1968

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Recommended Citation

Mathiowetz, Reinhold P., "Proposed Modifications to the Los Angeles Rattler Test" (1968). *Electronic Theses and Dissertations*. 3465.
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PROPOSED MODIFICATIONS TO THE LOS ANGELES RATTLER TEST

BY

REINHOLD P. MATHIOWETZ

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Civil Engineering, South Dakota
State University

1968

PROPOSED MODIFICATIONS TO THE
LOS ANGELES RATTLER TEST

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, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

Head, Civil Engineering Department Date

DEDICATION

This thesis is dedicated to my wife, Connie, whose support, assistance, and encouragement made this advanced study possible.

ACKNOWLEDGMENTS

The author wishes to express his deepest gratitude to Associate Professor Lorys J. Larson, Department of Civil Engineering, for his encouragement, assistance, and counsel throughout the course of this study. Appreciation is also extended to Professor Everett White, Department of Agronomy, and Thomas A. Biggar, Laboratory Technician, for their valuable assistance during this study.

Acknowledgment is extended to the South Dakota Department of Highways for their cooperation and to the Department of Civil Engineering for the use of equipment and facilities.

As a recipient of a National Science Foundation Traineeship, the author acknowledges the financial assistance from this source.

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INTRODUCTION

General

The amount of highway construction is increasing every year. As a result, there is an ever increasing demand for mineral aggregates. Engineers classify these mineral aggregates as the smaller rocks which are composed of one or more minerals.

In the state of California, between one-fifth and one-third of the 300 million dollars spent annually for the construction of highways is used for the procurement and placement of aggregates.(1) This cost is steadily increasing because of the depletion of the more accessible and higher quality aggregates. Because the traffic volume and loads are steadily increasing, the Interstate system as well as many other primary roads being built demand durable aggregates.

The selecting of high quality aggregates is not a new problem. Back in Roman times it was necessary to select suitable rocks for use as flag stones, a surfacing material of the time. Some of the highways of that era remain in excellent condition today as a result of the prudent selection of surfacing material.

It was not until the late nineteenth century, however, that the use of machines to simulate field conditions for the purpose of determining the durability of aggregates began. The first successful test for abrasion of aggregates was the Deval test. At the present time the Los Angeles rattler test is used by most of the State Highway Departments. It is considered the most effective test for determining the structural and abrasive qualities of an aggregate.

In the late 1940's however, it was observed that aggregates which had passed the Los Angeles rattler test were failing under field conditions. In 1947, Melville investigated a failure in Route 250 near Charlottesville, Virginia. From his investigation he concluded that the aggregates had weathered sufficiently to produce a layer of plastic fines which caused the failure.(2) Since then there have been many similar cases reported, especially in the western states.

As a consequence of these failures, many of the western states have been attempting to develop an empirical test that will determine the tendency of an aggregate to produce plastic fines. Washington, Oregon, Idaho, California, and South Dakota, as well as other states, have developed tests to determine the durability characteristics of aggregates. At the present time, none of these tests are universally accepted by other states or by the American Society for Testing and Materials.

The Los Angeles rattler test is a very simple test and requires little time to perform. The amount of time required to conduct a test is becoming increasingly important because labor costs are steadily rising. Also, with the high production of modern aggregate contractors, it is important to have a test which can be accomplished in a short period of time.

The Los Angeles rattler machine is an expensive piece of equipment and one that all state highway departments regard as standard equipment. Accordingly, this study was made with a view toward modifying the Los Angeles rattler test to include wet abrasion. This would make it possible to obtain the necessary durability information from a single laboratory test without appreciably adding to the cost of equipment.

Background

The breaking down of an aggregate is termed degradation. Erickson has defined degradation as "a breaking down and / or disintegration of particles of sand, gravel, or stone, primarily due to the alteration and subsequent decomposition of their mineral components, accelerated by the action of mixers, mechanical equipment, traffic or the elements."(1) Degradation of aggregates is divided into two types, namely, mechanical and weathering. Breese divides degradation into comminution degradation and alteration degradation respectively.(1)

In the first research of abrasion tests, the emphasis was placed on the comminution, or mechanical type of degradation. The Deval test and the Los Angeles rattler test were designed primarily to simulate field conditions in an empirical test. In the field there are several ways in which the aggregate is continuously degraded due to impact abrasion and the crushing effects of wheel loads. In a flexible pavement the aggregate also deteriorates due to the extra energy produced during construction. McNaughton discovered in his research that the particles of aggregate shift about and rearrange their positions in an aggregate-asphalt mixture under load so that they occupy the least possible space. The combination of load and movement produces a grinding effect which tends to round off the corners and edges thus producing fines which fill in the voids." Ordinarily, there is an increase in strength as the fines increase; however, if the voids become full and more fines are produced, there is a considerable loss of structural strength.(3)

During degradation studies in Indiana, Shelburne noted several important aspects about aggregates:

1. Aggregates vary in their resistance to crushing as measured by under-roller tests and the Los Angeles tests.
2. The rate of degradation is greater in softer aggregates 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 smaller size aggregate is more desirable than a course 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 in 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.(4)

Alteration degradation was first observed by Melville in 1947. His investigation was a result of failures on Route 250 near Charolottesville, Virginia. In his investigation, he observed that there was a plastic layer of fine particles between the surface layer and the macadam base. In some places this layer was as much as one-half inch thick although the road was only about two years old and the materials had all passed specifications at the time of construction. It appeared that the aggregates had weathered sufficiently to produce the fines that caused the failure.(2)

Since 1955, there have been many similar failures reported in the western states of Oregon, Washington, and Idaho. Research on the failures in Washington was conducted by Turner and Wilson. Their conclusions indicated that these failures were due to secondary materials in the aggregates.(5)

These secondary materials Scott defines as "minerals resulting from alterations of primary minerals. They are formed as a result of deep chemical weathering of igneous rocks by groundwater, air, hot gases, or dissolved organic acids, or by extrusion into water as in the case of submarine basalt." This alteration varies from partial replacement on the surface to complete replacement of the primary mineral by a less stable element which retains the shape of the original crystalline structure.(6)

There are only a few families of minerals that are contained in igneous rocks. The two principal minerals are the feldspars and the iron bearing minerals. The feldspars are altered to kaolin type clays and calcite. The calcite is water soluble and the clays are unstable and hydrophilic. The iron bearing minerals alter to limonite, chlorite, and serpentine. Chlorite and serpentine rapidly change to clays and are unstable. Limonite is more stable but is still much weaker than the original mineral it replaces.(6)

Scott also observed that the aggregates smaller than one-fourth inch were the most susceptible to disintegration. He also recommended that rock with more than 35 per cent secondary minerals should not be used in sizes smaller than three-fourths inch.(6) Turner and Wilson made the following correlation between field performance and the amount of secondary materials:(5)

0-20 per cent has no effect.

20-35 per cent produce some failures.

35-100 per cent produced almost certain failure.

