates the commonly encountered types of aggregates.

Assessment of the material’s suitability is made through a proper sampling procedure. Moreover, depth of groundwater or excessive over-burden may seriously impede operations at a deposit.

Many objectionable features of sand and gravel deposits are remediable by proper processing. Crushing may alleviate deficiencies in fine gravel or even in sand sizes. Crushing is also necessary if the aggregates are destined for use in asphaltic mixtures where the state requires a minimum number of fractured faces.

The quantity of aggregate that a deposit may yield can be roughly estimated by pacing. Depth and grading of material may be judged by examining banks of channels or other exposures.
Figure 2.19: Sediments at the base of a mountain as talus.

Figure 2.20: Windblown (Aeolian) sediments.
Figure 2.21: Sediments in braided channel

Figure 2.22: Sediments in meandering stream channel
Figure 2.23:  
Sediments in Delta

Figure 2.24:  Sediments in Coastal Zone
Figure 2.25: Shape of Commonly Encountered Materials
Sampling Aggregate Deposits:

The Bureau of Reclamation recommends the following sample sizes from preliminary exploratory pits:

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit-run sand and gravel if screened</td>
<td>600 lb.</td>
</tr>
<tr>
<td>Sand</td>
<td>200 lb.</td>
</tr>
<tr>
<td>No. 4 to 3/4&quot;</td>
<td>200 lb.</td>
</tr>
<tr>
<td>Each of other sizes</td>
<td>100 lb.</td>
</tr>
</tbody>
</table>

If the results are promising, the site is explored and investigated. The principle objectives are to obtain sufficient representative samples to permit accurate estimation of the quality and the quantity of materials available and to enable reliable prediction of what processing operations will be required. Sampling means includes the following: steel cased test holes, open test pits, or trenches. The methods used depend on local topography; area, shape, and depth of deposit; groundwater conditions; prevalence of large rocks; and considerations affecting economy. Test excavations should be distributed at intervals in keeping with uniformity and extent of the deposit and held to the minimum effective number.

Test pits are more frequently used in Wisconsin. Machine digging of test pits has frequently saved considerable time and money. Although machine-dug pits do not permit such precise sampling as hand-dug and shored test pits, they do give a general idea of the material in a deposit. The objective of the sampling is not to test all the material from a hand-dug test pit but to secure for screening all the material from a continuous column within the pit having a diameter of approximately two feet. When the bottom of the pit is cleared to a new level, the sample material is taken from a two foot diameter hole as deep as clean excavation permits. The remainder of the pit bottom is then excavated to the level of the bottom of the sample hole, and the procedure is repeated.

Hand-dug test pits may be about 16 square feet in bottom area and will require shoring if deeper than five feet or in unstable material. Precautions should be taken to prevent contamination of the samples by material that has fallen from the side of the pit. The bottom of the hole should be kept fairly level and of full size while excavation is in progress so that material removed in each lift may represent the corresponding portion of the deposit in both quantity and quality.

To ensure contamination-free sampling, closed-wall cribbing is preferred to skeleton shoring. A typical test-pit cribbing is shown.
When water is encountered, an efficient pumping system is necessary. A number of small, readily portable, gasoline powered, self-priming, centrifugal pump units are used. It is desirable that the suction hose be one-half inch larger than the discharge opening of the pump and not more than 15 feet long. This length limitation requires setting of the pump in the pit on a frame attached to the cribbing at intervals of about 12 feet. With the gasoline engine in the pit, it is necessary to pipe the exhaust gases well away from the pit.

Samples from the five foot lift or from differing strata should be separated carefully into the size contemplated for use. Moist material should be allowed to dry on canvas by spreading in the sun or by a suitable heating apparatus. Two sand samples should be taken at each five foot interval. If the sand gradings are not in close agreement, the results should be averaged for all reported tests.

Aggregate designated for asphaltic mixture requires processing as described in quarry operations.
REFER TO 7-9 THROUGH 8-74 IN THE AGGREGATE HANDBOOK
TROUBLESHOOTING TECHNIQUES

Problems: Causes and Solutions

Introduction

An intimate knowledge of the process under consideration is essential to keep the process under control. The control charts tell you when to look for a potentially-developing problem. Control charts do not, however, tell you when or what to look for. Such knowledge develops with experience.

This section is intended to present a compilation of possible problems and their possible causes and solutions. These problems are:

- Gradation variation
- Segregation
- Degradation
- Plain maintenance
- Too many fines
- Diminished product yield
- Wear of screen and noise
- Screen performance
- Flow control
- Contamination
- Crusher protection
- Dust control
- Noise control
- Waste water and recovery of fines
- Safety consideration

Gradation Variation

Causes:

- Operating at less than optimum capacity
- Segregation
- Degradation

1. Operating Capacity:

- Avoid production surges (crusher and screens)
- Balance loadings on all crushers and screens
  - Check:
    - Crusher setting
    - Power draw on crushers
    - Gradation of feed to crushers
    - Gradation of feed from crushers
    - Through-put tph
    - Gradations from screens
Segregation

**Definition:** Separation of one size of particles from a mass of particles under conditions favoring non-random distribution.

**Occurrence:** With movement and vibration

**Stockpiling:**
- Truck dumping
- Pushing by truck dozer
- Rubber-tire dozer
- Font-end loader
- Cone stockpile
- Tent-shape stockpile

**Solution:**
- Control height
- Use adjustable boom stacker
- Fractionating plant

Degradation

**Definition:** Breakdown of aggregate into smaller particles and dust formation

**Causes:** Dozers and multiple handling of softer aggregates

**Solution:**
- Produce coarser aggregates
- Experience and testing in projection

Problem: Plaint Maintenance

**Solution:**
- Preventive Maintenance Program:
  - Ensure equipment reliability
    - record keeping
    - history of problem areas
- Design Considerations
  - Drainage
  - Access
  - Crushing Stations
  - Screening Stations
  - Conveyors
Problem:

Cause: Crusher operating at high reduction ratio (overcrushing)

Solution:
- Operate at low reduction ratio.
- Use product separating screen.
- Reduce reduction ratio for re-circulated rock.

Note:
- Impact → produce higher P#4, less effective on small particles
- Compression → produce finer gradations

Problem: Diminished product yield → Breaking smaller than target size

Solution:
- Compression machines accentuate quantity of particle size near close-side setting (opening between crusher faces).
- Use smaller-sized feed.
- Impact gives better-shaped particles.
- Avoid slow rates of feeding.
- Avoid worn equipment.

Problem: Wear of screens and noise

Solution: Use rubber and polyurethane screens.

Problem: Screen Performance

Solution:
- Use screen with adequate capacity. Inadequate screens increase production cost
- Screen capacity proportional to screen width
- Increase screen length increase through-put but reduces efficiency (2 to 3 x W).
- Efficiency is the percent of undersize aggregate passing a screen deck (90-95%), (for scalping 75-85%).
Problem: Flow Control

Solution:
- Use a “gate” - effective control if size is small and moisture is low (avoid plugging and bridging).
- Mechanical feeder - regulates material not flowing through a gate or down a chute.

Primary Feeders:
- Vibrating Grizzly Feeder (popular)
- Stepdeck Grizzly Feeder
- Apron Feeder
- Reciprocating Plate Feeder

Secondary Feeders:
- Vibrating Pan Feeders
- Reciprocating Plate Feeders
- Conveyor Belt Feeders
- Special Feeders

Problem: Contamination of stockpiles due to other aggregate size or foreign material.

Solution:
- Intermixed material must be reprocessed
- Sold as non-specification material
- Install physical divider walls

Problem: Crushers Protection

Solution:
- Use a powerful permanent or electromagnetic magnet. Install magnet as close as possible to aggregate flow.
- Use metal detectors on conveyor belts.

Problem: Dust Control

Solution:
- Wet Suppression:
  Spraying water on aggregates and road
- Dry-collection Systems:
  Hood/enclosures like baghouse
Problem: Noise Control

Solution:
- Low profile process systems
- Handling: use rock-on-rock interface
- Rubber or polyurethane screen decks
- Building enclosures

Problem: Handling Waste Water and Recovery of Fines

Solution:
- Closed Circuit Settling Ponds:
  - Decantation (diminishing)
  - Requires large area
- Construction of Permanent Disposal Areas
  - Fines pumped from cleaning process
  - Must be pre-approved by authorities
- Concrete Containment Cells
- Clarifiers

Note: Use of flocculents causes rapid settling of coagulated fines.

Problem: Safety Considerations

Accidents
- 15% unsafe mechanical and physical conditions
- 85% absentmindedness, negligence, or ignorance

Solutions:
- Crushing Machinery:
  - provide ample workroom
  - platforms should be provided
  - crushing chambers shielded
  - guards for moving parts
- Screening Machinery:
  - walkways along screen slope
  - ample clearance
  - drive guards
  - safe access to screen decks
- Conveyors
  - walkways for service
  - pinch points protected
  - cages or guards on return idlers
Process Control
Trouble shooting

- Gradation Variation
  - Segregation
  - Degradation
  - Excess fines
  - Diminished product yield
  - Feed and flow
  - Operating capacity
  - Crusher and screen

Segregation

- Particles separate into non-random distribution
- Caused by movement and vibration
  - Stockpiling segregation
  - Segregation of feed to crusher
    - Loader- fine vs coarse in shot pile
    - Conveyor and chute feed
- Suggested solutions
  - Control height of drop(belt)
  - Management of loadout
  - Use alternate feed and stockpile methods
Degradation

- Breakdown of aggregate to smaller sizes
- Caused by attrition of softer aggregate particles by the type of handling equipment and number of times material is moved.

**Solutions**
- Produce initially to a coarser gradation
- Avoid tracked (dozer) equipment
- Limit handling and driving on stockpiles

Excess Fines

- Generation of fines is directly related to size reduction ratio.
- Impact crushers - higher P4
- Compression - finer gradations

**Solutions**
- Crush at lower reduction ratio
- Screen
Open and Shut Case

Open graded base course #1 was tested at load out and failed to meet specification. Excess percent passing the #4 and #8 sieves. Contractor process control testing was done on stopped belt samples.

