

Petrographic Examination of Natural Concrete Aggregates

L. DOLAR-MANTUANI

Structural Research Department, Hydro-Electric Power Commission of Ontario,
Toronto, Canada

Methods used in the petrographic examination of coarse and fine natural concrete aggregate are described. Features of aggregates, based on their composition, structure, and texture, influencing the quality of a concrete are discussed. In addition to standard petrographic methods the copper nitrate staining test has been found useful for both identification and appraisal of carbonate materials. Attention is also drawn to the need for further testing of special problem aggregates, such as the alkali-silica-reactive or the alkali-carbonate rock-reactive aggregates and those containing clay minerals.

The role of the petrographer is stressed in complementing and interpreting standard acceptance tests designed to determine the suitability of a given material as concrete aggregate.

•AGGREGATES for large concrete structures must be carefully selected in order to minimize service deterioration due to possible aggregate inadequacies. When natural aggregates are used it is sometimes necessary to consider a large number of gravel and sand deposits and rock quarries. Therefore, for quick yet satisfactory indications of the best deposits for intensive study, simple short-term standard acceptance tests which include cursory petrographic examinations are used.

This paper describes petrographic examinations of rocks and minerals that have been applied for many years in the preliminary analysis of aggregates intended for use in both large and small concrete structures by Ontario Hydro (1). The methods outlined reflect the fact that the aggregates examined have been mainly from the Canadian Shield, and from a region of Paleozoic and Cenozoic sediments.

Petrographic laboratories dealing with a considerably greater number of samples than Ontario Hydro, must usually simplify these methods even further. Examples of routine methods are those used by the Ontario Department of Highways and described by Hewitt (6). The methods outlined in this paper may, however, be included in every petrographic examination of concrete aggregate, and may also serve for examination of rocks used in other structural fields where special requirements demand additional examinations or emphasis of other properties.

Basis for Selection of Methods

Although intended mainly to classify and describe materials in their natural state, routine petrographic examinations usually include consideration of their behavior as structural materials. This point is emphasized in the following quotation from ASTM Designation C295-54, Recommended Practice for Petrographic Examination of Aggregates for Concrete (20):

Identification of the constituents of a sample is usually a necessary step toward the recognition of the properties that may be expected to influence the behavior of the material in its intended

use, but identification is not an end in itself. The value of any petrographic examination will depend to a large extent on the representativeness of the samples examined, the completeness and accuracy of the information provided to the petrographer concerning the source and proposed use of the material, and the petrographer's ability to correlate these data with the findings of the examination.

Furthermore, as stated by F. S. Fulton (3): "A knowledge of the ways in which rocks are formed, and of the various natural processes whereby their original characteristics are altered may lead to a better understanding of those intrinsic properties which determine the suitability of a rock also as a source of concrete aggregate."

Requirements for aggregate vary depending on the end use of the concrete. Aggregate characteristics determined petrographically include structure, texture and composition of the aggregate constituents. These may affect desirable properties in the concrete such as compressive and flexural strength, abrasion resistance, toughness, and durability. Durability implies resistance to climatic conditions, such as temperature changes, wetting and drying, and freezing and thawing. The concrete may also need to be especially resistant to heat, or to actions from such sources as polluted air, sulfate waters, organic acids, and alkalis. Concrete aggregates must be both physically and chemically compatible with the other constituents of the concrete.

The properties of aggregates may be either inherent in rocks and minerals or have been acquired through processes of alteration or weathering during geologic time. Material of acceptable quality in its fresh state may in the weathered state be completely unsuitable. The effect of weathering, although very important, is unfortunately difficult to describe and appraise, because the changes in structure, texture, and composition are continuous.

Economy may not be of immediate concern to a petrographer, but it can be the deciding factor in source selection from among two or more materials of equal or almost equal quality.