When the aggregates with secondary materials degrade, they form plastic fines. The plastic fines trap any available water, thus increasing the rate of breakdown. After enough fines are produced, the particles lose contact with each other and failure ultimately occurs.(7)

Development of Degradation Tests

In the mid nineteenth century, after John MacAdam invented the MacAdam road, it became important to select strong, nonabrasive rock for construction purposes. The Laboratoire des Ponts et Chaussees, in Paris, developed the first abrasion test in 1870. In 1878, Deval published the Deval Abrasion test. This was the first abrasion test accepted in the United States by the American Society for Testing and Materials.(2)

In this country, the first highway research was carried out at the American Highway Laboratory in 1893. Under the direction of L. W. Page. Page introduced a test for determining the cementing value of broken stone dust and also a test for toughness of aggregates by using the Page impact machine.(2)

Because of the shortcomings of the Deval test, the employees of the Los Angeles City Engineer's office developed the present Los Angeles rattler test in 1916. This test overcame most of the disadvantages of the Deval test and was considered more reliable.(2) In 1937 the American Society for Testing and Materials accepted the Los Angeles rattler test as a tentative abrasion test. Two years later it was adopted as a standard test.(8)

Goldbeck stated that the Los Angeles rattler agrees remarkably well with the service results.(9) However, in the late 1940's, it became apparent that the Los Angeles rattler test did not provide sufficient information with regard to aggregate quality. In 1947 a section of route 250 west of Charlottesville, Virginia, failed within two years after construction. The material had passed the Los Angeles rattler test but had given very poor service.(2)

The present Los Angeles rattler test determines the abrasive and structural characteristics of dry aggregates. In the failures reported, the aggregates formed a large amount of plastic fines which caused failure. As a consequence, there have been many attempts to modify the Los Angeles rattler test to produce the plastic fines similar to those encountered in aggregate failures.

At the Washington State Institute of Technology, Turner and Wilson did extensive research on modifications of the Los Angeles rattler test. The following modifications were attempted:

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 rotated.

The fines produced by these procedures did not have as great a percentage passing the number 200 sieve or as high a plasticity as the fines obtained using the ball mill test and were, therefore, dropped.(5)

At the University of Washington, Martin Ekse and Henry C. Morris also did research on modifying the Los Angeles rattler test. Using standard gradings, they removed the steel spheres and varied the duration of the test. They observed the following:

1. The wear in the first hour is high and tends to level off with increasing time.
2. Significantly, plastic material developes after approximately four hours.
3. The percentage of abrasion after four hours approaches that produced in the standard Los Angeles rattler test.
4. As the time is increased to eight hours, the per cent passing the number 200 sieve approaches the amount passing the number 12 sieve.
5. By using wet or moist aggregate, the percentage of wear was increased by about 10 per cent, however, cleaning the drum

after testing wet aggregate was considered to be too messy. Therefore, this procedure was abandoned.(10)

H. L. Day conducted research for the Idaho Department of Highways aimed at developing a suitable degradation test. In his research he used a 30 pound sample and rotated it in the Los Angeles rattler machine without metal spheres. He stated that the test appeared to have merit because of the large sample used but dropped it in favor of a wet abrasion test.(11)

Earl A. Sibley did research at the Washington State Institute of Technology. In his research he modified the Los Angeles rattler test by using a 5 pound sample, no metal spheres, and rotating it for 20,000 revolutions. He indicated that this method produced the necessary fines to duplicate those acquired under field conditions. It is important to note that 20,000 revolutions required 10.1 hours.(1)

C. R. Breese did extensive research for the state of Nevada in correlating existing degradation tests with a view toward possible development of a new test. In his report he stated that there appears to be universal agreement that the best method for determining secondary minerals is by petrographic analysis. This method, however, is time consuming, requires a trained petrographer, and is very impractical when a heterogeneous material is encountered.(1)

Breese attempted to correlate several degradation tests which are now being used by various Western states. He was not able to include the Idaho degradation test in his study because it required the use of a Deval testing machine which was not available. The tests that he correlated included: The elutriation test devised by C. M. Collins,(12) the jar mill test devised by Carl E. Minor,(13) the Washington degradation test,(14) and the California aggregate durability test.(15) In his study he used 83 aggregate samples, however, tests were not performed on all of the same samples.

It is important to note that all of the above degradation tests use a sedimentation analysis of the fine particles. This analysis is based on the principle of Stokes' Law, which states that the theoretical velocity of vertical settling for a particle can be computed by the following formula:(16)

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

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

By analyzing the above equation it can be observed that the larger and more dense particles have a greater settlement velocity. Therefore, in a specified amount of time, very fine particles will not travel as far as larger particles. In the degradation tests mentioned above a representative sample of the fine particles produced during the mechanical agitation of the aggregate is poured into a sand equivalent test cylinder. Seven milliliters of sand equivalent stock solution is added and the cylinder is filled with water to the 15 inch mark. The cylinder with its contents is thoroughly mixed by 20 inversions in 35 seconds and is allowed to settle for 20 minutes. The sediment height is then read. Poor aggregates which tend to produce plastic fines will have a very high sediment height.

Breese also correlated the degradation factors obtained by the various methods and also the sediment height obtained by each method. Using the method of linear regression for the above tests the following coefficients of correlation were obtained between the sediment heights. The first column indicates the two tests being correlated; the second column indicates the correlation; and the third column shows the number of samples upon which the correlation is based:

Collins method to Minor method	0.684	79
Collins method to Washington method	0.725	44
Collins method to California method (coarse)	0.623	70
Minor method to Washington method	0.853	42
Minor method to California method (coarse)	0.739	70
Washington method to California method	0.893	38

It is interesting to note that the Washington degradation test and the California coarse method produced the highest correlation with the coefficient of correlation being 0.893. Also, the Washington degradation test produced the highest coefficients of correlation when compared with the other tests.(1)

Objectives of Investigation

The objectives of this investigation were:

1. To modify the Los Angeles rattler test by including wet abrasion.
2. To determine a method for analyzing the fineness of the particles produced.
3. To correlate the modified Los Angeles rattler test with the Washington degradation test, the South Dakota degradation test, and the available performance records.

MATERIALS AND TESTING PROCEDURES

Aggregates Tested

In this study aggregate tests were conducted on 41 samples supplied by the South Dakota Department of Highways. They were obtained from various sources throughout the state. Table 1 lists the aggregate samples by number. This table also presents for each sample an estimated lithological aggregate composition furnished by the South Dakota State University Agronomy Department. Table 2 contains information on the field performance of the aggregate samples furnished by the South Dakota Department of Highways.

Most of the samples were gravels with a few having glacial origin. The gravels were generally composed of rounded particles. Some of the samples had been run through the crusher and contained a large percentage of sharp-edged particles. Three samples were composed entirely of crushed rocks from rock quarries.

The aggregate samples were furnished in two sacks, one containing 3/4 inch to 1/2 inch material and the other containing 1/2 inch to 3/8 inch. It was necessary to crush all the samples used in the Washington degradation test in order to obtain the necessary gradation.

Los Angeles Rattler Test

The South Dakota Department of Highways furnished results from the standard Los Angeles rattler test for all of the aggregate samples. After the samples were received, five samples were retested in the

South Dakota State University Materials Testing Laboratory, by the Los Angeles rattler method to compare the results obtained from the two laboratories.