- First Reaction:
- Action:
- Prevention/Solutions:

Fine…Fine…

Crushed gravel base course, grade #2 is being produced from material taken from a pit located in a glacial out-wash deposit. The produced material lacked P200 material, a minimum of 3%. The contractor has a portable plant using a primary jaw crusher with a secondary roll crusher.

- First Reaction:
- Action:
- Prevention/Solutions:
Process Control
Trouble Shooting

Am Not...Are Too...
The asphalt paving contractor is having difficulty controlling the mix properties. The problem was tracked to variation in the P200 in the aggregates. At times the P200 results were within the normal JMF range and at times the P200 increased. Crusher setup = Impactor as primary, secondary cone.

First Reaction:
Action:
Prevention/Solution:

Process Control
Trouble Shooting

Day and Night...
Gradation results for manufactured sand showed a wide range of variability with results clustered both high and low on the # 8 sieve. An impactor crusher was used to produce the aggregate.

First Reaction:
Action:
Prevention/Solutions:
Superpave - The shape of stone to come

The aggregate specifications for the Superpave system lay down strict requirements concerning particle shape. The system will be implemented nationwide in the United States by the year 2000. This means that not only must aggregate producers be aware of the specifications involved, they must also be able to meet these requirements.

Superpave is the improved asphalt pavement system developed in the by the Strategic Highway Research Program (SHRP). Superpave is a complete system for specifying asphalt binders and mineral aggregates, developing asphalt mixture design, and analyzing and establishing pavement performance predictions.

The Superpave mix design and analysis system are at present "provisional" and may be further developed. States can make any changes they like to the SHRP specification, provided each change makes the specification more restrictive than the Superpave standard.

For Superpave, particle shape requirements are a yes/ no specification. Once the specification is met, that’s it. Particle shape in itself is a very small part of the overall Superpave system, but it is a very important specification for the aggregate producer.

Superpave has two specifications related to the shape of the aggregate:

&127; Fine aggregate angularity (voids in the sand fraction)

&127; Coarse aggregate angularity (flat, elongated particles in the stone fraction). The separation point between the larger coarse and smaller fine aggregate is defined as No. 4, or 4.75 mm. Hence, coarse particles are 4.76 mm and larger, whereas any particle 4.75 mm or below is a fine particle.

The coarse specification for Superpave is intended to provide material suitable for asphalt. However, it is also the case that any improvement in the coarse particle shape of an aggregate will benefit any end product in which it is used, such as concrete or base materials.

Sticking with Superpave’s specification will ensure a high quality of total output.

Fine aggregate angularity The Superpave test for Uncompacted Void Content of Fine Aggregate uses a Standard Graded Sample based on a gradation of minus No. 8 to plus No.100 material as follows:
Figure 1 illustrates the apparatus used to conduct the voids test. The prepared sample is placed into the quart jar and then allowed to free flow into the cylinder below. By knowing the volume of the cylinder, the weight of the uncompacted material in the cylinder and the material's specific gravity, one can calculate the amount of air voids in the sample. The more voids, the more angular the particles.

<table>
<thead>
<tr>
<th>Size Fraction</th>
<th>Weight Fraction (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td># 8 to #16</td>
<td>44</td>
</tr>
<tr>
<td>#16 to #30</td>
<td>57</td>
</tr>
<tr>
<td>#30 to #50</td>
<td>72</td>
</tr>
<tr>
<td>#50 to #100</td>
<td>17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crusher</th>
<th>Material</th>
<th>% voids</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP500</td>
<td>Gravel</td>
<td>46.0</td>
</tr>
<tr>
<td>HP100</td>
<td>Limestone</td>
<td>49.4</td>
</tr>
<tr>
<td>Symons</td>
<td>Quartzite</td>
<td>48.6</td>
</tr>
<tr>
<td>HP500</td>
<td>Limestone</td>
<td>49.8</td>
</tr>
</tbody>
</table>

Table 1 Examples of voids in material crushed by a Nordberg new-generation cone crusher. Superpave requires a minimum of 45% voids.

Crusher implications

The major difference between the Superpave specification and the previous ones is that Superpave requires a minimum amount of voids. Concrete specifications have always required a maximum amount of voids to obtain the qualities required, but for Superpave the minimum amount of voids is necessary to ensure a high degree of internal friction in the fine aggregate and rutting resistance. Consequently, very well shaped particles will not provide sufficient voids - really good shape is not good for Superpave! This has
important implications for the types of crusher which can be used to produce aggregate for Superpave and manufacturers have been conducting tests accordingly. All the tests conducted by Nordberg personnel on field sample cone crusher discharges have produced voids test results between 45% to 55%, as illustrated by the examples in Table 1. Generally, no cone crusher has a problem meeting the voids specification for Superpave. Impact crushers, on the other hand, may produce too good a shape to meet the specification.

**Elongated Particles**

The test for Elongated Particle specification is conducted on the plus No. 4 (4.75 mm) raw material for the design mix in order to pre-qualify the material before determining the design mix.

To measure the dimensions shown in Figure 2, the ASTM D 4791 test procedure is employed, using the proportional calipers schematized in Figure 3. However, Superpave requires that the maximum-to minimum dimensions (c to a in Figure 2) are measured, whereas the normal test procedure utilizes the maximum- to-mid dimensions (c to b) to determine elongation and the mid-to-minimum (b to a) dimensions to determine flakiness. The Superpave dimension cannot exceed a 5:1 ratio and the maximum amount allowed is 10%.

The caliper device (Fig. 3) comprises a swinging arm with an adjustable pivot point between two fixed posts. The pivot point can be adjusted to achieve a 3:1 or a 5:1 ratio. The caliper is used to measure the maximum dimension of the particle on the left side and the minimum dimension on the right, as indicated in Figure 4 where a particle is being measured for a 5:1 ratio. As can be seen, the particle meets the specification but it is not an elongated particle because its minimum dimension is larger than the fixed determined right caliper setting.
One can safely say that, in general, impactors do a good job of shaping stone and can therefore usually meet the Elongated particle specification. But with cone crushers the situation varies. Newer technology machines, such as the HP cone, have no difficulty in meeting the 5:1, 10% specification. Field samples from crusher discharges measured at the 3:1 ratio are listed in Table 2. They show that new-generation cones can generate products to meet even tighter specifications than Superpave. It is also the case that, if a sample meets the 3:1, 20% specification, it will meet the 5:1, 10% specification. On the other hand, the old technology cone crushers have a harder time meeting this specification. As the majority of cone crushers out in the field are of the old technology type, there is a problem to solve.
Reduction ratio

Before trying to adjust or modify these older style crushers in order to improve particle shape, one should understand the factors that affect that shape. Contrary to what one might expect, reduction ratio rather than crusher type is the key influence. There is a very simple relationship between reduction ratio and particle shape: the higher the reduction ratio at any given crushing stage, the poorer the shape. Table 3 lists the results of tests on taconite conducted at the Nordberg Mineral Research and Test Center which clearly show the correlation between reduction ratio and the proportion of poorly shaped particles. Minimizing the reduction ratio for each stage of crushing in a circuit will improve the final product shape.

<table>
<thead>
<tr>
<th>Crusher</th>
<th>Material</th>
<th>% elongated</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP500</td>
<td>Gravel</td>
<td>4.8</td>
</tr>
<tr>
<td>HP100</td>
<td>Limestone</td>
<td>14.7</td>
</tr>
<tr>
<td>HP500</td>
<td>Limestone</td>
<td>7.7</td>
</tr>
<tr>
<td>HP300</td>
<td>Granite (3/8” chips)</td>
<td>13.6</td>
</tr>
</tbody>
</table>

Table 2 Examples of particle elongation in material crushed by a Nordberg new-generation cone crusher. Superpave requires a maximum amount of elongation of 20%.

<table>
<thead>
<tr>
<th>Reduction Ratio</th>
<th>Flakiness Index *</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.75</td>
<td>9.7%</td>
</tr>
<tr>
<td>3.60</td>
<td>12.2%</td>
</tr>
<tr>
<td>6.95</td>
<td>18.3%</td>
</tr>
</tbody>
</table>

*Flakiness Index is French specification

Table 3 Tests conducted by Nordberg’s Mineral Research and Test Center on taconite.

The effects of reduction ratio are the same for all crusher types. For example, a comparison of the product from a primary impactor with that from a tertiary will show that the primary produces a poorer shaped product than the tertiary. This is because the primary impactor is normally required to operate at a higher reduction. Keeping the reduction ratio as low as possible at each stage is a must.

Other influences

In practice, of course, each real plant has a fixed number of crushing stages and a fixed overall reduction that must be met. To overcome these design limits on reduction ratio one has to utilize other influences which will make the process act as if it is operating at a lower reduction. The other operating variables that can affect particle shape include:

- crusher type
- screen media
- feed gradation
- recirculating load
- energy input method
open or closed circuit operation
full and constant crusher operation
particle size to setting relationship
circuit material flow.

Not only does each of these characteristics have a varying amount of influence on particle shape but the amount of change in particle shape is also very much affected by the type of material being processed. The data considered below are only indicative of the influence of the various factors; they are not absolute values.

Crusher type

As regards ability to produce the best shape, impactors top the list of crusher types, followed in descending order of quality by new technology cone crushers, gyratory crushers, roll crushers, old technology cones, jaw and primary gyratory crushers. But remember that a cone crusher will break some materials, normally laminated rocks, into a more cubical product than an impactor can. Shales are a good example. Whereas an impactor will break shale along the bedding planes, yielding a flaky product, a cone crusher will break shale in all directions, yielding a more cubical product.