Numerous physical and some chemical standard acceptance tests are applied in appraising a material for structural purposes, with petrographic examination but one of the required steps. There are two main differences between the two approaches. First, unlike standard acceptance tests, petrographic examinations are not performed in a strictly prescribed manner. Second, petrographic examinations give information on the composition and quality of individual particles, whereas most standard acceptance tests provide data on bulk samples only.

The effectiveness of various petrographic methods depends, of course, on the materials to be studied. Established techniques for sedimentary rocks (Krumbein and Pettijohn, 7) are the most applicable not only because much concrete aggregate is of this origin but also because mortar and concrete products may be considered artificial forms of sandstones and conglomerate or breccias, respectively.

In carrying out petrographic examinations it may be necessary to focus attention on a particular characteristic of a material either because it is needed or because it may be harmful and is difficult to detect. Examples of this would include porosity of vuggy dolomites or of carbonaceous shaly sandstones, or special types of opal or chert in carbonate rocks.

More detailed examinations involving little more time may frequently yield important results. In some instances the petrographic examination will indicate the need for extensive physical and chemical testing to assess fully some potentially deleterious characteristics (10). The size and importance of the proposed structure also greatly influences identification for concrete aggregates.

Whenever possible, materials for structures are compared with materials of known satisfactory records in similar structures. This comparison may have to be based entirely on petrographic methods because no other method can provide such exact identification for concrete aggregates.

Knowledge that proposed and known materials are from the same source is alone usually insufficient to establish the quality of the proposed material, because frequently variations occur both vertically and horizontally throughout deposits. This applies

particularly in gravel and sand deposits. In quarries, composition and quality are usually more uniform. Even if materials in a structure have performed satisfactorily, the older the structure the less likely that present materials from the same general source will correspond exactly to those in that structure. Furthermore, as appropriately pointed out by ACI Committee 621(21), modern concreting techniques may be a factor in a material's suitability, "...it should not be overlooked that unfavorable service of old concrete without entrained air may not accurately indicate performance of concrete with the benefits of proper air entrainment."

For the foregoing reasons, decisions on aggregate materials are based more often on comparisons of economically available materials with other known materials, than on appraisals according to a given standard. Generalized standards cannot reflect the different criteria that should be applied, as these criteria are dependent on the end use of the material. In addition, the reasons for acceptance or rejection of a material or a source for one application may not be valid for other applications.

Petrographic tests often help to explain failures that occur in other tests by revealing the materials which cause failure. From experience gained through examination of materials that have failed in standard acceptance tests, the petrographer becomes more adept at appraising aggregates for structural purposes. The identification of harmful materials in a deposit may lead to recommendations of beneficiation procedures which would make acceptable an originally unsuitable aggregate (8).

Often in the formulation of specifications, petrographic findings make it possible to set limits on permissible quantities of harmful constituents of aggregates to be used for particular structures. The limits are established by using data from previous studies and information on the performance of existing structures. This requires close cooperation between the petrographer and the concrete technologist. The establishment of these compositional limits can be of great value because conformance with them may obviate the need for lengthy physical tests on aggregates.

In general specifications, reference is usually made to certain deleterious aggregate constituents such as coal, lignite, shale, and unsound chert, and the percentage limits tolerated are stated. Checking for conformance with these specifications inevitably involves petrographic examinations, but because the terms used in specifications are too vague for precise identification of the materials, judgment also must be used.

SAMPLING

In large agencies with extensive job specialization, trained field personnel normally do the sampling (14). In special instances involving the geological position of a sample to be tested, or collection of a particular material, a petrographer does the sampling. Procurement and retention of photographs of the exact areas sampled are advisable, especially where working pits or quarries are involved. Visual comparisons by means of such records, of the sampled area with those that may later be developed, may obviate the need for testing samples from the aggregate supply area.

According to long-established practice and in conformance with the specifications used in North America, the No. 4 sieve (4.76-mm size) is used for the first main separation into coarse and fine aggregates. Normally, the samples are separated into fractions by means of standard sieves so that the particles of the different constituents present may be counted rather than weighed.