The standard Los Angeles rattler test specifies the following procedure.

The test sample shall consist of clean aggregate representative of the material under test, oven dried to substantially constant weight. The weight of the sample prior to test shall be recorded to the nearest gram. In this study, the B grading was used. This consists of 2500 grams of material passing the 3/4 inch sieve and retained on the 1/2 inch sieve plus 2500 grams passing the 1/2 inch sieve and retained on the 3/8 inch sieve. The abrasive charge consists of 11 steel spheres having a total weight of 4584 ± 25 grams.

The test sample and the abrasive charge shall be placed in the Los Angeles rattler testing machine and the machine 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 number 12 sieve. The material coarser than the number 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. (8- 82)

South Dakota Degradation Test

The South Dakota Department of Highways also furnished the test results for the South Dakota degradation test. They designate this test as the "Wash Test for Determination of Durability of Aggregates". However, in this report, it will be referred to as the South Dakota degradation test. They state that their test is used to determine the ultimate breakdown of shale and other deleterious substances in aggregates. The test procedure is as follows:

1. Secure approximately 1500 grams of a representative aggregate sample.
2. Place the sample into a metal container with a water tight lid having a capacity of approximately one gallon. Add enough water to completely cover the sample.
3. Agitate in a rotap or similar shaker for two hours.
4. Let the sample settle and decant off any clear water.
5. Dry sample at not over 220° Fahrenheit.
6. Sieve on number 4 sieve.
7. Rub or wash fines from plus number 4 material.
8. Properly prepare the minus number 4 material and perform a one point plasticity index test.
9. Calculate and report the liquid limit and plasticity index to the nearest whole number. These results shall be designated as the Ultimate Liquid Limit and Ultimate Plasticity Index.(17)

Specific Gravity and Per Cent Absorption

All samples were tested for specific gravity and per cent absorption in the South Dakota State University Laboratory. These tests were performed according to the procedure outlined by the American Society for Testing and Materials.(8-77)

Washington Degradation Test

All samples were tested in the South Dakota State University Materials Testing Laboratory according to the procedure used by the Washington State Department of Highways. This test is used in an attempt to evaluate the degradation of an aggregate. The method used for this test is as follows:

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

1/2 inch - 1/4 inch	500 grams
1/4 inch - U. S. number 10	500 grams

Place sample in a 7-1/2" diameter x 6" high plastic canister (Tupperware), add 200 cc water, cover tightly, and place in a Tyler portable sieve shaker. The Tyler sieve shaker used in this study is shown in Figure 1. Run shaker for 20 minutes at 300 ± 5 oscillations per minute with a 1-3/4" throw on the cam. At the conclusion of the shaking time, empty the canister into nested number 10 and number 200 sieves, placed in a funnel over a 500 ml graduate to catch all water. Wash out the canister and continue to wash the aggregate with fresh water

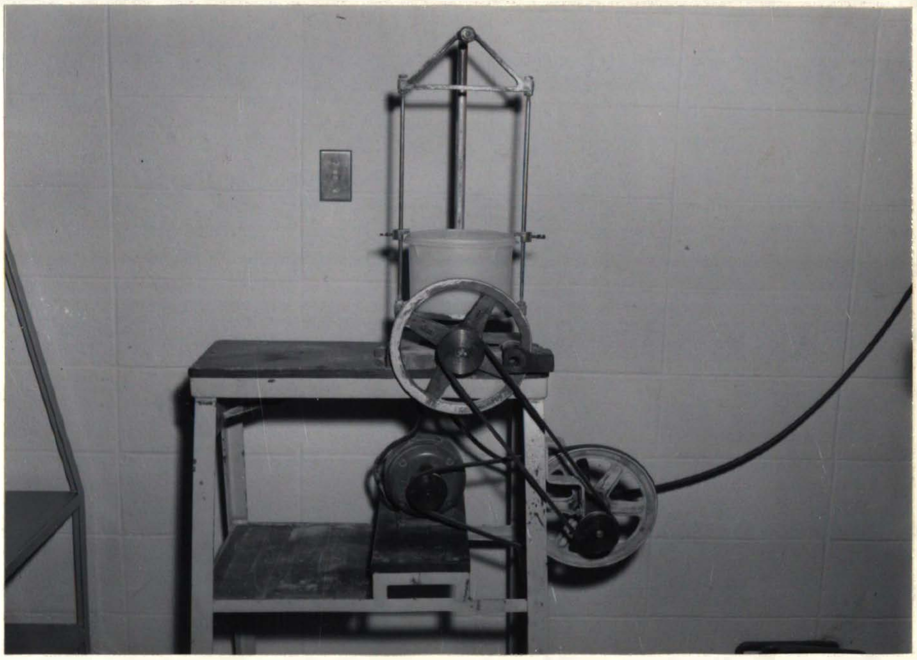

Figure 1. Tyler Portable Sieve Shaker

until the graduate is filled to the 500 ml mark. Caution: The aggregate may drain 50 - 100 ml of water after washing has been stopped. Save all aggregate.

Pour seven 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, then turning 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 rubber stopper in 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.

Place the aggregate retained on number 10 and number 200 sieves in the oven until dry, then sieve and record the weights retained on U. S. number 10 and number 200 sieves. Loss through each sieve is determined by subtraction from original weight, and recorded to nearest gram. Calculations:

Calculate the degradation factor by the following formula:

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

Where D = Degradation factor

L_{200} = Grams lost thru number 200 sieve

L_{10} = Grams lost thru number 10 sieve

H = Height of sediment in tube

This formula gives a weight of 30 per cent to the ratio of the loss through the number 200 and number 10 sieves, and 70 per cent to the quality of the fines as determined by the cleanness portion of the test. These values are arbitrary, but they are believed to have merit. Values may range from 0 to 100, with high values being the best materials. The formula was adjusted to place doubtful materials at about the midpoint of the scale, with poor ones below and good ones above that point.

The test was altered to include a number 4 sieve rather than the 1/4 inch sieve specified since it is more compatible with the aggregate sieve series.

Latest information from the Washington State Department of Highways indicates that they are conducting research in an attempt to base the test results entirely on the sediment height.(14)

Determination of Los Angeles Rattler Test Modifications

In attempting to modify the Los Angeles rattler test numerous variables were considered. These included the size and gradation of the sample, the abrasive charge used, the speed and duration of rotation, and a means of abrading the sample in the presence of water.

Wet abrasion was considered mandatory in determining the degradation characteristics. Therefore, it was necessary to render the Los Angeles rattler testing machine water tight. In order to accomplish this, a flat rubber gasket was cemented to the cover as shown in Figure 2. This proved to be the only required equipment modification.

A sample which failed the Washington degradation test was used to determine the effects of various modifications. These included varying the amount of water added to the sample and the number of revolutions in both the dry and wet state. From the results obtained it was decided to change the Los Angeles rattler test to include 250 revolutions with the aggregate dry plus 250 revolutions with 1000 ml of water added. This modification in itself did not provide results significantly different from the standard Los Angeles rattler test.

