RESULTS OF COOPERATIVE TESTS USING THE LOS ANGELES ABRASION MACHINE

By D O Woolf

Associate Materials Engineer, U S Bureau of Public Roads

SYNOPSIS

Check abrasion tests were made by 18 cooperating laboratories on a sample of crushed limestone of uniform quality to study the effect on the test result of differences in the design and operation of Los Angeles abrasion machines Remarkably concordant results were obtained, the mean deviation from the average for all laboratories being only 5 6 per cent Study of the features of the different machines shows that the weight of the abrasive charge and the design of the shelf affect the test result to the greatest extent Suggestions regarding the design of the shelf are made, and agreement with latest revised specifications for the construction and operation of the machine is recommended

The Los Angeles abrasion machine was devised by employees of the Los Angeles City Engineer's Office in 1916 Subsequently it was adopted by the California Division of Highways for use in testing coarse aggregates, and more recently it has been used by a number of other state highway, Federal, municipal, college, and commercial laboratories A number of state highway departments now use the Los Angeles test for the acceptance of coarse aggregates to be used in road construction, and have discarded the Deval abrasion and Page toughness tests which were formerly used for this purpose

Several investigations have been made comparing the Los Angeles and Deval test methods [1] The principal conclusions from these investigations may be summarized as follows

1 The Los Angeles test is more accurate and can be made much more rapidly than the Deval test

2 The loss in the Los Angeles test is produced largely by impact, which eliminates the need for the Page toughness test

3 The degree of angularity of the particle under test has very little influence on the test result Thus rounded or angular particles can be tested with little difference in the test results However, the shape of the particle does have considerable effect on the loss, and flat or elongated particles show a much higher percentage of wear than those of equal hardness which tend more toward spherical or cubical shape

4 The Los Angeles test is made on material prepared for use on the project, whereas the Deval abrasion and Page toughness tests require ledge rock which may not represent the material actually used

5 A definite agreement between the service records of materials used in surface treatment construction and loss in the Los Angeles test appears to have been found by one of the investigating laboratories Another found a correlation between the loss in the Los Angeles test and the compressive and flexural strength of concrete

Sufficient data seem to have been obtained to show the value of the Los Angeles test and to indicate that it can be used to replace the Deval abrasion and Page toughness tests The next

[1] The Los Angeles Abrasion Machine for Determining the Quality of Coarse Aggregate, by D O Woolf and D G Runner, Proc, A S T M, vol 35, pt II, p 511 (1935)

The Los Angeles Rattler Test as a Means of Evaluating Coarse Aggregates, by Thomas E Stanton, Jr, presented before the Committee on Materials, American Assn State Hwy Officials, Dec, 1935

The Los Angeles Rattler Test for Determining the Structural Quality of Coarse Aggregate, by the Division of Tests, Inspection and Research, Minn Dept of Highways, Investigation No 102, 1936 Supplement important feature in the study of the Los Angeles machine involved the design of the machine and the effect of variations in the design on the test result

The earlier specifications for the machine were not very explicit and machines constructed from the general description given showed some differences depending upon the interpretations made by the designer The effect which these differences in design and construction would have on the test result could not well be predicted and it was considered advisable to determine this by actual test Invitations to cooperate in these tests were sent by the Committee on Correlation of Research in Mineral Aggregates of the Highway Research Board to all laboratories which were equipped with the Los Angeles machine Favorable replies were received from 22 laboratories

In April, 1936, samples of crushed limestone from Riverton, Virginia, were sent to each of 22 laboratories by the Bureau of Public Roads with the request that the material be tested for wear in the Los Angeles machine and that the results and certain information regarding the construction and operation of the machine be furnished for study by the committee Reports were received from 18 laboratories Subsequent to the receipt of the reports, additional information was considered necessary and each laboratory was requested to furnish a sketch showing the design and dimensions of the shelf Table 1 shows information concerning the design and operation of the machines Figure 1 shows the different designs used in constructing the shelf in the machine