Selective screening

This practice is commonly used in Europe. The sized material is screened on a slotted cloth to remove flaky particles. This flaky fraction is crushed again to help improve its particle shape. It will now fill some of the voids in the feed, helping to improve the particle shape of the complete crusher discharge. Selective screening is generally performed by a split bottom deck on the screen.

Feed gradation

The results of tests in which the size of the feed was reduced are presented in Table 4. The feed top size was decreased from 100 mm to 50 mm, halving the reduction ratio and achieving a product with 38% fewer flakes present. A full and uniform feed gradation will also improve particle shape by promoting inter particle crushing rather than a narrow or gap graded feed, as explained later in this discussion.

Recirculating load

Operators tend to argue that a recirculating load increases wear rates and maintenance costs but serves no useful purpose. Not so. Raising the recirculating load by increasing the setting can achieve positive outcomes. Firstly, operating the crusher at a larger setting reduces the motor power draw, so cutting a major operating cost. Second, as shown by the example in Table 5, the use of a higher recirculating load can produce a better shaped product. In fact, in this particular case, deciding to recirculate material converted a non-saleable material to a saleable product that met the job specifications. And reduced the operating costs. That’s a result!
Modern cone crushers such as these HP crushers are well suited to meeting the Superpave specifications for aggregates.

**Energy application**

One reason why increasing the recirculating load improves particle shaping is the effect the higher setting has on the crushing process. The single particle crushing process is typical of old technology cone crushers. The particle is crushed between two surfaces and energy is applied in a controlled manner. Naturally, the energy for crushing is applied to the particle between two points. This results in long crack lengths and the formation of elongated particles. In contrast, the multilayered crushing process is promoted by opening up the setting. This provides a multitude of contact points on the particle or a random distribution of crushing energy. The results are shorter crack lengths and a more cubical product.

**Circuit type**

These benefits of operating the crusher at a higher setting can be achieved in a closed circuit configuration. For open circuit operation, a high reduction has to be applied in one pass to obtain the same product size. As shown by the data in Table 6, particle shape improves when the final product is produced in closed circuit.
Full and constant operation

A full cavity also promotes multi-layered crushing and hence better particle shaping. Operating the crusher at a constant feed rate allows the operator to control the other variables in order to optimize its production. The more control one has of the crushing process, the better one can produce the best particle shape possible.

Particle size-to-setting relationship

Particles closest in size to the C.S.S. typically have a better shape than those further away. Another interesting feature of this relationship is the fact that the slope of the line is steeper for sizes less than the setting than for those that are larger. This is due to the fact that the particles below the C.S.S. have a much higher reduction than the particles above.

Circuit flow

A circuit was designed to produce a minus 38 mm by 19 mm ballast. However, once it was set up and running, the operators found that the ballast did not meet particle shape requirements. A review of the circuit showed that the poorly shaped particles produced by the jaw crusher were going directly to the final product.

By redirecting the jaw discharge to the HP300 cone crusher instead of to the screen, two positive changes were achieved. First, all of the material going to final product now passed through the cone which produces a much better shaped product than the jaw crusher. Secondly, with the jaw crusher now supplying the cone, the feed was made finer and therefore the cone could operate at a lower reduction ratio. This helped improve the shape of all particles being produced by the cone to the extent that this circuit configuration did meet the ballast particle shape required.
Summary

Superpave is here to stay. This means that not only must aggregate producers be aware of the specifications involved, they must also be able to meet these requirements. Fine aggregate angularity for Superpave is a reachable specification with today’s equipment. The flat and elongated specification can be met by the new technology crushers and by the old technology crushers if properly applied.

To reiterate, although particle shape for asphalt products is the prime concern here, it is worth remembering that an improvement in particle shape will be of benefit in all uses of the product - concrete and base materials too.

Finally, the all-important reduction ratio. Whatever can be done to minimize the reduction ratio at every stage of crushing will significantly improve the particle shape of the final product.

By Tony Magerowski

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TOPIC H: AGGREGATE BLENDING
Obtaining the desired aggregate gradation, i.e., the gradation that will give you the greatest economy and also meet all of the specification requirements is usually a matter of blending together two or more aggregates from different sources. Rarely will a single aggregate source give you the desired gradation. Blending together combinations of coarse stone, coarse sand, fine sand, and mineral filler is quite common in order to get the desired gradation.

The preferred procedure for blending two or more aggregates is fairly simple and called the “Trial and Error Method.” It can be accomplished by performing the following four steps:

1. The first step is to do a gradation analysis on each material to be blended. Several samples should be obtained for each material and a gradation run on each sample. Care should be taken in obtaining the samples to be certain that they are representative of the material. The samples may be taken from the stockpiles or the cold feed bins. The gradations should then be averaged for each material and the average gradations entered in the appropriate columns (Percent Passing) on a blending worksheet. A few examples of blending worksheets are included in this manual section.

2. Step two is to enter the upper and lower specification limits for each sieve size in the right column of the worksheet. These limits pertain to the percent passing each sieve size.

3. The third step is to select the target gradation value for each sieve size that you want to aim for with the combined gradation. A common practice is to select a target value in the middle of the upper and lower limits for each sieve size. The selected target values should be entered in the column to the left of the specification limits column.

4. The fourth and last step is to determine the proportion of each aggregate to be blended together to obtain or get close to the target values. A good practice is to look at the target value for the No. 200 sieve first and then determine which of the materials to be blended will be the major contributors to the 200 sieve target value and then guess at the percentages of those materials needed to reach the target value. Using those percentages, calculate the amount of No. 200 material that will be contributed to see how close it comes to the target value. Then look at the target value for the No. 4 or No. 10 sieve and determine which of the materials to be blended will be the major contributor to that sieve and then calculate the percent of that material that will be needed to get close to the target value. The total percentage of these materials to be blended has to equal 100 percent. Add the percentages for the material contributing to the No. 4 or No. 10 sieve and the No. 200 sieve and subtract them from 100 percent and then divide the remaining percentage among the remaining materials to be blended as you feel would be appropriate.
The next step is to multiply the percentage of the material passing each sieve by the percentage of that material selected for blending. This data should be entered in the appropriate column (Percent Batch) to the right of the gradation column (Percent Passing) for each material. If 100 percent of a material passes a particular sieve, a 100 should be entered in the box and multiplied by the blending percentage for the material. After the percent passing each sieve has been multiplied by the percent of that material to be blended, the percentages of each material for each sieve size should be added across and the total entered in the column to the left of the target values. The actual values should be compared with the target values to see if they are close. If they do not compare satisfactorily, the blending proportions should be adjusted and another try made. This is why it is called the “Trial and Error Method.” The more experience you have with this method, the quicker you can get the answer.
### TOPIC H: Aggregate Blending

<table>
<thead>
<tr>
<th>Material</th>
<th>AGG #1</th>
<th>AGG #2</th>
<th>AGG #3</th>
<th>Combined Gradation</th>
<th>Target Value</th>
<th>Specification Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Percent Used</strong></td>
<td><strong>Coarse 60%</strong></td>
<td><strong>Intermediate 8%</strong></td>
<td><strong>Fine 32%</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>US Sieves</strong></td>
<td>Percent Passing</td>
<td>Percent Batch</td>
<td>Percent Passing</td>
<td>Percent Batch</td>
<td>Percent Passing</td>
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<td></td>
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<td>¾</td>
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<td>½</td>
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<td>100</td>
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<td>10-30</td>
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Student Problem No. 4: (1) Find the percent of each bin to use. (2) Calculate the combined gradation.
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### TOPIC H: Aggregate Blending

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Student Problem No. 5: (1) Calculate the combined gradation using the percentage shown. (2) Is the combined gradation with the job mix tolerance? (3) Is an adjustment needed?
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Solution to Student Problem No. 5
Adjustment – More fine material is needed.
Problem No. 6.

Sieve analysis performed on samples taken from three stockpiles yielded the average results shown below. Combine these materials to meet the specification limits.

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### BLENDING WORKSHEET

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Solution to Student Problem No. 6
Problem No. 7

The average test results on four aggregates were run to see whether they would meet FAA Specification P-401 for a Surface Course mix with a maximum size aggregate of ¾ inch. Combine these materials to see if they meet the specification.

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Solution to Student Problem No. 7
The specification limits on the ½" sieve cannot be met.
Problem No. 8

Determine the percent of each bin and mineral filler needed to produce a mixture meeting the specification requirements given below.

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Solution to Student Problem No. 8
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CONSTRUCTION CONTROL TECHNIQUES

...a series of training programs for quality control technicians and plant supervisors

job mix formulas & blending aggregates
"TRIAL and ERROR" METHOD

STEP 1
OBTAIN DATA
a. Gradation of Materials
b. Specification Limits
**Table: Specifications**

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**Step 2:** Select Target Value
### SPECIFICATIONS

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STEP 3

GUESS the PROPORTION
30% AGG. No. 1

70% AGG. No. 2

Combined Aggregate

STEP 4
CALCULATE the COMBINED GRADATION
5

STEP

COMPARE
RESULT

calculation ⇔ target
value

TRIAL AND ERROR METHOD

☑ Obtain data
☑ Select target value
☑ Guess the proportion
☑ Calculate combined gradation
☑ Compare calculation with target value
☑ Try again
### BLENDING WORKSHEET

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**Step 2**

**SELECT TARGET VALUE**

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### Step 2: Select Target Value

Select a target value from the combined gradation. This value will be used to adjust the proportion of each aggregate.

### Step 3: Guess the Proportion

After selecting the target value, estimate the proportion of each aggregate that should be used to meet the target value. This process may require some trial and error to achieve the desired gradation.
### Blending Works

#### Step 4: Calculate the Combined Gradation

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- (No. 8) $100 \times 50\% = 50$
- (No. 4) $90 \times 50\% = 45$
- (No. 8) $30 \times 50\% = 15$
- (No. 16) $7 \times 50\% = 3.5$
- (No. 20) $3 \times 50\% = 1.5$
- (No. 50) $1 \times 50\% = .5$
### Aggregate Blending

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**Notes:**

- Combined Gradation at 50% sieve:
  - 100 mm Grad.
  - 95 mm Grad.