After examining other degradation tests being used, it was felt that this test should also include the sediment height analysis of the fine particles. This analysis was accomplished by washing the Los Angeles rattler residual over a number 30 sieve and drying the fines. A representative sample was then selected from the residual for the sediment height analysis using a sand equivalent cylinder. However, this procedure proved to be extremely time consuming and was, therefore, discarded.

There was approximately a 25 to 1 ratio between the fines produced by the Washington degradation test method and the amount

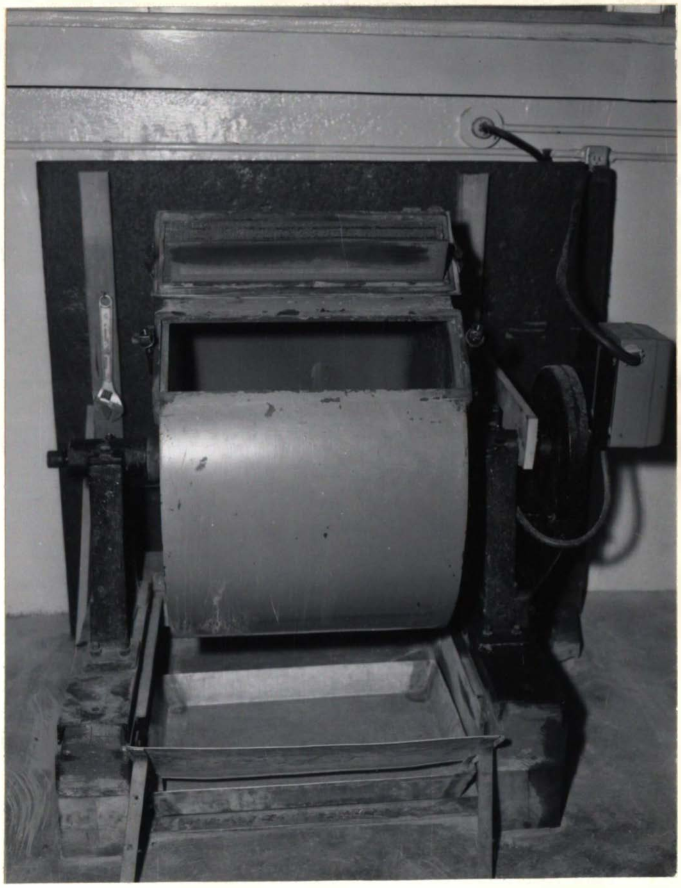

Figure 2. Los Angeles Rattler Testing Machine

passing the number 30 sieve from the modified Los Angeles rattler test. Therefore, it was decided to use a cylinder with a cross sectional area 25 times as great as the cross sectional area of a sand equivalent cylinder. This cylinder was constructed of acrylic plexiglas with a diameter of six inches and a height of 25 inches and was equipped with a water tight cover. It was graduated in tenths of an inch from the bottom to a height of 20 inches as shown in Figure 3.

The standard Los Angeles rattler test uses the number 12 sieve for determining the percentage loss. This sieve is not in the aggregate sieve series. Accordingly, for compatibility purposes, it was decided to use a sieve from that series to determine the percentage loss. It was not known which sieve should be used to replace the number 12 sieve, therefore, the percentage loss through the numbers 8, 16, and 30 sieves were determined.

Modified Los Angeles Rattler Test

After reviewing the modifications described above, it was decided to conduct a modified Los Angeles rattler test as follows:

1. Prepare the aggregate sample in the same manner as required for the standard Los Angeles rattler test using the B grading.
2. Introduce the test sample along with the abrasive charge into the Los Angeles rattler testing machine.
3. Rotate the drum for 250 revolutions at 33 rpm with the aggregate in the dry state. Add 1000 ml of water and rotate for 250 additional revolutions.

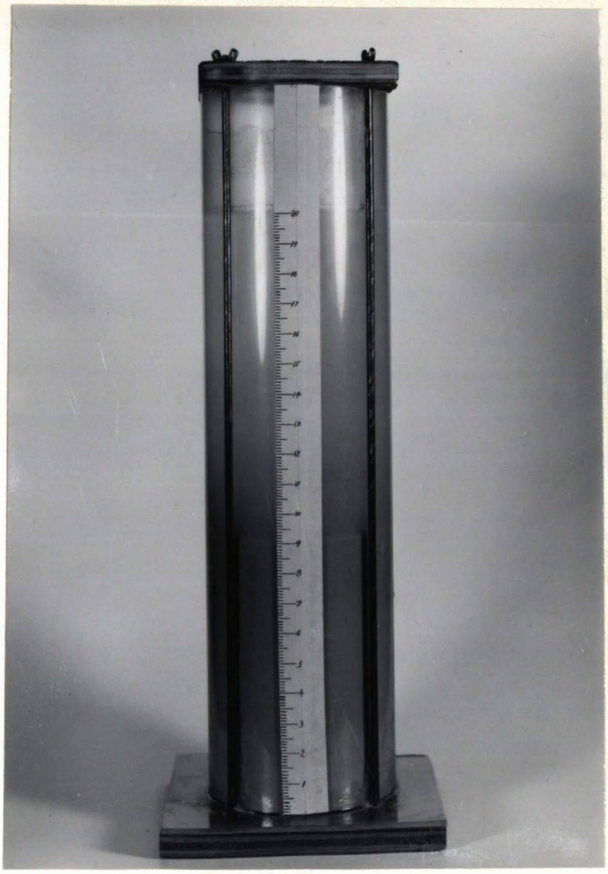

Figure 3. Large Graduated Cylinder

4. Wash the sample from the testing machine into a large pan placed beneath the machine.
5. Pour the entire contents of the pan into the large graduated cylinder previously prepared with 25 ml of sand equivalent stock solution.
6. Adjust the water level in the cylinder to the 20-inch mark.
7. Cap the cylinder and thoroughly mix the contents by inverting the cylinder 20 times within 30 seconds. Place the cylinder in an area out of direct sunlight and allow to settle.
8. After 20 minutes read the sediment height to the nearest one-tenth inch. Determine the average height of the coarse particles.
9. Wash the entire contents of the cylinder over a number 30 sieve.
10. Allow the fines to settle for 20 minutes and then decant enough clear water so that the entire contents of the pan can be washed into the graduate cylinder containing 25 ml of sand equivalent stock solution. Adjust the water level to the 20-inch mark.
11. Cap the cylinder and thoroughly mix by inverting 20 times within 30 seconds. Allow to settle in an area out of direct sunlight.
12. After 20 minutes, read the sediment height to the nearest one-tenth inch.

13. Sieve the coarse fraction over nested numbers 8, 16, and 30 sieves. Weigh the amount retained on each and record.

Liquid Limit and Plastic Limit Tests

The South Dakota Department of Highways furnished liquid limit and plasticity index for the fines produced during the standard Los Angeles rattler tests. The liquid limit and plasticity index were determined using the fines produced in the modified Los Angeles rattler test. These tests were performed in the South Dakota State University Materials Testing Laboratory according to the procedure outlined by the American Society for Testing and Materials.(18)

DISCUSSION OF TEST RESULTS

The results for the standard Los Angeles rattler test as reported by the South Dakota Department of Highways are shown in Table 3. It is interesting to note that only three samples failed the standard Los Angeles rattler test based upon a maximum loss of 40 per cent. These three samples also failed all other tests.