The size of sample required depends on the maximum particle size of the material available to the petrographer. Often, the coarsest fraction petrographically examined is that specified for the structure. More frequently, however, the coarse aggregates examined are limited to three fractions consisting of gravel or crushed rock in the sizes for standard laboratory acceptance tests—fractions retained on $\frac{3}{4}$ -in., $\frac{3}{8}$ -in., and No. 4 sieves. Usually, approximately 50 lb coarse aggregate and 2.5 lb fine aggregate quartered down from the entire representative sample are sufficient to provide 200 particles of each fraction for petrographic examination. In this way, enough material is available to insure that even the $\frac{3}{4}$ -in. fraction of a normal-weight coarse aggregate and the No. 8 size fraction of fine aggregate contain all essential constituents. If the material is not deficient in one or more size fractions, these quantities of both

coarse and fine aggregate will usually be sufficient for any special petrographic tests or examinations.

Fine and coarse aggregates are always appraised separately because the size of the particles may influence the choice of not only the physical test methods applied but also of the petrographic techniques.

COARSE AGGREGATE: FEATURES AND TEST METHODS

Coating

Before the petrographic examination is started, the aggregate sample is visually inspected to ascertain whether dust is present in an excessive amount. Rock dust adhering to the coarse aggregate as a form of coating (on wet particles in particular) may be crusher dust that accumulates during processing. It may result from insufficient separation of fine pit material, or it may accumulate from soft fine-grained particles that gradually disintegrate. Such accumulations occur more frequently in gravel from pits that contain silty and clayey seams and layers. Silty and clayey material may adhere to gravel surfaces so firmly that it is not removed by normal washing. Dust in excessive amounts may be concentrated in those parts of an aggregate pile that have been stocked longest.

Dust coatings are usually reported as materials passing the No. 200 sieve, and percentage limits are set in most specifications. If information on the amount of dust, where excessive, is not available, the amount is determined in the petrographic laboratory. In such instances and also if the amounts are borderline, additional information on the composition of the dusty coating can be useful. The dusty coating is collected by washing the sample over appropriate sieves, the finest being the No. 200. The wash-water is collected and evaporated, and the residue weighed. Then on an adequate sample of the minus 200 portion, the hydrochloric acid-insoluble test is performed, followed by the barium chloride test for the presence of sulfates. The acid-insoluble residue, mounted on slides, is examined microscopically, special attention being given to any clay minerals present.

The petrographic study of more or less firmly attached coatings is made on single particles by means of a lens or microscope.

Particle Shape

Usually, particle shape, which is most important for crushed aggregates, is the first feature to be determined. This determination and the counting of the 200 particles of each fraction are done together. Because particle shape of the crushed aggregate can be corrected (5), a shape analysis involving detailed measurements is normally not attempted unless the amount of flat and oblong particles, which are undesirable, approaches the permitted limits. Particle shape is classified under two general characteristics (19): roundness, i. e., the particle is rounded, subrounded, subangular or angular; and sphericity (the three-dimensional shape or shape proper) i. e., the particle is cubic, flat or oblong. For a quick determination of the roundness, comparison of the particle shape with appropriate charts is adequate (16). A smooth surface texture might suggest a greater roundness of particles than actually exists. Sphericity can be determined by the use of a simple divider set at a given ratio. The U. S. Corps of Engineers and Ontario Hydro have adopted the ratio 1:3 both for width to length and for thickness to width to distinguish between cubic, and either flat or oblong particles. For road material the ratio 1:4 (22) or 1:5 (23) is required, and the determination of fractured faces is frequently important in the assessment of the roundness of particles. Crushed particles are defined as those which have at least one or two fractured faces (20).