In general, the different machines agree very well with regard to the size of the drum One laboratory reports a diameter of 30½ in and two others report the use of metal ¼ or $\frac{7}{16}$ in thick The remainder, however, have practically the same dimensions Considerable differences are found in the construction of the shelf of the machine Thirteen of the 18 laboratories report that the shelf is built from an angle, and the remainder report the use of plate metal Fourteen laboratories report a square edge to the shelf The thirteen laboratories using a shelf built from an angle are about equally divided on the question of catching the charge on the inside or outside of the angle Six laboratories report no signs of wear on the shelf with tests varying in number from 4 to 500 The data furnished by the other laboratories, however, indicate that some wear may be found with as few as 50 tests Only two laboratories report that no gasket is used under the cover of their machines The remaining machines are equipped with gaskets of rubber, cork, felt, or canvas, which vary in thickness from 0 07 to 0 25 in Only a few of the machines are reported to leak dust, and the loss is stated to be small

An abrasive charge composed of cast iron balls is reported for 14 of the laboratories The remaining four laboratories report the use of steel balls, which are understood to be steel balls for bearing purposes All except three laboratories report the total weight of the abrasive charge to be within 50 grams of 5,000 grams Only three laboratories report the use of individual balls weighing outside the tolerances of 400 to 450 grams which were recommended at the time of these tests

For determining the loss in the test, 15 laboratories report the use of a sieve in which 10 wires and 10 openings-between-wires occupy a measured length of approximately 1 0 inch This agrees with the size of opening (0 065 inch) and diameter of wire (0 035 inch) shown by one manufacturer for a U S No 12 sieve meeting the requirements of A S T M Specification E 11-26 Two laboratories report the use of a sieve agreeing very closely with the opening and wire sizes shown in Specification E 11 for the No 12

TABLE 1

Details of Los Angeles Abrasion Machines

Laboratory number	Drum: Length	Drum: Diameter	Drum: Thickness	Shelf: Made from	Shelf: Mounted on	Shelf: Edge	Shelf: Effective width (1)	Shelf: Charge caught (2)	Shelf: Signs of wear	Shelf: Number of tests made	Gasket: Material	Gasket: Thickness	Abrasive charge: Total weight	Abrasive charge: Weight of one ball, Max	Abrasive charge: Weight of one ball, Min	Abrasive charge: Type of ball	Sieve measurement (3)	Test sample: Oven dried	Test sample: Washed after test	Test sample: Tolerance in weight
	inches	inches	inches	inches			inches					inches	grams	grams	grams		inches			grams
1	20	28	½	Angle 6 by 4 by ½	Cover	Square	3¼	Outside	No	57	Cork	¼	5,035	434	402	Cast iron	1 0	Yes	Yes	None
2	20	28	½	Angle 6 by 4 by ½	do	do	3⅛	do	Yes	100	Rubber	⅛	5,038	432	404	do	1 0	do	do	5
3	20 3/16	27¾	½	Angle 6 by 4 by ½	do	do	3½	do	Yes	100	Cork	⅛	5,004	423	403	do	1 0	do	do	None
4	20⅛	28	½	Plate	Drum	do	3½		Yes	95	Canvas	⅛	5,000	445	401	do	1 0	do	do	do
5	20	28	½	Angle 6 by 4 by ½	Cover	Rounded	3¼	Inside	Yes	1,500	None		5,000±50	429	415	do	1 0	No	No	1
6	20¼	28 1/16	½	Angle 2 by 3½ by ½	Drum	Square	3½	do	Yes	1,000	Cork	0 1	5,002	440	402	do	0 91	Yes	Yes	None
7	20	28	½	Plate	do	do	4		No	75	Hard rubber	⅛	4,996	435	412	Steel	10	Yes	Yes	do
8	20	28	½	Angle 6 by 3½ by ½	do	do	3 9/16	Outside	No	287	Felt	1/16	4,846	426	372	Cast iron	1 0	do	No	do
9	20	28	¼	Plate	Cover	do	4		Slight	200	Rubber	3/32	4,999	427	401	do	1 0	do	Yes	1
10	20	28	½	do	do	do	3½		do	50	do	1/16	5,035	420	416	Steel	1 0	do	do	10
11	20	30½	15/32	Angle 6 by 4 by ½	do	do	3½	Inside	do	350	Canvas	⅛	5,000	448	368	do	0 75	do	do	None
12	20	28	½	Angle 6 by 4 by ½	do	Rounded	3¼	do	do	80	None		5,040	425	405	Cast iron	1 0	No	No	5
13	20	28	½	Angle 2 by 3½ by ½	Drum	do	3¼	do	do	2,500	Rubber	3/32	5,013	420	410	do	0 98	do	Yes	None
14	20	28	½	Angle 6 by 4 by ½	Cover	Square	3⅜	Outside	No	500	do	0 1	5,000	423	412	do	1 0	Yes	do	1
15	20	28	½	Angle 6 by 4 by ½	do	Rounded	3¼	Inside	Yes	120	do	⅛	5,000	420	408	do	1 0	do	do	1
16	20	28	½	Angle 5⅝ by 4¼ by ¾	do	Square	3⅝	do	No	225	do	3/32	4,817	408	389	do	1 0	do	do	None
17	20	27⅞	7/16	Plate	Drum	do	3½		No	4	do	1/32	5,297	442	441	Steel	1 0	do	do	2
18	20	28	½	Angle 6 by 4 by ½		do	3½	Outside	Yes	100	do	1/16	5,024	428	407	Cast iron	0 93	do	do	10

