Iowa Department
of Transportation

INSTRUCTION TEXT
FOR
AGGREGATE INSPECTORS AND TECHNICIANS
TRAINING

OFFICE OF MATERIALS
HIGHWAY DIVISION
IOWA DEPARTMENT OF TRANSPORTATION

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JANUARY 1993

Chapter I

AGGREGATES

Introduction

Today's highways must have the strength and durability to sustain high volumes of traffic for many years. Since the pavements and base courses of these highways are composed largely of aggregates, these materials must be of a quality level that will permit satisfactory performance. Consequently, the role of the aggregate inspector is vital to securing good highway performance. Design and construction techniques can never satisfactorily compensate for the use of substandard aggregates. A well designed and constructed highway using good aggregates will provide good service for many years. A well designed and constructed highway using substandard aggregates will too soon become a maintenance problem.

This chapter contains general information on aggregates and the tests used to control their quality. Those aggregates commonly produced and used in Iowa will be emphasized, as will the tests which have been determined through experience to be the best measure of their quality. Other states or organizations use aggregates and tests which will not be covered in this booklet.

1.0 AGGREGATES DEFINED

Generally, aggregates are granular construction materials composed of hard mineral particles, crushed or uncrushed, which are or can be properly sized for the use intended. Glacial clay is composed of minute granular mineral particles and can be used as construction material. However, the term "aggregate" as used in this booklet will be referring to granular materials which contain, at most, only a few percent of particles which will pass through a #200 sieve (0.074 mm).

1.1 Coarse and Fine Aggregates: Aggregates are frequently referred to as "fine" or "coarse". There is no universally accepted particle size which separates fine aggregate from coarse aggregate. We have chosen the #4 (4.74 mm) sieve as the sieve size with which to make this separation. All particles which will pass through a #4 sieve, and be predominantly retained on the #200 sieve, are referred to as "fine aggregate". All particles which are retained on #4 or larger or sieves are referred to as "coarse aggregate".

1.2 Natural Aggregates: Natural aggregates are all those produced from naturally occurring materials, such as sand, gravel, limestone, etc., which can be modified by crushing, washing, or screening as necessary for the use intended.

1.3 WHAT IS AN AGGREGATE? (Choose the answer you believe to be correct and proceed to the section referenced.)

1.3.1 Organic mineral matter which has been properly sized for the use intended. (Go to Section 2.1)

1.3.2 Granular mineral matter which is or can be properly sized for the use intended. (Go to Section 3.2)

1.4 Synthetic Aggregates: Synthetic aggregates are all those produced from materials which have been mineralogically altered by artificial means. Expanded shales and clays (lightweight aggregate), fly ash, slag, etc., are examples of synthetic aggregates.

1.5 Manufactured Aggregates: Manufactured aggregates are produced by the mechanical crushing and sizing of either natural or synthetic materials. manufactured sand, for instance, could be made by crushing and sizing either an natural material such as limestone or synthetic material such as slag. However, even though a manufactured sand can be a natural aggregate it cannot be a natural sand. The reason for this is explained in the next paragraph, section 1.6.

1.6 Natural Sands and Gravels: Those aggregates referred to as "natural sand" or natural gravel" result from the natural disintegration of rock and are produced without artificial crushing. They can, however, be washed or mechanically sized.

Thus, the term "natural" is used in two different ways. There are natural aggregates as opposed to synthetic aggregates and natural sands or gravels as opposed to manufactured sands or gravels. Consequently, sand made by crushing quartzite or limestone is a natural aggregate but not a natural sand. The specifications require fine aggregates for concrete floors and pavements to be natural sands.

2.0 AGGREGATE USES

Aggregates are used in portland cement concrete, asphaltic concrete, bases, subbases, granular backfills, etc. A summary of the quality specifications for the construction aggregates listed in Division 41, Construction Materials, of the Standard Specifications. A summary of the gradation requirements for these aggregates. (Go to Section 3.0)

2.1 No:

Aggregates are composed of mineral particles. Though there are some who classify organic compounds as minerals, we are using the term as commonly defined to be inorganic elements or compounds only. (Go to Section 1.0)

3.0 AGGREGATE PROPERTIES AND CHARACTERISTICS

Ideally, construction aggregates should be composed of durable, abrasion-resistant particles free of any deleterious or objectionable materials such as clay, shale, coal, organic matter, etc. Their specific gravities and absorptions are important when they are incorporated into portland cement or asphaltic concrete mixes.

3.1 Resistance to Abrasion: Abrasion is the mechanical wearing away of aggregate particles by friction and impact. Aggregates with low resistance to abrasion will readily wear away when used as surfacing materials or when exposed in pavement surfaces. They also degrade with handling. Excessive handling of aggregates with low resistance to abrasion can result in their containing relatively high percentages of fine material, often above the maximum level specified for the #200 sieve for the particular aggregate involved.

3.1.1 Los Angeles Abrasion Test: Resistance to abrasion is determined by use of the Los Angeles Abrasion Machine, a cylindrical drum mounted on a horizontal shaft. A specified weight of coarse aggregate is placed in the machine along with a specified number of standard steel balls, the abrasive charge.

After rotation at 30-33 rpm for 500 revolutions, the percentage of the aggregate sample which has been abraded to pass a #12 sieve is reported as the loss due to abrasion, the percent of wear.

Natural gravels will generally develop wear losses of 20% to 35% when tested for abrasion resistance. Crushed limestone aggregates will generally develop wear losses of 30% to 45%. Losses of 45% or more are commonly accepted to be indicative of aggregates with poor resistance to abrasion.

3.2 Correct: (Go to Section 1.4 and continue.)

3.3 Durability & Soundness: These two terms are very similar in meaning and are often used interchangeably. The durability of an aggregate or other material is a measure of its ability to perform satisfactorily over an extended period of time. Soundness of an aggregate is a measure of its ability to resist the detrimental effects of exposure to natural forces.

Durability is tested only for coarse aggregate for portland cement concrete. The designations of class 2, Class 3 and 3i durability are used. class 3i aggregates are the most durable; Class 2 are the least durable. The best method to determine durability class is to observe the performance of a concrete pavement that was constructed with the coarse aggregate in question. If the pavement has performed satisfactorily for only 20 years it is Class 3 durability. Class 3i durability aggregates must perform satisfactorily for up to 30 years in interstate class highways. If the coarse aggregate, or a similar aggregate, has not been used in portland cement concrete pavements, we primarily rely on ASTM Designaton C666 Method B to make a laboratory determination of durability class. This consists of a series of 300 freeze and thaw test cycles on a concrete specimen.

Soundness is tested using Test Method No. Iowa 211-B, as described in Volume 1 of the Laboratory Manual and as summarized here in Section 3.3.2. This is a freeze and thaw test.

3.3.1 Good Resistance to Abrasion Would be Indicated by a High Percent Wear: (Choose one)

_____ True (Go to Section 4.3)

_____ False (Go to Section 8.0)

3.3.2 Method of Test for Determining the Soundness of Aggregates by Freezing and Thawing: Test samples of coarse aggregate are alternately frozen and thawed for a prescribed number of cycles - 16 cycles in Method "A" for higher quality aggregates, and 25 cycles in Method "C" for lower quality aggregates. In both methods, the percentage passing the #8 sieve, computed to a clean dry weight basis, is reported as the soundness loss.

Method "A": 0.5 percent methyl alcohol is added to water in which the sample is immersed for thawing. This test is particularly severe on limestone aggregates which contain 5 percent or more of insoluble material in the clay or silt-size particle range. Generally, these are also the limestones which fail to perform well when the use of sound stone is required.

Method "C": Test samples are thawed in water only. Freezing and thawing in water is not particularly severe, hence 25 cycles are required on this test while only 16 cycles are required when the water-alcohol solution is used. Any reasonably clean, coarse aggregate will perform well in this test and it is used for all materials which do not require high-quality aggregates. (Go to Section 3.4).

3.3.5 Correct: (Go to Section 5.6 and continue)

3.3.6 Incorrect:

Dense graded refers to the way the different sizes are proportioned. (Go back to Section 5.3 and check the other answer).

3.4 Absorption and Surface Moisture: Absorption and surface moisture may need to be determined (Iowa Test Method 201-A or ASTM Designation C 127 & C 128), so that the water content can be controlled. An aggregate particle's internal structure is made up of solid matter and voids that may or may not contain water. Terms used to describe the moisture content of aggregate are as follows:

3.4.1 Oven-dry, with no surface or internal moisture.

3.4.2 Air-dry, or dry at the particle surface but containing some interior moisture - this is somewhat absorbent.

3.4.3 Saturated-surface-dry, an ideal condition in which the aggregate can neither absorb water nor contribute water. In this condition the interior has absorbed all the moisture it can hold, but the surface is dry.

3.4.4 Damp or wet, containing moisture on the particle surface. Portland cement concrete batch weights of material must be adjusted for moisture conditions of the aggregates. (Go to Section 3.6 and continue)

3.5 <u>Incorrect</u>:

A dense graded aggregate has fewer voids. (Go to Section 5.5 and try again.)

3.6 <u>Specific Gravity</u>: Specific Gravity is a property which can be determined for all materials. Specific Gravity of a material is used in some calculations and tests for highway construction materials and is an important property for the aggregate inspector to understand. It is not a measure of aggregate quality.

Simply defined, specific gravity is the number of times heavier a material is than water. Stated another way it is the ratio of the weight of a material to the weight of an equal volume of water. Even another way of stating the definition would be to say that specific gravity is the relative density of a material to water. If it were not for tradition perhaps the term "relative density" would be more applicable than "specific gravity" as gravity has little to do with the matter except to provide the force which contributes to weight.

Test methods for determining specific gravity for fine and coarse aggregates are described in ASTM C-128 and C-127 or Iowa Test Method 201-A. In portland cement concrete calculations, the specific gravities of saturated-surface-dry aggregates are ordinarily used, that is, all the pores in each aggregate particle should be filled with moisture, but there should be no excess moisture on the particle surface at time of test. (Go to Section 3.8 and continue)

3.7 No:

The particle cannot contain surface moisture. (Go to Section 10.0 and select another answer.)

3.8 Deleterious Material: It is very important that the aggregate be kept clean and free from deleterious substances. For this reason, the specifications limit the amount of deleterious substances that can be present. These include shale, coal, and other light-weight material.

3.9 Unit Weight: Unit weight is a ratio of weight to volume, such as pounds per cubic feet. Unit weight is not a measure of quality, but is useful in converting weights of material to volumes. See ASTM Designation: C-29.

3.10 WHAT IS DURABILITY? (Choose one)

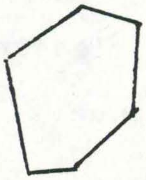
3.10.1 Ability to perform satisfactorily for an extended period of time. (Go to Section 7.0)

3.10.2 Ability to resist abrasion. (Go to Section 11.0)

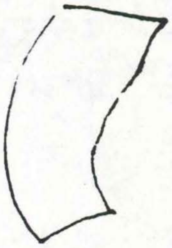
4.0 SHAPE AND SURFACE TEXTURE:

Particle shape of either coarse or fine aggregate may be angular, sub-angular, sub-rounded, or rounded.

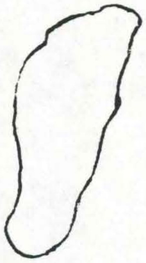
Angular



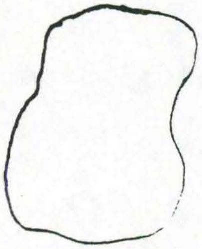
Sub-Angular



Sub-Rounded



Rounded



Aggregate particles should ideally be equa-dimensional and free of excessive amounts of flat and elongated pieces. Long, slivery aggregate pieces should be avoided. The shape of aggregate particles many times depends on the type of crusher used in the processing operation.

Particle shape and surface texture have a definite bearing on the quality of the finished product. Base courses composed of angular particles will compact and key together to form a dense, tight base, while elongated and rounded particles will slide and roll without compacting.

On the other hand, rounded particles tend to make plastic concrete more workable without a detrimental effect on the hardened concrete.

The texture of aggregate particles are normally defined in the following sequence: lithographic, sublithographic, fine grained, medium grained, and coarse grained (see fig. 1). Lithographic and fine grained particles are polished quite easily by normal traffic wear and in time become a maintenance problem. (Go to Section 5.0 and continue)

4.1 Correct: (Go to Section 5.5)

4.2 Correct: (Go to Section 5.4)

4.3 Incorrect:

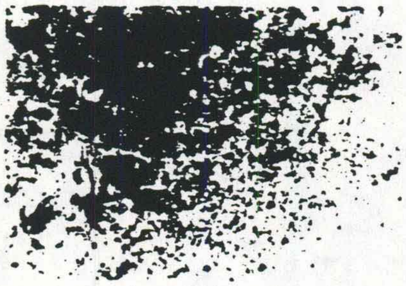
Good resistance results in a low percentage of material passing the No. 12 screen after testing. (Go to Section 3.3.1 and select the other answer.)

4.4 Correct: (Go to Section 12.0 and continue)

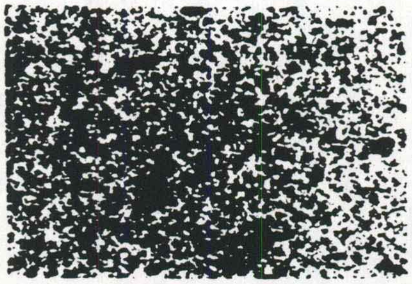
5.0 GRADATION:

Gradation is the particle size distribution of aggregates determined by using sieves with square openings. As an aggregate is moved or handled, there is a tendency for the particle sizes to separate. This separation is known as segregation. Limits are usually specified for the percentage of material passing each

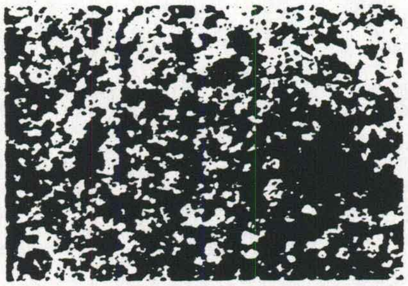
Lithographic - Less than 0.02 millimeters



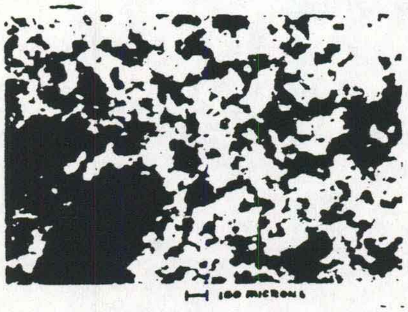
Sublithographic - 0.02 to 0.06 millimeters



Fine grained - 0.06 to 0.12 millimeters



Medium grained - 0.12 to 0.25 millimeters



Coarse grained - greater than 0.25 millimeters

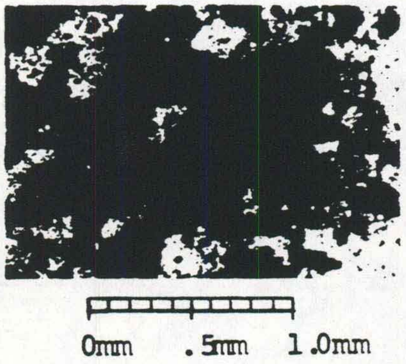


Figure 1

sieve. There are several reasons for specifying grading limits and maximum aggregate size. Deviations from the grading limits seriously affect the uniformity of finished work.

5.1 Dense Graded Aggregate: Dense graded aggregates contain a proportion of material in each particle size present such as to minimize the void spaces between particles.

5.2 Gap-Graded Aggregates: Gap or open-graded aggregates contain too great an amount of particles of nearly the same size. This produces an open-type mixture with large void spaces. There are not enough of the smaller sizes to fill the voids between the larger sizes. See Figure 2 for a comparison of dense and gap or open gradations of aggregates. (Go to Section 5.3 and continue)

5.2.1 No:

This refers to the Los Angeles Abrasion Test. (Go to Section 5.3 and check the other answer.)