General Observation

The initial megascopic examination of coarse aggregate involves recognition of each essential constituent and determination of its textural and structural features, and also of those accessory constituents the properties of which might determine the quality of

the aggregate as a structural material. A magnifying lens, a hammer, a knife, water, and dilute hydrochloric acid are the simplest aids used. The $\frac{3}{8}$ -in. fraction is found most convenient for first study because this size permits relatively easy identification of the rock constituents as well as of the different materials which may form part of the particle surface.

Although classification of aggregates by composition is a straightforward petrographic procedure, the details required for the different varieties may vary considerably from sample to sample. For aggregates composed mainly of rock of one type such as that obtained from one quarry or an indurated rock excavated from a limited area, more detailed classification of the various features of that particular rock are necessary. The need for details applies also for gravel derived from a pit very uniform in composition.

Surface Texture

Although surface texture no doubt influences the bond of both coarse and fine aggregate particles to cement paste, and accordingly can adversely affect the strength of concrete, standardized techniques for examination of this feature have not yet been developed (15). The description of aggregate-surface textures, based on visual observation, is usually limited to general terms such as granular, crystalline, glassy, polished, smooth, rough, dull, or surface marked. The surface may be described as furrowed and grooved, scratched, ridged, or dented; striated, etched, frosted (minute irregularities), or pitted (larger scattered irregularities) (7).

Visual Estimation of Other Surface Features

In the megascopic examination of aggregates, special attention is given to various objectionable impurities in the rocks or minerals, such as shaly seams, rusty accumulations, inclusions of chert, sulfates and sulfides, and more or less firmly adherent coatings. To evaluate the degree of harmfulness, the amounts of the various impurities are often estimated as percentages of the particle surface, the surface layer being assumed the most important feature in the eventual reaction with the cement paste. Such estimates can be made quickly and with reasonable accuracy, provided that a color difference exists. For proficiency in estimating, experience is essential, and can be acquired by comparison of estimated results with results obtained by the use of adequate visual aids (25), or by comparison of estimated percentages of rock constituents or other parameters in thin sections with those obtained microscopically by the point-count method.

Quality

Although in petrographic studies of an aggregate the influences of the physical and chemical properties of a constituent are usually appraised separately, the presence of a particular constituent may be both physically and chemically undesirable. Furthermore, the same constituent may be harmless under certain conditions but harmful under others, or even beneficial for one purpose but detrimental for another.

Harmful physical properties, evidenced as brittleness, lamination, and friability of constituents, are generally more readily established than harmful chemical properties. Physical properties depend to a great extent on the original structure and texture of the particle, and on the abundance and nature of pores and internal fractures in the material. Special attention must therefore be given to such features as porosity, vascularity, schistosity, presence of micaceous minerals, poor bond between grains and between grain assemblages after weathering, and insufficient cementation. For classification of the physical quality of individual particles the terms used are good or satisfactory, fair, and poor (12).

To appraise physical quality, in the course of routine examinations simple tests are performed on individual particles, for example, light hammer tapping or, for finer sizes, breaking of particles with the fingers. To determine whether particles are soft and/or friable, a varying pressure is applied to break pieces with a hammer, using a rotatory motion. The force exerted depends on the particle size. Rapid absorption of

a water drop on a rock surface may be the first indication that a particle is physically and perhaps also chemically objectionable.

Although subjective, such physical testing substantiates visual findings and has the advantage of involving entire individual particles. It helps to detect the presence of clay or mud balls or other similar incoherent particles and may indicate the degree of weathering of particular constituents of a sample. It may show the need for other specific standard tests to appraise the aggregate's physical quality.

The scratch hardness method (ASTM Test C 235-57, 20) in which individual particles are scratched on several faces with a brass rod that resembles a sharpened pencil may also be applied. The particles remain practically undamaged, thereby permitting the same samples to be tested by other methods. The scratch test with a knife is an important method for quick distinctions between chert and carbonate rocks of the same color, and between dolomite and chert containing carbonate inclusions.