(1) Width of shelf available for catching test charge
(2) Refers to angle used for shelf.
(3) Length occupied by 10 wires and 10 openings-between-wires in sieve used to determine the loss

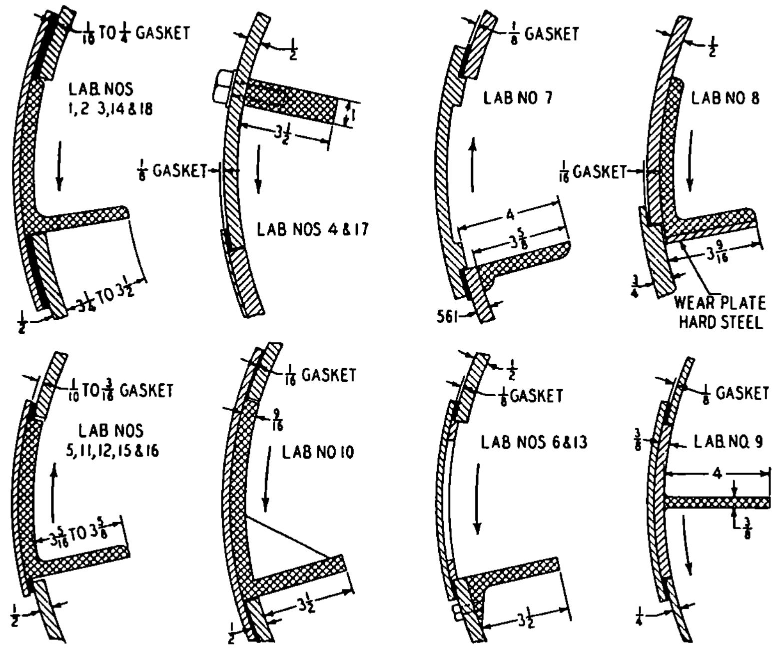

Figure 1. Types of Shelf Used in Los Angeles Abrasion Machine

TABLE 2
RESULTS OF COOPERATIVE TESTS

Laboratory number	Per cent of wear				Deviation from average	
	Sample 1	Sample 2	Sample 3	Average	Laboratory average	Grand average
					per cent	per cent
1	20 5	21 1		20 8	1 4	9 2
2	24 1	23 3		23 7	1 7	3 5
3	22 5	22 3	21 5	22 1	1 8	3 5
4	23 6	23 2	23 4	23 4	0 5	2 2
5	24 5	23 8	23 7	24 0	1 2	4 8
6	23 7	23 4	23 4	23 5	0 4	2 6
7	23 4	20 4	19 5	21 1	7 1	7 9
8	22 7	21 8	22 6	22 4	1 8	2 2
9	23 6	23 6	23 2	23 5	0 9	2 6
10	23 2	23 4	23 0	23 2	0 4	1 3
11	21 7	21 7	21 4	21 6	0 5	5 7
12	20 6	21 4	21 0	21 0	1 4	8 3
13	21 3	21 2	22 0	21 5	1 5	6 1
14	20 7	22 3		21 5	3 7	6 1
15	23 4	23 9	24 2	23 8	1 3	3 9
16	25 2	26 6		25 9	2 7	13 1
17	25 6	27 2	27 6	26 8	3 0	17 0
18	22 1	22 9		22 5	1 8	1 7
Average				22 9	1 8	5 6