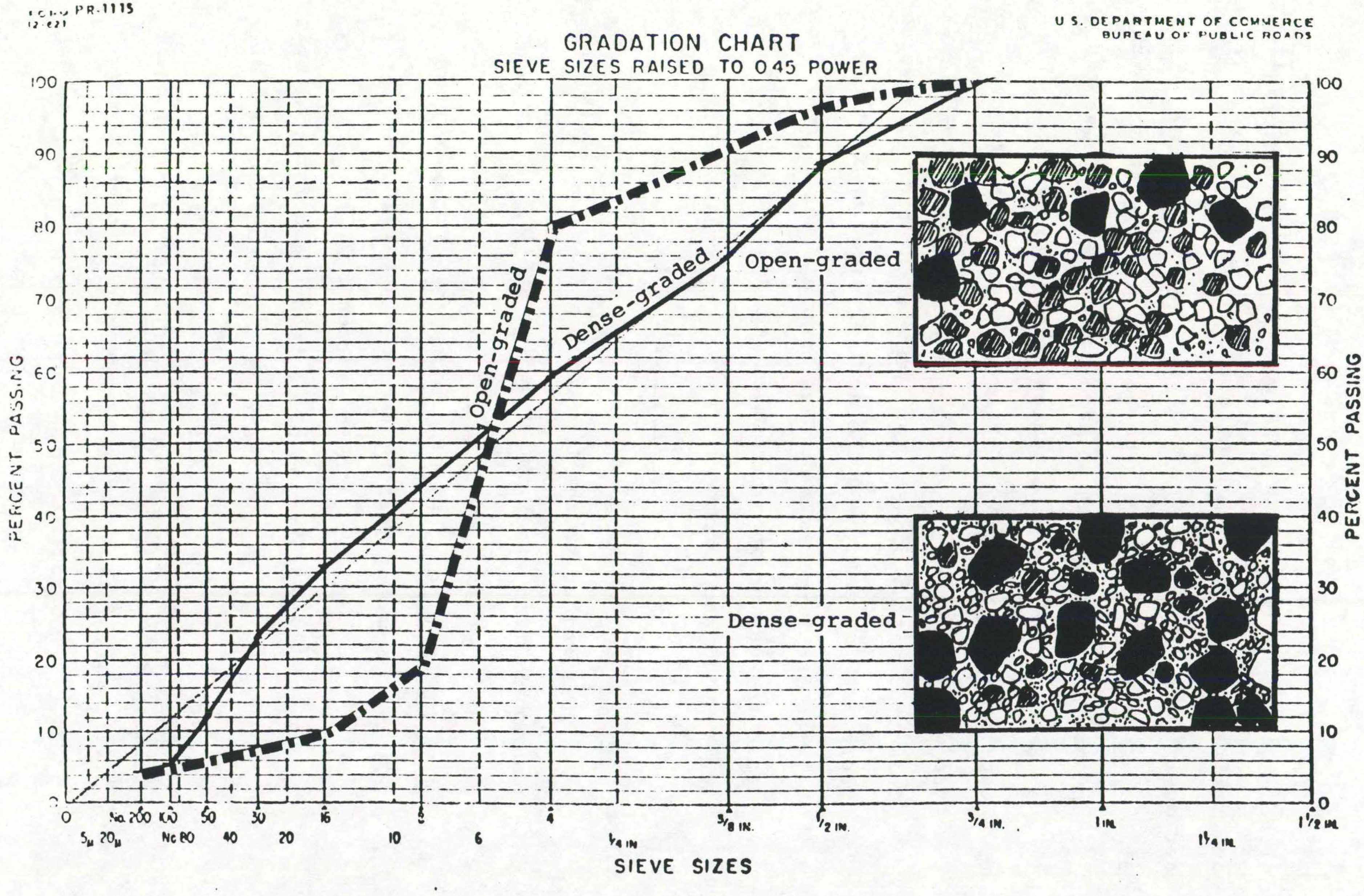
5.3 WHAT IS THE GRADATION OF AN AGGREGATE? (Choose one)

5.3.1 The amount passing the No. 12 screen after 500 revolutions. (Go to Section 5.2.1)

5.3.2 Size distribution of aggregate particles as measured by standard sieves. (Go to Section 4.2)

5.4 WHAT IS MEANT BY THE TERM DENSE GRADED? (Choose one)

5.4.1 Fairly equal amount of particles of each size. (Go to Section 4.1)



Gradation comparisons of Dense and Open Graded Aggregates
Figure 2

5.4.2 The sample has been graded for an adequate amount of time. (Go to Section 3.3.6)

5.5 WHICH HAS MORE VOIDS? (Choose one)

5.5.1 A dense-graded aggregate. (Go to Section 3.5)

5.5.2 A gap-graded aggregate. (Go to Section 3.3.5)

5.6 WHY DOES A GAP GRADE AGGREGATE HAVE MORE VOIDS? (Write in your answer)

____

____

____

(Go to Section 9.0)

5.7 Coarse-Graded: Coarse aggregates (those retained on the #4 sieve) normally consist of one of the following materials: 1) crushed stone, 2) gravel, or 3) synthetic aggregates such as furnace slag and expanded shale. The specified gradation for a coarse aggregate will depend upon the type of construction for which it is used. (See Appendix B)

5.8 Fine-Graded: Fine aggregate particles (those passing the #4 sieve and retained on the #200 sieve) consist of sand or other approved mineral material with similar characteristics, or a combination of these two. Specified fine aggregate gradations for various construction uses can be found in Appendix B. (Go to Section 6.0 and continue)

5.9 No:

The interior moisture must be at a saturated condition. If the particle contains some interior moisture, the level may be anywhere between oven-dry and saturated-surface-dry. (Go to Section 10.0 and select another answer.)

6.0 NOMINAL MAXIMUM SIZE:

Maximum size, top size, largest size, nominal size, and other similar terminology has the same meaning as nominal maximum size and is defined as the largest standard sieve size which may retain material when the aggregate is graded. Iowa Standard Specifications specify aggregate sizes for each class of construction. (See Appendix B) (Go to Section 10.0)

7.0 Correct: (Go to Section 4.0 and continue)

8.0 Correct:

If the material is resistant to abrasion, the percent passing the No. 12 screen after testing will be low. (Go to Section 3.3.2 and continue)

9.0 Gap-graded aggregates will contain an excess of one particular size, with not enough smaller sizes to fill in around this one size. (Go to Section 5.7)

10.0 SATURATED-SURFACE-DRY IS DEFINED AS: (Choose one)

10.1 Dry at the particle surface, but containing interior moisture. (Go to Section 5.9)

10.2 Containing all the interior moisture the particle will hold, with some moisture on the surface. (Go th Section 3.7)

10.3 Dry at the surface but containing all the interior moisture the particle will hold. (Go to Section 4.4)

11.0 Incorrect:

Abrasion alone does not determine durability. (Go to Section 3.10 and select the other answer.)

12.0 Plasticity Index: The plasticity index of an aggregate is determined in order to determine the presence and relative activity of contained clay minerals. In Iowa the Atterberg test (Iowa Test Method 109 A) is used to determine the plasticity index (P.I.) of a soil. The plasticity index is related directly to the amount of clay in a material and is determined by subtracting the plastic limit from the liquid limit.

The liquid limit (L.L.) is that water content, expressed in percent dry weight, at which the material passes from a plastic to a liquid state. In general, it is determined by adding water to a portion of the minus 40 sieve size material until a certain consistency is reached. After, at least, 15 minutes of aging in a humidity chamber, a small amount is transferred to a special pan on top of a liquid limit machine. A groove is made through the middle of the sample on the pan, separating the two halves by a fraction of an inch. The number of "drops" needed to bring a portion of the two halves back together is used to determine if the proper amount of water was initially added. If the initial amount of water was wrong, the sample is remixed and rerun. The final sample is then weighed, dried, and again weighed to determine the amount of water added, as well as the weight of the original grooved samples.

The Plastic Limit (P.L.) is that water content, expressed in percent dry weight, at which the material passes from a semi-solid state to a plastic state. Generally, it is determined by adding water to a portion of the minus 40 sieve size material and then rolling it between the palm of the hand and a clean dry table. If the "threads" reach 1/8 inch diameter without breaking, they are remade into balls and rolled again. When the balls cannot be made to reach the 1/8 inch diameter thread size without breaking, they are placed in a pan for weighing, drying, and reweighing to determine the weight of water, as well as the weight of the "threads".

The construction materials for which P.I. limits are required are listed in Appendix A.

13.0 SUMMARY: (Aggregates)

For the most purposes, aggregates must conform to certain requirements and should consist of clean, hard, strong, and durable particles free of chemicals, coatings of clay, or other fine materials that may affect construction.

Weak, friable, or freeze-thaw susceptible aggregate particles are undesirable for normal open highway construction. Aggregates containing natural shale or shaly particles, soft and porous particles, and certain types of chert should be especially avoided since they have poor resistance to weathering. Visual inspection may often disclose weaknesses in coarse aggregates.

(This completes this chapter. Consult your study schedule before continuing to the next chapter.)

CHAPTER 2

SAMPLING METHODS AND EQUIPMENT

Introduction

This chapter deals with the different sampling methods and equipment. Before beginning to study, be sure you have a copy of the current Field Testing Manual prepared by the Materials Office of the Highway Division.

Importance Of Proper Sampling

No other single phase of an Aggregate Inspector's duties is as important as obtaining a representative sample. At this point all of the money and time which will be expended on the remaining activities of testing and evaluating may be lost or rendered useless by an improper sampling technique on the part of the Aggregate Inspector. In other words, if the sample you take is not representative of the total material, it is absolutely impossible to end up with a test result that means anything. At the completion of instruction, you must know how to obtain a proper sample. Without this knowledge it is useless to proceed further into the areas of test procedure.

Sampling Frequency

Refer to Materials I.M. 204 in the Field Testing Manual. In the appendixes A through M of I.M. 204 are listed the minimum sampling frequencies of each material for various types of projects. More frequent sampling may be required for low or intermittent production or for widely varying test results.

Size of Sample

Refer to Materials I.M. 301 in the Field Testing Manual. You will note on Page 2 of I.M. 301 a list of the various construction materials. Immediately to the right of each material listed is a minimum number of pounds which must be secured for each field sample.

Random Sampling

Test samples should represent the total of the material being produced. This is normally accomplished by random sampling. The random sample should not be obtained because of any particular reason or notion. All material produced should have an equal chance of being tested. The inspector should not determine when or what to sample by judging if the material looks good, bad, or average, because that represents a judgment sample and not a random sample. Random samples are taken when the plant is operating at the usual rate for that plant.

It must be pointed out that not all test samples are random samples. Normally they will be the same, but there will be times when the inspector must choose the time of sampling such as new hammers placed on the secondary crusher, an area of clay in the quarry, or fine sand seams in a gravel pit. These things will directly affect gradation of the material and must be checked immediately to keep the material within proper limits.

During a normal day's operation, all samples taken and tested may be random samples if all operations are running consistently. Some days will have no random samples taken, such as the first days run to establish crusher settings, etc. Some days will have a combination of random and check samples.

Keep in mind that during normal, steady production the samples should be taken on a random basis to represent the total of the material being produced.

Location for Sampling

To help assure that representative samples are taken, one of the following methods will be used for obtaining aggregate samples: 1) obtaining a portion of the material carried on a conveyor belt, 2) intercept the complete material stream flow from the end of a conveyor belt or from overhead bin discharge, 3) sampling from the production stockpile (only for sand or as directed by the District Materials Engineer.)

To obtain an off-the-belt sample; stop the belt, insert a template (as illustrated in Fig. 1) at three or more separate locations along the belt, remove all material within the template, and combine it into the field sample. In belt sampling, the ends of the template should be spaced just far enough apart to get an increment that weighs approximately one-third the minimum weight of the field sample. If the template does not yield the minimum size of field sample in three locations, additional locations will be necessary. No less than three separate locations should be used in obtaining one field sample. All material within each increment is removed from all three or more increments and mixed back together to make one field sample.

When obtaining a field sample by interception of the aggregate stream flow, care must be exercised so that the sampling device (see Fig. 2) passes quickly through the entire stream flow and does not overflow. At least three separate passes shall be made with the sampling device when obtaining a field sample. Each pass is an increment of the field sample.

Stockpile sampling should be avoided. If it becomes absolutely necessary to obtain a sample from a stockpile, consult the District Materials Engineer to help you devise an adequate sampling plan.

Sample Records

It is the responsibility of the aggregate sampler to get all the necessary information to fill out reports properly. Some of this information is general and is used to fill out report headings. This includes type of material, intended use, location of producer, source, project number if one is available, contractor who will be receiving the material, and other general information. The information on the source itself should include section of the quarry or pit and the bed numbers (quarries) or working depths (pit). If special processing equipment is used it should be noted on the reports.

Samples are taken for either 1) field testing or 2) Central Laboratory testing. Those samples which are forwarded to the Central Laboratory of the Iowa DOT should be placed in a standard canvas sack furnished by the DOT and securely tied to prevent loss of material during shipping. Appropriate Form L 1 or 193 should be filled out completely and placed <u>inside</u> the sample sack. Other identification tags should be attached to the tie for shipping information.

Review

Sampling: Before you start out to take a sample, you should ask yourself these questions:

1. Are you sure that your plan for getting the sample is complete?
2. Have you checked on the approved method of taking the sample?
3. Do you know the weight of sample that is required?
4. Do you have the proper tools?
5. Do you have clean containers at hand for the sample?

Records: After you have obtained the sample, you should ask yourself these questions:

1. Are you sure the sample really represents the material?
2. Should you divide the sample and retain part of it?

3. Is the sample completely identified?
4. Does your record show the nature of the material, its intended use, and exactly when, where, and how the sample was taken?
5. Do you know the proper action to take if the sample fails to meet specification requirements?

You should now have a clear idea of what sampling is all about.

It's not always easy to get an adequate sample, but it's very important to use all the care you can. Always remember, if your sample is not representiative, your test results aren't worth the paper they're written on.

Complete the following questions:

1. A field sample is made up of at least:

_______________ (a) 12 increments

_______________ (b) 1 increment

_______________ (c) 3 increments

2. The weight of material required from the field sample to be used in an actual test is called:

_______________ (a) A sublot

_______________ (b) An increment

_______________ (c) A test sample

3. Nominal Maximum Size is the largest standard sieve size listed which (may) (will) retain material when the aggregate is graded.

