REPORT OF COMMITTEE ON CORRELATION OF RESEARCH IN MINERAL AGGREGATES

R R LITEHISER, *Chairman*

THE RELATION BETWEEN LOS ANGELES ABRASION TEST RESULTS AND THE SERVICE RECORDS OF COARSE AGGREGATES

By D O Woolf

Associate Materials Engineer, U S Bureau of Public Roads

SYNOPSIS

Because all States do not have the same range in quality of coarse aggregates, and one State with an abundance of hard rock will consider certain test values for quality as necessary which could not be used by other States, it must be emphasized that recommendations are subject to change with local conditions In general, however it appears that there is a definite relation between the loss in the Los Angeles test and the service record of materials used in concrete, bituminous construction and surface treatment On the basis of the data available, the following percentages of wear appear to be suitable for use in specifications to control the quality of coarse aggregates Concrete, 50 per cent, Bituminous surfacing, 40 per cent, Surface treatment, 40 per cent

Definite correlations between the loss in the Los Angeles test and the strength of concrete are found, the lower the percentage of wear the higher the concrete strength Definite correlations are also found with the results of a circular track roller test and a test for soft or friable pieces It appears that the Los Angeles test gives accurate indication of the quality of the material under test, and that its use in specifications controlling the acceptance of coarse aggregate is warranted

The proposal to adopt the Los Angeles abrasion test as a substitute for the present standard methods of determining the resistance to abrasion or impact of coarse aggregates has raised the question as to what relations exist between the results of this test and service behavior In 1935 the Committee on Correlation of Research in Mineral Aggregates of the Highway Research Board recommended that a study of this feature be made and a request for information was sent to all highway engineering authorities Considerable information was collected in 1935 and 1936 by the Board, and this was supplemented by additional data secured by the Bureau of Public Roads in 1937

For purposes of discussion the information which has been secured will be classified under two heads, first, that showing a direct comparison between the Los Angeles test result and the service record of the material, and second, that comparing the Los Angeles test result with strength tests of concrete or with wear tests of aggregates which simulate the action of traffic In presenting the data on service behavior effort has been made to present the information from different sources in similar terms in order to permit of ready comparison Also to insure that no error of interpretation has been made, laboratory reference numbers are given, where available, to designate the particular materials under consideration so as to permit ready checking of the service records reported here by the authorities from whom the data were obtained

COMPARISONS WITH SERVICE RECORDS

Data comparing the Los Angeles abrasion test results with service records have been obtained from eight State highway departments and a highway board in Australia In general, the data as presented in Tables 1 to 9 show the type of material, the Los Angeles abrasion test result, the service record of the material when used in concrete, bituminous pavement, or surface treatment construction, and a laboratory number designating the material The letter S indicates that the results in service have, in general, been satisfactory, the letter Q that the exact rating is in question and the letter U that generally unsatisfactory results have been obtained In a number of cases several samples of the same material are shown in the original data from which these tables were compiled In such cases the value shown in the table is the average of all the values reported Also the values given as the Los Angeles test result are generally averages of the two gradings permitted in the test method

Table 1 presents service records compiled by the Florida State Roads Department With only two exceptions all rock and blast furnace slag with Los Angeles test results of less than 40 percent are classed as being satisfactory for use in concrete, bituminous construction and surface treatment The two exceptions are a slag with a Los Angeles loss of 28 8 percent which is considered unsuitable for use in surface treatment, and a limestone with a Los Angeles loss of 38 2 and having a rough open texture which is considered questionable or unsuitable for all three types of construction Gravel from three sources with Los Angeles losses from 41 to 48 percent are classed as satisfactory for use in concrete and bituminous construction, but as questionable for use in surface treatment

