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Reliability Study of a Revision of the Modified Los Angeles Rattler Test Using Class "C" Graded Aggregates

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RELIABILITY STUDY OF A REVISION
OF THE MODIFIED LOS ANGELES RATTLER TEST
USING CLASS "C" GRADED AGGREGATES

BY

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RELIABILITY STUDY OF A REVISION

OF THE MODIFIED LOS ANGELES RATTLER TEST

USING CLASS "C" GRADED AGGREGATES

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser　　　　Date

Head, Civil Engineering Department　　　　Date

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INTRODUCTION

General

The concept of "economy" has become a concern to all engineers today. With the increasing demand for better roads and concrete structures, the engineer is forced to search for high-quality building materials. This nation's once vast supply of natural resources is being rapidly depleted because of this great demand.

Mineral aggregates, one such natural resource, are defined as small rocks composed of one or more minerals. The money needed for the purchase and placement of mineral aggregates is a major item in the cost of highway construction. Because of the economic factor, it has become necessary to know the quality of the mineral aggregates used in highway construction.

Characteristics of Aggregate Degradation

Both the producer and the user are concerned with a characteristic of an aggregate that may be best described as "durability." In a broad sense, durability means the ability of the aggregate to remain unchanged over a fairly long period of time in spite of adverse natural processes or forces to which it is subjected.(1) Durability, as it applies to mineral aggregates, means the ability to resist degradation.

Erickson has defined degradation as "A breaking down and/or disintegration of particles of sand, gravel, or stone, primarily due to alteration and subsequent decomposition of their mineral components, accelerated by the action of mixers, mechanical equipment, traffic or the elements." (2) Mechanical degradation is the result of stockpiling, placing, and compacting the aggregate during construction. Such traffic conditions as impact and abrasion may also cause mechanical degradation.

Pauls and Carpenter observed that the principal cause of aggregate degradation results from compaction or the rolling operation during construction.(3) Shelburn found as a result of his research that a bituminous coating gives only slight protection against degradation of the aggregates. Some of the more important results of his studies on the crushing of bituminous-coated surface treatment aggregates under compaction rollers were the following:(4)

1. Aggregates vary in their resistance to crushing as measured by under-roller tests and the Los Angeles Abrasion tests.

2. The rate of degradation is greater in softer aggregate than in harder aggregate and, likewise, is greater in the larger size than in the smaller size aggregate from the same source.

3. From a degradation viewpoint, the use of a smaller size aggregate is more desirable than a coarse size.

4. Particle shape affects the amount of degradation of aggregates as evidenced by the fact that crushed gravels showed approximately 1.3 times the degradation found for uncrushed gravels from the same source.

5. The degradation of aggregates under conditions of mixing, rolling, and traffic, as well as the Los Angeles abrasion machine, approaches a Fuller's curve as an ultimate. This fact suggests a possible trend toward longer gradings and approaching maximum density in design of surface treatment mixtures.

McNaughton discovered that under traffic loads aggregate shift about and rearrange themselves so that they occupy the least possible space. Because of this particle movement, a grinding effect occurs which tends to wear angular aggregate smooth. This wearing of the aggregate produces fines which fill the voids of the structure. Usually there is an increase in strength of the structure as the amount of fines produced increases; however, there is a loss in structural strength if more fines are produced than are needed to fill the voids.(5)

More recently Moavenzadeh and Goetz investigated aggregate degradation in bituminous mixtures, and some of their conclusions are as follows:(6)

1. The gradation of the mixture is the most important factor controlling degradation. Degradation decreases as the gradation becomes more dense.
2. Increase in compactive energy results in an increase in degradation of the mixture regardless of the form of this increase in energy. Degradation is more susceptible to change in magnitude of load than change in repetition of load.

3. When comparing the degradation between rounded aggregate and angular aggregate, it was found that the rounded aggregate can be expected to produce less degradation because the degradation resulting from wear is reduced.

Woolf found through his research that correlations between the loss in the Los Angeles Abrasion test and the strength of concrete indicate that the lower the percentage of wear, the higher the concrete strength.(7) In 1956, Jumper, Herbert, and Beardsley found that for each increment increase of one percent in the Los Angeles Abrasion test, there is a decrease in compressive strength of one percent in the concrete.(8)

All rocks, when exposed for a sufficient length of time to the atmosphere, undergo decay from disintegration and decomposition, together referred to as weathering. Disintegration is the breakdown into small particles by the action of the mechanical agents of denudation, such as rain, frost and wind, all of which are helped by gravity. Decomposition is the breakdown of mineral particles into new compounds by the action of chemical agents, such as acids in the air, rain, and river water.(9)

In 1947, Melville investigated weathering degradation on Route 250 near Charlottesville, Virginia. His investigation found the existence of a plastic layer, as much as one-half inch thick at places, between the road surface treatment and the underlying pavement. The surface treatment layer had been in service only two years, and the aggregate used had passed all requirements of the current Virginia Road Specifications. From this finding he concluded that the layer of plastic fines had resulted from the weathering of the aggregate in the surface treatment.(10)

In 1955, the states of Oregon, Washington, and Idaho also experienced road failures because of the degradation of the aggregates used. Turner and Wilson, working for the Washington Department of Highways, concluded from the results of a petrographic analysis that the aggregates studied were highly altered and that they had high percentages of harmful secondary minerals. This condition was aggravated by high porosity.(11)

Lewis Scott, geologist for the Oregon State Highway Department, defines secondary minerals as "Minerals resulting from alteration of primary minerals. These secondary minerals are formed as the result of deep chemical weathering of igneous rock by ground water, air or dissolved organic acids." The deterioration of the rock varies from partial alteration on the surface or margins of a crystal to the complete replacement of a primary mineral by a less stable mineral which retains the shape of the original crystal.(12)

Rhoades and Mielenz noted that secondary minerals may be introduced in the form of coatings, fracture fillings, intergranular cement, or simply as new interstitial material dispersed throughout the rock.(13)

The decomposition of fine-grained igneous rock is limited to a few families of minerals. The feldspars, which form up to 60 percent of basalts, are altered to Kaolin-type clays and calcite. The clays are unstable and usually extremely hydrophilic. Calcite is water soluble and breaks down readily. The iron-bearing minerals, which may form up to 50 percent of any one basalt sample and which give it its dark color, are altered to limonite, chlorite, and serpentine. Chlorite and serpentine are highly unstable and break down rapidly into clays. Limonite, although more stable, is much weaker structurally than the mineral it replaces.(12)

Minor found from his studies that many rock formations, particularly Eocene basalts, have undergone so much weathering that they are altered to montmorillonite clay. When this altered rock is used in highway construction as a base or surfacing material, the secondary clay mineral, which has a great affinity for water, breaks down into plastic fines. When the plastic fines permeate the base course, the latter loses stability rapidly and pavement failure soon follows. Failure is characterized first by longitudinal cracks in the wheel path followed by "alligatoring" and finally by breaking of the overlying flexible pavement into separate and distinct pieces.(14)

Scott observed that microscopic and field data both show that aggregate below one-fourth inch size are very susceptible to disintegration. He recommended that any aggregate containing more than 35 percent secondary minerals should not be used in sizes less than three-fourths inch. The limit of three-fourths inch is somewhat arbitrary, but very little deterioration has been observed on larger-sized particles.(12) Turner and Wilson made the following correlation between the percentage of secondary minerals present and the field performance of an aggregate:(11)

0-20%	secondary minerals has no effect.
20-35%	secondary minerals will produce some failures.
35-100%	secondary minerals will almost certainly cause failures.

Mica, one of the constituents of granites and schists, aggravates the degradation of the aggregates studied. Because of its thin, sheet-like structure, mica has very weak bonding forces.

Because aggregate degradation is influenced by so many factors, it can be seen that identification of the aggregate properties which cause degradation is a very important part of highway engineering.