4. You are sent out to sample a No. 57 concrete aggregate for gradation. You should obtain at least:

   ____________ (a) 20 pounds

   ____________ (b) 30 pounds

   ____________ (c) 50 pounds

5. In sampling from a bin discharge, your sampling device overflows as you pass it through the discharge stream. You should:

   ____________ (a) Discard the material

   ____________ (b) Keep all the material remaining in the pan

   ____________ (c) Strike off the heaped-up material, and keep only that material below the top of the pan.

6. List the three general areas from which samples may be obtained:

   1.____________________________________

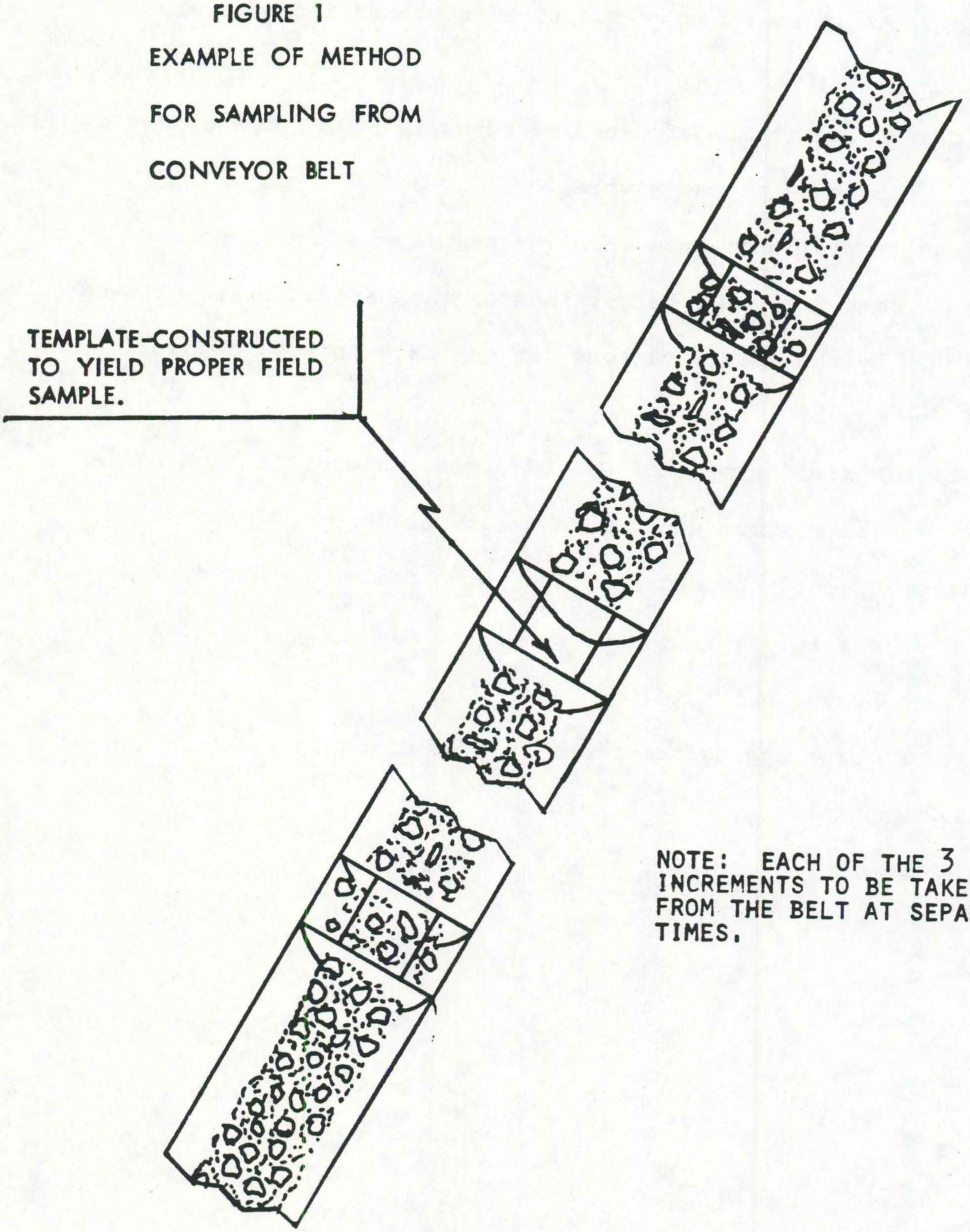
   2.____________________________________

   3.____________________________________

(After completing the above questions, consider your answers carefully to be sure they're correct. Then turn to the next page and check your answers.)

1. (c). At least 3 increments to be combined into a field sample.
2. (c). The quantity of material actually used for a specific test is a test sample.
3. (may). You don't know when you sample whether or not material will be retained on the largest sieve allowed by the specifications, so you have to assume that it <u>may</u> be.
4. (b). A field sample of No. 57 stone, which is 1 inch nominal maximum size, must weigh at least 30 pounds°
5. (a). Discard the material and swing faster on the next passes.
6. 1. Conveyor belt
   2. Flowing aggregate stream (bin or discharge)
   3. Stockpile as a last resort

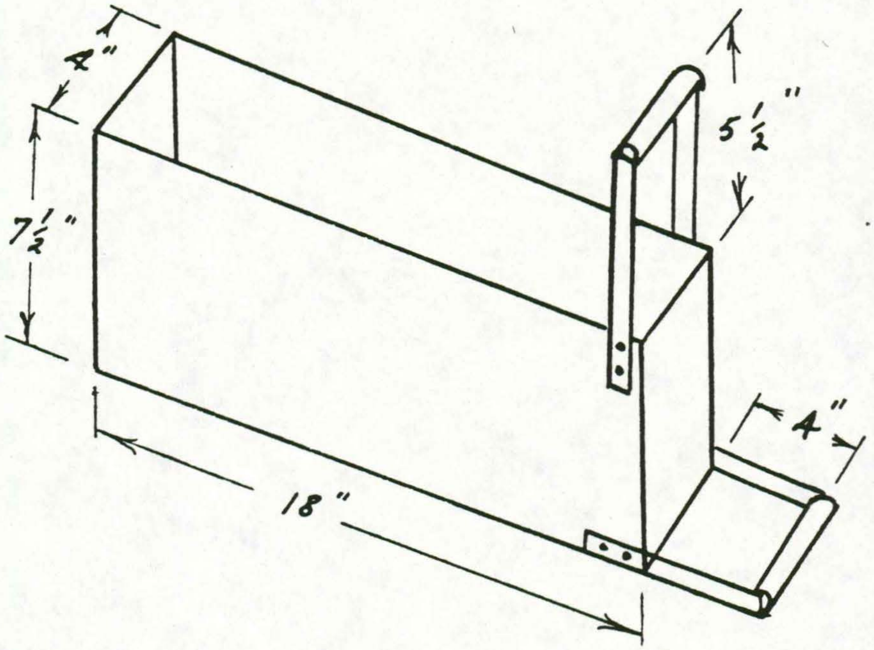
FIGURE 1
EXAMPLE OF METHOD
FOR SAMPLING FROM
CONVEYOR BELT

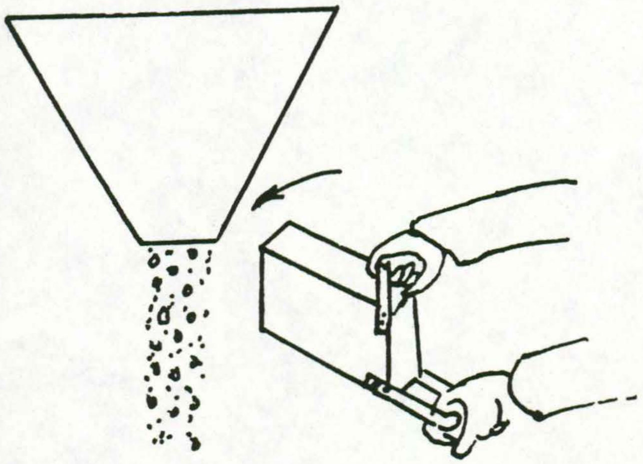


NOTE: EACH OF THE 3 INCREMENTS TO BE TAKEN FROM THE BELT AT SEPARATE TIMES.

FIGURE 2

ILLUSTRATION OF SAMPLING DEVICE WITH HANDLES





NOTE: PASS THE SAMPLING DEVICE QUICKLY THRU THE ENTIRE STREAM FLOW OF AGGREGATE.

CHAPTER 3

SIEVE ANALYSIS

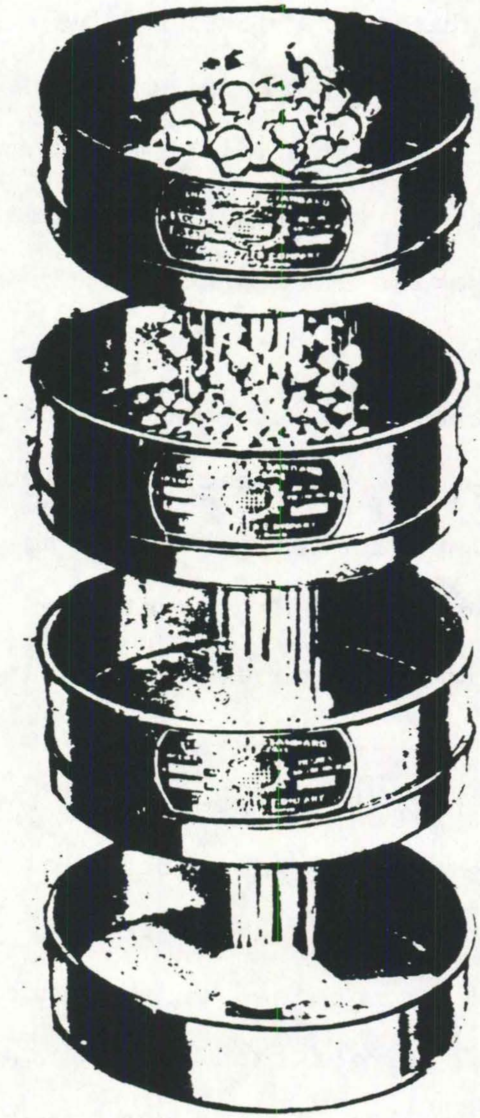
PART I

GENERAL REQUIREMENTS

Aggregate sieve analysis procedures are governed by the Standard Specifications of the Iowa Department of Transportation and the Materials Office Instructional Memorandum Manual. The applicable test methods in the Materials Manual are included primarily in the 300 series section under the subsection "Aggregate".

The initial study will be of the general requirements which are common to any sieve analysis. Then each individual situation such as fine aggregate sieve analysis, coarse aggregate sieve analysis, sieve analysis of an aggregate containing a combination of both coarse and fine aggregate, and the determination of the amount of material finer than the No. 200 sieve in aggregate by washing will be studied.

Sieve analysis is nothing more than the separation of a material based on particle size. For example, material which passes a 1-1/2 inch sieve and is retained on a 1 inch sieve would not contain any particle larger than 1-1/2 inches nor smaller than 1 inch. Sieves are normally arranged in a "nest" with the largest wire openings at the top of the nest and the smallest at the bottom. A nest of sieves is shown in the following picture:



Sieve	Weight of Aggregate In Sieve	% Retained	% Passing
S_1	W_1	$R_1=\frac{W_1}{W_T} \times 100$	$P=R_2+R_3+Rp$
	+		
S_2	W_2	$R_2=\frac{W_2}{W_T} \times 100$	$P=R_3+Rp$
	+		
S_3	W_3	$R_3=\frac{W_3}{W_T} \times 100$	$P=Rp$
	+		
Sp	Wp	$Rp=\frac{W_p}{W_T} \times 100$	
	$\overline{}$ W_T		

This effectively separates our sample into portions based on particle size. The next step in the operation is to weigh all the material which is retained on each sieve. For ease of understanding, the weight retained on sieve no. 1 or the top one will be W_1 and that the weight retained on sieve no. 2 will be W_2 and so forth. The sum of the weight of all the material retained on all sieves and in the pan is called W_T or Total Weight.

The percent of the total weight (W_T) retained on each sieve must be found first. This value is obtained for sieve S_1 by dividing the total weight W_T into the weight W_1 of material retained on sieve S_1 and multiplying this by 100. To obtain the percent of material retained on sieve S_1 the formula may be stated as follows:

$$(\%R) = \%\text{ Retained on Sieve } S_1 = \frac{W_1}{W_T} \times 100$$

To calculate percent retained on any sieve, merely divide the weight retained by total sample weight and multiply by 100.

Iowa Department of Transportation Standard Specifications normally set limits on the percent passing a given sieve; therefore, it is necessary to carry the calculation one step further. It is easy to see that everything in the pan passed the first sieve above it. Therefore, it stands to reason that the percent passing sieve S_3 in the diagram on page 3-2 is equal to the percent of material retained in the pan. This can be expressed by the following formula:

% Passing Sieve S_3 = % Retained in Pan

% Passing $_3$ = % Retained $_p$

The material passing S_2 would be all of the material retained below S_2 which would include the material designated as % R_3 plus % R_p.

Then it could be said that the percent of material passing S_2 equals % R_3 + % R_p.

Which is the formula for obtaining the percent passing the sieve designated as S_1.

(a) $\frac{R_1+R_2+R_3+R_p}{W_T}$ ---------------------- Go to Page 3-5

(b) $\frac{R_2+R_3+R_p}{W_T}$ ---------------------- Go to Page 3-6

NO. Remember that it was stated the percent passing included all of the material retained on all sieves below; however, it does not include any material retained on the sieve in question, in this case S_1.

Go back and read page 3-3, 4, then go to page 3-6.

YES. Answer (b) is correct, the material retained on all sieves below S_1 in this case would have had to pass S_1 before it could reach the other sieves.

This is the manner in which all gradations are calculated. It is really very simple once one thinks about it.

Now turn to Materials I.M. 302 and 303 and read the test equipment listed under Apparatus for each of these tests.

Now itemize the equipment listed without turning back to the test procedure:

MATERIALS I.M. 302 - FINE AGGREGATE

(a) ______________________________

(b) ______________________________

(c) ______________________________

(d) ______________________________

(e) ______________________________

(f) ______________________________

MATERIALS I.M. 303 - COARSE AGGREGATE

(a) ______________________________

(b) ______________________________

(c) ______________________________

(d) ______________________________

(e) ______________________________

Turn to Page 3-8.

The list of testing equipment asked for on Page 3-7 is:

Fine Aggregate

(a) Balance
(b) Sieves
(c) Sieve Shaker
(d) Oven or Hot Plate
(e) Wash Pan
(f) Fiber Bristle Sieve Cleaning Brush

Coarse Aggregate

(a) Balance
(b) Sieves
(c) Sieve Shaker
(d) Oven or Hot Plate
(e) Wash Pan

Why do you think that a fiber brush was listed as part of the apparatus for the fine aggregate test and not for the coarse aggregate test? Write your answer in the space provided below:

Turn to Page 3-9.

The fine aggregate sieves consist of Nos. 4, 8, 16, 30, 50, 100, 200 and pan. Sieves numbered 4 and 8 can be cleaned by inverting the sieve over a pan and tapping the sieve and/or pushing (without abusive force) the particles out of the mesh into the pan. Care should be exercised in cleaning the sieves to avoid damaging the wire mesh by bending or breaking the wires. A fiber bristle brush should be used for cleaning the No. 16, 30, and 50 sieves. Do not use a brush or any external force to attempt to clean the No. 100 or No. 200 sieve. These sieves may be cleaned in a sonic bath. If clogging of the mesh occurs on these finer sieves belonging to the Department of Transportation, they should be returned to the Central Laboratory for cleaning.

Both Materials I.M.'s 302 and 303 require a drying oven or hot plate for the sample preparation. The oven is required to maintain 230° ± 9° F. or 110° ± 5° C. To dry the sample with either the oven or hot plate, the sample is dried until a constant weight is reached and maintained. Precaution should be taken when drying on a stove; the sample should be stirred to prevent over heating which may cause the materials to "pop" or "sputter".

The balance used to weigh the material retained in each sieve and the total weight must be sensitive to within 0.1 percent of weight of the sample to be tested. To determine if the scales meet the sensitivity requirements, move the decimal point three places to the left on the total sample weight. This will give the minimum units which must make all weighings for this sample. For example, if a sample has a total weight of 500 grams then it will be necessary to make all weight determinations to the nearest one half (0.5) gram.

If a sample weighs 10,000 grams, what is the minimum accuracy to which it must be weighed?

(a) 1 Gram

(b) 10 Grams

(c) 100 Grams

The answer, of course, is (b) 10 grams. If you arrived at a different answer, recalculate the answer by writing down the total sample weight, in this case 10,000. When placing the decimal three places left we get 10.000 or ten grams. Keep in mind that it is good practice to weigh this sample more accurately but as a minimum the accuracy must be at least to the nearest 10 grams.

The sieves cannot be checked to make sure that they meet all the requirements of AASHTO Designation M-92 (referred to in the test method) since the equipment is not readily available. However, there are several things which can and should be checked each time the sieves are used. For instance, if the sieve cloth is loose in the frame or if the wires are bent, loose, or broken, then it will be evident that this particular piece of equipment should be repaired or replaced.

This concludes the discussion of equipment and general theory of sieve analysis. Now consideration of the sieve analysis of fine aggregate will begin.

CHAPTER 3

PART II

FINE AGGREGATE

Fine aggregate is generally considered as being predominately material which passes a No. 4 sieve. This is commonly referred to as "minus 4" material. The equipment required by the test procedure has been discussed; however, this has been of a general nature.

The procedure for determining the particle size distribution of a fine aggregate is, in theory, the same as that previously discussed. Consideration needs to be given to specific details at this time.

First, consider the equipment necessary to conduct the test. Of coarse, sieves meeting the requirements of AASHTO M-92 will be needed. They must also consist of a series of sizes such as are necessary to determine compliance with the governing specifications. Sieves for fine aggregate gradation are normally eight (8) or twelve (12) inches in diameter. Most of the testing facilities will have a mechanical shaker available, although manual powered sieve shaking is permitted. The balance must be sensitive to 0.1% of the total sample. Therefore, we must use a balance which will weigh to:

(Choose the correct answer)

(a) 0.1 gram	Go to Page 3-12
(b) 0.5 gram	Go to Page 3-12
(c) 1.0 gram	Go to Page 3-12
(d) Depends on sample size	Go to Page 3-12

The correct answer to this question is (d). Now read Materials I.M. 301. Materials I.M. 301 says that the minimum sample size will depend on the material being sampled.