TABLE 1

COMPARISON BETWEEN LOS ANGELES TEST RESULT AND SERVICE RECORD BY FLORIDA STATE ROAD DEPARTMENT

Sample No	Type of material	Description	Los Angeles per cent of wear	Service record		
				Concrete	Bituminous construction	Surface treatment
54673	Rock	Dolomite	14 8	S	S	S
54671	"	Chert	15 2	S	S	S
54577	Slag	80 pound	23 2	S	S	S
54678	"	"	28 0	S	S	S
54676	"	71 pound	28 8	S	S	U
54670	Rock	Limestone	31 0	S		S
54675	"	"	34 8	S		S
54674	"	"	38 2	Q	U	U
54672	"	"	40 9	Q		U
54667	Gravel	Quartz	41 2	S	S	Q
54669	"	"	43 4	S	S	Q
54668	"	"	48 5	S	S	Q

Table 2 presents a comparison between the Los Angeles test result and the service record of materials used in surface treatment work based on data supplied by the Georgia State Highway Board Both rock and blast furnace slag with Los Angeles losses of 40 percent or less are found to have satisfactory service records

Data furnished by the Kansas State Highway Commission giving service records for concrete and bituminous construction are shown in Table 3 All materials had satisfactory service records

TABLE 2

COMPARISON BETWEEN LOS ANGELES TEST RESULT AND SERVICE RECORD BY GEORGIA STATE HIGHWAY BOARD

Type of material	Description	Los Angeles percent of wear	Service record in surface treatment
Slag	Copper	14 6	S
Rock	Limestone	26 1	S
Slag	Blast furnace	27 3	S
Rock	Dolomite	38 2	S
"	Granite	40 2	S
Gravel	Quartz	49 1	U
Rock	Granite	61 9	U

The data indicate that satisfactory results were secured with materials having losses as high as 47 4 percent in the case of concrete and 40 8 percent in the case of bituminous construction

Data furnished by the North Carolina State Highway and Public Works Commission regarding the behavior of materials in surface treatment construction are shown in Table 4 All materials found to be satisfactory for this use have percentages of wear in the Los Angeles test of less than 40

TABLE 3

COMPARISON BETWEEN LOS ANGELES TEST RESULT AND SERVICE RECORD BY KANSAS STATE HIGHWAY COMMISSION

Sample No	Type of material	Description	Los Angeles per cent of wear	Service record	
				Concrete	Bituminous construction
27061	Rock	Limestone	30 8	S	S
27039	"	"	31 8	S	S
27069	"	"	32 4	S	S
27070	"	"	40 0	S	S
27071	"	Calcareous sandstone	40 8	S	S
27099	"	Limestone	47 4	S	

TABLE 4

COMPARISON BETWEEN LOS ANGELES TEST RESULT AND SERVICE RECORD BY NORTH CAROLINA STATE HIGHWAY AND PUBLIC WORKS COMMISSION

Sample No	Type of material	Description	Los Angeles per cent of wear	Service record
				Surface treatment
11	Rock	Granite	17 4	S
9	"	Limestone	19 9	S
8	"	"	21 3	S
10	"	Dolomitic limestone	24 2	S
7	"	Granite and diorite	36 4	S
2	"	Granite gneiss	37 9	S
12	Gravel	Quartz—gneiss	41 9	Q
13	"	Quartz	42 6	Q
3	Rock	Granite gneiss	47 1	U
16	Gravel	Quartz	47 6	Q
1	Rock	Dolomitic limestone	47 8	Q
4	"	Pegmatitic granite	50 6	Q
15	Gravel	Quartz	53 0	Q
14	"	"	54 1	Q
6	Rock	Granite	57 0	U
5	"	"	62 4	U

Table 5 presents data furnished by the Ohio Department of Highways showing the service record of materials in concrete and bituminous construction With for use in the types of construction mentioned No explanation of the behavior of these two questionable materials was furnished