**Formulas:**

- AGG. #2, Percent Used = 50
- Combined Gradation:
  - 50% Sieve: 100 mm Grad.
  - 50% Sieve + 50% Sieve: 95 mm Grad.

---

### Blending Worksheet

**Table:**

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**Notes:**

- Combined Gradation at 50% sieve:
  - 100 mm Grad.
  - 95 mm Grad.

**Formulas:**

- AGG. #2, Percent Used = 50
- Combined Gradation:
  - 50% Sieve: 100 mm Grad.
  - 50% Sieve + 50% Sieve: 95 mm Grad.
### CALCULATE THE COMBINED GRADATION

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**TARGET VALUE**

**SPEC LIMITS**
### Answer to Student Problem

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| 1/16"  | 1/8"   | 1/4"   | 3/8"   | 1/2"   | 3/4"   | 1/16"  | 1/8"   | 1/4"   | 3/8"   | 1/2"   | 3/4"   | 1/16"  |
| 1/16"  | 1/8"   | 1/4"   | 3/8"   | 1/2"   | 3/4"   | 1/16"  | 1/8"   | 1/4"   | 3/8"   | 1/2"   | 3/4"   | 1/16"  |
| 1/16"  | 1/8"   | 1/4"   | 3/8"   | 1/2"   | 3/4"   | 1/16"  | 1/8"   | 1/4"   | 3/8"   | 1/2"   | 3/4"   | 1/16"  |
### BLENDING WORKSHEET

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category: Aggregate Blending

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</table>

**Obtain Data**

---

**Note:** The Blending Worksheet is used to calculate the percentage of each material needed for a specific blend. The table above shows the percentage distribution for each size of rock, sand, and other materials used in blending.
### Blending Worksheet

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>U.S. GRADES</th>
<th>PERCENT USED</th>
<th>PERCENT PASSING</th>
<th>PERCENT PASSING</th>
<th>PERCENT PASSING</th>
<th>PERCENT PASSING</th>
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<th>TARGET VALUE</th>
<th>SPEC LIMITS</th>
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**SELECT TARGET VALUE**

### Blending Worksheet

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<th>PERCENT PASSING</th>
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<th>PERCENT PASSING</th>
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<th>SPEC LIMITS</th>
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**GUESS THE PROPORTION**
### Blending Worksheet

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<th>Designated Gravel</th>
<th>Coarse Sand</th>
<th>Fine Sand</th>
<th>Filler</th>
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<td>100</td>
<td>90-100</td>
</tr>
<tr>
<td>1 &amp; 3/4</td>
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<td>100</td>
<td>80</td>
</tr>
<tr>
<td>1 &amp; 1/2</td>
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<td>100</td>
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</tr>
<tr>
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### Blending Worksheet

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<th>Fine Sand</th>
<th>Filler</th>
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<td>PERCENT PASSING</td>
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<td>100</td>
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</tbody>
</table>

**Math Calculations:**

1. \( \frac{15}{2} = 1.8 \)
2. \( 0.03 \times 80 = 2.4 \)
3. \( 1.8 + 2.4 = 4.2 \)
### Blending Worksheet

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>CRUSHED GRANUL</th>
<th>COARSE SAND</th>
<th>FINE SAND</th>
<th>FILLER</th>
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</thead>
<tbody>
<tr>
<td>PERCENT USED</td>
<td>%</td>
<td>%</td>
<td>15%</td>
<td>3%</td>
</tr>
<tr>
<td>U.S. SIEVES</td>
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<td>PERCENT BATCH</td>
<td>PERCENT PASSING</td>
<td>PERCENT BATCH</td>
</tr>
</tbody>
</table>

**15% FINE SAND**

**ADD** 3% FILLER

**SUBTRACT** 18% CRUSHED GRANUL, COARSE SAND

**KNOWN** 82%

---

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>CRUSHED GRANUL</th>
<th>COARSE SAND</th>
<th>FINE SAND</th>
<th>FILLER</th>
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</thead>
<tbody>
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<td>U.S. SIEVES</td>
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<td>PERCENT BATCH</td>
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**135 FINE SAND PASSING NO. 8 SIEVE**

**ADD** 30

**16.5 FINE SAND PLUS FILLER**

---

<table>
<thead>
<tr>
<th>SIEVE NO.</th>
<th>GRADE</th>
<th>NO. 8</th>
<th>FINES</th>
<th>NO. 30</th>
<th>FINES</th>
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### Aggregate Blending

**Blending Worksheet**

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<th>Filler</th>
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</table>

**300 Target Value**

- Minus 16.5 Finesand-Filler = \( \frac{13.5}{.94} = 14\% \)

**Blending**

14% Coarse Sand

15% Fine Sand

3% Filler

Add 32% Total

Subtract 68%
### Blending Worksheet

<table>
<thead>
<tr>
<th>Material</th>
<th>Crushed Value</th>
<th>Crushed Stone</th>
<th>Pileville Sand</th>
<th>Gravel Value</th>
<th>Combined Gradation</th>
<th>Target Value</th>
<th>Specific Limits</th>
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#### Student Problem

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<th>Gravel Value</th>
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PROBLEM
1. Find the percent used
2. Calculate the combined gradation

<table>
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<tr>
<th>MATERIAL</th>
<th>BIN #3</th>
<th>BIN #2</th>
<th>BIN #1</th>
<th>FILLER</th>
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### Problem 1: Find the Percent Used
1. Calculate the combined gradation

#### Blending Worksheet

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<td>Percent</td>
<td>Percent</td>
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<td>Percent</td>
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</tbody>
</table>

### Trial and Error Method
- Obtain data
- Select target value
- Guess the proportion
- Calculate combined gradation
- Compare calculation with target value
- Try again
REFER TO 3-68 THROUGH 3-71 IN
THE AGGREGATE HANDBOOK
DEFINITIONS:

Biased Sampling: A sampling procedure whereby certain individual measurements have a greater chance of being included than others.

Characteristic: A term used for measurable quantities such as percent passing, percent voids, percent A.C., etc.

Control: As defined in the *American Heritage Dictionary*, control is “the ability to regulate.”

Discrete Data: Data that can assume only certain value. Discrete data results from a process of counting.

Population (Universe): The entire set of observations that are of interest in a statistical investigation, for example, a lot. Generally it requires a large number of observations (data).

Process Capability: A process combining materials, equipment, and operator(s).

Quality: As defined in the *American Heritage Dictionary*, quality is “a characteristic or attribute of something.”

Sample: Some portion of a population. A sample may refer to an aggregate or asphaltic concrete sample that is collected for testing to evaluate the material under construction.

Specifications: Set of instructions and rules governing the characteristics of a material control should include allowable variations in materials sampling and testing, called tolerance.

Specimen: Refers to the material that is obtained for testing. A sample may consist of four specimens.

Statistical: Quality Assurance: The use of statistical data is to regulate a characteristic or attribute of something. The word “regulate” means that the management of the process is an essential part of quality control.

Statistics: As defined in the *American Heritage Dictionary*, statistics is “the mathematics of the collection, organization on an interpretation of data.”

Random Sampling: A sampling procedure whereby any individual measurement in the population is as likely to be included as any other.
INTRODUCTION TO QC/QA

Preface:

Quality, quality control, and statistical quality control are terms which are widely used and misused in conversation and advertising. This is because the concepts that these words represent have become very popular in this period of constantly increasing prices and apparently decreasing quality. **Quality improvement can only be achieved through the proper application of the tools and techniques of quality control.** The first step in learning how to use these tools is to understand the meaning of these words in the context of the production of goods and services. The principle requirement for applying quality control is simply the existence of a process that produces a good such as an aggregate and/or asphaltic mixture.

Statistical quality control is simply a tool, or more precisely, a set of tools that utilizes certain mathematical principles in providing information for management to use in making decisions regarding quality. Although topics such as mathematics, statistics, and probability might seem too formidable, the **actual techniques used are relatively simple and require little knowledge in any of these fields. No previous background in statistics is required of the student, and only a minimal background in mathematics is assumed.**

Requirements of Quality Control:

There are three basic functions that are vital to the control of any operation. These are as follows:

1. Establishment of standards or specifications
2. Comparison of performance with standards
3. Corrective action

Wisconsin DOT has already completed the required specifications for asphaltic mixtures. There are current efforts by Wisconsin DOT to expand the special provisions for QC/QA to the aggregate industry and to the production of Portland Cement Concrete, PCC.

The development of the standards or specifications should take into consideration all variables associated with the product in a given locality. These variables include materials, production equipment, sampling and testing, and product performance. As an outcome of this assessment, reasonable and attainable tolerances will be established. The function of quality control then becomes necessary to assure the achievement of the established standards of quality.
Factors Influencing Quality Control:

There are qualitative and quantitative factors which affect quality control. Among the qualitative factors that influence quality control are the following:

1. Competent and well-trainer workers
2. Equipment condition and maintenance
3. Working conditions

The quantitative factors include:

1. Collection of data
2. Analysis of data

Data must also be used to assess current performance so that comparisons can be made with the existing standards and so that the significance of observed deviations (using control charts) can be determined. This is necessary in order to decide if and when corrective actions should be taken.

In order for a program of quality control to be effective, it should attend to both the qualitative and quantitative contributors to quality. It may be assumed that the qualitative factors are receiving the proper attention through training and maintenance; then, the application of the techniques of statistical quality control should result in substantial improvement in quality.

Categories of Statistical Quality Control:

The application of statistical quality control falls in two major categories:

1. Process control (quality control)
2. Acceptance control (quality assurance)

The major set of tools used in process control are control charts. The major set of tools used in acceptance control (quality assurance) are acceptance sampling plans or simply acceptance samples.