Table 4 shows the percentage loss obtained using South Dakota State University's Los Angeles rattler testing machine. Comparing the results obtained with those of the South Dakota Department of Highways, it is noted that the University's testing machine averaged about two percentage points lower.

The South Dakota degradation test results furnished by the South Dakota Department of Highways are shown in Table 5. They specify that the maximum plasticity index allowed for various usages is as follows: A maximum of six for base materials, 6 to 10 for subbase, and 15 for gravel surface roads.* Considering a maximum plasticity index of six for acceptable material, 18 of the aggregate samples were rejected.

The per cent absorption and specific gravity of the aggregate samples are shown in Table 6. All of the samples that had absorption

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* Private conversation with Mr. Helmer E. Everson, Engineer of Tests, South Dakota Department of Highways.

greater than three per cent failed the Washington degradation test and the modified Los Angeles rattler test. Most of the same samples also failed the South Dakota degradation test.

The results obtained using the Washington degradation test are recorded in Table 7. When using a minimum degradation factor of 40 for acceptable materials, 14 samples were unacceptable. Of these 14 samples, five also failed to pass the South Dakota degradation test.

The results of the modified Los Angeles rattler test are shown in Table 8. At the outset of this study, it was thought that it might be possible to eliminate the sieve analysis by replacing it with the height of the coarse aggregate as determined in the large graduated cylinder. However, the results were not consistent with other tests, and therefore, this idea was abandoned.

In the modified Los Angeles rattler test, the amounts retained on the numbers 8, 16, and 30 sieves were recorded. The percentage loss through each sieve was calculated and compared to the standard Los Angeles rattler test values. It was observed that the loss through the number 16 sieve approached the value obtained for the standard Los Angeles rattler test. Aggregates that abraded into very fine particles provided the best comparison. Other aggregates showed a slightly higher rating using the number 16 sieve. The slight relaxation on this part of the test would be countered by the inclusion of the sediment height analysis.

The water temperature was maintained at approximately 17° C for determination of all sediment heights. The sediment height using the entire sample in the graduated cylinder and the sediment height obtained using the minus 30 fraction were slightly different. This was probably due to the warming of the water during the settlement period between the two procedures. By examining Stokes' Law, it is noted that as the water temperature increases the settling velocity increases. This is due to decreases in the density and viscosity of water as the water temperature increases.(19)

Table 8 shows that all samples with a high percentage passing the number 16 sieve produced failing sediment heights. For such samples it would not have been necessary to determine the percentage loss through the number 16 sieve. On the other hand, aggregates which do produce low sediment heights may break down into larger particles as a result of structural weaknesses. Therefore, it is necessary to determine the percentage loss through the number 16 sieve for aggregates which pass the sedimentation portion of the test.

Basing the modified Los Angeles rattler test results on a maximum sediment height of 12 inches and a maximum loss through the number 16 sieve of 40 per cent, 16 samples were rejected as unsatisfactory. Of these 16 samples, 11 also failed the Washington degradation test.

Table 9 gives the liquid limits and plasticity index for the fines produced by the Los Angeles rattler tests and the modified Los Angeles rattler tests. It is important to note that only one sample produced plastic fines when subjected to the two tests. However, in the modified Los Angeles rattler test there was a sufficient amount of very fine particles produced to obtain sediment heights comparable to those obtained using the Washington degradation test. Using the method of linear regression, a coefficient of correlation of 0.80 was obtained between the modified Los Angeles rattler sediment height and the Washington degradation sediment height.(20) Figure 4 shows this correlation.

A comparison of all degradation test results is shown in Table 10. Note that two samples failed only the Los Angeles rattler test; two failed only the Washington degradation test; and 10 failed only the South Dakota degradation test. Eleven samples failed and nine passed all three tests.

Table 2 shows 14 samples with poor to fair performance records; 10 of these failed the modified Los Angeles rattler test. However, two samples with a good performance record also failed the modified Los Angeles rattler test. The Washington degradation test produced a similar comparison.

For several reasons, the performance records received from the South Dakota Department of Highways were not considered to have been rated under comparable circumstances. First, the samples were grouped according to the districts from which they originated, with each group being rated by the district personnel. Second, several aggregate samples were not used for all types of service because of