TABLE 5

COMPARISON BETWEEN LOS ANGELES TEST RESULT AND SERVICE RECORD BY OHIO DEPARTMENT OF HIGHWAYS

Sample No	Type of material	Description	Los Angeles per cent of wear	Service record	
				Concrete	Bituminous construction
9	Rock	Limestone	20 5	S	S
10	"	"	23 3	S	S
15	Slag	83 5 lb	27 9	S	S
11	Rock	Limestone	28 5	S	S
5	Gravel	Crushed	28 7	S	S
1	"		28 9	S	S
6	"	Crushed	29 6	S	S
2	"		31 0	Q	Q
16	Slag	72 5 lb	32 0	S	S
13	Rock	Limestone	32 7	S	S
3	Gravel		32 8	Q	Q
12	Rock	Limestone	33 2	S	S
4	Gravel		37 2	Q	Q
8	"	Crushed	38 8	Q	Q
17	Slag	69 5 lb	47 8	Q	Q
14	Rock	Limestone	58 0	Q	Q

TABLE 6

COMPARISON BETWEEN LOS ANGELES TEST RESULT AND SERVICE RECORD BY SOUTH CAROLINA STATE HIGHWAY DEPARTMENT

Sample No	Type of material	Description	Los Angeles per cent of wear	Service record		
				Concrete	Bituminous construction	Surface treatment
A-21778	Rock	Granite	33 4	S	S	S
A-21781	"	"	34 8	S	S	S
A-23260	"	"	41 1	S	S	S
A-22269	Gravel	Siliceous	46 2	S[1]	Q	Q
A-22497	"	"	46 3	S[1]	S	
A-22422	"	"	52 5	S[1]	U	U
A-22421	"	"	53 9	S[1]	U	U
A-21198	Rock	Dolomitic marble	58 2	S		
A-22492	"	Gneiss	67 4	S	U	U
A-22423	Gravel	Siliceous	74 0	U	U	U

[1] For structural service only

the exception of gravel from two sources, all materials with Los Angeles losses of less than 35 percent are found suitable

Service records for materials used in concrete, bituminous surfacing, and surface treatment are given in Table 6 based

on information furnished by the South Carolina State Highway Department These data show materials with Los Angeles losses of 41 percent or less to be satisfactory for use in surface treatment Materials with losses to 46 percent are considered satisfactory for use in bituminous construction and a rock with a loss of 67 percent is considered suitable for use in concrete Four samples of gravel with losses between 46 and 54 percent are considered suitable for structural concrete only

Data furnished by the Texas State Highway Department giving service

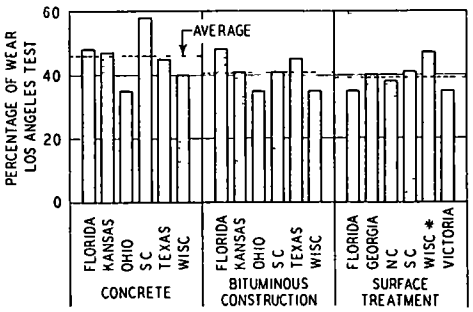

Figure 1 Maximum Percentage of Wear in Los Angeles Test for Material of Satisfactory Service Record

*** Traffic Bound Surfacing**

records for materials used in concrete and bituminous construction are shown in Table 7 With only five exceptions all samples of rock and gravel with Los Angeles test losses of less than 45 percent are found to be satisfactory for use in both types The five exceptions include three limestones with losses of 30 2, 31 6 and 37 5 percent, a siliceous gravel with a loss of 30 6 percent, and a quartzite with a loss of 42 7 percent The limestone with a loss of 30 2 percent is considered satisfactory for use in concrete but questionable for bituminous surfacing The gravel is stated to be laminated, and this may account for its poor service record Two of the three limestones were taken from sources which apparently contained material of variable quality, and it is possible that the low values given represent material of better quality than has been supplied for use All materials with losses above 45 percent are stated to be unsuitable for bituminous construction and those above 51 percent to be unsuitable for use in concrete