In the classification of an aggregate by chemical quality, the observer must concentrate on unsound materials that are part of the original rock composition or have been produced by various alteration and weathering processes in later stages of the rock's history. Such substances are limonite, clay minerals, chert, certain zeolites (laumontite, heulandite) and volcanic glass. According to the literature, the number of minerals and rocks that contain harmful substances seems to increase from year to year, partially because more nearly exact identification of potentially harmful substances in structural materials is now possible. No doubt some findings on the general quality of rocks and minerals must continuously be revised as new information becomes available. Aggregate constituents are classified chemically as being either innocuous or deleterious, or as suspected of being deleterious if their effects cannot be established exactly.

From the numerical distributions of the various particles in each fraction, tables of aggregate constituents with varieties subdivided according to their expected qualities are prepared. The weighted average for the whole sample is calculated by taking into account the weighted grading.

Staining Method

For speeding up the megascopic identification of the mineral constituents and providing additional information on the quality of an aggregate, staining techniques are very useful. In the structural branch of applied petrography they are mainly conducted on carbonate rocks and minerals. In the staining method used in the Ontario Hydro Laboratory (2), 200 particles of each fraction are immersed at room temperature in a copper nitrate solution¹. Consequently most fractions of a sample are examined in two sets of 200 pieces each, one set by the staining method and the other by routine examinations, each revealing different properties of the same constituents. Therefore, 200 particles for each fraction is considered sufficient for routine examinations, even though the ASTM prescribes petrographic examination of at least 300 particles. (C 295, 20).

The prolonged copper nitrate staining test shows not only the differences between the carbonate and noncarbonate rocks, and between carbonate rock types, the limestones and dolomites, but also in the carbonate rocks it shows the presence, type and development of silicate impurities such as quartz, feldspar grains, chert, and clayey films, seams and accumulations, each of which has a bearing on the quality of aggregates. Not only can these impurities be identified by absence of stain but also shaly accumulations and shaly particles may disintegrate to various degrees. Scaling, splitting, laminating and irregular cracking indicate unsatisfactory quality (Figs. 1 and 2). Examination of the stained gravel fractions before petrographic examination of the unstained sample has proved advantageous because some properties and varieties of the materials are more easily recognized after staining.

¹ Fifty-one grams hydrated copper nitrate, $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$, are dissolved in 200 ml of water. Before washing the specimens in tap water at the end of the test, they are briefly immersed in a strong ammonia solution to stabilize the blue stain produced by the complex copper salts.

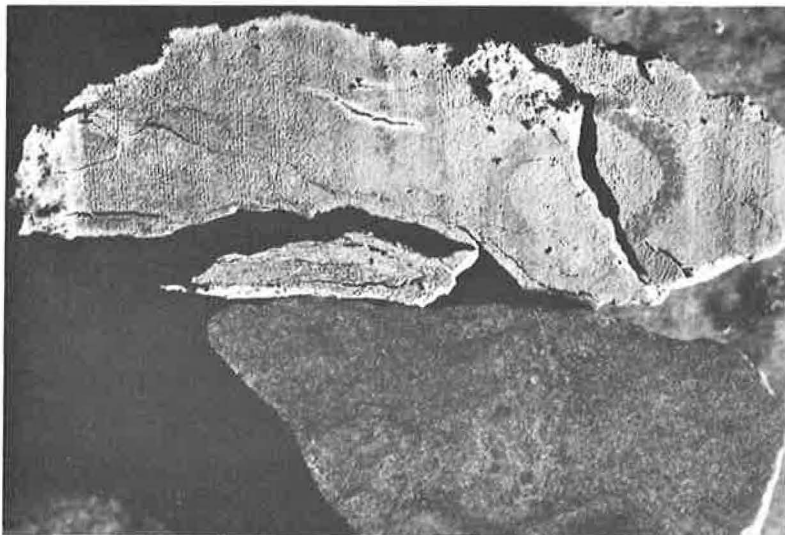


Figure 1. Two pieces of shaly (argillaceous) limestone obtained by cutting through a single particle; lower piece (not stained) with darker shaly, hardly recognizable stripes; upper piece with numerous splits and cracks caused by 16-hr copper nitrate staining test (2). (3.9x)