History of Degradation Tests

Higgins was the first to recognize the need for tests to measure the quality of aggregates used in highway construction. In 1780 he stated, "I have thought that the small stones, which constitute the gravel chosen for our roads, could not be reduced to dust so soon as they are now by the heavy carriages."(15)

The first abrasion test for stone was developed in 1870 at the Laboratoire des Ponts et Chaussees in Paris. Deval, in 1878, invented a test to determine the resistance of mineral aggregates to abrasion. It was one of the first tests approved by the American Society for Testing and Materials in 1908.(10)

L. W. Page did the first highway research in the United States at Harvard University in 1893. He also introduced a test for the cementing value of broken stone dust and a test for toughness by the Page impact machine.(10)

As the testing of aggregate became a standard practice, several shortcomings became apparent with the Deval method. These shortcomings led the way to the development of the Los Angeles Rattler (LAR) test in 1916 by the Los Angeles City Engineer's Office.(10) This test was simple and rapid; and results were concordant with field conditions as represented by circular track tests.(16) For these reasons the American Society for Testing and Materials adopted the Los Angeles Rattler test as the standard Los Angeles Abrasion test in 1939.(17)

Goldbeck observed in his research that the Los Angeles Rattler test corresponded better with road service results than either the toughness test or the Deval Abrasion test.(18) Woolf noted that there was a definite relationship between the loss in the Los Angeles Abrasion test and the service records of materials used in concrete, bituminous construction and surface treatment.(7)

There have been many attempts made to modify the Los Angeles Rattler Test. These modifications have been attempted because the standard test determines the abrasive characteristics of dry aggregate. However, that test does not produce sufficient plastic fines.

In 1956 at the Washington State Institute of Technology, Turner and Wilson conducted research on modifications of the Los Angeles Rattler test. They attempted three modifications:(11)

1. The number of revolutions were doubled.
2. Different gradations of materials were used.
3. The baffle plate in the drum was replaced with a concave moulding to turn the sample as the drum revolved.

The fines produced by these procedures did not approach those from the ball mill tests in percentage passing the #200 sieve. These results indicated that there was still too much fracture and not enough wear; therefore, further tests with this machine were discontinued.(11)

Ekse and Morris conducted research in modifying the Los Angeles Rattler Test at the University of Washington in 1959. Using standard gradings of aggregate, they conducted tests with the Los Angeles machine using no surcharge of steel spheres. By varying the duration of the tests, they observed the following:(19)

1. The rate of degradation is high during the first hour and then tends to level off as the fine material accumulates.

2. Significant plasticity develops in the fine material after about four hours of abrasion. The fine material then continues to become more plastic as abrasion is continued.

3. Four hours of abrasion time in the modified test produces a percentage of wear approaching that in the standard Los Angeles Rattler test.

4. The percentage of wear resulting from the modified Los Angeles Rattler test is in general increased by about 10 percent if the aggregate is moist or wet rather than dry. Also the tendency to produce plastic fines is accelerated in the case of moist or wet aggregate.

5. When abrasion time was increased to eight hours, it was found that the percentage of material passing the #200 sieve approaches that passing the #12 sieve.

In 1962 the Idaho Department of Highways under the direction of H. L. Day conducted research in developing a test to determine aggregate quality. A 30-pound sample was used in the Los Angeles abrasion machine without using any metal spheres. This test appeared to have merit, particularly because the sample was large and permitted a number of tests to be run on the degraded aggregate. However, this test was abandoned in favor of the wet abrasion process using the Deval machine. (20)

Sibley, working for the Washington State Institute of Technology in 1958, did further research in modifying the Los Angeles Rattler Test. His modification consisted of using a five-pound sample at 20,000 revolutions and using no steel spheres. The wear on the material was obtained solely by allowing the material to slide on the inside face of the drum and to be mixed by the action of the steel shelf.

This method produced the same amount of fines as obtained under field conditions, but the time required for the test was 10.1 hours.(21)

In 1966 Breese, working for the state of Nevada, correlated the results of several degradation tests with the hope of developing a new test.(22) The tests he studied were the air elutriation test devised by Collins, (23) the jar mill test devised by Minor,(14) the Washington degradation test,(24) and the California aggregate durability test.(25)

It is important to note that all four degradation tests use a sedimentation analysis for the fines produced. This sedimentation analysis is based on Stoke's Law which states that the theoretical velocity of vertical settling can be computed by the following formula:(26)

$$V = gd^2 \frac{(D_1-D_2)}{18u}$$

where:
g = acceleration due to gravity, cm/sec/sec
D_1 = density of settling particle, gram/cm^3
D_2 = density of water, gram/cm^3
d = diameter of settling particles, cm
u = dynamic viscosity of water, dyne-sec/cm^2

According to Stoke's Law, larger and more dense particles have a faster settling velocity. For this reason, coarse-grained particles would provide lower sediment heights than fine-grained particles.

In all four degradation tests that Breese studied, a representative sample of the fines produced was poured into a sand equivalent cylinder along with seven milliliters of sand equivalent stock solution. The water level was adjusted to the 15-inch mark, and the cylinder was mixed by inverting it approximately 20 times in 35 seconds. The cylinder was then set aside for 20 minutes after which the sediment height was observed. The poorer quality aggregates, which produce plastic fines, had a higher sediment height than the high quality aggregates. Using the linear regression method of correlation for the degradation factors and sediment heights of all the tests, Breese found that the Washington degradation test produced the highest coefficients of correlation when compared with the other tests.(22)

Platts and Lloyd studied six degradation tests in Alaska. The tests they studied were (a) Oregon air degradation test, (b) California durability test, (c) Washington degradation test, (d) Idaho kneading compactor degradation test, (e) Idaho abrasion degradation test, and (f) the Alaska degradation test. The Washington degradation test was recommended for the following reasons:(27)

1. Test results and field evaluations correlate very well.
2. It has but one numerical value on which to base the quality of any given aggregate.
3. Although similar to the California durability test, it provided more consistent results.

Mathiowetz, in 1968, modified the Los Angeles Rattler test to include wet abrasion, loss determined by a sieve in the aggregate sieve series, and a sediment height test using an acrylic Plexiglas cylinder, 6 inches in diameter by 25 inches high. Some of his conclusions were these:(28)

1. The modified Los Angeles Rattler test appears to be as reliable as the Washington degradation test in determining unsatisfactory aggregates.

2. It is not necessary to sieve out the coarse particles before sedimentation since these settle out very rapidly and have minor effects on the settlement of the fines.

3. The modified Los Angeles Rattler test does not produce as many plastic fines as the Washington degradation test. However, it provides comparable sediment heights.

In 1970 Smith compared the modified Los Angeles Rattler test proposed by Mathiowetz (28) with the standard Los Angeles Rattler test, the Washington degradation test, and the petrographic analysis. The following are some of his conclusions:(29)

1. The modified Los Angeles Rattler test is reliable for distinguishing between desirable and undesirable aggregates and, therefore, could possibly replace the standard Los Angeles test, the Washington degradation test, and the petrographic analysis.

2. The Washington degradation test does not appear to degrade lightweight aggregate as much as the modified Los Angeles Rattler test.

3. The modified Los Angeles Rattler test compared with the petrographic analysis better than did the Washington degradation test.

4. The modified Los Angeles test results can be reproduced to within the tentative limits of $\pm$ one percent abrasion loss and $\pm$ 1.25 inches in the sediment height.

5. The advantages of the modified Los Angeles Rattler test are these:
   a. Sample preparation is simple and quick.

b. Total time to perform the test is usually less than one man-hour.

c. The test sample is five times as large as the Washington degradation test sample. This larger sample increases the probability of obtaining more representative results.

Since 1936 all aggregates to be used in construction on Bureau of Reclamation projects have been examined and analyzed petrographically as a part of the basis for their selection. The petrographic examination is performed not only to determine the potential degree of reactivity of the aggregates but also to establish their physical quality.(30) The Corps of Engineers has used petrographic analysis in their work since before 1940.(31) The American Society for Testing and Materials in 1954 adopted a standard procedure for the Petrographic Examination of Aggregates for Concrete.(17-233) The objections to the petrographic examination are that it is time-consuming, that it requires the services of a trained petrographic expert and that it is not adaptable to field laboratory use.