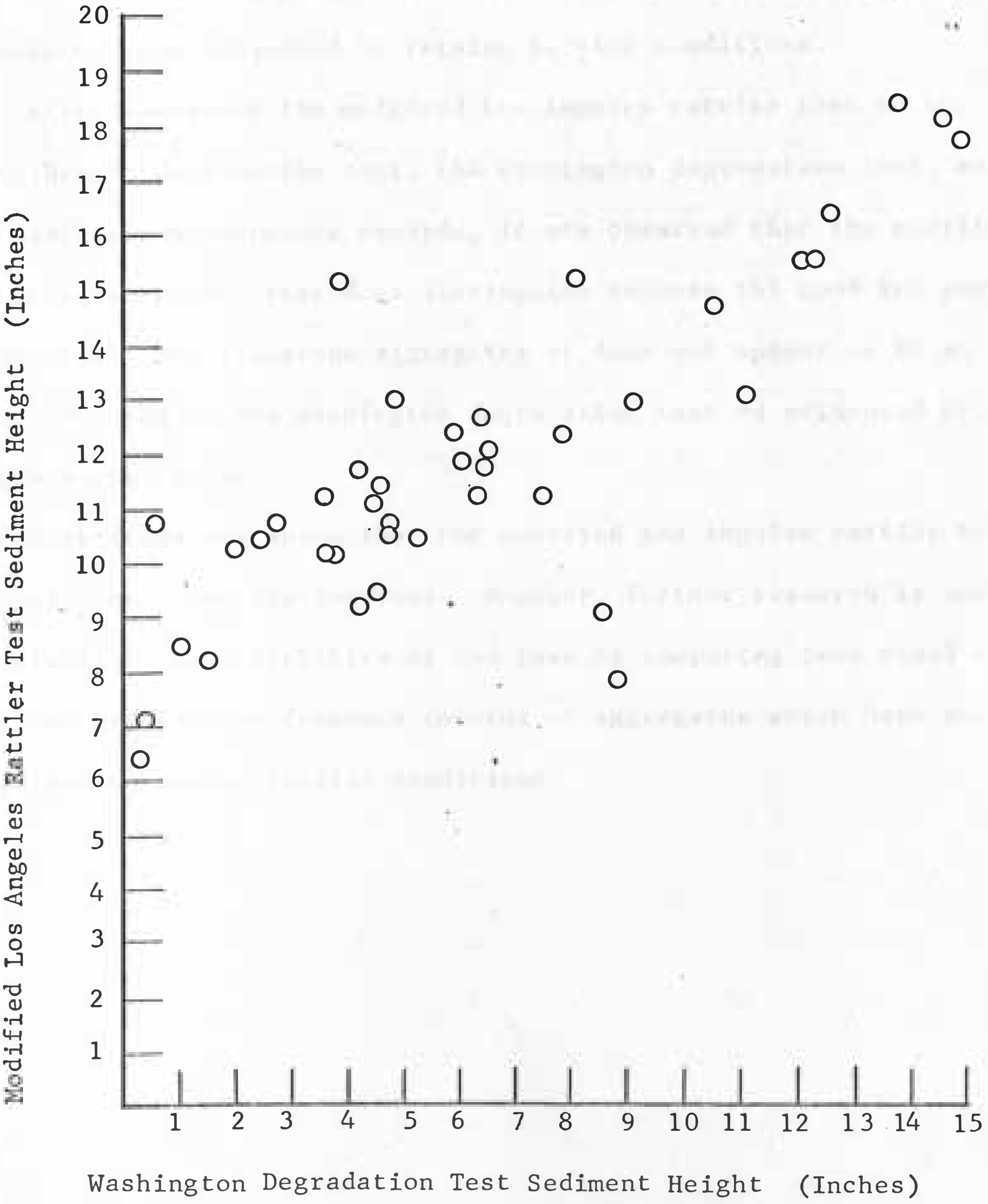

Figure 4. Modified Los Angeles Rattler Test Sediment Height vs Washington Degradation Test Sediment Height

the poor ratings they received by the South Dakota degradation test. Third, the samples were used in different parts of the state and, therefore, were subjected to varying service conditions.

After comparing the modified Los Angeles rattler test to the South Dakota degradation test, the Washington degradation test, and the available performance records, it was observed that the modified Los Angeles rattler test does distinguish between the good and poor aggregates. For limestone aggregates it does not appear to be as discriminating as the Washington degradation test as evidenced by sample number 20744.

This study has shown that the modified Los Angeles rattler test has merit as a degradation test. However, further research is needed to establish the reliability of the test by comparing test results with the complete performance records of aggregates which have been subjected to severe traffic conditions.

SUMMARY AND CONCLUSIONS

Summary

Based on the test results obtained in this study the following modified Los Angeles rattler test procedure is proposed.

1. Prepare the sample in the same manner as required for the Los Angeles rattler test using the B grading.
2. Place the test sample and the abrasive charge into the Los Angeles testing machine. Rotate the machine for 250 revolutions with the aggregate dry. Add 1000 ml of water and rotate for 250 additional revolutions.
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.
4. Adjust the water in the cylinder to the 20-inch mark. Cap the graduated cylinder and mix by inverting from end to end 20 times within 30 seconds. Suspend a thermometer in the solution and allow to settle in an area not subject to direct sunlight.
5. After 20 minutes read the water temperature and record the sediment height to the nearest tenth of an inch.
6. Wash the entire contents of the cylinder over a number 30 sieve and dry the portion retained on the sieve to constant weight.

7. Sieve the dry part over a number 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 a fraction with the per cent loss in the numerator and the sediment height in the denominator.

The modified Los Angeles rattler test has the following advantages over some of the other degradation tests.

1. The preparation of the sample is very simple and requires little time.
2. The total amount of time required to perform the test should be less than one man hour.
3. The test uses a 5000 gram sample, which is five times as large as the Washington degradation test sample. This increases the probability of obtaining a more representative sample.
4. The test does not appear to reject acceptable limestones as readily as does the Washington degradation test.

Conclusions

This research has produced the following conclusions:

1. Water for the sedimentation analysis should be maintained at room temperature.
2. The modified Los Angeles rattler test appears to be as reliable as the Washington degradation test in determining unsatisfactory aggregates.
3. 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.
4. The modified Los Angeles rattler test does not produce as many plastic fines as the Washington degradation test. However, it provides comparable sediment heights.
5. The modified Los Angeles rattler test specifications for the maximum percentage passing the number 16 sieve should be maintained the same as for the percentage passing the number 12 sieve now required for the standard Los Angeles rattler test.
6. The maximum allowable sediment height should depend upon the service requirement for a given aggregate. However, aggregates producing sediment heights greater than 12 inches should be considered undesirable.

Areas of Future Study

1. A series of tests should be made to determine whether or not the residual from the standard Los Angeles rattler test will produce sediment heights comparable to those obtained from the modified Los Angeles rattler test.
2. A correction factor for variations in temperature of the water in the sedimentation cylinder should be determined for use in all degradation tests.
3. A series of tests should be performed on a group of samples to determine the statistical reproducibility of the modified Los Angeles rattler test.

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APPENDIX

TABLE 1

ESTIMATED LITHOLOGICAL AGGREGATE COMPOSITION

Sample No.	Percentage of Constituents	Constituents
20459	35	limestone
	35	granite
	25	diorite - andesite
	2	quartizite
	1	iron-manganese cemented chert pebbles
	1	shale
20460	50	granite
	40	limestone
	8	andesite - diorite
	2	shale
20461	25	granite
	20	shale
	20	cherty limestone
	10	diorite
	5	chert
	5	iron-manganese concretions
	5	sandstone
	5	quartzite
	5	quartz
20482	35	limestone
	30	granite
	15	quartzite
	5	sandstone
	5	chert
	5	diorite
	5	andesite
20483	20	granite
	20	sandstone and quartzite
	20	chert and chalcedony
	17	quartz
	15	limestone
	4	iron concretions
	4	diorite

TABLE 1 (Continued)

Sample No.	Percentage of Constituents	Constituents
20484	42	limestone
	38	granite
	10	andesite
	10	diorite
20525	46	granite
	33	andesite
	15	limestone
	4	quartzite
	2	chert
20526	55	granite
	25	limestone
	10	andesite
	5	iron-manganese concretions
	4	diorite
	1	quartzite
20527	100	Sioux quartzite
20528	35	granite
	30	limestone
	15	iron concretions
	14	quartzite
	6	andesite
20529	45	granite
	40	limestone
	10	andesite
	2	iron concretions
	2	diorite
20530	45	limestone
	35	granite
	10	quartzite
	4	chert and jasper
	3	andesite
	2	schist
	1	iron concretions

TABLE 1 (Continued)

Sample No.	Percentage of Constituents	Constituents
20532	100	limestone
20550	40	dark-colored gneiss
	35	granite
	20	limestone
	5	chert
20553	60	quartz
	20	jasper and chalcedony
	15	andesite
	3	shale or slate
	2	iron concretions
20569	20	cherty limestone
	20	iron concretions
	18	sandstone and conglomerate
	17	chert and jasper
	10	quartz
	10	granite
	5	quartzite
20570	30	granite
	25	cherty limestone
	20	limestone
	15	andesite
	5	shale
	4	sandstone
	1	iron concretions
20619	45	granite
	35	limestone
	11	sandstone
	5	andesite porphory
	2	chalcedony
	1	iron-manganese concretions
	1	diorite

TABLE 1 (Continued)