If a particularly important carbonate material is to be studied or if a carbonate rock is of suspect quality, groups of particles apparently of the same rock variety are stained, or single $\frac{3}{4}$ -in. particles are examined in detail. For the examination of single $\frac{3}{4}$ -in. pieces, a thin section of each particle is prepared, and the staining and the hydrochloric acid-insoluble tests are applied to the remainder of each particle. The acid-insoluble residue is examined microscopically in mounted sections immersed in oils of various refractive indexes and the percentages of the noncarbonate constituents of the rock are estimated.

FINE AGGREGATES: FEATURES AND TEST METHODS

The examination procedures for fine (sand-sized) aggregates are similar to those for coarse aggregates except that handling and observation are more complicated because of smaller particle size. It is understandable that many methods have been developed for dealing with sands, particularly if the specific requirements of the various fields such as stratigraphy, glaciology, and economic geology are considered. For examinations of fine aggregates, however, these methods are normally not entirely applicable, and must be modified to meet the needs of the construction industry.

The fractions into which fine aggregates are commonly separated are those retained on sieves Nos. 8, 16, 30, 50 and 100, and passing No. 100 sieve; the last fraction might be divided into two fractions: that retained on, and that passing No. 200 sieve. Although some of these fractions are usually more abundant than others, examination of only one or two of the more abundant fractions does not suffice. The composition of a sand varies from fraction to fraction, and therefore the results obtained on one or two fractions cannot be extrapolated to include the entire sample. In examinations of sands, especially of the coarser-sized fractions even if present in relatively small amounts, a quite detailed classification of the constituents, particularly of those with a poor record, is frequently required.

Microscopic Examination

The 200 particles for each of the fractions from No. 8 to No. 50 are examined in reflected light under a stereoscopic microscope. Either a special needle of bakelite or a brass needle insulated with a rubber sleeve is used for handling the fine-sized fractions. The fractions No. 50 to passing Nos. 100 and 200 are examined in mounted