Objectives of Investigation

The objectives of this investigation were:

1. To compare the modified Los Angeles Rattler test proposed by Mathiowetz with the standard Los Angeles Rattler test, the Washington degradation test, and the petrographic analysis, using a "C" gradation of the aggregate.

2. To identify minerals which may cause road failures.

3. To determine the reproducibility of the modified Los Angeles Rattler percent loss and sediment heights using "C" gradation.

MATERIALS AND TESTING PROCEDURES

Aggregates Tested

In this study aggregate tests were conducted on 60 samples furnished by the National Forests in Region 1. These samples were obtained from the states of Montana, Idaho, and Washington, and consisted of crushed basalt, siltstone, quartzite, granite, granodiorite, schist, or gneiss. Petrographic analysis was used to determine the major minerals or rocks that composed 51 of the 60 samples tested, and the results of this analysis are listed in TABLE 1. Additional crushing of the samples was necessary in order to obtain a "C" gradation for the modified Los Angeles Rattler test.

Old and New Washington Degradation Tests

The procedure for the Washington degradation test is as follows: (24)

The material to be tested should be crushed to pass the 1/2-inch sieve, washed over a #10 sieve and dried to constant weight. Make up samples graded as follows:

1/2" - 1/4"	500 grams
1/4" - U. S. #10	500 grams

Place sample in a 7 1/2-inch diameter by 6-inch high plastic canister (Tupper Ware), add 200 cc water, cover tightly, and place in a Tyler Portable Sieve Shaker. (Soiltest #CL-300, suitably motorized to provide agitation described below.)

Run shaker for 20 minutes at 300±5 oscillations per minute with a 1 3/4-inch throw on the cam. At the conclusion of the shaking time, empty the cannister into nested #10 and #200 sieves, placed in a funnel, over a 500 ml graduate to catch all water. Wash out the cannister and continue to wash the aggregate with fresh water until the graduate is filled to the 500 ml mark. Caution: water adhering to the aggregate may drain 50-100 ml after washing has been stopped.

Pour 7 ml of sand equivalent stock solution into a sand equivalent cylinder. Bring all solids in the wash water into suspension by capping the graduate with the palm of the hand and turn the cylinder upside down and right side up as rapidly as possible about 10 times. Immediately pour the liquid into the sand equivalent cylinder to the 15-inch mark and insert the rubber stopper in the cylinder.

Mix the contents of the sand equivalent cylinder by alternately turning the cylinder upside down and right side up, allowing the bubble to traverse completely from end to end. Repeat this cycle 20 times in about 35 seconds.

At the conclusion of the mixing time, place the cylinder on the table, remove the stopper and start the timer. After 20 minutes, read and record the height of the sediment column to the nearest 0.1 inch.

The only difference between the old and the new Washington degradation test is that in the old test the aggregate retained on the #10 and the #200 sieves is placed in the oven until dry. After drying, the aggregate is sieved and the weights retained on these sieves are recorded. Loss through each sieve is determined by subtraction from the original weight and recorded to the nearest gram.

Calculation of the Washington Degradation Factor is as follows:(24)

Old formula

$$D = \left[0.3\left(1.00 - \frac{L_{200}}{L_{10}}\right) + 0.7\left(\frac{6-0.4H}{6+0.6H}\right)\right] 100$$

Where: D = old Washington Degradation Factor
H = height of sediment (floc) in tube
L_{200} = grams lost through #200 sieve
L_{10} = grams lost through #10 sieve.

This formula gives a weight of 30 percent to the ratio of the loss through the #200 and the #10 sieves, and a weight of 70 percent to the quality of the fines as determined by the cleanness portion of the test.

New formula

$$D = \left(\frac{15 - H}{15+1.75H}\right) 100$$

Where: D = new Washington Degradation Factor
H = height of sediment (floc) in tube

As can be seen, this formula is based entirely on sediment height.

In both formulas the values may range from 0 to 100, high values being the best materials. The formulas were adjusted to place doubtful materials at about the midpoint on the scale. Region 1, U. S. Forest Service, has set the minimum passing Washington Degradation Factor at 25 for road surfacing aggregates.

The Washington Degradation Factors were determined at the Materials Testing Laboratory, United States Forest Service, Region 1, Missoula, Montana. The sediment heights for the Washington degradation test, which were not furnished, were calculated by Smith (29) and this writer using the new formula. These data are shown in TABLE 2.

Standard Los Angeles Rattler Test for "C" Graded Aggregates

The standard Los Angeles Rattler test procedure according to the American Society for Testing and Materials is as follows:(17-92)

The test sample shall consist of clean aggregate representative of the material being tested, and oven dried to substantially constant weight. The weight of the sample prior to testing shall be recorded to the nearest gram. Use a "C" graded material. This consists of 2500 grams of material passing the 3/8-inch sieve and retained on the No. 3 (1/4-inch) sieve plus 2500 grams passing the No. 3 sieve and retained on the No. 4 (4.76-mm) sieve. The abrasive charge consists of eight steel spheres having a total weight of 3330 ± 20 grams.

The test sample and the abrasive charge shall be placed in the Los Angeles Rattler testing machine and the drum rotated at a speed of 30 to 33 revolutions per minute for 500 revolutions. After the prescribed number of revolutions, the material shall be discharged from the machine and sieved on a #12 sieve. The material coarser than the #12 sieve shall be washed, oven dried to substantially constant weight, and weighed to the nearest gram. The difference between the original weight and the final weight of the test sample shall be expressed as a percentage of the original weight. This value is normally thought of as the Los Angeles Rattler number or percent loss.

These values may range from 0 to 100, the lower values representing the better materials. A maximum passing number for the standard Los Angeles Rattler test has been specified as 40 for surface courses and surface treatment. A maximum passing number of 50 has been established for concrete and base courses for concrete pavements.(17)

All the standard Los Angeles Rattler numbers were determined by this writer at the Civil Engineering Laboratory, South Dakota State University, Brookings, South Dakota. TABLE 3 includes these values.

Modified Los Angeles Rattler Test for "C" Graded Aggregates

The following is the modified Los Angeles Rattler test procedure used in this study:

1. Prepare the sample in the same manner as required for the standard Los Angeles Rattler test using "C" grading.
2. Place the test sample and the abrasive charge into the Los Angeles testing machine. Rotate the machine for 500

revolutions with the aggregate dry. Add 1000 ml of water and rotate for 250 additional revolutions. A flat rubber gasket was cemented to the cover of the machine to render it watertight.

3. Wash the entire contents of the machine into a large pan placed beneath the machine. Then, wash the entire contents of the pan into the large graduated cylinder previously prepared with 25 ml of sand equivalent stock solution. The cylinder used is constructed of acrylic Plexiglas, 6 inches in diameter by 25 inches high. (See Figure 1)

4. After initial settling of the particles, adjust the water in the cylinder to the 20-inch mark by adding or draining water. Cap the graduated cylinder and mix by inverting from end to end 20 times within 30 seconds. Suspend a thermometer at the 10-inch mark in the solution and allow the floc to settle in an area not subject to direct sunlight.

5. After 20 minutes read the water temperature to the nearest 0.1 of a degree centigrade and record the sediment height to the nearest 0.1 inch.

6. Wash the entire contents of the cylinder over a #30 sieve and dry the portion retained on the sieve to constant weight.