All equipment should be kept clean and in satisfactory working order. Always check each sieve prior to use for loose, bent or broken wires. A clean work area will aid in preventing errors and increases efficiency. Keep these checks in mind when starting the preparation of the test portion from the field sample.

First, determine the proposed use of the material under test. The Standard Specifications and Special Provisions will determine which sieves are required for this particular test. It will also determine the maximum size of the material to be tested. Use Form 180, Sieve Analysis Worksheet, for the recording of all data. An example of this form appears on page 3-18.

According to Materials I.M. 301, what is the minimum test sample weight for gradation testing of Class V Concrete Aggregate?

(a) 1.0 lbs.

(b) 2.5 kg.

(c) 1.0 kg.

(d) 5.0 kg.

Turn to page 3-13.

The correct answer to the question on page 3-12 is (c). Note that the units for the minimum test sample is kilograms.

Now read Materials I.M. 302, Method of Test for Sieve Analysis of Fine Aggregate. The three methods of obtaining the gradation test sample from the field sample are:

1. Sample splitter (I.M. 336)
2. Method of quartering (I.M. 336)
3. Small scoopfulls of material from various locations.

Explain why one should not attempt to select the sample to an exact predetermined weight?

As stated in the I.M., the sample should be the end result of the sampling method. This means that sampling to an exact weight becomes a selective reduction of sample size. However, sampling by quartering or splitting is an impartial method and does not become selective.

The next step in determining the sieve analysis of fine aggregate is to determine the amount of material finer than a No. 200 sieve. Read I.M. 306.

If the Materials I.M. 301 asks for a sieve analysis sample weight of 1.0 kg, what minimum sample weight should be used in determining the quantity passing the No. 200 sieve?

(a) 2.5 kg.

(b) 2.0 kg.

(c) 0.5 kg.

(d) Use entire sample

On page 1 of Materials I.M. 306 the correct sample weights are given. The correct answer is (d), use entire sample. Using the entire gradation sample for determining the amount less than No. 200 is normal for fine aggregates since the largest fine aggregate sample is usually 1.0 kg. or less.

The sample is next placed in an oven which is maintained at a uniform temperature of 110° ± 5° C. or 230° ± 9° F. and dried to a constant weight. A hot plate may also be used. After the sample has cooled to room temperature, it is weighed. This weight is noted as the original dry weight. The selection of a sample to the exact minimum weight should not be attempted.

The sample is next placed in a wash pan large enough to permit the sample to be covered with water. The wash pan is then vigorously agitated for 5 to 10 seconds without losing any of the sample. Pour the wash water off of the sample through a No. 200 sieve. When pouring the wash water through the No. 200 sieve, it may be necessary to lightly tap or vibrate the sieve in order to keep the mesh open. Continue to use clean water for washing the sample until the water passing through the No. 200 sieve appears almost clear.

In order to determine the % finer than No. 200 by washing, rinse the material retained on the No. 200 sieve back into the original sample, dry this sample, allow it to cool and weigh it. The results can be calculated from the formula:

% finer than No. 200 by washing =

$$\frac{\text{Original dry wt. - Washed dry wt.}}{\text{Original dry wt.}} \times 100$$

Problem: Assume the original dry weight to be 594 grams and the washed dry weight to be 591.5 grams. What would be the % finer than No. 200?

(a) 0.4%

(b) 0.3%

(c) 4.0%

(d) 3.0%

Turn to the next page for the answer:

The answer would be (a). The correct calculations would appear like this:

$$\% \text{ Finer} = \frac{594.0 - 591.5}{594.0} \times 100$$

$$= \frac{2.5}{594.0} \times 100 = .00421 \times 100$$

$$= 0.4\%$$

On Form 180, Sieve Analysis Worksheet in Materials I.M. 302, under Fine Sample, the weight of the material passing the No. 200 lost by washing (2.5 grams) is recorded. The values for the original dry weight and the dry weight of the washed sample are recorded in the appropriate boxes. The difference between the two is the washing loss in grams. This value is also recorded under the Wt. Retd. in the Wash Sieve Size.

To complete the sieve analysis on the remaining washed and dried fine aggregate sample, the remaining sample is placed in the top sieve of the nest of required sieves. Materials I.M. 30[2] explains the test sieving procedure as such:

> Begin the sieving operation by means of a lateral and vertical motion of the sieves so as to keep the sample moving continuously over the surface of the sieves. In no case should the particles in the sample be turned or manipulated through the sieves by hand. Continue the sieving until not more than 0.5 percent by weight of the total washed sample passes any sieve during one minute of continuous sieving. A shaker provided with an electric motor should be run for a period of at least 10 minutes. When the sieving action is such that the particles are not sieved to completion in the time allowed, the cause may be overloading of the sieves. If this condition cannot be corrected by adjusting the sample size on future tests, the washed and dried sample should be divided for sieving and then recombined for weighing.

The material retained in each sieve and the pan should next be weighed and recorded on Form 180 in the Fine Sample area under Wt. Retained. Note that the weights were carried to the nearest 0.5 gram for our examples on page 3-18. Check to assure that not more than 0.5 percent of the original weight was lost in sieve analysis. This is done by totaling the weights retained on each sieve plus the pan, but does not include washing loss. This total is divided by the dry weight of the sample <u>after washing</u>. The percentage value obtained must be 99.5% or greater.

The next page contains three test problems for you to complete. At this point calculate to see if each meets the 0.5% tolerance. The answers are listed on page 3-19.

Form 180
12-71

IOWA DEPARTMENT OF TRANSPORTATION

SIEVE ANALYSIS WORKSHEET

Lab. No.	Material	Material	Material
Co & Proj.			
Producer			
Contractor			
Sampled by	Date	Date	Date
Sample Loc.			

COARSE SAMPLE

Orig. Dry Weight			
Dry Wt. Washed Sample			

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.
1 ½"															
1.05"															
3/4"															
.525"															
3/8"															
4															
8															
Total +4															
Pan															
Total															

FINE SAMPLE

Orig. Dry Weight	558.0	563.5	549.0
Dry Wt. Washed Sample	557.0	562.0	547.5
Washing Loss			

SIEVE SIZE	Wt. Retd.	% Retd.		% Passing	SPECS.	Wt. Retd.	% Retd.		% Passing	SPECS.	Wt. Retd.	% Retd.		% Passing	SPECS.
			Final					Final					Final		
3/8"	0.0					0.0					0.0				
4	12.0					0.0					6.0				
8	61.0					74.0					69.0				
16	111.5					136.0					89.0				
30	175.0					171.5					156.0				
50	115.5					139.5					173.5				
100	55.0					35.0					48.0				
200	21.5					2.0					4.5				
Wash															
Pan	2.0					1.5					1.0				
Total															
Less +4															
Passing # 4															

Date Reptd.	Previous	Date Reptd.	Previous	Date Reptd.	Previous
Cont. Quantity	Today	Quantity	Today	Quantity	Today
	To Date		To Date		To Date
Tested by	Date	Tested by	Date	Tested by	Date

The answers to the three gradations are:

Left example: Does not meet the 0.5% tolerance

Center example: Does meet the 0.5% tolerance

Right example: Does meet the 0.5% tolerance

Left example calculations:

Total retained weight = 553.5 gr.

Dry wt. washed sample = 557.0 gr.

553.5 ÷ 557.0 = 99.4% which is less than 99.5%

Center example calculations:

Total retained weight = 559.5 gr.

Dry wt. washed sample = 562.0 gr.

559.5 ÷ 562.0 = 99.6% which is greater than 99.5%

Right example calculations:

Total retained weight = 547 gr.

Dry wt. washed sample = 547.5 gr.

547 ÷ 547.5 = 99.9% which is greater than 99.5%

The total retained weight should not be greater than the dry weight of the washed sample. If questions still exist on calculating this tolerance, review pages 3 & 4 of I.M. 302 and the problem gradations on page 3-18.

In order to know the total amount finer than the No. 200 sieve, we need to calculate the amount lost due to washing the sample through a No. 200 sieve. On page 3-18 the left example is not valid since it did not pass the 0.5 per cent tolerance. Now calculate the amount in grams of the washing loss for the center and right examples. The answers with calculations appear on the next page.

Calculations for determining washing loss are:

Center example:

Original dry weight = 563.5 grams

Dry wt. after washing = 562.0 grams

563.5 - 562.0 = 1.5 grams

Right example:

Original dry weight = 549.0 grams

Dry wt. after washing = 547.5 grams

549.0 - 547.5 = 1.5 grams

These values should be recorded in the "Washing Loss" box and the "Wt. Retd." column after Wash.

To determine the total amount passing the No. 200 sieve, add the weight retained in the pan and the weight loss due to washing. Calculate this value for the two examples. The correct answers appear on the next page.

The total amount of material finer than the No. 200 sieve for each of the two examples is:

	Center Ex.	Right Ex.
Wt. Retd. in pan (grams)	1.5	1.0
Washing Loss (grams)	1.5	1.5
Total % pass No. 200	3.0 gr.	2.5 gr.

The total amount retained on each sieve has now been found but the <u>percentage</u> retained on each sieve must be calculated. Part I of this chapter showed the correct way to calculate per cent retained on each sieve. The general formula was:

Percentage Retained on Sieve No. 1 =

$$\frac{\text{Wt. Retained on Sieve No. 1}}{\text{Original Dry Wt. of the sample}} \times 100$$

The weight retained on each sieve has been explained previously. The original dry weight of the sample is also previously known for our examples. Remember that the original dry weight includes minus No. 200 material. Now calculate the % retained on each sieve for the two examples. Place the answers on the appropriate boxes on page 3-18.

The correct answers appear on page 3-22.

Form 180
12-71

IOWA DEPARTMENT OF TRANSPORTATION

SIEVE ANALYSIS WORKSHEET

Lab. No.		**Material**		**Material**		**Material**
Co & Proj.						
Producer						
Contractor						
Sampled by		**Date**		**Date**		**Date**
Sample Loc.						

COARSE SAMPLE

Orig. Dry Weight
Dry Wt. Washed Sample

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.
1 ½"															
1.05"															
3/4"															
.525"															
3/8"															
4															
8															
Total +4															
Pan															
Total															

FINE SAMPLE

Orig. Dry Weight	558.0	Orig. Dry Weight	563.5	Orig. Dry Weight	549.0
Dry Wt. Washed Sample	557.0	Dry Wt. Washed Sample	562.0	Dry Wt. Washed Sample	547.5
Washing Loss		Washing Loss	1.5	Washing Loss	1.5

SIEVE SIZE	Wt. Retd.	% Retd.		% Passing	SPECS.	Wt. Retd.	% Retd.		% Passing	SPECS.	Wt. Retd.	% Retd.		% Passing	SPECS.
			Final					Final					Final		
3/8"	0.0					0.0	0.0				0.0	0.0			
4	12.0					0.0	0.0				6.0	1.1			
8	61.0					74.0	13.1				69.0	12.6			
16	111.5			VOID		136.0	24.1				89.0	16.2			
30	175.0					171.5	30.4				156.0	28.4			
50	115.5					139.5	24.8				173.5	31.6			
100	55.0					35.0	6.2				48.0	8.7			
200	21.5					2/0	0.4				4.5	0.8			
Wash						1.5					1.5				
Pan	2.0					1.5	0.6				1.0	0.5			
Total						561.0	99.6				548.5	99.9			
Less +4															
Passing # 4															

Date Reptd.	Previous	Date Reptd.	Previous	Date Reptd.	Previous
Cont. Quantity	Today	Quantity	Today	Quantity	Today
	To Date		To Date		To Date
Tested by	Date	Tested by	Date	Tested by	Date

Notice that the total of the percentages retained on each sieve and the pan does not equal 100%. If this occurs the percentages should be altered by prorating the percentages so that they do total 100%. For example, the center problem on page 3-22 has a total of 99.6% retained. This leaves 0.4% to be prorated so that they do total 100%. This proration should be done to the largest percentages retained. In this case, by judgment the following should be added:

Sieve Size	% Retd.	Plus	Total
16	24.1	0.1	24.2
30	30.4	0.2	30.6
50	24.8	0.1	24.9
		0.4	

The total percentage retained would now be 100%. Now complete the center and right problems so they total 100% retained. Page 3-24 shows possible solutions.

Form 180
12-71

IOWA DEPARTMENT OF TRANSPORTATION

SIEVE ANALYSIS WORKSHEET

Lab. No.	**Material**	**Material**	**Material**
Co & Proj.			
Producer			
Contractor			
Sampled by	**Date**	**Date**	**Date**
Sample Loc.			

COARSE SAMPLE

Orig. Dry Weight
Dry Wt. Washed Sample

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X ______	% Psg. Final	SPECS.
1 ½"					
1.05"					
3/4"					
.525"					
3/8"					
4					
8					
Total +4					
Pan					
Total					

COARSE SAMPLE

Orig. Dry Weight
Dry Wt. Washed Sample

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X ______	% Psg. Final	SPECS.
1 ½"					
1.05"					
3/4"					
.525"					
3/8"					
4					
8					
Total +4					
Pan					
Total					

COARSE SAMPLE

Orig. Dry Weight
Dry Wt. Washed Sample

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X ______	% Psg. Final	SPECS.
1 ½"					
1.05"					
3/4"					
.525"					
3/8"					
4					
8					
Total +4					
Pan					
Total					

FINE SAMPLE

Orig. Dry Weight 558.0
Dry Wt. Washed Sample 557.0
Washing Loss

SIEVE SIZE	Wt. Retd.	% Retd.		% Passing	SPECS.
			Final		
3/8"	0				
4	12				
8	61				
16	111.5				
30	175			VOID	
50	115.5				
100	55				
200	21.5				
Wash					
Pan	2				
Total					
Less +4					
Passing # 4					

Date Reptd.		**Previous**	
Cont. Quantity		**Today**	
		To Date	
Tested by		**Date**	

FINE SAMPLE

Orig. Dry Weight 563.5
Dry Wt. Washed Sample 562.0
Washing Loss 1.5

SIEVE SIZE	Wt. Retd.	% Retd.		% Passing	SPECS.
			Final		
3/8"	0	0.0			
4	0	0.0			
8	74	13.1			
16	136	24.2			
30	171.5	30.6			
50	139.5	24.9			
100	35	6.2			
200	2	0.4			
Wash	1.5				
Pan	1.5	0.6			
Total	561	100.0			
Less +4					
Passing # 4					

Date Reptd.		**Previous**	
Quantity		**Today**	
		To Date	
Tested by		**Date**	

FINE SAMPLE

Orig. Dry Weight 549.0
Dry Wt. Washed Sample 547.5
Washing Loss 1.5

SIEVE SIZE	Wt. Retd.	% Retd.		% Passing	SPECS.
			Final		
3/8"	0	0.0			
4	6	1.1			
8	69	12.6			
16	89	16.2			
30	156	28.5			
50	173.5	31.6			
100	48	8.7			
200	4.5	0.8			
Wash	1.5				
Pan	1	0.5			
Total	548.5	100.0			
Less +4					
Passing # 4					

Date Reptd.		**Previous**	
Quantity		**Today**	
		To Date	
Tested by		**Date**	

Next is the determination for the percent passing each sieve. Recall pages 3-1 and 2. There, it was stated that the percent passing equals the percent retained on each lower sieve plus the pan. This would be represented by the formula:

$P_1 = R_2 + R_3 + ... + R_p$

where P_1 = percent passing sieve 1

R_2 = percent retained on sieve 2

R_3 + ... = percent retained on successive sieves

R_p = percent retained in the pan

However, an easier method exists to calculate the percent passing each sieve. By subtracting the percent retained on a particular sieve from the percent passing the next larger sieve, the amount passing that particular sieve is obtained.

The following is an example illustrating this:

From page 3-24 center problem P_{16} = 30.6+24.9%+6.2%+0.4%+ 0.3%+0.3%

= 62.7%

or $P_{16} = P_8 - R_{16}$ and $P_8 = P_4 - R_8$ = 100%-13.1% = 86.9%

So 86.9%-24.2% = 62.7%

At this point turn back to page 3-18 and calculate the percent passing each sieve. The correct answers are shown on page 3-26.