A process which is operating within certain limits that can be specified numerically in terms of the quality characteristic being measured is said to be in control. Variation is highly associated with highway materials and construction. Variation is therefore inevitable as an inherent part of the process being observed. The acceptable variation due to the random causes is called random variation, and these are due to the following:

1. Variation in material properties
2. Variation in sampling and testing
Variation due to causes that are not part of this random system leads to excessive variation which is not acceptable. Such non-random causes of variation are referred to as **assignable causes**. A process exhibiting variation that is subject to assignable causes is said to be **out of control**.

**The Relationship of Statistics, Process Capability, and Specifications:**

We can measure the characteristic of a test, say percent passing a given sieve, and then we can use statistics to interpret this data and predict the percentage of tests that will be within this range. The information on the process capability can be used to determine if a given process will produce a product (aggregate, asphalt mixture) that meets given specification.

**The Relationship of Process Capability and Quality Control:**

Once the process capability is known, the production can be monitored to determine when the process control has changed. The control charts are used for this purpose. Our knowledge of the process capability will let us calculate the likely minimum and maximum values that a sample average would have if the process continues unchanged. When the sample average shifts outside these values, we have reasons to believe that the process has changed and needs correction. This scope is the heart core of the Technician II training, whether for the aggregate or the bituminous mixtures.
Control Charts

Definition

A control chart is simply a graph that reflects the variability of a process variable (sieve size, density, moisture content, asphalt content, etc.) with respect to time.

Uses of Control Charts

Control charts are tools for recording observations made on a process and indicating when the process is apparently out-of-control. The benefits of a control chart are shown in Figure 4.5.1. In Wisconsin, a trend of the moving average into the warning band indicates an out-of-control process. When an out-of-control process is indicated, the process is stopped, and an attempt is made to locate and eliminate the assignable causes. Control charts do not identify the source(s) of variability associated with the process control. Assignable causes can be eliminated if we identify them. Figure 4.5.2 identifies the types of variation. Examples of assignable causes might be when the gradation for an aggregate blend goes out of specifications due to a hole in one of the sieves or because the cold feed conveyor setting is incorrectly adjusted. Process control is discussed in Section 4.6.

Chance causes are something that a contractor or material supplier must learn to live with. They cannot be eliminated, but it may be possible to reduce their effects.

Construction of Control Charts:

There are many types of control charts. The simplest of these is referred to as a music bar chart, shown in Figure 4.5.3. These charts plot individual results in chronological order. Plots of this type can show trends as they develop. It is also possible to show the specification tolerance limits so that test results outside specification requirements can be identified.

A control chart includes a centerline, an upper control limit, UCL, and a lower control limit, LCL. The state also added an upper warning limit, UWL, and a lower warning limit, LWL. The various limits are illustrated in Figure 4.5.4.

The centerline is drawn horizontally across the chart and represents the mean of the sample data, i.e., represents the JMF design value for a given sieve size, target average density, etc.

The upper control limit, UCL, and lower control limit, LCL, are constructed on the basis of availability of many (lot or population) data. Two approaches will be considered.
BENEFITS OF CONTROL CHARTS

- early detection of trouble
- decreased variability
- establish process capability
- reduce price adjustment costs
- decrease inspection frequency
- basis for altering spec limits
- permanent record of quality
- provide a basis for acceptance
- instill quality awareness

Figure 4.5.1: Benefits of Control Charts
Variation

- Chance Causes
- Assignable Causes

Assignable Causes

- Can be eliminated
- *IF* we can identify them

Figure 4.5.2: Types of Variation
CONTROL CHART

Upper Control Limit

Data Points

Target Value

Lower Control Limit

Figure 4.5.3: Music Bar Chart
Figure 4.5.4: Components of a Control Chart
CONTROL CHARTS

Control charts are defined as graphs to reflect variability of a characteristic over a period of time. Standardized control charts shall be maintained by the contractor QC staff at a location agreed upon by the contractor and engineer.

If the contractor is operating more than one production site for the project, he/she shall provide separate control charts for each production site producing material.

Individual test results obtained by the contractor shall be recorded on the control charts as soon as possible on the same day as the tests are run. For roadbed samples, the engineer (QA staff) will post results of assurance tests as soon as data is available.  

Control charts shall be maintained and kept current as a minimum for the following and for both production and roadbed samples. Separate control charts shall be kept for all mathematically random selected production and roadbed samples.

Gradation of aggregate expressed in percent passing sieve sizes. Separate charts shall be kept for 2", 1-1/2", 1", 3/4", 3/8", #4, #8, #10, #16, #30, #40, #50, #100, and #200. (Only the sieve sizes pertaining to the applicable specification need be recorded on the charts.)

Control charts are not required for fractured particle count or other sample elements which the contractor may include in the testing. Fractured particle counts (thin and elongated particle for concrete pavement) are required to be recorded by the contractor and other sample data obtained at the contractor=s choice may be recorded for information only.

Control charts shall contain pertinent identification information as well as the plotted data. In addition to the individual test points of the contractor QC and engineer QA, a moving average of the last four QC data points shall be plotted.

Control charts shall include both upper and lower control limits and upper and lower warning limits. The area between the control limit and warning limit is the warning band.

The following example illustrates a typical method for computing moving average values. The example utilizes aggregate gradation data for the 3/8 inch sieve fraction which coincides with the example gradation charts (refer to Figure 10).

---

2The specification QA testing will be performed on the split samples taken from the roadbed. There is no QA testing required by the specification for production samples.
EXAMPLE

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Test % Pass 3/8&quot;</th>
<th>Sum of Last Four Values</th>
<th>Average of Last Four Values, % Pass 3/8&quot;</th>
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</thead>
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<tr>
<td>1</td>
<td>60</td>
<td>B</td>
<td>B</td>
</tr>
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<td>2</td>
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<td>B</td>
<td>B</td>
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<tr>
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<td>61</td>
<td>B</td>
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</tr>
<tr>
<td>10</td>
<td>65</td>
<td>244</td>
<td>61</td>
</tr>
</tbody>
</table>

As shown in Figure 10, the control limits (specification limits) are 40 and 70%. The warning limits (two percentage point warning band inside the control limits) are 42 and 73 respectively, for the lower and upper, as defined by the special provision specifications.³

Ideally, gradation test results should be near the specification mid-points for as many of the applicable sieve fractions as possible. This will best assure the contractor will avoid exceeding the specified limits. Operating near the limits for one or several sieves represents an insecure situation for the contractor.

Figure 10 is a control chart plotted using the 3/8 inch sieve fraction data of the example above. This same format shall be used for control charts for all sieve fraction required by the specifications.

Attachment 11 is a generic form sheet which may be used to calculate moving average values for the aggregate gradation sieve fractions. Attachment 3 is a generic form sheet for plotting control charts for the gradation sieve fractions. These two attachments may be reproduced, as needed, to perform the control chart plotting work.

³Note that special provisions specify a warning band of 2% for all sieve fractions except 0.5% for the No. 200 for QMP, Base Courses, and QMP, CABC with Density. The warning band for QMP, Aggregate for Concrete Pavement is 1% for all sieve fractions except 0.5% for the No. 100 and No. 200.
FIGURE 10: EXAMPLE CONTROL CHART FOR AGGREGATE GRADATION (3/8 INCH SIEVE FRACTION)
CORRECTIVE ACTION FOR ROADBED SAMPLES ONLY

When the moving average trend for any of the control chart values is towards the warning limits, the contractor shall consider corrective action (refer to Figure 11, Example A). The corrective action undertaken may be to increase the sampling and testing rate, to inspect laboratory equipment. To inspect plant equipment, to initiate adjustments in controlling the manufacturing process, to change materials or quantities, and combinations of these actions. Blending of two or more aggregates on the roadbed to correct the gradation is prohibited as a corrective measure. However, remixing the aggregate on the roadbed may be proposed as a correction, particularly if segregation appears to be the problem.

Corrective action shall always be documented. In addition to documenting corrective actions, resulting effects of the corrective actions shall be recorded.

When the moving average for any of the control chart values exceeds the warning limits, the contractor shall notify the engineer (refer to Figure 11, Example B). This should be done immediately after the value has been determined. When a second consecutive moving average value for a particular property exceeds the warning limits (refer to Figure 11, Example C), the contractor and engineer shall discuss a course of corrective action. The corrective measure(s) shall be performed by the contractor. For QMP, Base Courses, and QMP, CABC with Density, the frequency shall increase to one random sample/test for each 500 tons placed.
FIGURE 11: CONTROL CHART TRENDS AND CORRECTIVE ACTIONS

EXAMPLE A: Moving average trend is towards upper warning limit.

ACTION: The Contractor shall consider corrective action. This should happen as early as the 4th individual point and definitely by the 5th. Document action, if any taken.

EXAMPLE B: Moving average value exceeds the upper warning limit.

ACTION: The Contractor shall notify the Engineer when the first moving average point is obtained which exceeds the UWL (point 8). Document corrective action, if any taken.

EXAMPLE C: A second consecutive moving average value exceeds the upper warning limit.

ACTION: The Contractor and Engineer shall discuss a course of corrective action when the 2nd consecutive moving average point (point 9) exceeds the upper warning limit. Document the corrective action taken.
Figure 11 has demonstrated the three control chart patterns presented in the preceding two paragraphs. The appropriate action to be taken by the contractor is indicated on the figure for each example.

In the foregoing examples illustrated in Figure 11, the data trends from the start are toward the upper warning limit. The prudent contractor and QC staff will be watching the data trend and making decisions to alter the trend, hopefully before the conditions in either Example B or C occur. The contractor should want to take action as soon as test data confirms something is not right in the process.

In the previous Figure 11, Example C, there are a number of conditions which can result. One condition is that following the corrective action, after four additional individual tests, the property may improve as evidenced by a new moving average point which is not in the warning band. In this case, the contractor may continue production/placement of aggregate since the problem appears to be corrected (refer to Figure 12, Example A).