sieve, and the remaining laboratory reports a measured length indicating the use of a U S No 14 sieve

In preparing the sample for test, 15 of the laboratories oven-dry the material, and the same number report that the sample is washed following the test All laboratories limit the tolerance on the initial weight of the test sample to 10 grams or less

The results of the tests made by the cooperating laboratories are shown in Table 2 and Figure 2 In five cases sufficient material for only two tests was received, but the other 13 laboratories reported the results of three tests each The results show very good agreement between different laboratories The mean deviation from the average for all laboratories is 5 6 percent. Parenthetically, reference to work on the Deval abrasion machine shows this value to be of the same magnitude as the agreement usually found by a single laboratory between repeated Deval tests. Only two laboratories report deviations from the average of over 10 percent Only one laboratory shows a marked difference between the results of the three tests made in its machine, and the mean deviation from the average for each laboratory is only 1 8 percent Practically all laboratories are able to duplicate their own test results, and to agree closely with results obtained by other laboratories

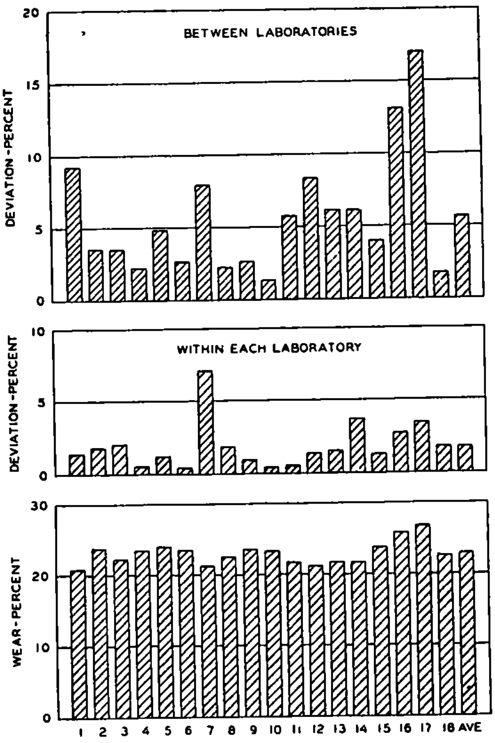

Figure 2. Results of Coöperative Abrasion Tests Using the Los Angeles Machine

Study of the available data indicates that some of the average results which differ considerably from the average for all laboratories may be explained Laboratory 17, which found a loss of 26 8 percent against the average for all laboratories of 22 9 percent, used an abrasive charge weighing 5,297 grams. The excessive weight of the abrasive charge is believed to be the reason for the higher loss found by this laboratory. Laboratory 1, which found a loss of 20 8 percent, used a cork gasket ¼ in thick under the cover for the drum This had the effect of reducing the working width of the shelf to 3¼ inches, and is believed to be the probable reason for the lower loss obtained by this laboratory Laboratory 11, which found a low loss, reports the use of a drum measuring 30½ inches in diameter This would be expected to give a high loss due to the greater distance through which the charge falls However, this laboratory states that the length occupied by 10 wires and 10 openings-between-wires in their sieve used to determine the loss is 0 75 inch This measurement corresponds closely with that for a No 14 sieve manufactured by a certain concern, and the probabilities are that the low loss found by this laboratory is due mainly to the use of this sieve Tests made by the Bureau of Public Roads have shown a difference in the percentage of wear of about 5, depending on whether the U S No 12 or U S No 16 sieve was used to determine the loss It is possible then that if laboratory 11 had used a No 12 sieve its loss would have been about 2 percent higher, and in close agreement with the average for all laboratories