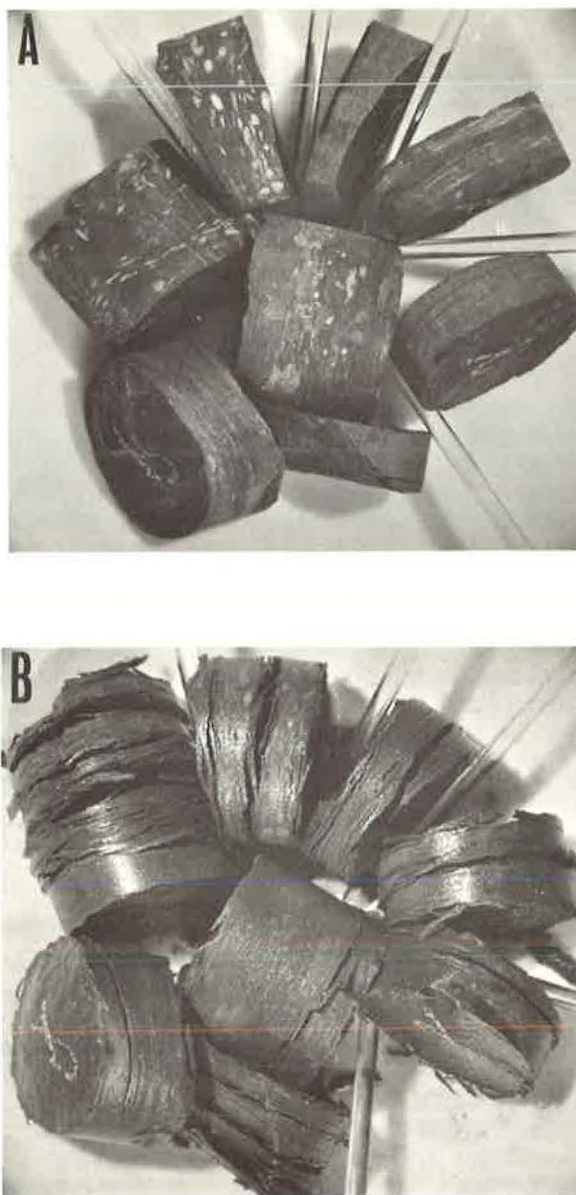


Figure 2. (A) Drill cores of shaly (argillaceous) limestone and calcareous shale. Not recognizable are the amount and development of clayey material in parallel, very narrow seams. White spots are fossil remnants. (B) The same samples, after subjection to an 18-hr copper nitrate staining test. Lamination of shaly seams is clearly visible (2). (0.9x)

sections in transmitted light under a petrographic microscope. Canada balsam is normally the mounting medium but immersion oils may be used instead. cursory examination of a fraction under the same magnification as used for the next finer size has been found useful in preventing overemphasis of some features which are more visible under the greater magnification.

Additional Tests

In addition to microscopic examinations of original material, the copper nitrate staining test is performed on fractions Nos. 8 to 50, inclusive. The lower limit is the

No. 50 sieve size because finer particles are easily lost in subsequent washing. In order to check the results for the finer fractions, the acid-insoluble test followed by the barium chloride test for sulfates are performed on these fractions at least, and may be warranted for all sand-sized fractions if sufficient carbonate constituents are present.

In more exact determinations, for the larger fractions, those particles not easily identified are examined in thin sections obtained by grinding the tops from 2 to 6 particles attached to a glass slide with Canada balsam. Each particle of carbonate rock suspected to be of poor quality may be dissolved in hydrochloric acid on a spot plate. The effects of reaction of the particles with the acid, and subsequently the remaining insoluble residue, are observed with a microscope. For these examinations stained particles can also be used since the blue color is eliminated by hydrochloric acid.

Quality

Classification by quality of the fine-aggregate constituents may be based largely on the results obtained for the larger-sized particles from the same pit; that is for gravel from gravel-sand pits and for the larger-sized sand fractions or the over-size fractions, if available, from a sand pit. If physical quality appears unsatisfactory, the larger sand fractions are examined by rolling each particle under a spatula. In this way some information is obtained on brittleness, and on the more important characteristic, friability. Distinctly poor particles such as clay lumps and slaking shales are recognizable by their disintegration in water. The coarser fractions are much more convenient than the finer ones for appraisal of the chemical quality of sand when this quality depends on products developed in intensely altered and/or weathered rocks.

Studies of gravel-sand deposits have shown that the disintegration of rocks into sand-sized fractions is frequently beneficial because sand fractions usually consist largely of nonharmful mineral constituents remaining from coarse- or medium-grained weathered rocks. This is particularly true for fine sand fractions. Fine sand fractions may, however, contain undesirable rock constituents such as clay lumps, slaking shales, minutely grained shaly carbonate rocks, chert, and volcanic glass. Some constituents may be harmless in very fine particle sizes but extremely harmful in somewhat larger sizes; for example, opal (9). Certain substances such as micaceous minerals may accumulate in the finest fractions and must be classified as physically poor because their perfect cleavage prevents a good bond to the cement paste in concrete.

Knowledge of the fine-aggregate grading is important because the quality cannot be improved by recombination of the original fractions but only by blending with other sands. The percentage and composition of the minus 200 size fraction are determined, because this fraction can have an appreciable influence on the quality of a concrete.

The results of analyses of fine-aggregate samples are recorded as particle counts of the various constituents, except for the minus 100 and minus 200 fractions for which the quantities for the constituents are only estimated. The results are arranged as described for the coarse aggregate.