In a second case following the corrective action, after four additional individual tests, the property is not improved as evidenced by a new moving average still in the warning band. At this time, the contractor shall notify the engineer (just as in Figure 11, Example B). The steps following the initial notification of the engineer, outlined before, shall be repeated (refer to Figure 12, Example B).

For the condition outlined in the foregoing paragraph, the significant point is that no material has been produced outside specification limits (control limits). At worst, considerable material will be placed with test results in the control chart warning band if this situation exists for some time before the contractor is able to correct the situation. The important point here is that the contractor should be making every effort to get the process under control. If this is accomplished at some point by making the proper adjustments without the material test results exceeding the specifications, all is well.
FIGURE 12. CONDITIONS RESULTING FROM FIGURE 9, EXAMPLE C.

EXAMPLE A: The contractor notifies the engineer at test 7. At test 8 the contractor and engineer discuss an action to take and increase frequency of random sample/test to 1 each 500 tons placed. At test 12 the new moving average of 4 is within the warning limits and the contractor continues production with the problem, seemingly, resolved.

EXAMPLE B: The contractor notified the engineer at test 7. At test 8 the contractor and engineer agree on corrective action to take. At test 12 the new moving average of 4 remains in the warning band and the contractor notifies the engineer as in Figure 9, Example B and the ensuing steps are repeated. Note this may substantially reduce the rate of placement do to frequency of testing.
The continuing effort of the contractor to correct the process is the key to the engineer being willing to permit this repetitive (cycle) process for an extended period. Given certain conditions the contractor could theoretically operate in the warning band for the duration of a project with increased frequency in sample/testing. Should such a possibility become reality, the situation should be resolved between the contractor and engineer by their jointly determining how it will be handled.

When the moving average exceeds the control limits, the material represented shall be considered deficient. This is the worst of the three conditions because now the contractor is producing/placing aggregate, which is outside the specified limits. Presumably, too, the contractor has been acting in good faith to the best of his/her ability to correct the problem.

Up to this point in the corrective action process, all three special provisions, 1) QMP, Base Courses, 2) QMP, CABC with Density, and 3) QMP, Aggregate for Concrete Pavement, are identical. The first two special provisions listed above will be addressed in Subsection 7.1 of this manual. The third special provision listed above (QMP, Aggregate for Concrete Pavement) will be addressed in Subsection 7.2 of this manual.

7.1 Payment for QMP, Base Courses, and QMP, CABC with Density when the Moving Average Exceeds the Control Limits

Aggregate with test results outside the control limits is considered deficient and will be subject to reduced payment according to the special provision specification. Under this condition of reduced payment, if the material has been incorporated into the work and is accepted and remains in place, reduced payment will be applied starting with the placed tonnage from the first moving average point to exceed the control limit and end with the placed tonnage of the first moving average point to come within the control limit. Refer to Figure 13 for examples of material subject to reduced payment.

In Example A of Figure 13, if the specified frequency of sampling of 500 tons is used after point 5, the quantity of aggregate between test points 9 and 11 which is subject to reduced payment is 1,000 tons. At point 12, the normal frequency of testing is resumed. Following the specification, compensation for the 1,000 tons of aggregate is at 90 percent of the contract unit bid price as long as the material on any individual sieve does NOT exceed the control limits by more than five percentage points. If any individual sieve is exceeded by more than five percentage points, the engineer will refer to Subsection 106.5 and subsequently 105.3 and 105.10 of the WisDOT Standard Specifications. Example B of Figure 11 provides another situation where 3,500 tons of material is subject to reduced payment as indicated.

Reduced payment, as outlined above, shall apply for all randomly selected sample/test results outside the control limits including if caused by equipment breakdown. Reduced payment applies, too, when the contractor=s testing data has been proven incorrect and actual test results are outside the control limits.
FIGURE 13. CONTROL CHART EXAMPLES OF DEFICIENT MATERIAL WHICH IS SUBJECT TO REDUCED PAYMENT.

Test # 1 2 3 4 5 6 7 8 9 10 11 12

* Material subject to reduced payment.

EXAMPLE A: The contractor notifies the engineer at test 4. At test 5 the contractor and engineer discuss a corrective action to take and increase sampling/testing to 1 each 500 tons placed. At test 9 the new moving average is outside the control limit and the testing frequency stays at 1 per 500 tons. At test 9 the first moving average is outside the control limits and reduced payment begins and continues to point 11 which is the first moving average to come back inside the control limit. Point 11 moving average is still in the warning band and the testing frequency remains at 1 per 500 tons until point 12 which is inside the warning limit.

EXAMPLE B: Engineer is notified at point 4 that the moving average is outside the control limits. The engineer and contractor discuss a corrective action to include increase sample/test frequency because the material is outside the control limit the contractor should stop and adjust the production process. At point 4 reduced payment begins and ends with point 11 (3500 tons) at 90% of contract unit price providing the upper limit is not exceeded by more than 5%.
Payment for QMP, Aggregate for Concrete Pavement

When the moving average of four random samples/tests exceeds the control limits, the material represented shall be considered deficient. Payment for deficient material produced outside the control limits shall be in accordance with Subsection 106.5 of WisDOT’s Standard Specifications. Refer to Figure 14 for examples of material subject to reduced payment.

Example A of Figure 14, test 5 meets two criteria: 1) the second moving average to exceed the warning limits, and 2) the first moving average to exceed the control limit. The quantity of aggregate represented by test point 5 moving average is subject to Subsection 106.5.

Example B of Figure 14 as in Example A, at point 5 the contractor and engineer discuss a course of corrective action. It is suggested that the contractor may want to increase the testing frequency at this point to reduce the risk of large quantities of material being subject to 106.5. The moving average is discontinued until point 9. It is determined that point 9 moving average is outside the control limits also. The material represented by point 9 moving average is subject to 106.5 also.

Once the second consecutive moving average exceeds the warning limit, the contractor has one opportunity to run four additional individual tests to establish a new moving average. The moving average from that point on must fall within the warning limits (between the upper and lower warning limits) before the contractor has another opportunity to conduct four additional individual tests and calculate a new moving average.

The scenario presented in Example B, Figure 14, indicates the contractor does not have the quality control process under control. The moving average continues to be plotted. The contractor may continue to produce material in the warning band without penalty, but each time the moving average exceeds the control limit, the contractor is subject to 106.5.
FIGURE 14. CONTROL CHART EXAMPLE OF DEFICIENT MATERIAL FOR QMP, AGGREGATE FOR CONCRETE PAVEMENT

* Material subject to subsection 106.5 of the WisDOT Standard Specifications.

EXAMPLE A:  At point 4 the contractor notifies the engineer. At point 5 the engineer and contractor discuss a course of action. The material represented by test point 5 moving average is subject to the WisDOT Standard Specification, subsection 106.5. After four additional individual tests the new moving average is within the warning limits, the contractor may continue production with no additional penalties.

* Material subject to subsection 106.5 of the WisDOT Standard Specifications.

EXAMPLE B:  This example is the same as example A through point 5. After four additional individual tests point 9 moving average exceeds the control limit, therefore, the material represented by point 9 is also subject to 106.5. The material represented by point 9 is at the discretion of the engineer. Theoretically the moving average of test data results could continue in the warning band indefinitely.
TOPIC J: WisDOT Quality Management Program
CMM 8.30, 8.34

Please visit the following link for the latest version:

http://roadwaystandards.dot.wi.gov/standards/cmm/
TOPIC K: QMP Base Aggregate
Item 301.0100

Please visit the following link for the latest version:

http://roadwaystandards.dot.wi.gov/standards/cmm/
TOPIC L: WisDOT Standard Specifications
Section 301, 305, 460, and 501

Please visit the following link for the latest version:

http://roadwaystandards.dot.wi.gov/standards/cmm/
Note: Check the CMM link to verify the latest version

http://roadwaystandards.dot.wi.gov/standards/cmm/
MATERIAL DATA REPORTING FOR QC, QA, QV, IA ON HIGHWAY CONSTRUCTION PROJECTS

Materials Reporting Systems Tutorials

**Materials Information Tracking**

MIT collects data on a wide range of Materials in an AASHTO and ASTM format for QA, QC, IA and Verification requirements. Also, collect Tester and Sampler certifications information.

**Materials Reporting System Hot Mix Asphalt**

MRSHMA effectively implements QMP by collecting field data entered by the contractor by lot and subplot for transmission to the State agency.

**Materials Reporting System Portland Cement Concrete**

MRSPCC effectively implements QMP by collecting field data entered by the contractor by lot and subplot for transmission to the State agency.

The above is from the Atwood Systems website:

http://www.atwoodsystems.com/resources/
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The above is from the Atwood Systems website:

http://www.atwoodsystems.com/resources/
Atwood Systems

Software in use by Wisconsin Department of Transportation

<table>
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<tr>
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<th>DESCRIPTION</th>
<th>USAGE</th>
<th>DEPLOYMENT TARGET</th>
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<tr>
<td>Project Tracking (PT)</td>
<td>Manages all phases of a project. FIT provides field data to this system.</td>
<td>WISDOT Staff.</td>
<td>WISDOT LAN</td>
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<td>Materials Tracking (MTS)</td>
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<td>WISDOT Staff.</td>
<td>WISDOT LAN</td>
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<td><strong>FIELD BASED REPORTING SYSTEMS</strong></td>
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<td>WISDOT Staff. Contractors.</td>
<td>Atwood Web Site</td>
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<td>Activity Reporting System</td>
<td>Reports on project activity and material test results.</td>
<td>WISDOT Staff.</td>
<td>Atwood Web Site</td>
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<tr>
<td>Data Management System</td>
<td>Manages data replication / synchronization from field sites to MTS and Project Tracking.</td>
<td>Atwood Systems</td>
<td>Atwood Systems</td>
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8-10.1 Control of Materials

8-10.1.1 Approval of Materials Used in Work

The service life of a highway is dependent upon the quality of the materials used in its construction, as well as the method of construction. Control of materials is discussed in standard spec 106.1. The spec provides that only materials conforming to the requirements of the contract must be used, and the contractor is responsible for furnishing materials meeting specified requirements. Only with permission of the engineer can the contractor provide materials that have not been approved, as long as the contractor can provide evidence that the material will be approved later. The department's intention is to hold payment of items until the required materials information is provided by the contractor.