Table 8 shows service record data for concrete, bituminous construction, and traffic bound surfacing furnished by the Wisconsin State Highway Department The data are not complete in that service records for all three classes of construction are not shown for a majority of the materials However, all materials with a Los Angeles loss of less than 40 percent are stated to be satisfactory for use in those types of construction where a record is available With the exception of one sample, a dolomite, all materials with losses of 47 percent or less were reported as satisfactory for use in traffic bound surfacing This surfacing was placed largely on town or county roads and presumably carried only light traffic

In Table 9, the service record of materials used mainly in surface treatment construction is given from records furnished by the Country Roads Board of the State of Victoria, Australia [1] All rock and gravel with a Los Angeles loss of 35 per cent or less are stated to have excellent to fair service records, but the Board concludes that a maximum loss of 20 percent should be used for the best surfacing materials

A summation of the foregoing information is presented in Figure 1, with the findings of the different highway authorities grouped according to type of construction Some liberties have been taken in presenting these data in that the values given may include a few materials without satisfactory service rec-

[1] The Los Angeles Abrasion Test, by A H Gawith, *Main Roads,* Vol 8, No 2, Feb 1937, p 54

TABLE 7

COMPARISON BETWEEN LOS ANGELES TEST RESULT AND SERVICE RECORD BY TEXAS STATE HIGHWAY DEPARTMENT

Sample No	Type of material	Description	Los Angeles per cent of wear	Service record	
				Concrete	Bituminous construction
2979	Rock	Rhyolite	16 1	S	S
2992	"	Dolomitic	19 0	S	S
1934	Gravel	Siliceous	20 6	S	S
2951	"	"	22 2	S	S
3699	Rock	Limestone	22 2	S	S
2838	Gravel	Siliceous	24 5	S	S
2815	"	"	25 4	S	S
3557	"	"	25 6	S	S
3754	"	"	25 7	S	S
3723	Rock	Limestone	26 3	S	S
3672	"	"	26 9	S	S
3000	Gravel	Limestone and siliceous	27 0	S	S
2873	Rock	Limestone	27 2	S	S
3698	"	"	27 5	S	S
2243	Gravel	"	29 0	S	S
3092	Rock	"	29 1	S	S
2898	Gravel	Siliceous	30 0	S	S
2767	"	Limestone	30 1	S	S
3670	Rock	"	30 2	S	Q
3538	Gravel	Siliceous	30 6	Q	U
2975	Rock	Calcareous shale	30 8	S	S
2667	Gravel	Limestone	31 3	S	S
3766	Rock	"	31 6	U	U
3013	"	"	32 2	S	S
3823	"	"	33 2	S	S
3668	"	"	34 5	S	S
3783	"	"	35 1	S	S
3724	"	"	36 3	S	S
3803	"	Dolomite	36 3	S	S
3014	"	Limestone	37 5	Q	U
2367	Gravel	Siliceous	37 9	S	S
2824	Rock	Limestone	38 2	S	S
3228	"	"	39 3	S	S
3111	"	Quartzite	42 7	Q	Q
3824	"	Limestone	42 8	S	S
2368	Gravel	Siliceous	42 8	S	S
3229	Rock	Limestone	44 4	S	S
3805	"	"	46 9	Q	U
3725	"	"	49 2	Q	U
3816	"	"	50 5	Q	U
3015	"	"	54 3	U	U
2675	"	"	60 1	U	U
3669	"	"	62 0	U	U
2674	"	"	65 9	U	U

ords However, the attempt has been made to show a maximum value for the Los Angeles percentage of wear which includes all materials of satisfactory service record and excludes the majority of materials which have proved unsatisfactory In general, it will be noted that the values given for bituminous surfacing are somewhat lower than those for concrete, and those for surface treatment are still lower This follows the general trend of the specification limits which have already been established for the Los Angeles test by several State Highway Departments