Form 180
12-71

IOWA DEPARTMENT OF TRANSPORTATION

SIEVE ANALYSIS WORKSHEET

Lab. No.	Material	Material	Material
Co & Proj.			
Producer			
Contractor			
Sampled by	Date	Date	Date
Sample Loc.			

COARSE SAMPLE

Orig. Dry Weight			
Dry Wt. Washed Sample			

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X ______	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X ______	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X ______	% Psg. Final	SPECS.
1 ½"															
1.05"															
3/4"															
.525"															
3/8"															
4															
8															
Total +4															
Pan															
Total															

FINE SAMPLE

Orig. Dry Weight	558.0	563.5	549.0
Dry Wt. Washed Sample	557.0	562.0	547.5
Washing Loss		1.5	1.5

SIEVE SIZE	Wt. Retd.	% Retd.		% Passing	SPECS.
			Final		
3/8"	0				
4	12				
8	61				
16	111.5				
30	175		VOID		
50	115.5				
100	55				
200	21.5				
Wash					
Pan	2				
Total					
Less +4					
Passing # 4					

SIEVE SIZE	Wt. Retd.	% Retd.		% Passing	SPECS.
			Final		
3/8"	0	0.0		100	
4	0	0.0		100	
8	74	13.1		86.9	
16	136	24.2		62.7	
30	171.5	30.6		32.1	
50	139.5	24.9		7.2	
100	35	6.2		1.0	
200	2	0.4		0.6	
Wash	1.5				
Pan	1.5	0.6			
Total	561	100.0			
Less +4					
Passing # 4					

SIEVE SIZE	Wt. Retd.	% Retd.		% Passing	SPECS.
			Final		
3/8"	0	0.0		100	
4	6	1.1		98.9	
8	69	12.6		86.3	
16	89	16.2		70.1	
30	156	28.5		41.6	
50	173.5	31.6		10.0	
100	48	8.7		1.3	
200	4.5	0.8		.5	
Wash	1.5				
Pan	1	0.5			
Total	548.5	100.0			
Less +4					
Passing # 4					

Date Reptd.	Previous	Date Reptd.	Previous	Date Reptd.	Previous
Cont. Quantity	Today	Quantity	Today	Quantity	Today
	To Date		To Date		To Date
Tested by	Date	Tested by	Date	Tested by	Date

When reporting out the results of the sieve analysis, the results are reported to two significant figures. This means that when the percentages are 10% or greater the numbers are rounded to the nearest whole percent leaving two significant figures as shown in examples 1, 2, and 3. When the percentages are less than 10% but greater than 0.04% the numbers are rounded to the nearest tenth of a percent as shown in examples 4, 5, and 6. For example:

1. 10.9% = 11%
2. 14.2% = 14%
3. 13.5% = 14% (round to the nearest even percentage)
4. 9.3% = 9.3%
5. 0.6% = 0.6%
6. 0.08% = 0.1%

This completes the discussion of fine aggregate sieve analysis. The next discussion is on coarse aggregate sieve analysis.

CHAPTER 3

PART III

COARSE AGGREGATE

The sieve analysis of coarse aggregate involves the same theory of gradation as fine aggregate; ie, particle distribution of the coarse aggregates is determined by passing the material through a series of successively smaller sieves. However, the sieve frames in this case are square and are substantially constructed in such a manner that will prevent loss of material during sieving. AASHTO M-92 covers the specifications which govern these screens.

Materials I.M. 303 covers the method of test for sieve analysis of coarse aggregates. The apparatus necessary to conduct the test has previously been discussed. The sample size necessary for each applicable material has also been discussed in I.M. 301.

At this time read I.M. 303 sections A,B,C, and D.

Section C, Sample Preparation, discusses preparing the sample for sieving. It states that where the percent of absorbed moisture is essentially constant for different particle sizes, oven drying is not necessary. Since this is a judgment without some experience with the aggregate, the most accurate method is to oven dry the sample to a constant weight. After cooling, record the original dry weight on Form 180, Sieve Analaysis Worksheet, under the coarse sample area. Page 3-29 shows the form with an original dry weight value added.

Form 180
12-71

IOWA DEPARTMENT OF TRANSPORTATION

SIEVE ANALYSIS WORKSHEET

Lab. No.	Material	Material	Material
Co & Proj.			
Producer			
Contractor			
Sampled by	Date	Date	Date
Sample Loc.			

COARSE SAMPLE	COARSE SAMPLE	COARSE SAMPLE
Orig. Dry Weight 11548	Orig. Dry Weight	Orig. Dry Weight
Dry Wt. Washed Sample	Dry Wt. Washed Sample	Dry Wt. Washed Sample

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X ____	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X ____	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X ____	% Psg. Final	SPECS.
1 ½"															
1.05"															
3/4"															
.525"															
3/8"															
4															
8															
Total +4															
Pan															
Total															

FINE SAMPLE	FINE SAMPLE	FINE SAMPLE
Orig. Dry Weight	Orig. Dry Weight	Orig. Dry Weight
Dry Wt. Washed Sample	Dry Wt. Washed Sample	Dry Wt. Washed Sample
Washing Loss	Washing Loss	Washing Loss

SIEVE SIZE	Wt. Retd.	% Retd.		% Passing	SPECS.	Wt. Retd.	% Retd.		% Passing	SPECS.	Wt. Retd.	% Retd.		% Passing	SPECS.
			Final					Final					Final		
3/8"															
4															
8															
16															
30															
50															
100															
200															
Wash															
Pan															
Total															
Less +4															
Passing # 4															

Date Reptd.	Previous	Date Reptd.	Previous	Date Reptd.	Previous
Cont. Quantity	Today	Quantity	Today	Quantity	Today
	To Date		To Date		To Date
Tested by	Date	Tested by	Date	Tested by	Date

Next complete the actual sieve analysis operation. The Materials I.M. 303 lists the procedure as:

> The sieving operation must be conducted by means of a lateral and vertical motion of the sieve, accompanied by a jarring action so as to keep the sample moving continuously over the surface of the sieve. Do not attempt to turn or manipulate the sample through the sieve by hand. Continue sieving until not more than 0.5 percent by weight of the total sample passes any sieve during one minute of sieving. On that portion of the sample retained on the No. 4 sieve, the above described procedure for determining thoroughness of sieving is to be carried out with a single layer of material. When mechanical sieving is used the thoroughness of sieving is to be tested by using the hand method described above. If sieving to completion as described above is not accomplished, reduce the amount of material carried on the sieve and/or sieve for a longer period of time.

The sieve sizes which are tested for compliance for percent passing are listed in the Standard Specifications, Iowa Department of Transportation. The sieves normally used are:

1-1/2"
1.05"
3/4"
.525"
3/8"
No. 4
No. 8

NOTE: 1.05" and .525" sieves (Tyler designation) are used for Iowa Department of Transportation testing.

This group of sieves should prevent a buildup of a material on any one sieve due to an overload. If an overload should exist, reduce the amount of material on that sieve and sieve the remaining amount through as the sieve load allows.

After the sieving operation has been completed, weigh the material retained on each sieve. This data is recorded for the appropriate sieve size on Form 180. Then check to assure that not more than 0.5 percent of the original weight was lost in sieve analysis. This is done by totaling the weights retained on each sieve plus the pan. This total is divided by the original dry weight of the sample after drying. The percentage value obtained must be 99.5% or greater. The next page includes three examples. Calculate the loss due to sieve analysis and determine if it meets the 0.5% tolerance.

Form 180
12-71

IOWA DEPARTMENT OF TRANSPORTATION

SIEVE ANALYSIS WORKSHEET

Lab. No.	Material	Material	Material
Co & Proj.			
Producer			
Contractor			
Sampled by	Date	Date	Date
Sample Loc.			

	COARSE SAMPLE	COARSE SAMPLE	COARSE SAMPLE
Orig. Dry Weight	11276	11344	11493
Dry Wt. Washed Sample			

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.
1 ½"	0					0					111				
1.05"	1110					837					912				
3/4"	2200					2112					2713				
.525"	2705					2983					3201				
3/8"	2813					2681					2617				
4	2107					2061					1119				
8	201					434					639				
Total +4															
Pan	117					168					170				
Total															

	FINE SAMPLE	FINE SAMPLE	FINE SAMPLE
Orig. Dry Weight			
Dry Wt. Washed Sample			
Washing Loss			

SIEVE SIZE	Wt. Retd.	% Retd.		% Passing	SPECS.	Wt. Retd.	% Retd.		% Passing	SPECS.	Wt. Retd.	% Retd.		% Passing	SPECS.
			Final					Final					Final		
3/8"															
4															
8															
16															
30															
50															
100															
200															
Wash															
Pan															
Total															
Less +4															
Passing # 4															

Date Reptd.	Previous	Date Reptd.	Previous	Date Reptd.	Previous
Cont. Quantity	Today	Quantity	Today	Quantity	Today
	To Date		To Date		To Date
Tested by	Date	Tested by	Date	Tested by	Date

The correct method to determine if the sieving procedure meets the 0.5% loss tolerance is to divide the total of the weights retained on each sieve by the original dry weight. The calculations would be:

Left Example Problem:

Total weight retained =

= (1110+2200+2705+2813+2107+201+117)

= 11,253 grams

Original Dry Weight = 11,276 grams

% = 11,253/11,276 = 99.8%

The weight loss is within the 0.5% tolerance.

Center Example Problem:

11,276/11,344 = 99.4%

The weight loss is not within the 0.5% tolerance.

This sample should be discarded for this reason.

Right Example Problem:

11,482/11,493 = 99.9%

The weight loss is within the 0.5% tolerance.

The next procedure is to determine the percentage retained on each sieve. To do this, divide the weight of the material retained on each sieve and in the pan by the total original dry weight of the sample. Do this for the two examples. The correct values are on the next page.

Form 180
12-71

IOWA DEPARTMENT OF TRANSPORTATION

SIEVE ANALYSIS WORKSHEET

Lab. No.	Material	Material	Material
Co & Proj.			
Producer			
Contractor			
Sampled by	Date	Date	Date
Sample Loc.			

COARSE SAMPLE

Orig. Dry Weight	11276		11493
Dry Wt. Washed Sample			

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.
1 ½"	0	0.0									111	1.0			
1.05"	1110	9.8									912	7.9			
3/4"	2200	19.5									2713	23.6			
.525"	2705	24.0									3201	27.9			
3/8"	2813	24.9									2617	22.8			
4	2107	18.7									1119	9.7			
8	201	1.8									639	5.6			
Total +4															
Pan	117	1.0									170	1.5			
Total	11253	99.7									11482	100.0			

FINE SAMPLE

Orig. Dry Weight			
Dry Wt. Washed Sample			
Washing Loss			

SIEVE SIZE	Wt. Retd.	% Retd.		% Passing	SPECS.	Wt. Retd.	% Retd.		% Passing	SPECS.	Wt. Retd.	% Retd.		% Passing	SPECS.
			Final					Final					Final		
3/8"															
4															
8															
16															
30															
50															
100															
200															
Wash															
Pan															
Total															
Less +4															
Passing # 4															

Date Reptd.	Previous	Date Reptd.	Previous	Date Reptd.	Previous
Cont. Quantity	Today	Quantity	Today	Quantity	Today
	To Date		To Date		To Date
Tested by	Date	Tested by	Date	Tested by	Date

A typical calculation for obtaining the percent retained on any sieve would be:

$$\% \text{ Retained} = \frac{\text{Wt. Retained}}{\text{Orig. Dry Wt.}} \times 100$$

For the left example on page 3-34 on the 3/4" sieve, the percent retained is:

$$\% \text{ Retained} = \frac{2200 \text{ gr.}}{11276 \text{ gr.}} \times 100$$

$$= 19.5\%$$

When the total percent retained does not equal 100%, prorate the difference among the largest percentages retained. In the case of the left example, the amount to be prorated is:

$$100\% - 99.7\% = 0.3\%$$

Spread this equally about the three largest percentages retained.

Prorate the left example. The right example does not need prorating because the total percent retained adds to 100%. Possible solutions appear on the next page.

Form 180
12-71

IOWA DEPARTMENT OF TRANSPORTATION

SIEVE ANALYSIS WORKSHEET

Lab. No.	**Material**	**Material**	**Material**
Co & Proj.			
Producer			
Contractor			
Sampled by	**Date**	**Date**	**Date**
Sample Loc.			

COARSE SAMPLE

Orig. Dry Weight	11276		11493
Dry Wt. Washed Sample			

SIEVE SIZE	**Wt. Retd.**	**% Retd.**	**% Retd. X ______**	**% Psg. Final**	**SPECS.**	**Wt. Retd.**	**% Retd.**	**% Retd. X ______**	**% Psg. Final**	**SPECS.**	**Wt. Retd.**	**% Retd.**	**% Retd. X ______**	**% Psg. Final**	**SPECS.**
1 ½"	0	0.0									111	1.0			
1.05"	1110	9.8									912	7.9			
3/4"	2200	19.6									2713	23.6			
.525"	2705	24.1									3201	27.9			
3/8"	2813	25.0									2617	22.8			
4	2107	18.7									1119	9.7			
8	201	1.8									639	5.6			
Total +4															
Pan	117	1.0									170	1.5			
Total	11253	100.0									11482	100.0			

FINE SAMPLE

Orig. Dry Weight			
Dry Wt. Washed Sample			
Washing Loss			

SIEVE SIZE	**Wt. Retd.**	**% Retd.**		**% Passing**	**SPECS.**	**Wt. Retd.**	**% Retd.**		**% Passing**	**SPECS.**	**Wt. Retd.**	**% Retd.**		**% Passing**	**SPECS.**
			Final					**Final**					**Final**		
3/8"															
4															
8															
16															
30															
50															
100															
200															
Wash															
Pan															
Total															
Less +4															
Passing # 4															

Date Reptd.	**Previous**	**Date Reptd.**	**Previous**	**Date Reptd.**	**Previous**
Cont. Quantity	**Today**	**Quantity**	**Today**	**Quantity**	**Today**
	To Date		**To Date**		**To Date**
Tested by	**Date**	**Tested by**	**Date**	**Tested by**	**Date**

Many of the aggregate specifications have a limitation on the amount of material passing the No. 200 mesh sieve. For this reason a determination of the percent passing the No. 200 sieve must be made.

According to I.M. 301 and 306, what is the minimum sample weight needed for determining the quantity passing the No. 200 sieve for concrete coarse aggregate stone (Mix 2-8)?

(a) 2500 grams
(b) 1000 grams
(c) 500 grams
(d) None of the above

According to I.M. 301, the minimum field sample in lbs. for concrete coarse aggregate (Mix 2-8) is 50 lbs. The minimum test sample in grams for sieve analysis is 10,000 grams. According to I.M. 306 a 10,000 gram sieve analysis sample requires a 2500 gram sample for determining the quantity passing the No. 200 sieve. Answer (a) would be the correct answer.

The 2500 gram sample can be a "build up" sample obtained from the material retained on each sieve of the previous sieve analysis, or by splitting down.

Since the total percentage retained on all sieves is 100, multiply the percentage retained on each individual sieve and in the pan by an appropriate number so that the actual "built-up" test sample for washing will be of the size required in Matls. I.M. 306. For material requiring 2500 grams multiply by 26 and for material requiring 1000 grams multiply by 11. This insures a sample of slightly more than the minimum required weight. For the three examples, assume a 2500 gram sample is needed to calculate the percent passing the No. 200 sieve. Find the weight needed to be saved from each sieve to complete the fines test. The correct weights appear on the next page.

Form 180
12-71

IOWA DEPARTMENT OF TRANSPORTATION

SIEVE ANALYSIS WORKSHEET

Lab. No.		Material		Material			Material	
Co & Proj.								
Producer								
Contractor								
Sampled by		Date			Date		Date	
Sample Loc.								