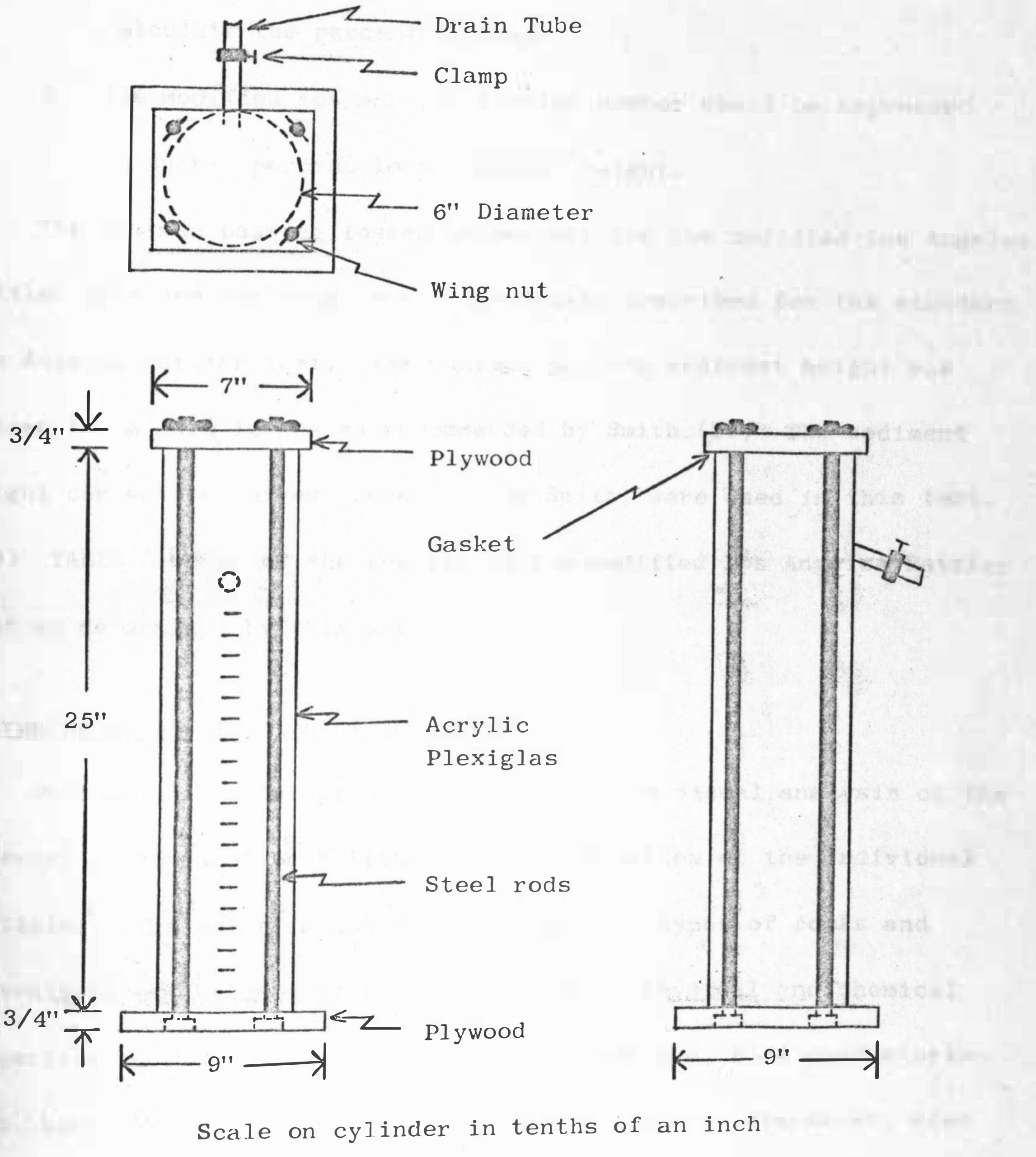

FIGURE 1. Sediment Height Cylinder for Modified Los Angeles Rattler Test

7. Sieve the dry part over a #16 sieve and weigh the amount retained. Subtract this weight from the original weight and calculate the percentage loss.

8. The modified Los Angeles Rattler number shall be expressed as such: percent loss/sediment height.

The maximum passing losses in percent for the modified Los Angeles Rattler test are the same as was previously described for the standard Los Angeles Rattler test. The maximum passing sediment height was chosen to be 13.0 inches as recommended by Smith.(29) The sediment height correction curves, developed by Smith, were used in this test. (29) TABLE 3 contains the results of the modified Los Angeles Rattler Test as determined by this writer.

Petrographic Examination of Aggregates

Petrographic examination of aggregate is a visual analysis of the material in terms of both lithology and properties of the individual particles. The relative abundance of specific types of rocks and minerals is established by this examination. Physical and chemical properties such as particle shape, surface texture, pore characteristics, hardness, and potential alkali reactivity are determined; also the presence of contaminating substances is established.(17-233)

Dr. Donald W. Hyndman, at the University of Montana, performed the petrographic analysis on 51 of the 60 samples tested.(32)

Sample Nos. 3040, 3041, 3052, 3111, 3112, 3113, 3114, 3142, and 3225 were not available for this analysis. The major minerals or rocks that composed each of the 51 samples tested are recorded in TABLE 1. Dr. Hyndman also determined if the aggregate samples were acceptable as road aggregates; and those that failed are listed in TABLE 4.

DISCUSSION OF TEST RESULTS

The main objective of this study was to determine whether the modified Los Angeles Rattler test, singly, can identify low quality aggregates which now requires the standard Los Angeles Rattler test, the Washington degradation test, and a petrographic analysis. The following shows how the results from the modified Los Angeles Rattler test compared with the results of the other three tests.

A rank-difference method of correlation (33) was applied to the results of three of the four tests. It could not be applied to the petrographic analysis results because the specimens were not given a numerical value under this examination. For the rank-difference correlation, the results of the three tests were ranked in order from high quality to low quality aggregates. (See TABLE 5) The sediment height and percent loss portions of the modified Los Angeles Rattler test for both "B" and "C" gradations were used in this correlation.

The correlation coefficient, p, was 0.968 between the standard LAR test and modified LAR test using the "C" gradation of the aggregate. The coefficient was 0.871 for these same two tests using the "B" gradation. Both of these coefficients are quite high and, therefore, significant. It is thought that the 1000 ml of water used in the modified Los Angeles Rattler test caused enough additional degradation to offset the use of the #16 (1.19-mm) sieve instead of the #12

(1.68 mm) sieve, which is used in the standard Los Angeles Rattler test.

The correlation coefficient between the modified LAR sediment height, "C" gradation, and the Washington degradation test was 0.773. However, between the modified LAR sediment height, "B" gradation, and the Washington degradation test, a 0.709 coefficient was obtained. It is thought that the additional 250 revolutions of the dry aggregate during the testing of the "C" gradation of the samples may explain why there is a higher correlation between the "C" gradation than the "B" gradation when both are compared to the Washington degradation test. Since the modified LAR test includes abrasion and impact to produce plastic fines, these additional revolutions through additional abrasive and impact forces, may have produced the necessary increase in plastic fines to give the "C" gradation test a closer correlation with the Washington degradation test. It was noted that 46 of the 51 samples compared showed a higher sediment height for the "C" gradation than the "B" gradation, which again may be explained by the additional 250 revolutions in the "C" gradation tests. A correlation coefficient of 0.771 was obtained for the comparison between the modified LAR sediment height, "C" gradation test, and the modified LAR sediment height, "B" gradation test. A coefficient of 0.829 was found between the modified LAR percent loss, "C" gradation test, and the modified

LAR percent loss, "B" gradation test. These correlations are also quite substantial.

The standard LAR test yielded only one specimen higher and 58 specimens lower in percent losses than the modified LAR test. There was an average difference of 5.61 percent abrasion loss between the two tests. It was felt that this large difference between the percent losses resulted from the 250 additional revolutions of the modified LAR test.

The Washington degradation test has proven its reliability in detecting those aggregates which produce plastic fines. It is thought that the modified Los Angeles Rattler test may be as reliable, since both tests use a sedimentation analysis. A polynomial regression correlation (34) was used between the Washington degradation sediment height and the modified Los Angeles Rattler sediment height. It was observed that the parabolic equation, $Y = -0.322 -0.146 +0.047X^2$, provided the best index of correlation, i = 0.798, as is shown by the line in FIGURE 2. Eighteen specimens failed the modified LAR sediment height analysis, but only fifteen failed the Washington degradation sediment height analysis. The Washington degradation test relies entirely on the sediment height analysis.