Sample No.	Percentage of Constituents	Constituents
20630	40	limestone
	35	granite
	5	chert, flint and jasper
	5	andesite
	5	sandstone
	5	quartzite
	5	diorite
20631	100	quartzite
20632	40	granite
	40	limestone
	15	andesite
	2	iron-manganese concretions
	1	amphibole schist
	1	diorite
20737	87	quartz - chalcedony
	10	sandstone and quartzite
	2	andesite
	1	limonite
20744	100	limestone
20802	80	impure limestone
	19	sandstone and siltstone
	1	arkosic rocks
20883	40	limestone
	15	andesite porphyry
	15	quartzite
	15	granite
	14	rhylotic porphyry
	1	shale
20995	60	granite
	34	limestone
	3	andesite
	1	cherty limestone
	1	chert
	1	shale

TABLE 1 (Continued)

Sample No.	Percentage of Constituents	Constituents
20997	45	granite
	35	limestone
	10	andesite
	5	chert
	3	quartzite
	2	iron concretions
20999	65	limestone
	20	sandstone and siltstone
	15	jasper
4000	60	granite
	35	limestone
	5	manganese and chert
4013	50	quartz
	30	chert and flint
	10	limestone
	8	quartzite
	1	shale
	1	iron concretions
4071	95	hard sandstone
	5	sandstone
4123	90	sandstone
	10	chalcedony, jasper and chert
4294	45	limestone
	35	granite
	10	diorite
	5	andesite
	5	sandstone and quartzite
4295	40	limestone
	30	granite
	10	diorite
	10	quartzite
	5	andesite
	3	iron-manganese conglomerate
	2	chert and chalcedony

TABLE 1 (Continued)

Sample No.	Percentage of Constituents	Constituents
4296	50	limestone
	20	granite
	15	diorite
	10	cherty limestone
	2	iron concretions
	1	slate
	1	quartzite
	1	chalk
4297	25	limestone
	20	granite
	20	iron-cemented shale concretions
	15	chert, flint and jasper
	10	iron-manganese concretions
	5	sandstone
	5	diorite and andesite
4298	25	limestone
	25	sandstone
	19	quartzite
	15	quartz
	10	chert and flint
	5	amphibole and diorite
	1	slate
4316	35	quartz
	30	chalcedony and jasper
	10	shale and slate
	10	granite
	5	sandstone
	5	limestone
	4	diorite
	1	iron-manganese concretions
4408	50	jasper and chert
	40	sandstone
	5	quartz
	5	andesite porphrey

TABLE 1 (Continued)

Sample No.	Percentage of Constituents	Constituents
4409	95	sandstone and siltstone
	5	iron-manganese concretions
4410	60	limestone concretions from Pierre shale
	20	jasper, chert and flint
	10	quartz
	5	arkosic minerals
	4	sandstone
	1	iron-manganese concretions

TABLE 2

PERFORMANCE RECORD ESTIMATE

Sample No.	Type of Service Base Course	Bituminous Mat	Gravel Surfacing	Subbase Gravel
20459	none	none	good	none
20460	good	good	good	good
20461	satisfactory	satisfactory	satisfactory	satisfactory
20482	none	none	none	none
20483	fair	fair	good	fair
20484	good	good	good	good
20525	none	none	none	none
20526	good	good	good	good
20527	none	none	none	none
20528	fair	fair	good	good
20529	none	none	none	none
20530	good	good	none	good
20532	none	none	fair	good
20550	none	none	none	good
20553	none	none	none	none
20569	good	good	good	good
20570	none	none	none	none
20619	fair	none	none	none
20630	none	none	none	none
20631	none	none	none	none
20632	good	good	good	good
20737	none	none	good	good
20744	good	good	good	good
20802	fair	none	poor	none
20883	good	good	good	good
20995	good	fair	good	good
20997	good	good	good	good
20999	fair	fair	fair	good
4000	none	none	none	none
4013	fair	none	none	none

TABLE 2 (Continued)

Sample No.	Type of Service			
	Base Course	Bituminous Mat	Gravel Surfacing	Subbase Gravel
4071	fair	good	none	good
4123	fair	poor	fair	good
4294	good	none	none	none
4295	none	none	good	none
4296	good	none	none	none
4297	none	none	none	none
4298	good	good	good	good
4316	good	fair	none	good
4408	good	good	good	good
4409	fair	poor	fair	good
4410	fair	none	none	good

TABLE 3

LOS ANGELES RATTLER TEST RESULTS

Sample No.	L.A.R.* Loss	Sample No.	L.A.R.* Loss
20459	24	20737	28
20460	25	20744	29
20461	27	20802	54
20482	30	20883	26
20483	26	20995	23
20484	25	20997	26
20525	22	20999	36
20526	24	4000	28
20527	21	4013	28
20528	30	4071	31
20529	26	4123	42
20530	23	4294	36
20532	37	4295	24
20550	25	4296	32
20553	27	4297	30
20569	38	4298	30
20570	27	4316	26
20619	24	4408	32
20630	28	4409	44
20631	24	4410	27
20632	28		

* Los Angeles Rattler

TABLE 4

CORRELATING LOS ANGELES RATTLER TEST RESULTS

Sample No.	L.A.R.* Loss
20526	19
20527	20
20619	22
20630	25
20744	29

* Los Angeles Rattler

TABLE 5

SOUTH DAKOTA DEGRADATION TEST RESULTS

Sample No.	Liquid Limit	Plasticity Index	Sample No.	Liquid Limit	Plasticity Index
20459	35	11	20737	28	6
20460	33	5	20744	22	6
20461	49	13	20802	24	4
20482	23	5	20883	20	4
20483	36	9	20995	38	10
20484	24	6	20997	30	7
20525	22	5	20999	26	7
20526	39	12	4000	28	7
20527	-	-	4013	29	9
20528	26	5	4071	20	NP
20529	30	7	4123	36	6
20530	33	6	4294	20	3
20532	20	4	4295	34	10
20550	25	5	4296	23	3
20553	28	10	4297	29	6
20569	36	9	4298	19	3
20570	35	9	4316	43	15
20619	33	9	4408	21	5
20630	30	9	4409	33	4
20631	-	-	4410	37	14
20632	26	5			

TABLE 6

AGGREGATE PROPERTIES

Sample No.	Specific Gravity	Per Cent Absorption	Sample No.	Specific Gravity	Per Cent Absorption
20459	2.67	2.05	20737	2.60	0.76
20460	2.66	2.16	20744	2.70	0.04
20461	2.49	6.37	20802	2.45	4.95
20482	2.68	1.68	20883	2.61	1.32
20483	2.65	2.35	20995	2.68	1.46
20484	2.70	1.80	20997	2.66	2.18
20525	2.67	0.98	20999	2.78	4.43
20526	2.72	0.68	4000	2.69	1.16
20527	2.66	0.02	4013	2.65	0.72
20528	2.62	3.90	4071	2.37	2.01
20529	2.68	1.98	4123	2.18	11.60
20530	2.66	1.96	4294	2.67	2.13
20532	2.65	2.20	4295	2.68	1.79
20550	2.71	0.89	4296	2.67	2.80
20553	2.63	0.72	4297	2.62	4.31
20569	2.68	1.15	4298	2.62	1.85
20570	2.69	1.42	4316	2.67	0.93
20619	2.69	1.56	4408	2.55	2.82
20630	2.68	1.12	4409	2.20	11.95
20631	2.65	0.13	4410	2.61	2.17
20632	2.69	1.80			