COARSE SAMPLE

Orig. Dry Weight 11276
Dry Wt. Washed Sample

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X 26	% Psg. Final	SPECS.
1 ½"	0	0.0	0		
1.05"	1110	9.8	255		
3/4"	2200	19.6	510		
.525"	2705	24.1	627		
3/8"	2813	25.0	650		
4	2107	18.7	486		
8	201	1.8	47		
Total +4					
Pan	117	1.0	26		
Total	11253	100.0	2601		

COARSE SAMPLE

Orig. Dry Weight
Dry Wt. Washed Sample

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X	% Psg. Final	SPECS.
1 ½"					
1.05"					
3/4"					
.525"					
3/8"					
4					
8					
Total +4					
Pan					
Total					

COARSE SAMPLE

Orig. Dry Weight 11493
Dry Wt. Washed Sample

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X 26	% Psg. Final	SPECS.
1 ½"	111	1.0	26		
1.05"	912	7.9	205		
3/4"	2713	23.6	614		
.525"	3201	27.9	725		
3/8"	2617	22.8	593		
4	1119	9.7	252		
8	639	5.6	146		
Total +4					
Pan	170	1.5	39		
Total	11482	100.0	2600		

FINE SAMPLE

Orig. Dry Weight
Dry Wt. Washed Sample
Washing Loss

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. Final	% Passing	SPECS.
3/8"					
4					
8					
16					
30					
50					
100					
200					
Wash					
Pan					
Total					
Less +4					
Passing # 4					

FINE SAMPLE

Orig. Dry Weight
Dry Wt. Washed Sample
Washing Loss

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. Final	% Passing	SPECS.
3/8"					
4					
8					
16					
30					
50					
100					
200					
Wash					
Pan					
Total					
Less +4					
Passing # 4					

FINE SAMPLE

Orig. Dry Weight
Dry Wt. Washed Sample
Washing Loss

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. Final	% Passing	SPECS.
3/8"					
4					
8					
16					
30					
50					
100					
200					
Wash					
Pan					
Total					
Less +4					
Passing # 4					

Date Reptd.		Previous		Date Reptd.		Previous		Date Reptd.		Previous	
Cont. Quantity		Today		Quantity		Today		Quantity		Today	
		To Date				To Date				To Date	
Tested by		Date		Tested by		Date		Tested by		Date	

The sample is next subjected to I.M. 306, "Method of Test For Determining The Amount Of Material Finer Than The No. 200 Sieve In Aggregate By Washing". This I.M. procedure determines only the portion that is lost in washing the sample. To this must be added the amount of "minus" No. 200 material obtained when dry sieving. Therefore upon completion of the procedure outlined in Matls. I.M. 306, sieve the washed and dried sample over a No. 4 or No. 8 sieve and discard the retained material. Place the material passing the No. 4 or No. 8 sieve on a nest of sieves including Nos. 16, 30, 200 and pan. (The No. 16 and 30 sieves are included to protect the No. 200 sieve) and after a minimum time of 5 minutes on a mechanical shaker, determine only the weight of the material in the pan.

By adding the amount lost by washing (minus No. 200) and the amount lost due to dry sieving (minus No. 200), the total amount of minus No. 200 material can be determined. Dividing this value by the dry weight of the sample (before washing) gives the total percent passing the No. 200 sieve.

Materials I.M. 303 gives guidelines for carrying out calculations on sieve analysis operations. These are:

> For computing the percentages retained and the consequent percentages passing each sieve, the computations are carried out to the nearest 0.1 percent so that the percentages retained will add to a total of 100.0 percent. In reporting the sieve analysis, however, these results are shown to only two significant figures, i.e., to the nearest percent for percentages above 10 and to the nearest tenth of a percent for lower results.

Rounding-Off: When rounding off a number, choose that which is nearest. If two choices are possible, as when the digits dropped are exactly 5, choose the one ending with an even digit. Examples are as follows:

Calculated Value	Rounded-Off Value
10.4%	10%
10.5%	10%
10.6%	11%
11.4%	11%
11.5%	12%
11.6%	12%
6.45%	6.4%
6.55%	6.6%
6.65%	6.6%

This completes the sieve analysis of coarse aggregate discussion.

CHAPTER 3

PART IV

SIEVE ANALYSIS OF COMBINED AGGREGATES

The final method of test to be discussed in Chapter 3 is sieve analysis of combined aggregates. A combined aggregate sample containing very coarse to extremely fine materials must be tested somewhat differently than previously studied. At this time, read test method I.M. 304 which explains the correct procedure for accomplishing the test.

The I.M. lists similar apparatus to previous tests. The one difference is that this I.M. calls for a tub for washing the sample whereas previous I.M.'s discussed called for a wash pan. Explain the difference here.

The wash tub is necessary because to wash a No. 4 box sieve which measures 12 inches by 12 inches, a large tub is necessary.

As with past sieve analysis procedures, the sample size to be obtained from the field is determined by I.M. 301. What is the minimum field sample size for 1" asphalt treated base material?

(a) 50 lbs.
(b) 30 lbs.
(c) 20 lbs.
(d) 10 lbs.

The minimum field sample size for 1" asphalt treated base material is 30 lbs. The minimum sieve analysis sample for the coarse aggregate as determined by I.M. 301 is 5000 grams.

Two samples are necessary to determine the combined sieve analysis. The coarse aggregate sample size is determined by I.M. 301 as illustrated above. The fine aggregate sample is taken from the remaining field sample. A sample large enough to ensure a 500 gram sample passing the No. 4 sieve must be taken.

The coarse sample is placed into an oven at 230 ± 9^{o} F. or 110 ± 5^{o} C. and dried to a constant weight. A stove or hot plate may also be used. Avoid overheating which may cause the sample to "pop" or "sputter". After cooling, the original dry weight is measured and recorded. Record this value under Coarse Sample - Original Dry Weight on Form 180. See example on page 3-45.

The sample is next sieved on the No. 4 sieve. All material passing this sieve is discarded. The remaining sample is washed in a No. 4 box sieve in the large wash tub. The I.M. describes the washing procedure as:

> Wash the remaining plus No. 4 material by placing suitable increments on a No. 4 box sieve and agitating the sieve and its contents in a tub of water, or by placing the plus 4 material in a large wash pan. Any clay lumps present must be broken up and passed through this sieve in the washing process.

Caution should be taken to avoid loss of material over the side of the No. 4 box sieve.

The washed sample is placed on a stove and dried to a constant weight. After cooling, determine the washed sample weight. This value is recorded on Form 180 under Coarse Sample - Dry Wt. Washed Sample. See example.

The material is next sieved on screens complying with specifications. Normally, sieving requires the use of the following sieves:

1-1/2"
1.05"
3/4"
0.525"
3/8"
No. 4

The sieving operation is described as:

> Sieve the washed and dried sample on the required coarse sieves, ending with the No. 4 sieve. The sieving operation must be conducted by means of a lateral and vertical motion of the sieve, accompanied by a jarring action so as to keep the sample moving continuously over the surface of the sieve. Do not attempt to turn or manipulate the sample through the sieve by hand. Continue sieving until not more than 1 percent by weight of the residue passes any sieve during one minute.

Each sieve must be thoroughly cleaned after each sieve operation in order to avoid loss of material during sieving. The weights from each sieve is recorded on Form 180 for the appropriate sieve size. See example on page 3-45. The total amount retained must be within the 0.5% loss tolerance similar to coarse aggregate (I.M. 303) sieve analysis. Calculate the tolerance for the example. The correct answer is 100%.

The percent retained on each sieve is next calculated by dividing the amount retained on each sieve by the original dry weight and multiplying by 100. These values are recorded

Form 180
12-71

IOWA DEPARTMENT OF TRANSPORTATION

SIEVE ANALYSIS WORKSHEET

Lab. No.	Material	Material	Material
Co & Proj.			
Producer			
Contractor			
Sampled by	Date	Date	Date
Sample Loc.			

COARSE SAMPLE

Orig. Dry Weight	2800	Orig. Dry Weight	Orig. Dry Weight
Dry Wt. Washed Sample	1306	Dry Wt. Washed Sample	Dry Wt. Washed Sample

SIEVE SIZE	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.	Wt. Retd.	% Retd.	% Retd. X _____	% Psg. Final	SPECS.
1 ½"															
1.05"															
3/4"	0	0.0		100.0											
.525"	224	8.0		92.0											
3/8"	490	17.5		74.5											
4	590	21.1		53.4											
8															
Total +4	1304	46.6													
Pan	2														
Total	1306														

FINE SAMPLE

Orig. Dry Weight	1045	Orig. Dry Weight	Orig. Dry Weight
Dry Wt. Washed Sample	965	Dry Wt. Washed Sample	Dry Wt. Washed Sample
Washing Loss	80	Washing Loss	Washing Loss

SIEVE SIZE	Wt. Retd.	% Retd.		% Passing	SPECS.	Wt. Retd.	% Retd.		% Passing	SPECS.	Wt. Retd.	% Retd.		% Passing	SPECS.
			Final					Final					Final		
3/8"															
4	491	–													
8	157	28.2	15.1	38.3											
16	73	13.2	7.0	31.3											
30	94	17.0	9.1	22.2											
50	42	7.6	4.1	18.1											
100	52	9.4	5.0	13.1											
200	32	5.8	3.1	10											
Wash	80														
Pan	24	18.8	10.0												
Total	1045	100.0	53.4												
Less +4	491														
Passing # 4	554														

Date Reptd.	Previous		Date Reptd.	Previous		Date Reptd.	Previous	
Cont. Quantity	Today		Quantity	Today		Quantity	Today	
	To Date			To Date			To Date	
Tested by		Date	Tested by		Date	Tested by		Date

on Form 180. The percent passing each sieve is next calculated and recorded. In the example the 8% retained on the 0.525" screen is subtracted from the 100% which passed the 3/4" screen. The percent passing is calculated down to the No. 4 screen. As a check, the percent passing the No. 4 plus the total percent of +4 retained should equal 100.0% (53.4%+46.6%).

The fine aggregate sample (with at least 500 grams passing No. 4) is subjected to I.M. 302, "Method of Test for The Sieve Analysis of Fine Aggregate."

The values for the percent retained for the fine aggregate are multiplied with the percent passing the No. 4 sieve. For example, the amount passing the No. 4 is .534 for the example. Multiplying by 28.3% the portion retained on the No. 8 sieve, 15.1 percent is obtained as the final percent retained based on the entire sample. This calculation is carried out for all sieves from the No. 8 down through the pan.

The percent passing each of the fine sieves is calculated by subtracting its final percent retained from the percent passing of the next larger sieve. For the example, the percent passing the No. 8 is:

$$53.4\% - 15.1\% = 38.3\%$$

This completes the study of sieve analysis.

CHAPTER 4

AGGREGATE SOURCE INSPECTION

INTRODUCTION

Aggregate source inspection involves monitoring the quality of the material being produced from an approved source. Prior to being designated as an approved source, preliminary testing or production will usually have occurred at the site to establish the potential quality of material obtainable. Although at times further assurance samples are required, most construction aggregates are delivered to a project with the only quality requirement being that they were obtained from an approved source. This can be done because the quality level of an aggregate as measured by soundness or abrasion tests remains essentially the same unless some significant change has occurred, either in the material or in the manner in which it was produced. It is the responsibility of the Materials Inspector to recognize when any such change has occurred and to obtain such samples as necessary to establish the quality of aggregate being produced under the changed conditions. The factors causing change are somewhat different in quarries than in sand and gravel pits and each shall be covered separately.

QUARRIES

There are many reasons why an aggregate from a particular quarry can test differently with respect to quality than that previously produced. Most of these reasons fall into the following categories:

a) Ledge Control: The quarry ledge has not been maintained in the same beds.

b) Lateral Variations: One or more beds in the quarry ledge have changed laterally in quality.

c) Faulted and Dipping Beds: The beds are offset along a fault or have such an irregular surface that the quarrying operation cuts across beds to the extent that the same beds are not always being worked.

d) Deleterious Materials: The quarry ledge has become intruded with pockets or seams of clay or shale and associated weathered material.

e) Production Changes: Production methods have changed to the extent that a similar product is not being obtained.

1.0 LEDGE CONTROL

As an aid in identifying the various beds and/or quality units in a quarry, geologic sections have been prepared for most sources, Fig. 1.1. The various beds are identified by a number and a description. The geologic age of the source is also noted and the relative position of the source age-wise can be found on a time chart such as Fig. 1.2. Every layer or bed or rock in a quarry can be quite different in quality while often times quite similar visibly. Consequently, when material is being

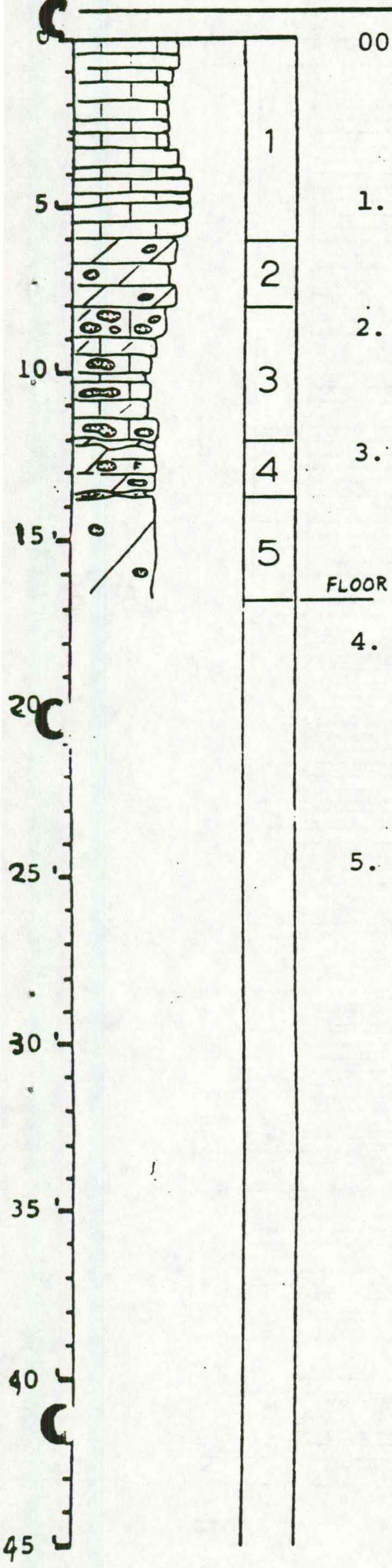
4-3

SW¼ Sec. 23 T. 95 R. 15 Co. Floyd

Peterson 5/6/75

Carville Qr.