Of the 60 samples tested, 22 passed all four tests, 7 failed the standard Los Angeles Rattler test, 14 failed the percent loss portion of the modified Los Angeles Rattler test, 18 failed the sediment

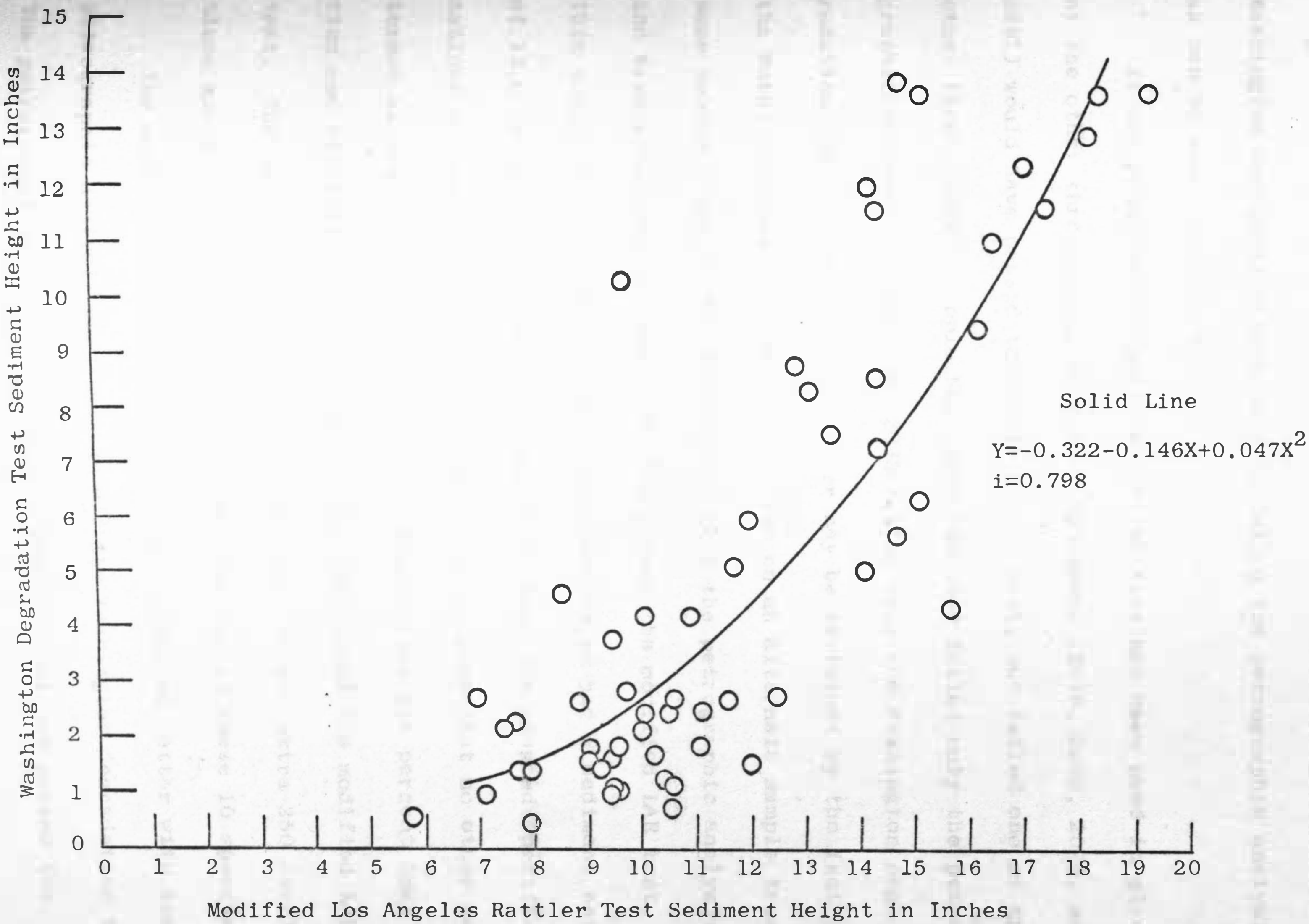

FIGURE 2. Washington Degradation Test Sediment Height vs Modified Los Angeles Rattler Test Sediment Height

height portion of the modified Los Angeles Rattler test, 15 failed the Washington degradation test, and 12 failed the petrographic analysis as can be seen in TABLE 4.

If the modified Los Angeles Rattler test had been used in place of the other three tests, only four specimens (2076, 2080, 2096, and 2561) would have passed the modified LAR test, but failed one of the other three tests. Sample Nos. 2076 and 2080 failed only the petrographic analysis. Sample No. 2096 failed only the Washington degradation test; however, this failure may be explained by the fact that the Washington degradation test was run on an alternate sample from the same source. Sample No. 2561 failed both the petrographic analysis and Washington degradation test, but passed the modified LAR test. This sample was in the "unsure" range because it had a sediment height of 13.0 inches and percent loss factor of 35. The adopted specifications of the modified LAR test failed 10 samples that no other test termed as failing. Of these samples, four failed the percent loss portion and six failed the sediment height portion of the modified LAR test. The additional fine material produced by the extra 250 revolutions may explain why the modified LAR test failed these 10 specimens.

The modified Los Angeles Rattler test compared better with the petrographic analysis results than did the Washington degradation test. The petrographic analysis failed five samples that had passed the

Washington degradation test compared to only three samples passed by the modified Los Angeles Rattler test.

The modified Los Angeles Rattler test failed, by percent loss, all the specimens that had failed the standard Los Angeles Rattler test. It also failed seven additional samples that the standard LAR test had not failed. These additional failures may have resulted because of the water present and/or to the extra 250 revolutions in the modified test.

Sample Nos. 1887, 2760, and 3225 failed both the modified Los Angeles Rattler test and the Washington degradation test. Based upon these tests, it is believed that these specimens would have also failed the petrographic analysis had they been available for examination.

Igneous or metamorphic rocks such as pegmatite, aplite, gneiss, granite, or schist were the main rocks to fail, by percent loss, the standard and modified Los Angeles Rattler tests. The primary minerals composing these igneous and metamorphic rocks are quartz, plagioclase, muscovite, and orthoclase. These minerals belong to the mica and feldspar groups of silicate minerals. It was observed that the aggregates which settled quickly during the sedimentation analysis of the modified LAR test were from the mica and feldspar groups of minerals.

The sedimentary rocks that were found unsuitable by both the modified LAR test and the Washington degradation test were primarily limestone, shale, sandstone, and siltstone. The primary minerals which composed these sedimentary rocks were quartz, calcite, illite, and orthoclase. These aggregates produced a large amount of plastic fines during the testing. All but two of the 12 specimens which had sediment heights above 14.0 inches in the modified LAR test contained two or more minerals common in sedimentary rocks.

It is of interest to note that Sample Nos. 2148 and 2584, both composed of quartzite, had extremely high sediment heights, 19.1 and 17.3 inches respectively. This large amount of plastic fines may be explained for Sample No. 2148 by the fact that it contained a few parallel veins of shale. Sample No. 2584 did not contain any minerals common to sedimentary rocks, and the reason for the high sediment height is unknown.

A strong advantage of using the 500 revolutions with the aggregate dry plus 250 revolutions with water added is that the entire standard Los Angeles Rattler test is a part of the modified Los Angeles Rattler test. When an aggregate is to be tested, the standard LAR test can be run on the sample first. If the aggregate fails the standard LAR test, the modified LAR test need not be run. However, if the aggregate passes the standard LAR test, the modified LAR test can then be run on the sample. This procedure is not possible if only 250 revolutions of the dry aggregate are used before the wet portion of the modified LAR test is run.