The standard specs encourage recovered and recycled materials to be incorporated into the work to the maximum extent possible, consistent with standard engineering practice. Standard spec 106.2.2 and Wisconsin statute 16.754 require the use of American made materials to the extent possible. On federally funded projects, all steel products must be produced in the United States, and manufacturing and coating processes must be performed in the U.S. These "Buy America" requirements are discussed in CMM 2-28.

8-10.1.2 Contractor and Department Designated Materials Persons

Standard spec 106.1.2 requires the contractor to designate a dedicated materials person (CDMP) who will be responsible for submitting all contractor materials information to the engineer. The department should also designate a dedicated materials person (WDMP) who will be in direct contact with the contractor's designee. Standard spec 106.1.2 requires the CDMP to communicate with all subcontractors to ensure that sampling, testing, and associated documentation conforms to the contract. The contract also makes the CDMP responsible for submitting materials information from the prime contractor and subcontractors to the WDMP, promptly reporting out-of-specification test results, collecting and maintaining all required materials certifications, and regularly communicating with the WDMP regarding materials issues on the contract.

The WDMP should provide a project-specific sampling and testing guide (E-Guide) to the contractor at the preconstruction conference. The E-Guide is created from the following site:

http://www.atwoodsystems.com/sysportal.htm

Both the CDMP and WDMP should review and supplement the E-guide before work operations begin to ensure that testing methods, frequencies, and documentation requirements conform to the contract.

The CDMP and WDMP are charged with working together throughout the life of the contract to ensure that contract materials requirements are met and any issues that might arise related to either non-conformance or non-performance are dealt with promptly. The ultimate goal is to make sure that problems with materials are brought to light and timely corrective action taken before those materials problems compromise the quality or acceptability of the completed work.

The CDMP should coordinate contractor materials related activities and do the following:

- Establish methods and work expectations with the WDMP.
- Provide all QMP test data and control charts from the prime contractor and subcontractors.
- Deal with all materials-related concerns from the WDMP.

The WDMP is responsible for administration of the contract with regards to contract materials requirements and should do the following:

- Communicate or meet weekly with the CDMP to discuss outstanding materials issues on the contract.
- Monitor the submittals from the CDMP to ensure timeliness and completeness.
- Review contractor submittals to verify materials requirements are met.
- Inform the Project Leader of non-conforming materials issues and discuss actions to be taken.
- Prepare materials documentation for inclusion into the project files.
8-10.2 Approval of Materials
All materials used in a project are subject to the engineer's approval before incorporation into the work. Approval of materials is discussed in standard spec 106.3. Approval is generally accomplished by material tests and/or analysis. This can be done by using approved product lists, certification, or sampling and testing. Unless the contract specifies otherwise, the contractor must follow manufacturer's recommended procedures for products incorporated into the work. Refer to CMM 8-45 for details of acceptance types.

8-10.3 Quality Management Program
Sampling and testing on WisDOT projects is performed according to the Quality Management Program (QMP). QMP is presented in CMM 8-30 and the following CMM sections.

8-10.4 Independent Assurance Program
The Independent Assurance Program (IAP) is an element of the Quality Management Program intended to ensure that test data from project acceptance testing is reliable, including sampling procedures, testing procedures, and testing equipment. Quality verification (QV), quality assurance (QA), and quality control (QC) are integral parts of the IAP. Further information about the Independent Assurance Program can be found in CMM 8-20.

8-10.4.1 Quality Verification (QV)
Quality verification (QV) sampling is done by a department representative, and is taken independently from the quality control samples to validate the quality of the material.

8-10.4.2 Quality Assurance (QA)
Under the quality assurance (QA) program, a department representative observes sampling and testing performed by the contractor, by testing split samples. Further detail about quality verification and quality assurance is provided in CMM 8-20.

8-10.4.3 Quality Control (QC)
Quality control for materials testing includes all contractor/vendor operational techniques and activities that are performed or conducted to fulfill the contract requirements.

8-10.5 Nonconforming Materials
8-10.5.1 General
The department does not want material not meeting contract specifications incorporated into the work. Standard spec 106.5 gives the engineer the authority to either reject nonconforming materials or to allow the nonconforming materials to remain in place. If materials are found to be unacceptable before or after placement into the work, the engineer may reject the materials, and the contractor must remove the materials from the site at no cost to the department. Materials that have been tested and approved at their source or otherwise previously approved, but have become damaged or contaminated before use in the work, are also subject to rejection by the engineer.

To ensure consistency in the decisions made for acceptance of non-conforming material or workmanship, the engineer should involve the region oversight engineer before finalizing any decision. This will help keep central office informed about contractor or material problems that may require action with a change in specifications or discipline of a contractor. If any technical questions remain about the acceptance or rejection of nonconforming materials refer to the appropriate technical expert in the Bureau of Technical Services.

8-10.5.2 Nonconforming Materials Allowed to Remain in Place
8-10.5.2.1 Deciding Whether or not to Allow Material to Stay in Place
Good engineering judgment is required when making decisions on nonconforming materials. The engineer may choose to approve nonconforming materials, allow them to remain in place, and adjust the contract price. When making the decision to direct the contractor to remove and replace the materials versus leave the materials in place, it's important to consider the following:
- Long-term consequences on quality and durability.
- Implications on the project's life cycle costs, service life, serviceability, and maintenance.
- Socioeconomic, environmental, and aesthetic considerations.
- Impacts on traffic, staging, and construction timeframes.

8-10.5.2.2 Deciding Whether or Not to Apply Price Reduction
After the engineer has decided to allow nonconforming materials to remain in place, he or she must carefully evaluate each situation in deciding whether to take a price reduction. The goal is to achieve consistency statewide in administering price reductions for nonconforming materials that are allowed to remain in place.
Results of retests and related quality tests should be considered. The following list includes some examples of the types of factors the engineer must consider to decide if a price reduction is warranted and how much it should be:

- Has the contractor been conscientious to provide quality by carefully controlling materials and construction operations?
- Has the contractor been proactive and made good use of QC data to maintain and improve quality?
- Did the engineer provide the contractor with non-conforming test results within the contractual timeframe, if specified?
- If timeframes are not specified, did the engineer provide non-conforming test results in time for the contractor to make process or materials corrections?
- Upon becoming aware of a materials quality problem, has the contractor responded quickly to correct it?
- Is the nonconforming test an isolated incident or a recurring situation?
- How does the nonconforming test compare to the rest of the project data:
  - Have material test results been well within specification requirements or consistently at the very limit of what is acceptable?
  - How many tests are nonconforming vs. how many tests have passed?
  - How far out of spec is the non-conforming test?

8-10.5.3 Price Reductions Specified in the Contract with Administrative Items

If price reductions are included in the specifications or special provisions for certain nonconforming items, the price reductions should be administered using the appropriate 800 series administrative items. Since the price reductions are included in the contract language, the engineer can add the 800 series items to the contract without going through the complete change order process. Approval by a DOT representative and contractor representative are not necessary, though it's good practice to communicate the changes to all parties. Further guidance on the 800 series administrative items is provided in CMM 2-38.

For payment of nonconforming items with associated administrative items, pay for the installed quantity and bid price of the work item under the original bid item. The pay reduction will be accounted for using the administrative item. Compute the price reduction by multiplying the quantity of nonconforming material by the original unit price and the percent price reduction. The pay units of all administrative items are DOL. Document all calculations, and pay for the (negative) total calculated price reduction as the pay quantity, with 1 dollar as the pay unit.

**Example 1**

- Contractor placed total of 19,000 SY of Concrete Pavement 9 inch
- 670 SY (12' x 500') is 1/8" - 1/2" under plan thickness
- Standard spec 415.5.2 directs to pay 80% contract price for this range (20% reduction)
- Bid unit cost is $35/SY

Using original bid item, pay 19,000 SY at $35/SY = $655,000
Compute price reduction = 670 SY x $35 x -0.20 = -$4,690
Add the administrative item 804.6005 Nonconforming Thickness Pavement to the contract, with unit price of $1.00
Pay quantity of -$4,690
Net pay = $655,000 - $4,690 = $650,310

Paying for nonconforming items this way allows for clean tracking of as-built quantities. The use of administrative items can easily be tracked to monitor specific items that are frequently the target of price reductions. This can help the department develop improved specifications and construction methods.

8-10.5.4 Price Reductions Not Specified in the Contract

If specific price reductions are not outlined in the contract specifications or special provisions, standard spec 106.5 gives the engineer the option to take a price reduction on nonconforming materials allowed to remain in place. The engineer has latitude to decide whether a price reduction is appropriate, and what amount the price reduction should be.

For payment of nonconforming items, use full quantity and bid price of the work item. Apply the price reduction by submitting a change order that creates a new item with the same bid item number but with the supplemental
8-45.1  Acceptance Procedures, Documentation, and Reporting

Documentation and reporting for materials acceptance is equal in importance to Item Record Account documentation. The basis of acceptance for contract materials is accomplished in several ways, depending on the material. The type of reporting and documentation is a function of the acceptance type.

Materials test reporting and documentation is to be done using the WisDOT electronic Materials Tracking System (MTS). The MTS is a computerized filing and reporting system for construction materials tests and documents. All construction materials tested and inspected for WisDOT projects are reported on the MTS. The overall MTS has three basic components, the MTS (LAN/WAN attached), Materials Information Tracking System (MIT), and the Materials Tracking website. Region and central office laboratory personnel can enter data directly into the Oracle database via a Local Area Network (LAN) attachment provided through the MTS. The MIT is used for entering tests from the field.