Heckman-Reynolds



00: Overburden ±3.0'

CEDAR VALLEY FORMATION
(Coralville Member)

1. Limestone; light brown; medium crystalline; very petroliferous; carbonaceous laminations; thin to platy bedding. ±6.0

2. Dolomite; light brown; coarse crystalline; a few small calcite-filled vugs- as 3 or 4 beds; very hard. 2.0'

3. Limestone; light, pinkish gray; medium crystalline; dolomitic; many large calcit-filled vugs in zones parallel to bedding; flaggy beds 0.3-0.6' thick; upper 1.0' is a distinctive zone of highly concentrated calcite-filled vugs. ±4.0'

4. Dolomite; light, pinkish gray; fine crystalline; many calcite-filled vugs and "birdseye" calcite; a few small pelecypod fragments; as 3 or 4 wavy beds; reddish brown shale parting at the base; irregular reddish brown shaley bed 0.2' thick at top; hard. ±1.6'

5. Dolomite; light, pinkish gray; medium crystalline; has a few small calcite-filled vugs and "birdseye" calcite; massive but fractured; hard. ±3.0'

FIGURE 1.1

STRATIGRAPHIC COLUMN OF IOWA

SYSTEM	SERIES	GROUP	FORMATION	DESCRIPTION	THICKNESS	(MILLION YEARS)
Quaternary	Pleistocene		Wisconsin	loess, glacial till and interbedded sand and gravel	600'	
			Illinoian			
			Kansan			
			Nebraskan			1
Cretaceous		Colorado	Carlile	shale	350'	
			Greenhorn	limestone and shale		
			Graneros	shale		
		Dakota		sandstone and shale	200'	90
Permian(?)			Fort Dodge beds	gypsum, red and green shales in Webster County only	50'	280
Pennsylvanian	Virgil	Wabaunsee	French Creek	shale	210'	
			Jim Creek	limestone		
			Friedrich	shale		
			Grandhaven	limestone		
			Dry	shale		
			Dover	limestone		
			Langdon includes (Nyman Coal)	shale		
			Maple Hill	limestone		
			Wamego	shale		
			Tarkio	limestone		
			Willard	shale		
			Elmont	limestone		
			Harveyville	shale		
			Reading	limestone		
			Auburn	shale		
			Wakarusa	limestone		
			Soldier Creek	shale		
			Burlingame	limestone		
			Silver Lake	shale		
			Rulo	limestone		
			Cedar Vale (includes Elmo bed at top)	shale		
			Happy Hollow	limestone		
			White Cloud	shale		
			Howard	limestone		
			Severy (includes Nodaway coal bed at base)	shale		
		Shawnee	Topeka	limestone	180'	
			Calhoun	shale		
			Deer Creek	limestone		
			Tecumseh	shale		
			Lecompton	limestone		
			Kanwaka	shale		
			Oread	limestone		
		Douglas	Lawrence	shale	110'	
			Stranger	shale		
	Missouri	Pedee	Iatan	limestone		
			Weston	shale		
		Lansing	Stanton	limestone	90'	
			Vilas	shale		
			Plattsburg	limestone		
		Kansas City	Bonner Springs	shale	215'	
			Wyandotte	limestone and shale		
			Lane	shale		
			Iola	limestone and shale		
			Chanute	shale		
			Drum	limestone		
			Quivira	shale		
			Westerville	limestone		
			Cherryvale	shale		
			Dennis	limestone and shale		
			Galesburg	shale		
			Swope	limestone		
			Ladore	shale		
			Hertha	limestone		
		Pleasanton	undifferentiated	shale and sandstone, thin coal beds	40'	
	Des Moines	Marmaton	Lenapah	limestone	145'	
			Nowata	shale		
			Altamont	limestone and shale		
			Bandera	shale		
			Pawnee	limestone and shale		
			Labette	shale		
			Fort Scott	limestone		
		Cherokee	undifferentiated	shale, sandstone, thin limestones and coal	755'	310
Mississippian	Meramec		Ste Genevieve	shale and limestone	140'	
			St Louis	sandy limestone		
			Spergen	limestone		
	Osage		Warsaw	shale and dolomite	250'	
			Keokuk	cherty dolomite and limestone		
			Burlington	cherty dolomite and limestone		
	Kinderhook and undifferentiated		Gilmore City	limestone, oolitic	820'	
			Hampton	limestone and dolomite		
			McCraney	limestone		
			English River	siltstone		
			Maple Mill	shale		
			Aplington	dolomite		
			Sheffield	shale		345
Devonian	Upper		Lime Creek	dolomite and shale	225'	
			Shell Rock	limestone and dolomite		
	Middle		Cedar Valley	limestone and dolomite	270'	
			Wapsipinicon	limestone and dolomites, shales in middle		390
Silurian	Niagaran		Gower	dolomite	300'	
			Hopkinton			
	Alexandrian		Kankakee	cherty dolomite	100'	
			Edgewood	sandy dolomite		425
Ordovician	Cincinnatian		Maquoketa	dolomite and shale	300'	
	Mohawkian		Galena	dolomite and chert	320'	
			Decorah	limestone and shale		
			Platteville	limestone, shale and sandstone	70'	
	Chazyan		St Peter	sandstone	50-230'	
	Beekmantown		Prairie du Chien	sandy and cherty dolomite and sandstone	290'	500
Cambrian	St. Croixan	Trempealeau	Madison[a]	sandstone	188'	
			Jordan			
			Lodi[a]			
			St Lawrence	dolomite		
			Franconia	glauconitic sandstone, siltstone, shale	160'	
		Dresbach	Galesville	sandstone	550'	
			Eau Claire	sandstone and shale, dolomite		
			Mt Simon	sandstone		600*
Precambrian				sediments (sandstones), igneous, and metamorphic rocks		

[a] recognized only in extreme northeast Iowa

Iowa Geological Survey
[illegible]

FIGURE
1.2

produced on the basis of previously established quality, we must be sure that the quarry ledge is in the same beds as before, or if it isn't, that any of the new beds in the ledge are of a quality that will assure specification compliance of the final product.

In quarries where bedding planes are distinct and continuous, it is a simple matter for the producer to maintain a ledge in the same beds and for the inspector to ascertain which beds they are. When there are no good bedding planes the producer can have difficulty remaining in the same beds and the inspector can have difficulty in knowing exactly which beds are being worked.

Satisfactory ledge control can be maintained by applying the answers to the following questions to the source being used.

1.1 Do specifications or special provisions require ledge control? Some materials do, such as coarse aggregate for portland cement concrete and graded stone base. Refer to Appendix A.

1.2 Does the production history indicate that the finished product will be borderline on quality or well within the requirements?

1.3 What is the quality level of the beds which might be added to the ledge?

1.4 Could the additional beds improve a borderline product or cause it to fail?

1.5 Could the additional beds be of such poor quality that they should not be incorporated into the manufacture of any product?

Often, all that is necessary is a proper identification of the ledge being worked so as to compile a dependable production history for the source. When in doubt, always consult the appropriate supervisor. (Go to 3.0)

2.0 Wrong: (Go to Section 1.1)

3.0 Quarries are situated in either "good" or "poor" rock and all the aggregate produced from a particular quarry will be of the same quality. (Select the right answer proceed as directed).

________ True (Go to Section 4.3)

________ False (Go to Section 6.0)

4.0 LATERAL VARIATIONS

Most lateral variations in bed quality are caused by the effects of weathering. Other lateral variations are due to the factors of deposition which were present when the bed was formed. Some geologic units characteristically show very little lateral variation (like the Galena Formation), others show a lot (like the St. Louis Formation). Lateral variations may or may not affect the quality of the bed. Each case has to be evaluated individually.

4.1 Lateral Variations Due to Weathering: Generally, the upper beds of any quarry that are above the ground water table will oxidize to a buff or brown color. They may have been partially dissolved and become quite friable and soft. This can lower the resistance to abrasion considerably but usually has little effect on soundness. Sometimes the clay overburden of a quarry has infiltrated the upper beds to the extent that they become undesirable. Both of these situations can usually be handled satisfactorily on a judgment basis. When uncertain, consult the appropriate supervisor.

4.2 Lateral Variations Inherent to the Rock: These can be caused by actual compositional changes in a bed or by changes in thickness. A 0.2' thick shale bed may increase to a very troublesome 1' or more in thickness, requiring benching and removal, Figure 4.1. A limestone or dolomite bed may suddenly pinch out, becoming replaced by sandstone or some other type of rock. This happens frequently in the Meramecian Formations common in southeastern Iowa, but not too often elsewhere.

More common are compositonal changes characteristic of those geologic formations which contain breccias, angular fragments of rock in generally shaly matrices, Figure 4.2. Breccia thicknesses can vary considerably within the same quarry, often affecting beds in the adjacent quarry ledges. At other times, beds will gradually change in composi-

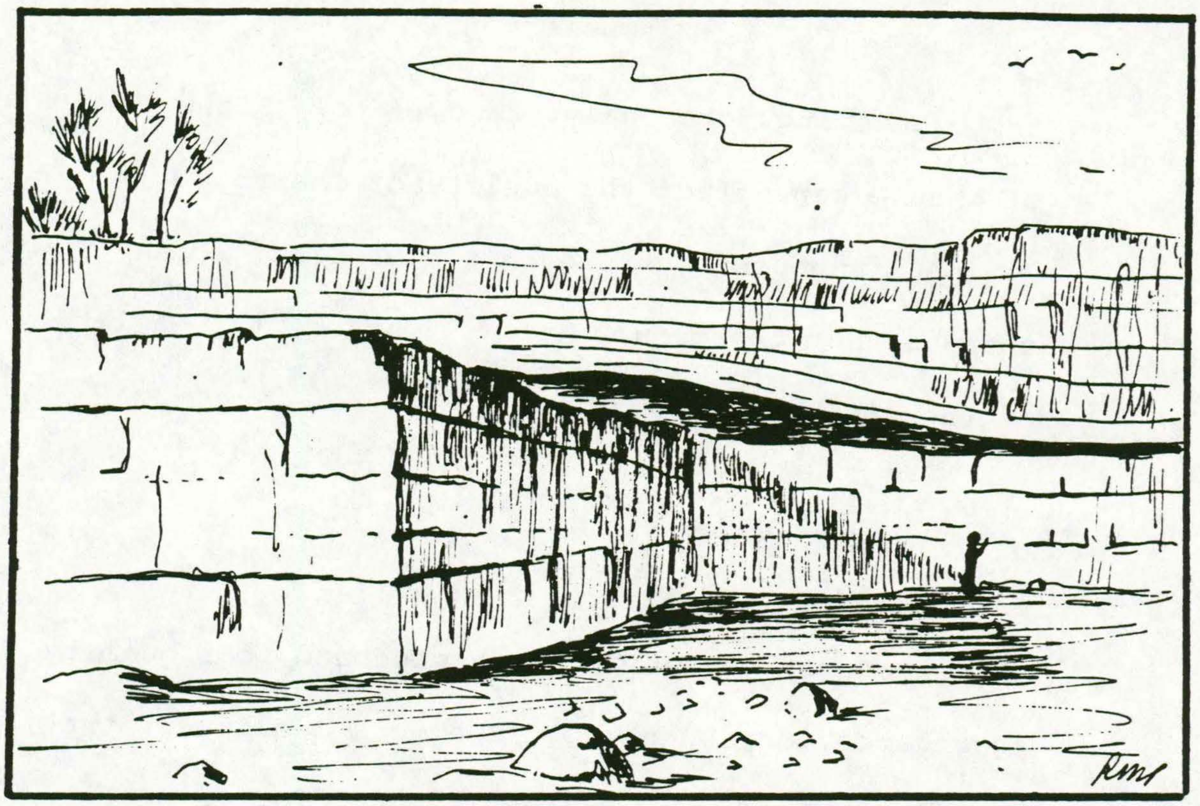


Figure 4.1

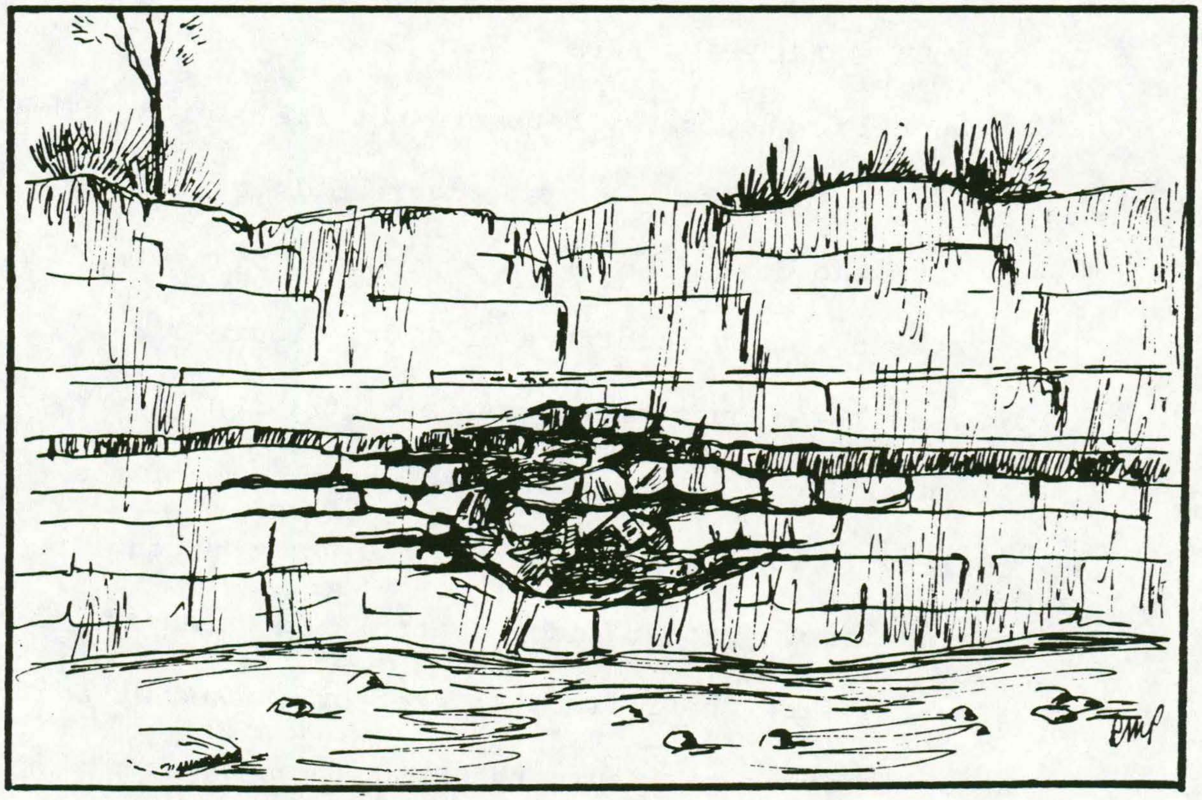


Figure 4.2

tion, becoming more shaly, sandy, etc. Either type of change can affect the quality of the rock.

An inspector must learn and be alert to any changes that can occur that will affect the quality of the finished product.

4.3 Wrong:

A quarry can supply both good and poor quality aggregates, dependent upon the rock quality of the beds in each of its working ledges. (Go to Section 1.0 and try again).

5.0 FAULTED AND DIPPING BEDS

Frequently, the quarry beds are not flat lying. They may dip at a uniform angle, Figure 5.1, or they may roll up and down from 1' to 2' to commonly as much as 8' over a lateral distance of 100', Figure 5.2. When either situation occurs, a flat-lying quarry floor will cut across beds that may not be of the quality level required for the aggregate product becoming made. Proper ledge control might require that a quarry floor be raised, lowered or worked at an angle in order to insure the production of complying material.