TABLE 7

WASHINGTON DEGRADATION TEST RESULTS

Column Identification

Column 1 - Sample Number
Column 2 - Sediment Height in Inches
Column 3 - Grams Lost Through No. 10 Sieve
Column 4 - Grams Lost Through No. 200 Sieve
Column 5 - Degradation Factor, D

1	2	3	4	5
20459	6.4	43	6	41
20460	6.0	63	27	46
20461	14.8	98	52	15
20482	4.5	63	31	49
20483	5.2	41	15	49
20484	3.0	55	13	66
20525	4.2	44	16	55
20526	3.6	38	16	57
20527	0.3	19	7	85
20528	12.0	76	32	24
20529	6.4	50	21	42
20530	4.7	36	16	50
20532	8.8	34	20	28
20550	1.5	46	14	76
20553	2.5	28	12	64
20569	11.0	64	23	28
20570	7.8	37	14	38
20619	2.0	37	16	68
20630	4.8	47	21	49
20631	0.4	30	3	92
20632	4.5	43	19	51
20737	0.6	35	11	84
20744	8.5	38	18	32
20802	12.2	133	82	17
20883	4.8	42	20	48
20995	5.8	49	17	46
20997	4.4	41	25	46
20999	12.5	100	68	15
4000	3.7	39	16	56
4013	3.8	43	13	59
4071	1.0	32	8	82
4123	13.8	117	67	14
4294	7.4	60	33	34
4295	6.2	49	16	45
4296	9.0	52	27	27
4297	10.4	49	21	28
4298	2.7	50	18	64
4316	6.3	47	22	41
4408	4.1	38	23	48
4409	14.4	122	77	13
4410	8.0	37	21	28

TABLE 8

MODIFIED LOS ANGELES RATTLER TEST RESULTS

Column Identification

Column 1 - Sample Number
Column 2 - Per Cent Lost Through No. 8 Sieve
Column 3 - Per Cent Lost Through No. 16 Sieve
Column 4 - Per Cent Lost Through No. 30 Sieve
Column 5 - Sediment Height of the Minus 30 Fraction in Inches
Column 6 - Height of Coarse Fraction in Inches
Column 7 - Sediment Height of Total Sample in Inches

1	2	3	4	5	6	7
20459	29	24	21	12.8	5.2	12.1
20460	29	24	21	11.2	6.0	11.9
20461	30	25	21	17.3	6.3	17.8
20482	34	29	26	9.5	4.9	9.5
20483	28	22	18	9.9	5.9	10.5
20484	29	24	21	7.8	5.3	10.1
20525	25	21	19	8.9	5.8	9.3
20526	24	19	17	9.1	5.2	10.2
20527	25	19	--	1.4	5.6	6.4
20528	34	29	26	14.7	5.5	15.6
20529	29	24	22	10.7	5.8	11.7
20530	24	20	18	9.6	6.0	10.8
20532	39	32	29	7.9	5.2	7.9
20550	28	22	19	7.8	5.7	8.2
20553	29	22	18	8.5	5.9	10.5
20569	36	28	22	12.5	6.0	13.1

TABLE 8 (Continued)

1	2	3	4	5	6	7
20570	27	23	20	11.3	5.6	12.4
20619	25	21	18	9.4	5.5	10.3
20630	31	27	24	10.6	5.3	10.6
20631	24	20	18	1.6	5.7	7.1
20632	29	25	22	10.4	5.6	11.4
20737	29	23	19	10.2	5.5	10.8
20744	31	25	21	9.6	5.3	9.1
20802	63	55	50	14.6	4.1	15.6
20883	29	23	20	12.2	5.4	13.0
20995	28	23	20	11.1	5.3	12.4
20997	29	25	22	8.8	5.2	11.1
20999	52	43	31	15.6	4.4	16.4
4000	32	25	20	11.0	5.2	11.3
4013	30	25	23	13.2	5.7	15.2
4071	35	27	23	1.9	6.5	8.6
4123	49	41	37	17.4	5.7	18.4
4294	36	31	28	11.3	5.1	10.7
4295	25	20	18	11.0	5.6	11.3
4296	33	27	24	12.1	5.3	13.0
4297	32	26	22	13.8	5.5	14.8
4298	34	28	25	10.9	5.2	10.7
4316	27	21	19	11.2	5.7	12.7
4408	36	29	26	10.9	5.6	11.7
4409	50	41	36	17.9	5.9	18.2
4410	30	24	20	13.4	5.7	15.3

TABLE 9

LIQUID LIMIT AND PLASTICITY INDEX FOR STANDARD AND MODIFIED LOS ANGELES RATTLER TESTS RESIDUAL

	Standard Test		Modified Test	
Sample No.	Liquid Limit	Plasticity Index	Liquid Limit	Plasticity Index
20459	22	NP	20	NP
20460	21	NP	20	NP
20461	29	3	34	5
20482	20	NP	18	NP
20483	24	NP	21	NP
20484	19	NP	18	NP
20525	19	NP	17	NP
20526	18	NP	18	NP
20527	18	NP	20	NP
20528	21	NP	19	NP
20529	21	NP	20	NP
20530	22	NP	21	NP
20532	19	NP	17	NP
20550	18	NP	17	NP
20553	17	NP	16	NP
20569	29	NP	26	NP
20570	20	NP	18	NP
20619	19	NP	19	NP
20630	20	NP	18	NP

TABLE 9 (Continued)

Sample No.	Standard Test Liquid Limit	Standard Test Plasticity Index	Modified Test Liquid Limit	Modified Test Plasticity Index
20631	17	NP	--	--
20632	19	NP	18	NP
20737	19	NP	18	NP
20744	18	NP	17	NP
20802	21	NP	19	NP
20883	19	NP	17	NP
20995	20	NP	20	NP
20997	20	NP	19	NP
20999	22	NP	21	NP
4000	19	NP	18	NP
4013	17	NP	17	NP
4071	22	NP	--	NP
4123	30	NP	28	NP
4294	19	NP	19	NP
4295	21	NP	20	NP
4296	21	NP	20	NP
4297	25	NP	23	NP
4298	18	NP	18	NP
4316	23	NP	21	NP
4408	18	NP	18	NP
4409	30	NP	30	NP
4410	19	NP	21	NP

TABLE 10

COMPARISON OF DEGRADATION TESTS

Col-1 Passed All Three Tests	Col-5 Failed MLAR Test*
Col-2 Failed All Three Tests	Col-6 Failed South Dakota & MLAR Tests*
Col-3 Failed South Dakota Test	Col-7 Failed Washington & MLAR Tests*
Col-4 Failed Washington Test	Col-8 Failed Washington & South Dakota Tests

* Modified Los Angeles rattler test

1	2	3	4	5	6	7	8
20460	20461	20483	20532	20883	20459	20528	none
20482	20569	20526	20744		20995	20802	
20484	20570	20529	4294		4013	4123	
20525	20999	20553			4316	4296	
20527	4410	20619				4297	
20530		20630				4409	
20550		20997					
20631		4000					
20632		4295					
20737							
4071							
4298							
4408							