Investigations of Manufactured Sand

Because of possible concentrations of harmful material in finer portions during crushing, manufactured sand (and especially crusher fines if used as aggregate) require more detailed examinations. A detailed determination of the composition of crusher fines may be advisable even if the fines are not intended for use as fine aggregate. For comparison of crushed aggregate samples of the same rock formation from different quarries or from different layers of the same quarry, a knowledge of the weighted total composition of crusher fines may provide a better basis than appraisal of the coarse fractions of the crushed rock which cannot be examined in the same detail because of their larger size.

SPECIAL AGGREGATES: DETAILED EXAMINATION

Alkali-Silica-Reactive Aggregates

Special petrographic investigations may be concerned with alkali reactivity, manifested by excessive expansion of concrete. Such expansion can be produced by reaction

of chert varieties, silica modifications, acid or intermediate volcanic glass, devitrification products and tuffs of such volcanics, and at least some phyllite (13) with high-alkali cement. Special attention must therefore be given to these substances during any examination of a sample derived from an area suspected of containing such materials.

Alkali-Carbonate Rock-Reactive Aggregate

Particular varieties of carbonate rocks should be added to the list of deleterious aggregates because they cause rapid excessive expansion when used in concrete made with high alkali cement and exposed to humid conditions. These carbonate rocks cannot be identified by standard acceptance tests including those used for establishing excessive expansion, such as the mortar bar test (17). To prevent the use of such highly expansive material in concrete, the development of relatively quick tests that will give reliable results are being studied in various laboratories (4, 18, 24).

Aggregates Containing Clay Minerals

Information on the type of clay minerals present in aggregates such as shales or argillaceous carbonate rocks can be very significant (11). Dependable classification of such clays into the three main groups, the kaolinitic, illitic and montmorillonitic, is usually very time-consuming, however. Fortunately, various tests may be applied to determine if a suspected rock will perform unsatisfactorily because of the amount and type of clay minerals present. In addition to the results of thin-section examinations of suspected rocks and determinations of their acid-insoluble residues in mounted sections, evidence of damage by the prolonged copper nitrate staining and the sulfate soundness tests, and of high absorption, indicate whether the clay minerals will be detrimental.

As further objectionable materials in aggregates are found, new methods for detecting them must be developed and many such methods are started in petrographic laboratories. Frequently these methods become so easily performed and yield such reproducible results that they become standard acceptance tests.

PETROGRAPHIC EXAMINATIONS ASSOCIATED WITH STANDARD ACCEPTANCE TESTS

Often it is desirable to obtain specific information about the composition and fabric of the portion of an aggregate sample that is used for standard acceptance tests. This is feasible, however, for material used for large structures or for special purposes. The task of the petrographer is to examine the sample after, and preferably, also before the acceptance test has been performed to insure that the material used in the various tests is of the same composition as the sample examined petrographically. This step is important because many tests are performed on some fractions only and not on the entire sample.

If acceptance test results are conflicting or unexpected, or indicate that the sample is borderline, additional petrographic information facilitates the decision on acceptance or rejection of a material. Petrographic examinations are mandatory if trends appear that seem related to the location of the sources or to variations in the composition of materials from one source.

In some instances, petrographic examination of a material after acceptance tests have been performed may have little immediate value. Nevertheless, exact identification of any undesirable material may be useful if petrographic examination is later required for quick comparison of seemingly identical materials from the same or nearby sources. The data may provide valuable clues to the types of rocks present in petrologically similar areas. The increasing emphasis now being given to acquiring knowledge of the kind of material that behaves in a particular way, rather than repetition of empirical tests must be considered a forward step.

CONCLUSION

Petrographic examinations complement standard acceptance tests. Such examinations may confirm the results of acceptance tests and indicate not only the additional tests required but also which tests can be omitted. The petrographer greatly accelerates and facilitates the application of information obtained from either good service performance of material that was expected on the basis of laboratory testing, or poor service performance of material that gave good results in physical tests. Petrographic description of a material is not an end in itself, but must be related to the service features required. Constant close cooperation between petrographer and concrete technologist is therefore desirable.

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