To determine the reproducibility of the modified Los Angeles Rattler test, 10 samples were run twice. It was found that the sediment height could be reproduced to an average of $\pm$ 1.75 inches with a range from 0 to 4.6 inches. The 10 samples tested varied by an average of 3.2 percent abrasion loss with a range from 0 to 14 percent. Sample No. 2563 (1977) had two cans of aggregate for testing and upon inspection it was discovered that each can contained a different type of rock with apparently different mineral compositions. This discovery explains why there was such a large difference in reproduction of this sample. Excluding Sample No. 2563, it was found that the sediment height could be reproduced to an average of $\pm$ 1.43 inches with a range from 0 to 3.7 inches. The abrasion loss could be reproduced to an average of 2 percent with a range from 0 to 5 percent. The above shows that the modified LAR test can be reasonably reproduced.

Since 5000 grams is used in the modified Los Angeles Rattler test while only 1000 grams is used in the Washington degradation test, the results of the modified LAR test should be more representative of the quality of the aggregate. Better reproducibility is normally achieved using a larger sample.

CONCLUSIONS AND ADVANTAGES

Conclusions

This research study has led to the following conclusions:

1. The modified Los Angeles Rattler test using class C graded aggregate is reliable in distinguishing between high quality and low quality aggregates and, therefore, could possibly replace the standard Los Angeles Rattler test, the Washington degradation test, and the petrographic examination.
2. A more favorable comparison was noted between the modified Los Angeles Rattler test and the petrographic analysis than between the Washington degradation test and the petrographic analysis.
3. The 250 additional revolutions used in the "C" gradation tests gives the modified Los Angeles Rattler test a better comparison with the results of the Washington degradation test.
4. It is confirmed that the micas and feldspars are the primary minerals that cause degradation.
5. Based upon 10 samples, the modified Los Angeles Rattler test can be reproduced within the limits of ± 1.43 inches in the sediment height and ± 2 percent abrasion loss.

6. A correlation coefficient of 0.968 was found between the standard Los Angeles Rattler test and the modified Los Angeles Rattler test. A coefficient of 0.798 was obtained between the modified Los Angeles Rattler test sediment height and the Washington degradation test sediment height.
7. A correlation coefficient of 0.771 was obtained between the modified LAR sediment height, "C" gradation test, and the modified LAR sediment height, "B" gradation test. A coefficient of 0.829 was obtained between the modified LAR percent loss, "C" gradation test, and the modified LAR percent loss, "B" gradation test.

Advantages

Advantages of the modified Los Angeles Rattler test are:

1. Testing time usually requires about one man-hour.
2. Since the standard LAR test is a part of the modified LAR test, the standard test can be run first on a sample. If the sample fails the standard test, the modified test need not be run. However, if the sample passes the standard test, the modified test can then be finished on the aggregate sample.
3. Because the testing sample is five times larger than the Washington degradation test sample, there is a greater probability of obtaining more representative results.

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APPENDIX

TABLE 1

PETROGRAPHIC EXAMINATION OF AGGREGATES

Sample No.	Percentage of Major Rocks or Minerals	Type of Major Rocks or Minerals
1801	35	quartz
	30	plagioclase(albite)
	30	orthoclase
	5	carbonate(dolomite)
1805	52	muscovite
	28	quartz, plagioclase
	10	biotite
	10	carbonate
1887	UNAVAILABLE	
1909	62	glass(densely clouded with ilmenite)
	30	plagioclase(feldspar) labradorite
	4	chlorophaeite
	3	olivine
	1	bowlingite
1922	50	quartz, feldspar
	45	chlorite
	3	calcite
	2	muscovite
1953	33	calcite-cemented quartz siltstone
	33	soft, non-calcareous maroon shale
	33	moderately soft shale to siltstone

TABLE 1 (Continued)

Sample No.	Percentage of Major Rocks or Minerals	Type of Major Rocks or Minerals
1959	40	plagioclase(bytownite: very high in Ca)
	40	glass(high SiO_2)
	15	augite
	3	magnetite or ilmenite
	2	bowlingite
1960	40	plagioclase(bytownite: very high in Ca)
	40	glass(high SiO_2)
	15	augite
	3	magnetite or ilmenite
	2	bowlingite
2022	60	quartzite
	40	granodiorite
2026	major	calcite
	major	quartz
	minor	cherty, clastic limestone
	minor	non-calcareous quartzite
	minor	non-calcareous angular basalt
2074	45	quartz
	45	plagioclase(albite)
	3	orthoclase
	3	biotite
	3	actinolite
	1	epidote
2075	65	soda amphibole(some hornblende cores)
	10	quartz
	7	plagioclase
	7	orthoclase
	5	epidote

TABLE 1 (Continued)

Sample No.	Percentage of Major Rocks or Minerals	Type of Major Rocks or Minerals
	3	ilemite
	1	sphene
	1	biotite
	1	apatite
2076	40	plagioclase(albite)
	30	actinotite(motted)
	17	hornblende
	5	alkale-amphibole
	5	epidote
	3	ilmenite
	2	quartz
2079	62	quartz
	26	carbonate
	5	illite
	5	plagioclase
	1	chlorite
	1	hematite(finely divided, red
2080	42	quartz siltstone
	15	quartzite
	13	calc-silicate gneiss
	10	dolomite
	8	argillite
	4	(leuco)granite
	2	pyroxenite
	2	porphyritic volcanic
	2	limestone
	2	rusty limestone
2094	36	schist to gneiss
	29	schist
	21	aplite
	14	pegmatite

TABLE 1 (Continued)

Sample No.	Percentage of Major Rocks or Minerals	Type of Major Rocks or Minerals
2096	45	sandstone
	21	siltstone
	15	amphibolite
	10	argillite
	9	assorted chert, granite volcanic
2122	76	quartzite--moderately fine-grained
	12	quartzite--fine grained
	12	volcanic rock
2123	52	plagioclase
	22	quartz
	22	orthoclase and microcline
	3	biotite
	1	muscovite
2124	60	gneiss
	13	quartz
	13	amphibolite
	6	schist
	6	feldspar
	2	altered amphibolite
2125	100	basalt(80 plagioclase, 10 augite, 7 olivine, 3 magnetite)
2126	72	quartzite
	14	bedded chert
	14	andesite
2137	79	calc-silicate rock
	17	diopside-biotite-quartz gneiss
	4	aplite

TABLE 1 (Continued)

Sample No.	Percentage of Major Rocks or Minerals	Type of Major Rocks or Minerals
2138	38	biotite-actinolite-quartz gneiss
	31	quartzite
	31	pegmatite-aplite
2139	39	rhyolite
	25	biotite-hornblende granite
	11	mica granodiorite
	9	pegmatite
	8	calc-silicate rock
	8	miscellaneous
2141	42	plagioclase
	35	orthoclase perthite
	20	quartz
	3	biotite
2142	52	quartzite
	35	diopside-quartz-feldspar-biotite gneiss
	9	aplite
	4	muscovite-biotite-feldspar-quartz-schist
2144	38	diopside-feldspar-quartzite
	23	quartz diorite
	15	feldspathic quartzite
	8	biotite-muscovite schist
	8	vein quartz
	8	biotite dacite
2145	55	diopside quartzofeld-spathic gneiss
	20	biotite quartzofeld-spathic gneiss
	16	pegmatite
	9	metavolcanic

TABLE 1 (Continued)

Sample No.	Percentage of Major Rocks or Minerals	Type of Major Rocks or Minerals
2148	100	quartzite(no thin section)
2180	100	pink limey shale(no thin section
2181	82	plagioclase(labradorite)
	8	augite
	3	bowlingite
	3	magnetite
	2	olivine
	2	calcite
2182	48	plagioclase(labradorite)
	35	brown glass
	12	augite
	5	magnetite
2183	45	glass, charged with fine opaques
	40	plagioclase(labradorite)
	10	augite
	5	olivine
2187	50	argillite
	16	quartz-rich siltstone
	13	siltstone
	9	sandy-silty argillite
	5	phyllitic siltstone
	5	sandstone
	2	quartzite
2222	60	quartzite
	20	dolomite-quartz siltstone
	20	biotite-quartzofeld-spathic gneiss