Laboratories 12 and 13 used a shelf with an effective width of 3¼ in which is the apparent reason for the low loss found by them Laboratories 5 and 15 also used a 3¼-in. effective width shelf but secured test values somewhat higher than the average for all laboratories Laboratory 7 used a shelf of 4 in effective width and found a loss very close to those for laboratories 12 and 13 Laboratory 16 used an abrasive charge weighing only 4,817 grams, which indicates that a low loss would be obtained but instead found a relatively high percentage of wear It seems apparent that the width of the shelf and the weight of the abrasive charge are not the only variables in this series of tests which had an important bearing on the test result Some other features which cannot be identified with the data at hand must have exerted considerable influence to furnish the test results which were obtained

It has been the experience of the Bureau of Public Roads that wear or displacement from its normal position of the shelf has a considerable effect on the test result This indicates the possibility that the results found by some of the laboratories were affected by wear or bending of the shelf If the shelf were bent from its normal position, the probabilities are that the impact on the test sample would be reduced and a low result obtained.

One question frequently raised regarding the Los Angeles test has been that of using steel balls instead of the cast iron balls which are specified It seems that some laboratories have difficulty in securing cast iron balls of the specified weight, and have used steel balls which are readily obtained from dealers in machine supplies Unfortunately, little information comparing the two types of balls can be obtained from this series of tests Although four laboratories used steel balls as the abrasive charge, only one used a test procedure conforming in all particulars with the specifications for the method of test This one laboratory found a test value agreeing very closely with the average for all the laboratories Although it is possible that either type of ball may be used with satisfactory results, the information available here does not warrant any definite statements on this question

The latest revisions of the Los Angeles abrasion test which have been included in the tentative method adopted by the American Association of State Highway Officials and the American Society for Testing Materials require in part the following:

"A shelf which projects 3½ in into the drum, and extends the full length of the drum, shall be attached to the cover or to the inside of the drum The surface of the shelf which catches the charge shall be rectangular and shall lie in a radial plane

"If an angle is used as the shelf, the machine shall be rotated in such a direction that the charge is caught on the outside surface of the angle."

These specifications indicate clearly that the shelf shall project exactly 3½ inches beyond the inside surface of the drum The requirement that the outside face of the angle shall catch the charge, if such is used for the shelf, eliminates the effect of variables such as rounded heads of rivets holding the shelf to the cover or drum, the tapered leg of the angle as used by laboratories 6 and 13, and the rounded edge of the angle as used by laboratories 5, 12, 13, and 15 It must be pointed out that if an angle fastened to the cover is used, the thickness of the gasket when under pressure must be considered to insure that a 3½-in effective width of the shelf is obtained.

One feature which has not been covered by the latest revisions of the tentative method is that the inside surface of the cover should be flush with the inside surface of the drum If as in the case of laboratory 7 the inside surface of the cover is depressed and the charge is caught against the cover, the shelf may be assumed to have a greater effective width than is intended Consequently to insure uniform conditions the inside surface of the cover should be flush with that of the drum, and the specifications should be amended to so require

CONCLUSION

In spite of the several variables found between the different machines, this series of tests shows that the Los Angeles abrasion test method permits good correlation of results between different laboratories When the slight changes necessary to place the different machines in agreement with the latest specifications are made, it is confidently expected that little if any difference will be found between the results of cooperating laboratories

With the establishment of a design of machine which appears to be satisfactory, the major feature which remains in the investigation of the Los Angeles test is the determination of acceptable test limits for specification purposes This can be accomplished by comparing test results with the known service record of materials used in different types of road construction It is understood that considerable information of this nature has already been obtained for study by the committee and it is hoped that a report covering the findings will be available at an early date

DISCUSSION

PROF J S CRANDELL, *University of Illinois* What is considered a narrow shelf and what is a wide shelf?

MR WOOLF The narrowest shelf which we found any laboratory to have was $3\frac{1}{4}$ in The widest was 4 in