The engineer should follow these guidelines for material documentation:

- Inspect all manufactured products as soon as possible after delivery.
  - Include all approved lists, certified sources, and pre-qualified products.
  - Record in the project record relevant inspection information.
- Verify that products delivered match the certifications, approved list, etc.
- Review all Certifications of Compliance and Certified Reports of Test and Analysis.
- Reference all Certifications, shop inspection reports, and other external documents using the MTS/MIT prefix 900 report.

All materials documentation and reporting must be completed and entered in the MTS no more than 60 working days after the work completion date.

Manufactured products must be inspected at the job site as soon as possible after arrival for evidence of damage or noncompliance even though these materials are covered by prior inspection testing or certification.

Those materials normally source inspected, but which arrive at the job without appropriate marking, indicating that they have been accepted at the source, must be field inspected or tested and the basis for acceptance must be documented in the inspector’s diary.

8-45.1.1 Materials Testing and Acceptance Guide

The Materials Testing and Acceptance Guide, CMM 8-50 details many of the sampling, testing, and documentation requirements for various materials. The instructions shown in this guide are recommended minimum requirements. In many cases, it may be appropriate to increase the frequency and scope of certain testing and acceptance activities in order to properly administer the materials specifications. In all cases, it is appropriate to closely observe produced materials for visual evidence of changes in quality and to then adjust testing frequencies, as required, to adequately evaluate their quality.

Sampling and testing procedures of certain unique materials are described in the standard specs and other contract documents. The instructions in this guide are intended to supplement those in other contract documents.

8-45.1.2 E-Guide

E-Guide is an automated system that produces condensed sampling, testing and documentation guidance for material requirements for a project. It generates the guidance in two basic ways. For the project bid items, the system automatically generates guidance. For non-standard special provision (SPV) items, the system requires manual input of the SPV material requirements contained in the project proposal. CMM 8-50 should be cross checked when an E-Guide is developed since it contains detailed information and it breaks material information out by type. The E-Guide system for developing a project specific sampling and testing guide is available at:

http://www.atwoodsystems.com/syslinks.cfm

The WisDOT project material coordinator shall prepare the E-Guide and provide a copy to the contractor's material coordinator. Consult the region materials engineer or region person responsible for construction
materials for guidance when developing the E-Guide.

The E-Guide does not supersede material requirements in the Standard Spec or the CMM. The contractor is contractually bound to supply the information if required in the Standard Spec, CMM or Special Provisions.

The region materials engineer or region person responsible for this area must be consulted regarding doubts as to the adequacy of compliance of source inspected materials, need for field inspection and reports, waiver of testing, unlisted items, evaluation of certifications, or other questions regarding acceptance procedures.

Table 1 below defines the general documentation requirements for each materials acceptance type. Table 2 provides the MTS prefixes for all material types. Figure 1, Figure 2, and Figure 3 show example test reports.
<table>
<thead>
<tr>
<th>Documentation Required</th>
<th>Acceptance Type</th>
<th>MIT/MTS Document</th>
<th>MTS Documentation Time Line</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTS Report.</td>
<td>Verification tests- C.O. Laboratory</td>
<td>Various MTS prefixes as appropriate. See Table 2 for a list of prefixes.</td>
<td>No later than one week after completion of test.</td>
<td>Test entry by C.O. Lab personnel.</td>
</tr>
<tr>
<td></td>
<td>Approved Product Lists- WisDOT</td>
<td>Reference on MTS prefix 900 or 155</td>
<td>No later than 60 days after contract work completion date.</td>
<td>Test entry by project personnel.</td>
</tr>
<tr>
<td>Form DT 1823, Report of Shop Inspection.</td>
<td>Source or Shop Inspection</td>
<td>Reference on MTS prefix 900 or 155</td>
<td>No later than 60 days after contract work completion date.</td>
<td>Test entry by project personnel.</td>
</tr>
<tr>
<td>Cert. of Compliance MTS reference report.</td>
<td>Manufacturers Certification of Compliance</td>
<td>Reference on MTS prefix 900 or 155</td>
<td>No later than 60 days after contract work completion date.</td>
<td>See note below (1).</td>
</tr>
<tr>
<td>Cert. Report of Test MTS reference report.</td>
<td>Certified Report of Test</td>
<td>Reference on MTS prefix 900 or 155</td>
<td>No later than 60 days after contract work completion date.</td>
<td>See note below (1).</td>
</tr>
<tr>
<td>Verification tests-MTS Report.</td>
<td>Field Sampling and Testing</td>
<td>Aggregates- MTS prefix 162, 217 HMA- MTS prefix 254 HMA Nuclear Density- MTS prefix 262 Concrete Cylinders – MTS prefix 130 Earth Work Density- MTS prefix 232</td>
<td>No later than one week after completion of test.</td>
<td>All aggregate and HMA QV testing done must be entered by the qualified lab doing the testing. When QV and Companion Cylinder testing is done the data must be entered by the qualified laboratory doing the testing. Refer to Figure 1, Figure 2, and Figure 3 for examples of prefix 155 reports for verification of contractor QMP and QC testing.</td>
</tr>
</tbody>
</table>

(1) Certifications must be evaluated promptly for adequacy, completeness, and compliance with the specifications. The certification reviewer must make appropriate notations, initial, and date the document when the review is completed.
The Quality Management Program Award recognizes outstanding certified highway materials technicians who have displayed exceptional leadership roles in developing quality materials used in highway construction projects.

These winners are chosen from contractors, consultants, and the Wisconsin Department of Transportation. It is this industry support and joint partnering that makes this program a success.

Some of the qualities attributed to the award winners include HTCP certification, HTCP promotion, development of cost savings, development of time savings, quality improvement, being a team player and possessing a positive attitude.
This Outstanding Individual or Team is Nominated to Receive this Year’s “Quality Management Program Award”

Individual/Team: ___________________________ Employer: ___________________________
Address: ___________________________ Work Address: ___________________________
City/State/Zip: ___________________________ City/State/Zip: ___________________________
Telephone: ___________________________ Telephone: ___________________________
Fax: ___________________________

List individual or team nominated:

Identify outstanding individual or team achievement(s) that exemplify this nomination for the “Quality Management Program Award:

*Application submitted by: ___________________________ Date: ___________________________
Do you wish to remain anonymous? □ Yes □ No
(* Required for nomination)

Please fax (608) 342-1982 or send completed application before November 1 of each year to Highway Technician Certification Program, University of Wisconsin-Platteville, 049 Ottensman Hall, 1 University Plaza, Platteville, WI 53818-3099.
Quality Management Program Award
Nomination Application

This Outstanding Individual or Team is Nominated to Receive this Year’s “Quality Management Program Award”

Individual/Team: ________________________ Employer: ________________________
Address: ______________________________ Work Address: ______________________________
City/State/Zip: _________________________ City/State/Zip: _________________________
Telephone: ____________________________ Telephone: ____________________________
Fax: __________________________

List individual or team nominated:

Identify outstanding individual or team achievement(s) that exemplify this nomination for the “Quality Management Program Asphalt Award:

*Application submitted by: ________________________ Date: ________________________
Do you wish to remain anonymous? ☐ Yes ☐ No
(* Required for nomination)

Please fax (608) 342-1982 or send completed application before November 1 of each year to Highway Technician Certification Program, University of Wisconsin-Platteville, 049 Ottensman Hall, 1 University Plaza, Platteville, WI 53818-3099.
OOPS! Found an error?

Course Title: ____________________________

Please describe the error and the page or topic where you found it:

We might have questions. How can we reach you?

Name: _________________________________

E-Mail: _________________________________

Phone: _________________________________

Note to Development Team: Send updates to htcp@uwplatt.edu, or call 608.342.1545, or mail to HTCP, 1 University Plaza, University of Wisconsin-Platteville, Platteville, WI 53818.

THANK YOU!
Course Evaluation
The HTCP would appreciate your thoughtful completion of all items on this evaluation. Your comments and constructive suggestions will be carefully studied and will serve as a valuable resource to improve our course presentations:

Course: 

Date: 

1. **Overall rating of this program:**

<table>
<thead>
<tr>
<th></th>
<th>Outstanding</th>
<th>Above Average</th>
<th>Average</th>
<th>Below Average</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did the course meet your expectations?</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>How well were you satisfied with the quality and quantity of the course materials?</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Comments about course materials/visual aids: ____________________________________________  

2. **Instructor:** ____________________________

<table>
<thead>
<tr>
<th></th>
<th>Outstanding</th>
<th>Above Average</th>
<th>Average</th>
<th>Below Average</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness of course presentation:</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Responsiveness and interaction with students:</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Ability to communicate:</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Knowledge of course content:</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

3. **Please fill in and rate overall effectiveness of laboratory instructor(s)/guest lecturer(s):**

<table>
<thead>
<tr>
<th></th>
<th>Outstanding</th>
<th>Above Average</th>
<th>Average</th>
<th>Below Average</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Comments: Please make additional comments about individual laboratory instructor(s)/guests lecturer(s) quality of instruction: ____________________________________________  

_________________________________________
4. Administrative Evaluation:

<table>
<thead>
<tr>
<th></th>
<th>Outstanding</th>
<th>Above Average</th>
<th>Average</th>
<th>Below Average</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registration procedure:</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Classroom atmosphere:</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Laboratory equipment:</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Parking</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Comments: Please make additional comments about registration procedures, classroom atmosphere, laboratory equipment, and parking: ________________________________

5. What did you like most about the course? ________________________________

6. What did you like least about the course? ________________________________

7. Please comment about overall course quality and length: ____________________

8. The HTCP may wish to use your comments in our next brochure ________________

To use your comments, we must have your name and address:

Name: ___________________________________________________________________

Title: __________________________________________________________________

Organization: __________________________________________________________________

Address: __________________________________________________________________

City/State/Zip: __________________________ Phone: __________