TABLE 1 (Continued)

Sample No.	Percentage of Major Rocks or Minerals	Type of Major Rocks or Minerals
2516 (2221)	55	sericite-quartz siltstone
	27	dolomitic sericite-quartz siltstone
	9	limonitic sericite-quartz siltstone
	9	quartzite
2555 (1996)	67	quartz
	20	muscovite
	8	feldspar
	5	biotite
2556 (2220)	38	altered granite
	32	arkosic siltstone
	27	porphyritic rhyolite
	3	quartz
2557 (2013)	45	granodiorite
	21	diopside-plagioclase-quartz gneiss
	17	leucogranite
	11	other igneous rocks
	3	quartzite
	3	biotite-hornblende diorite
2561 (2136)	59	plagioclase(altered to albite)
	15	biotite(altered to chlorite and sphene)
	12	hornblende
	8	quartz
	4	sericite
	2	calcite

TABLE 1 (Continued)

Sample No.	Percentage of Major Rocks or Minerals	Type of Major Rocks or Minerals
2562	50	quartz
(2143)	30	plagioclase(oligoclase)
	13	orthoclase-microcline
	6	biotite
	1	muscovite
2563	50	plagioclase
(1977)	25	quartz
	15	hornblende
	10	biotite
2584 (2186)	100	quartzite(no thin section)
2635	65	sanidine
(1927)	25	quartz
	5	granophyre
	2	plagioclase(oligoclase)
	2	hornblende
	1	biotite
2756	45	orthoclase perthite
(1928)	30	quartz
	24	plagioclase(albite)
	1	limonite
2757	52	muscovite
(1832)	28	quartz-plagioclase
	10	biotite
	10	carbonate
2758	38	dacite(volcanic rock)
(2085)	32	quartz siltstone
	22	granodiorite
	3	rhyolite
	3	amphibolite
	1	quartzofeldspathic gneiss
	1	chert

TABLE 1 (Continued)

Sample No.	Percentage of Major Rocks or Minerals	Type of Major Rocks or Minerals
2759	35	plagioclase
(2140)	25	olivine
	20	glass choked with opaques
	20	augite
2760	100	argillite(maroon)
(1444)		
2761	40	granitic
(1798)	40	siltstone(feldspathic)
	20	siltstone(shaley)
3040	NA*	NA*
3041	NA*	NA*
3052	NA*	NA*
3111	NA*	NA*
3112	NA*	NA*
3113	NA*	NA*
3114	NA*	NA*
3142	NA*	NA*
3225	NA*	NA*

*Unavailable for examination

TABLE 2

OLD AND NEW WASHINGTON

DEGRADATION TEST RESULTS

Sample No.	Washington Sediment Height in inches	Washington Degradation Factor, D Old	New
1801	1.3	78	79
1805	9.3	24	18
1887	12.1	29	8
1909	2.7	38	53
1922	2.4	65	66
1953	12.8	5	6
1959	1.7	76	74
1960	2.2	74	68
2022	NA**	NA**	NA**
2026	4.9	52	43
2074	1.1	59	82
2075	0.5	78	91
2076	3.8	58	52
2079	13.8	24	3
2080	2.7	68	62
2094	2.4	67	66

**Test results unavailable

TABLE 2 (Continued)

Sample	Washington Sediment Height in inches	Washington Degradation Factor, D	
		Old	New
2096(2583)	8.7*	31*	21*
2122	1.0	85	84
2123	2.0	76	70
2124	1.3	77	79
2125	1.8	75	73
2126	11.4	28	11
2137	1.6	75	75
2138	1.0	75	84
2139	0.4	65	93
2141	0.9	88	85
2142	1.2	83	81
2144	1.1	78	82
2145	2.7	60	53
2148	13.5	10	4
2180	10.9	73	12
2181	1.4	76	78
2182	0.7	81	88
2183	0.9	82	85

*Obtained from different sample (number in parenthesis) but same source.

TABLE 2 (Continued)

Sample No.	Washington Sediment Height in inches	Washington Degradation Factor, D Old	New
2187	11.8	26	9
2222	2.8	68	61
2516	4.2	51	48
2555(1996)	2.8	69*	61
2556(2220)	1.5	77*	77
2557(2013)	2.8	73*	61
2561	8.2	38	23
2562	10.1	52	15
2563	1.6	76	75
2584	11.5	22	10
2635	5.9	55	36
2756	2.4	68	66
2757	5.0	48	42
2758	1.8	71	73
2759	2.0	71	70
2760	13.5	19	4
2761	13.5	15	4
3040	4.1	NA**	49

*Obtained from different sample (number in parenthesis) but same source.

TABLE 2 (Continued)

Sample	Washington Sediment Height in inches	Washington Degradation Factor, D	
		Old	New
3041	4.1	NA**	49
3052	7.4	NA**	27
3111	5.7	NA**	37
3112	6.2	NA**	34
3113	NA**	NA**	43
3114	7.1	NA**	29
3142	4.7	NA**	44
3225	8.4	NA**	22

**Test results unavailable

TABLE 3

STANDARD AND MODIFIED

LOS ANGELES RATTLER(LAR) TEST RESULTS

Sample No.	Standard LAR No.	Modified LAR No.	Modified LAR Sediment Height in inches @ 20 C
1801	26	30	7.8
1805	22	29	16.1
1887	20	29	16.9
1909	20	24	10.5
1922	17	23	11.0
1953	22	31	18.0
1959	22	26	9.0
1960	19	24	7.7
2022	24	30	8.4
2026	27	34	14.0
2074	16	20	9.5
2075	21	24	5.8
2076	19	24	9.4
2079	18	27	14.6
2080	21	28	11.5
2094	41	47	10.3
2096	28	38	12.8

TABLE 3 (Continued)

Sample No.	Standard LAR No.	Modified LAR No.	Modified LAR Sediment Height in inches @ 20 C
2122	24	28	9.4
2123	48	53	9.9
2124	29	35	9.2
2125	20	27	9.5
2126	21	27	14.2
2137	39	46	10.1
2138	40	44	10.5
2139	22	27	7.9
2141	77	73	9.4
2142	49	55	7.9
2144	33	40	10.3
2145	14	19	8.8
2148	29	43	19.1
2180	25	31	16.3
2181	17	22	9.0
2182	20	25	10.4
2183	28	33	7.1
2187	15	21	14.1
2222	21	25	12.4

TABLE 3 (Continued)

Sample No.	Standard LAR No.	Modified LAR No.	Modified LAR Sediment Height in inches @ 20 C
2516	30	41	15.6
2555	20	27	9.7
2556	33	39	11.9
2557	34	46	6.9
2561	30	35	13.0
2562	56	58	9.7
2563	37	44	9.3
2584	20	26	17.3
2635	21	26	11.9
2756	37	41	10.0
2757	37	46	11.7
2758	24	29	10.9
2759	17	20	7.3
2760	24	32	18.2
2761	25	32	15.0
3040	28	32	10.8
3041	59	65	10.0
3052	23	30	13.4
3111	23	30	14.6

TABLE 3 (Continued)

Sample No.	Standard LAR No.	Modified LAR No.	Modified LAR Sediment Height in inches @ 20 C
3112	25	31	15.0
3113	UNABLE TO OBTAIN SUFFICIENT SAMPLE		
3114	20	24	14.2
3142	61	63	8.5
3225	19	24	14.2