TABLE 8

COMPARISON BETWEEN LOS ANGELES TEST RESULT AND SERVICE RECORD BY WISCONSIN STATE HIGHWAY DEPARTMENT

Sample No	Type of material	Description	Los Angeles per cent of wear	Service record		
				Concrete	Bituminous construction	Traffic bound surfacing
1	Rock	Trap	11 1	S	S	S
4	Gravel	Igneous	18 4	S		
5	Rock	"	18 9			S
6	Gravel	Mixed igneous	19 4	S		S
7	"	" "	19 4	S		
8	"	" "	20 2	S		
9	Rock	Dolomitic	21 8			S
10	Gravel	Mixed igneous	22 2	S		
11	"	" "	22 3	S		
12	"	Igneous	22 3			S
13	"	"	22 5			S
14	"	"	23 5	S		
15	Rock	Dolomitic	25 1	S	S	S
16	Gravel	"	25 2			S
18	Rock	"	26 0		S	S
20	Gravel	"	27 3	S		S
21	"	Mixed igneous and sedimentary	27 7			S
22	Rock	Dolomitic	28 1	S	S	S
23	Gravel	"	28 2	S		S
24	Rock	"	28 4			S
25	Rock	"	28 4			S
27	Gravel	Mixed dolomitic and igneous	30 1	S		
28	"	Dolomitic	30 6	S		
29	Rock	"	30 8			S
30	Gravel	"	31 5	S		S
31	Rock	"	33 7	S		S
33	Gravel	Mixed dolomitic and igneous	34 1	S		
34	Rock		35 3		S	
35	Gravel	Dolomitic-igneous	35 5	S		
37	"	Mainly dolomitic	36 1			S
38	Rock	Dolomitic	36 3			S
39	"	"	38 0			S
41	Gravel	Mainly dolomitic	39 3	S		
43	Rock	Dolomitic	43 8			Q-U
46	"	"	47 2			S

COMPARISONS WITH OTHER TESTS

Figure 2 shows the results of tests made by the Michigan State College comparing the loss in the Los Angeles test with the loss in a circular track roller test In both tests all materials

were prepared with the following grading.

Passing	1½-inch	sieve,	percent	100
"	1½-inch	"	"	80
"	1- "	"	"	60
"	¾- "	"	"	40
"	½- "	"	"	0

The material passing the no 10 sieve after each test was considered as the loss and was expressed as a percentage of the original weight of the material In the roller test, the samples were subjected to a maximum of 500 passes of a cast iron roller loaded to 200 lb per inch of width These results show a definite correlation between the two tests It is interesting to note that 500 passes of the roller were required to secure a loss approaching that obtained in the Los Angeles test

Data comparing the loss in the Los Angeles test with flexural or compressive strengths of concrete have been furnished by several State highway departments, and are shown in Figures 3 to 6, inclusive In Figure 3 flexural test results representing a large number of tests made by the Georgia State Highway Department over a period of three years show a very good correlation with the results of the Los Angeles test Proportions specified by Georgia for concrete pavement con-

TABLE 9

COMPARISON BETWEEN LOS ANGELES TEST RESULT AND SERVICE RECORD BY COUNTRY ROADS BOARD, STATE OF VICTORIA, AUSTRALIA

Sample No	Type of material	Description	Los Angeles per cent of wear	Service record
9534	Rock	Basalt	12 4	Excellent
9708	"	"	12 9	"
9416	"	Dolerite	15 3	Very good
9359	"	Rhyolite	15 5	Satisfactory
9483	"	Basalt	16 8	Very good
9419	"	Dacite	18 1	Satisfactory
9349	"	Basalt	22 0	Good
9704	"	Limestone	23 5	Fair
9351	"	Basalt ..	24 3	Good
9472	"	"	24 3	Fair to good
9550	"	Sandstone	28 6	Fair
9348	"	Basalt	28 8	Fair
9350	"	"	30 0	Fair to good
9464	"	Granite	34 6	Fair
9275	Gravel		35 0	Fair
9352	Rock		37 0	Poor
9499	"	Quartz	41 0	Fair (light traffic)
9573	"	Sandstone	43 6	" " "
9345	"	Quartzite	44 0	" " "
9265	"	Shale	46 0	" " "
9357	"	Sandstone	54 8	" " "
	"	Quartz	55 0	Poor