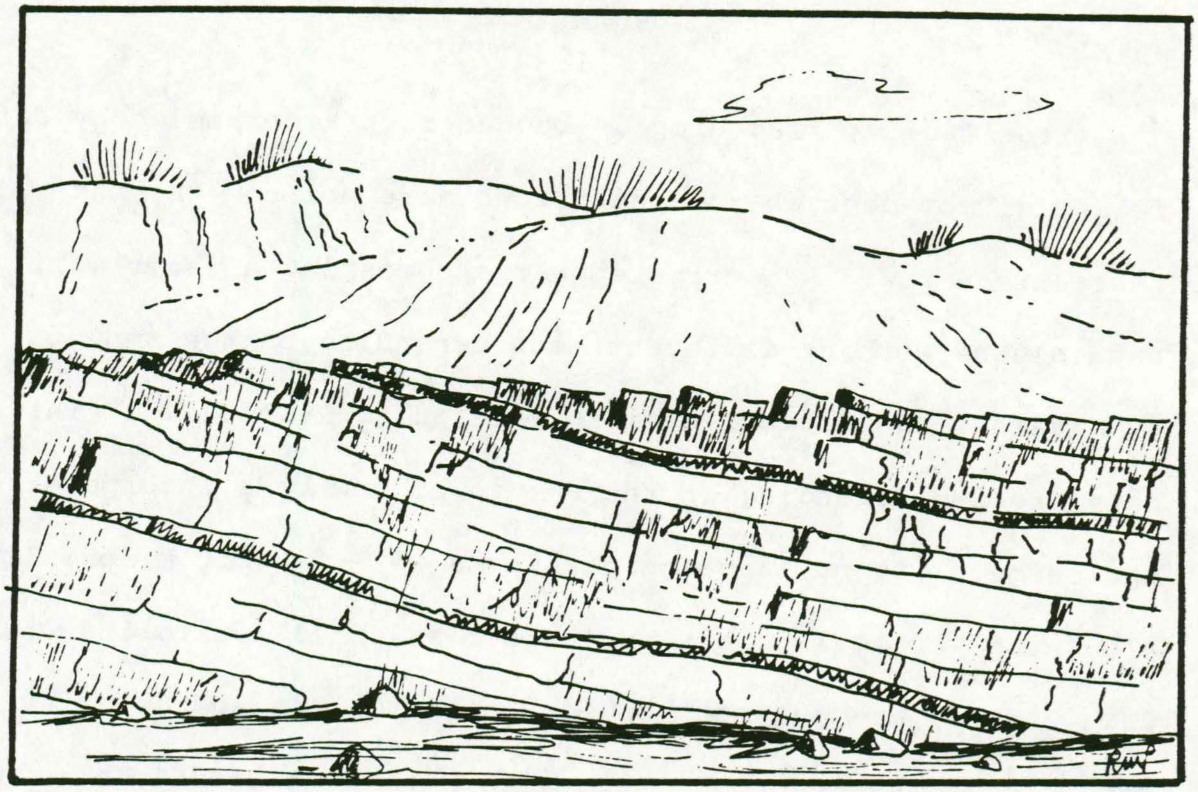


Figure 5.1

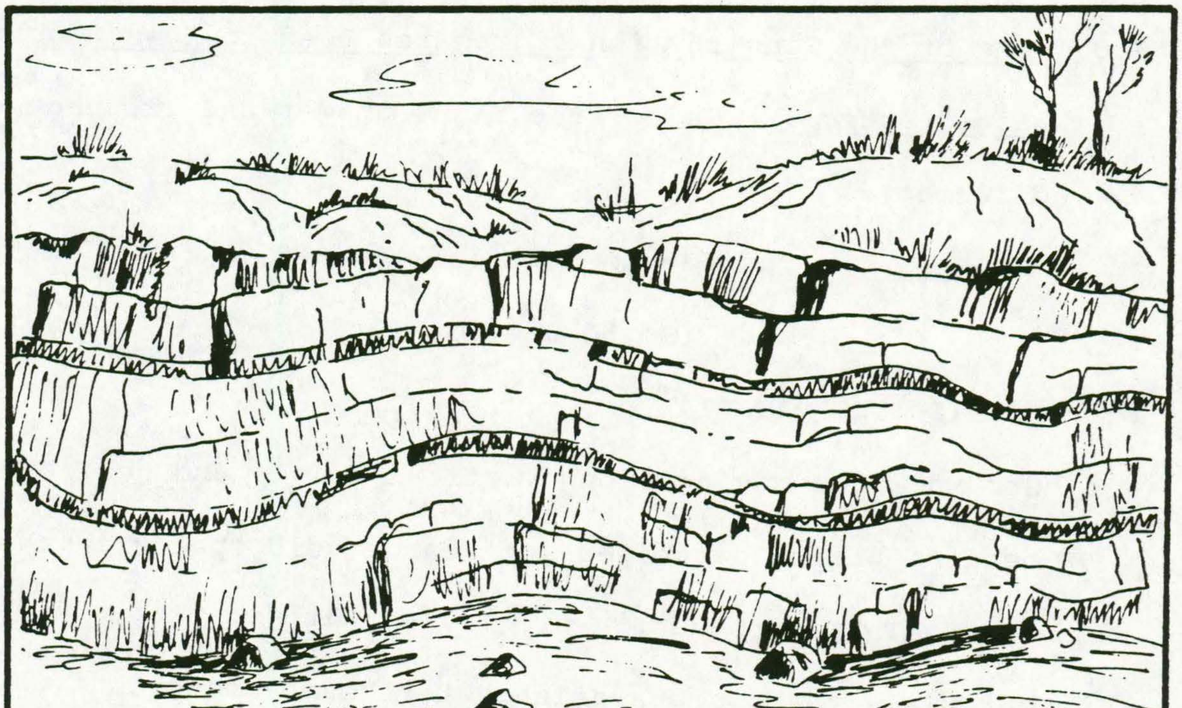


Figure 5.2

True faults, fractures in bedded rock accompanied by differential movement in the fault zone, are not common, but there are a few. A quarry ledge transgressing a fault will suddenly be working different beds depending on the amount of movement that occurred along the fault, Figure 5.3. This can be a problem depending on the nature of new beds incorporated into the ledge. Often, large joint blocks will exhibit minor slippage along the vertical joints and appear as small faults in a quarry face. These are the most common in the Galena and Cedar Valley Formations, massive rock units with well developed joint systems. (Go to Section 7.0).

6.0 Correct: (Go to Section 4.0 and continue)

7.0 None of the Construction aggregates Used in Iowa Require Ledge Control. (Select the right answer and proceed as directed).

_____ True (Go to Section 2.0)

_____ False (Go to Section 10.0)

8.0 DELETERIOUS MATERIALS

Ground water moving along vertical joints and horizontal bedding planes has often left large void spaces in the rock. These frequently are filled with clay or other materials that were available to the moving ground water,

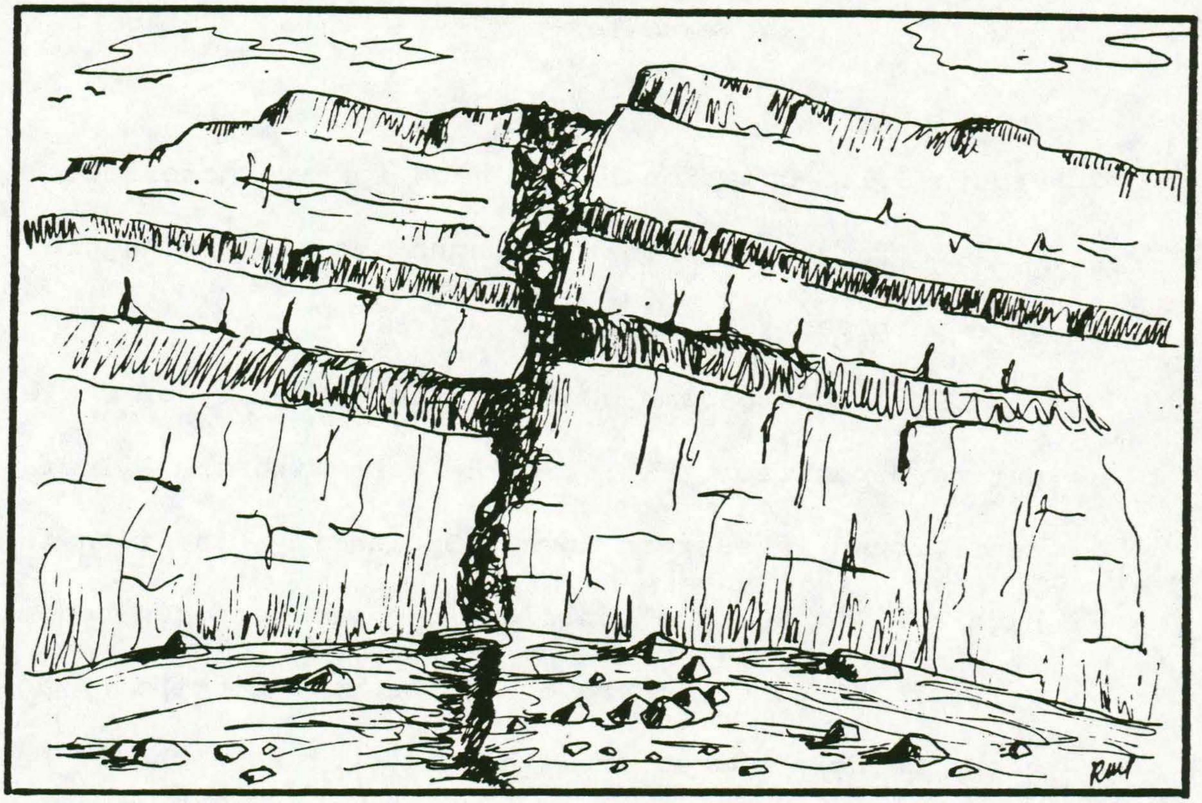


Figure 5.3

Figure 8.1. Occasionally so much foreign material will be in the rock that it cannot be used for aggregate purposes.

Some rock became contaminated with clay or shale during deposition. This is the case with the Silurian reefs found in eastern Iowa. Ordinarily, the rock is of high quality but the contained clay pockers can become very troublesome, Figure 8.2. The clay content of aggregates being produced from this type of rock should be monitored closely when there are limits placed on clay lumps, clay balls, etc.

9.0 PRODUCTION CHANGES

Some products can be made at certain quarries only by benficiating the material during the manufacturing process. For instance, when a quarry ledge consists of beds with argillaceous partings on the bedding planes, the removing or scalping of the minus 3/4" from the primary crusher may remove enough of this material to substantially improve the soundness of the final product. These situations should be documented in the source files, so that any future production employs

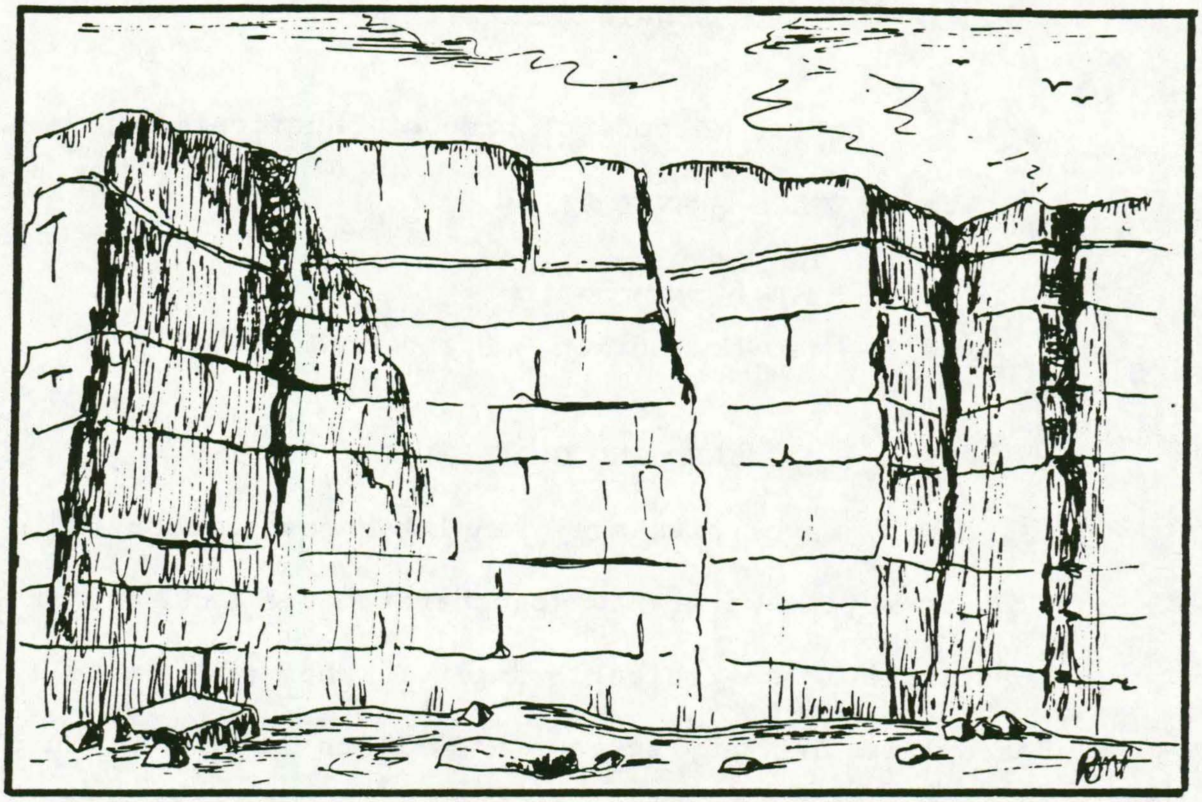


Figure 8.1

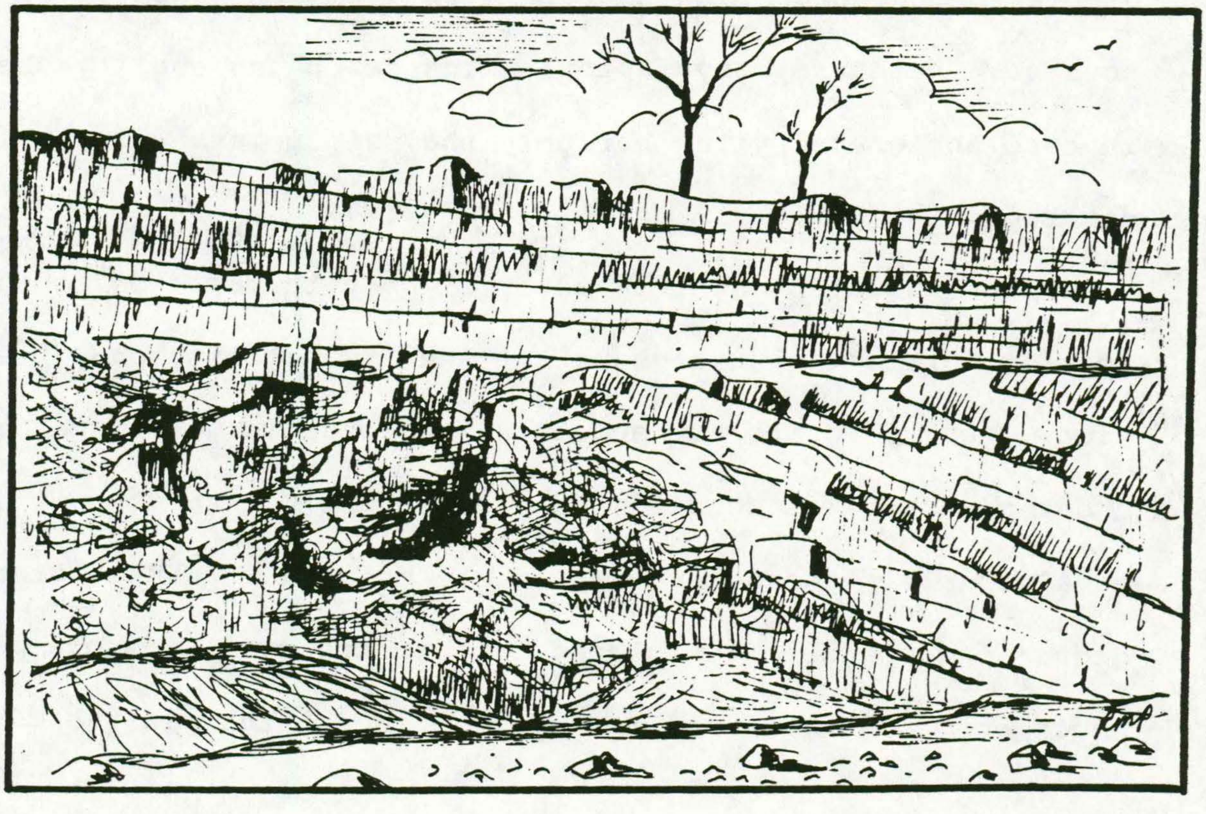


Figure 8.2

equal or better methods of product benefication.

(Go to SAND AND GRAVEL PITS)

10.0 <u>Correct</u>: (Go to Section 8.0 and continue)

SAND AND GRAVEL PITS

Sand and gravel pits are granular deposits located in areas where moving water has concentrated the sand and gravel-size particles in sufficient quantity. They are generally in or adjacent to the many streams and rivers in Iowa or in glacial outwash deposits where the melting glacier ice had generated the water flow necessary to form sand and gravel deposits. There are many factors which can cause quality changes in sand and gravel pits, but only the main points will be covered.

Flowing water deposits material only in relation to the load it carries (always changing) and its velocity and direction. Most deposits are accumulations over long time periods under a variety of conditions. Consequently, the deposit can be alternately coarse or fine, dirty or clean. Thus a greater degree of dependence is placed on the production methods and equipment to give a uniform quality product than in the case of crushed stone. Any change in production equipment or methods, in the area or depth of working, or in the appearance of the product should be noted since any one could signal a changed quality level in the final product.

Most gravel coarse aggregates perform fairly well in pavements because they contain relatively high percentages of extremely durable igneous materials. Combined with the igneous materials are good to poor quality limestones, and of course, the cherts, iron spalls, shale particles and other objectionable materials that frequently cause gravel pavements to have a poor appearance. Held within the specified limits, the objectionable materials will not affect the durability of pavement. The quality of the limestone fraction can affect the durability of pavement but is often overlooked because its combination with the igneous particles generally results in acceptable if not desirable pavement.

When necessary, gravel coarse aggregates can be separated and tested according to rock type using a modification of the ASTM Standard Recommended Practice for Petrographic Examination of Aggregates for Concrete. This can be extremely helpful in identifying the types and amounts of poor quality materials present.