TABLE 4

COMPARISON OF DEGRADATION TESTS

Passed All Four Tests		Failed Standard Los Angeles Rattler Test	Failed Modified Los Angeles Rattler Test By % Loss	Failed Modified Los Angeles Rattler Test By Sediment Height	Failed Washington Degradation Test	Failed Petrographic Analysis
1801	2139	2094	2094	1805	1805	1805
1909	2145	2123	2123	1887*	1887*	1953
1922	2181	2141	2137	1953	1953	2076
1959	2182	2142	2138	2026	2079	2079
1960	2183	2562	2141	2079	2096	2080
2022**	2222	3041*	2142	2126	2126	2094
2074	2555	3142*	2148	2148	2148	2180
2075	2556		2557	2180	2180	2187
2122	2758		2562	2187	2187	2561
2124	2759		2563	2516	2561	2756
2125	3040*		2756	2584	2562	2757
			2757	2760	2584	2761
			3041*	2761	2760	
			3142*	3052*	2761	
				3111*	3225*	
				3112*		
				3114*		
				3225*		

* Petrographic Analysis Unavailable

** Washington Degradation Test Unavailable

TABLE 5

RANK DIFFERENCE CORRELATIONS

Sample Number	Standard Los Angeles Rattler Test "C" Grading	Standard Los Angeles Rattler Test "B" Grading	Modified Los Angeles Rattler Test "C" Grading	Modified Los Angeles Rattler Test "B" Grading	Modified Los Angeles Rattler Test-Sediment Height "C" Grading	Modified Los Angeles Rattler Test-Sediment Height "B" Grading	Washington Degradation Test
1801	36.0	52.0	29.0	34.5	5.0	2.5	11.5
1805	21.0	35.5	24.0	44.0	47.0	45.0	47.0
1887	14.0	9.5	26.0	8.5	55.0	56.0	53.0
1909	14.0	9.5	9.5	6.0	29.5	7.0	27.0
1922	4.5	5.0	6.0	2.5	33.0	12.5	24.0
1953	25.0	14.5	33.0	14.0	57.0	49.5	54.0
1959	25.0	14.5	16.0	14.0	13.0	2.5	17.0
1960	9.0	20.5	9.5	8.5	4.0	18.0	22.0
2022	30.0	NA*	29.0	19.0	8.0	1.0	NA*
2026	38.0	32.0	39.0	37.0	43.0	41.0	37.0
2074	2.5	1.0	2.5	1.0	19.5	16.0	8.5
2075	21.0	17.5	9.5	14.0	1.0	9.0	2.0

* Sample Unavailable for Test

TABLE 5

RANK DIFFERENCE CORRELATIONS

Sample Number	Standard Los Angeles Rattler Test "C" Grading	Standard Los Angeles Rattler Test "B" Grading	Modified Los Angeles Rattler Test "C" Grading	Modified Los Angeles Rattler Test "B" Grading	Modified Los Angeles Rattler Test-Sediment Height "C" Grading	Modified Los Angeles Rattler Test-Sediment Height "B" Grading	Washington Degradation Test
2076	9.0	2.5	9.5	4.5	17.0	5.0	32.0
2079	6.5	20.5	20.0	14.0	48.5	55.0	58.0
2080	21.0	9.5	24.0	19.0	35.0	28.5	27.0
2094	53.0	53.0	53.0	53.5	27.0	33.5	24.0
2096	37.0	43.5	42.0	42.0	40.0	39.0	46.0
2122	30.0	20.5	24.0	27.0	17.0	42.0	6.5
2123	54.0	55.0	54.0	55.0	23.0	23.0	20.5
2124	42.0	43.5	40.5	40.0	14.0	19.0	11.5
2125	14.0	23.0	20.0	19.0	19.5	5.0	18.5
2126	21.0	25.0	20.0	27.0	45.0	53.5	50.0
2137	51.0	46.5	51.5	46.5	26.0	17.0	15.5
2138	52.0	48.5	49.5	46.5	29.5	32.0	6.5

TABLE 5

RANK DIFFERENCE CORRELATIONS

Sample Number	Standard Los Angeles Rattler Test "C" Grading	Standard Los Angeles Rattler Test "B" Grading	Modified Los Angeles Rattler Test "C" Grading	Modified Los Angeles Rattler Test "B" Grading	Modified Los Angeles Rattler Test-Sediment Height "C" Grading	Modified Los Angeles Rattler Test-Sediment Height "B" Grading	Washington Degradation Test
2139	25.0	2.5	20.0	8.5	6.5	14.5	1.0
2141	59.0	59.0	59.0	60.0	17.0	33.5	4.5
2142	55.0	57.0	55.0	57.0	6.5	21.5	10.0
2144	46.0	45.0	46.0	52.0	34.0	20.0	8.5
2145	1.0	48.5	1.0	49.5	11.5	35.5	27.0
2148	42.0	27.5	47.0	39.0	59.0	60.0	56.0
2180	33.0	35.5	33.0	38.0	54.0	58.0	49.0
2181	6.5	14.5	4.5	14.0	11.5	9.0	13.0
2182	14.0	25.0	13.0	22.5	28.0	12.5	3.0
2183	39.5	38.0	38.0	42.0	2.0	9.0	4.5
2187	2.5	9.5	4.5	14.0	50.0	57.0	52.0
2222	18.0	9.5	14.0	22.5	39.0	35.5	30.0

TABLE 5

RANK DIFFERENCE CORRELATIONS

Sample Number	Standard Los Angeles Rattler Test "C" Grading	Standard Los Angeles Rattler Test "B" Grading	Modified Los Angeles Rattler Test "C" Grading	Modified Los Angeles Rattler Test "B" Grading	Modified Los Angeles Rattler Test-Sediment Height "C" Grading	Modified Los Angeles Rattler Test-Sediment Height "B" Grading	Washington Degradation Test
2516	42.0	41.0	44.0	46.5	53.0	52.0	35.0
2555	14.0	25.0	20.0	22.5	21.5	5.0	30.0
2556	45.0	39.5	43.0	34.5	37.5	24.0	14.0
2557	47.0	50.5	48.0	49.5	10.0	21.5	30.0
2561	44.0	46.5	40.5	46.5	41.0	37.0	44.0
2562	56.0	58.0	56.0	58.0	21.5	30.5	48.0
2563	49.0	32.0	49.5	34.5	15.0	37.5	15.5
2584	14.0	20.5	16.0	27.0	56.0	59.0	51.0
2635	21.0	27.5	16.0	22.5	37.5	30.5	40.0
2756	49.0	54.0	45.0	51.0	24.5	27.0	24.0
2757	49.0	50.5	51.5	53.5	36.0	40.0	38.0
2758	35.0	35.5	29.0	31.0	31.5	25.0	18.5

TABLE 5

RANK DIFFERENCE CORRELATIONS

Sample Number	Standard Los Angeles Rattler Test "C" Grading	Standard Los Angeles Rattler Test "B" Grading	Modified Los Angeles Rattler Test "C" Grading	Modified Los Angeles Rattler Test "B" Grading	Modified Los Angeles Rattler Test-Sediment Height "C" Grading	Modified Los Angeles Rattler Test-Sediment Height "B" Grading	Washington Degradation Test
2759	4.5	9.5	2.5	4.5	3.0	14.5	20.5
2760	30.0	5.0	36.0	8.5	58.0	51.0	56.0
2761	33.0	39.5	36.0	42.0	51.5	46.5	56.0
3040	39.5	42.0	36.0	34.5	31.5	48.0	33.5
3041	57.0	5.0	58.0	56.0	24.5	26.0	33.5
3052	27.5	29.5	29.0	27.0	42.0	43.0	43.0
3111	27.5	35.5	29.0	27.0	48.5	49.5	39.0
3112	33.0	29.5	33.0	31.0	51.5	46.5	41.0
3113	NA*	32.0	NA*	31.0	NA*	44.0	NA*
3114	14.0	17.5	9.5	2.5	45.0	11.0	42.0
3142	58.0	56.0	57.0	59.0	9.0	28.5	36.0
3225	9.0	14.5	9.5	14.0	45.0	37.5	45.0

*Unable to Obtain Sample