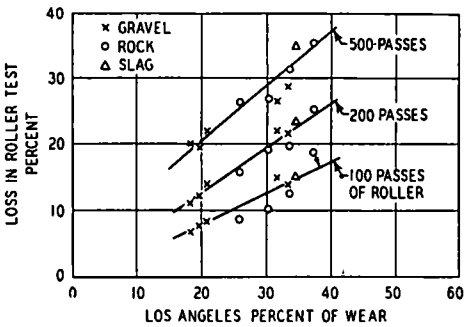

Figure 2 Relation Between Losses in Los Angeles Test and Circular Track (Roller) Test (Data from Michigan State College)

struction were used in this work Figure 4 presents the results of a laboratory investigation made in Texas with four different aggregates a hard limestone with a Los Angeles loss of 29 1 percent, a blue-gray quartzite with a loss of 33 1 percent, a red sandstone with a loss of 70 percent, and a soft limestone with a loss of 74 2 percent The materials were prepared to approximately the same grading, and made into concrete with three different mixes using 5, 7, and 9 gallons of water per sack of cement Due to differences in the aggregates, slightly different cement factors (sacks per cubic yard of concrete) were obtained for each water content The average cement factor for the 9-gallon mix was about 1 0 bbl , for the 7-gallon mix it was about 1 2 bbl and for the 5-gallon mix it was about 1 7 bbl To permit ready comparison with other data these average cement factors have been indicated in the figures in place of the governing water content It will be noted that the effect of quality of aggregate is more pronounced in the rich mix than in either of the others This tendency is also revealed in Figure 5 which shows the corresponding relation between Los Angeles abrasion loss and crushing strength

Figure 6 gives the results of a series

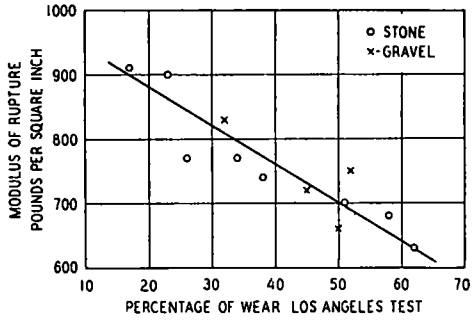

Figure 3 Relation Between Flexural Strength of Concrete and Los Angeles Abrasion Loss (Data from Georgia State Highway Department)

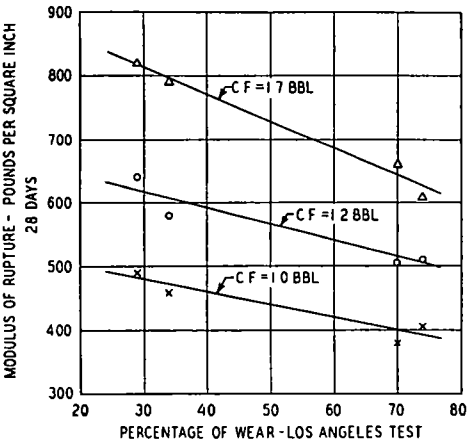

Figure 4 Relation Between Los Angeles Abrasion Loss and Flexural Strength of Concrete. (Data from Texas State Highway Department) .

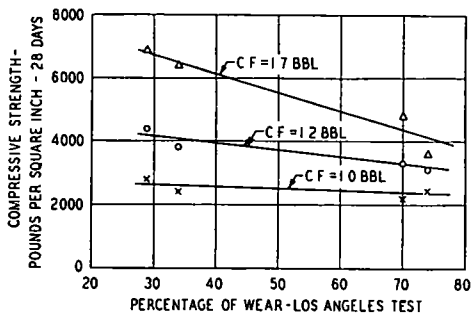

Figure 5 Relation Between Los Angeles Abrasion Loss and Compressive Strength of Concrete (Data from Texas State Highway Department)

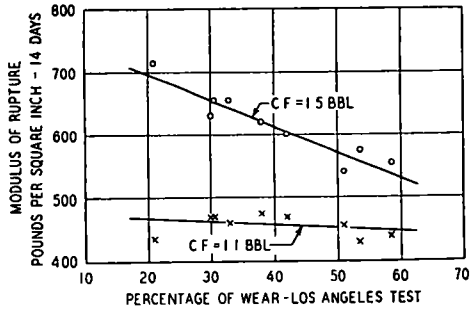

Figure 6 Relation Between Los Angeles Abrasion Loss and Flexural Strength of Concrete (Data for Crushed Stone from Nine Commercial Quarries in N Carolina)

of tests involving samples of granite and limestone from nine commercial quarries in North Carolina Similar relations to those indicated in Figure 4 are found These data emphasize the importance of taking into consideration the influence of the quality of the coarse aggregate in connection with the design of paving mixtures In the case of the nine commercial crushed stones in North Carolina a maximum difference of about 150 lb in modulus of rupture resulted when the cement content was held constant at 1 5 bbl Mixes designed for strength would compensate for this as well as other variables inherent in the method of arbitrary proportioning However it should be recognized that characteristics of aggregates other than resistance to abrasion such as, for example, surface texture, will also affect the strength of concrete

Data furnished by the Pennsylvania Department of Highways comparing the Los Angeles test result with determinations of the amount of soft or friable particles in gravel are given in Figure 7 In the test for soft pieces, particles between $\frac{5}{8}$ in and $1\frac{1}{4}$ in were loaded without impact to a total of 200 lb, and larger particles to 400 lb Particles which crushed under these loads were considered to be soft or friable A definite relationship is found between the test for soft pieces and the Los Angeles test although several samples depart somewhat from the general trend

CONCLUSION

Some difficulty was found in attempting to summarize the data discussed in this paper This is due to the fact that all states do not have the same range in quality of coarse aggregrates, and one state with an abundance of hard rock will consider certain test values for quality as necessary which could not be used by other states Consequently it must be emphasized that recommendations given here are subject to change to suit local conditions

In general, it appears that there is a definite relation between the loss in the Los Angeles test and the service record of materials used in concrete, bituminous construction and surface treatment On the basis of the data available, the following percentages of wear appear to be

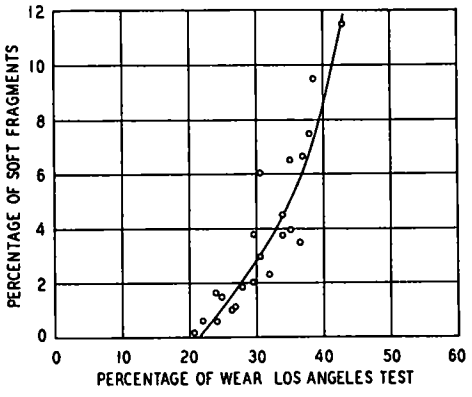

Figure 7 Relation Between Percentage of Soft Fragments in Gravel and Los Angeles Abrasion Loss (Data from Pennsylvania State Highway Department)

suitable for use in specifications to control the quality of coarse aggregates

	Percent
Concrete	50
Bituminous surfacing	40
Surface treatment	40

Definite correlations between the loss in the Los Angeles test and the strength of concrete are found, the lower the percentage of wear the higher the concrete strength Definite correlations are also found with the results of a circular track roller test and a test for soft or friable pieces

In conclusion, it appears that the Los Angeles test gives accurate indication of the quality of the material under test, and that its use in specifications controlling the acceptance of coarse aggregates is warranted