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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

# DURABILITY OF AGGREGATES

By

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# DURABILITY OF AGGREGATES

By

T. W. Smith*

Aggregates play an important part in the construction of highways in the cities, counties and State of California. A check of our records indicate that between one-fifth and one-third of the funds expended for construction of highways is for the procurement and placement of aggregates; hence, with a budget of approximately 300 million dollars for major construction projects on highways in California during the next fiscal year, this would result in 60 to 100 million dollars for aggregates on these projects. A more specific example involves a thirteen mile portion of road that will be constructed on the new Westside Freeway through Stanislaus County. It is estimated that the construction cost of the project will be 63 million and that aggregates will total 1.8 million or 29%.

The production, processing, testing and control of aggregates is an ever present consideration in providing better highways for the traveling public. The complexity of the

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problems connected with aggregate production is emphasized by the depletion of sources of suitable aggregate; by the necessity for beneficiation processes in aggregate production; and by the ever present desire to secure good quality aggregates and at the same time reduce or keep the cost within reasonable limits.

On the whole we might say that the producer would like for an aggregate to be easily and economically produced, the user would like for it to have ideal structural characteristics; and the buyer would want it to be cheap and last forever.

The usual tests that are used to control the quality of aggregates are grading, specific gravity, unit weight, absorption, soundness, Los Angeles rattler, R-value, cleanness, and sand equivalent. Generally, not all of these tests are applied to any one aggregate product. These tests are used on the premise that they will control the quality, suitability, and usefulness of the aggregate as well as these same attributes of the finished product that is produced from the aggregates.

Both the producer and the user are concerned with a characteristic of the aggregate that is best described as durability. By durability in the broad sense we mean the ability of the aggregate to remain unchanged over a fairly long period of time in spite of the natural processes or forces to which it is subjected.

As an indication of the concern over durability of aggregates, the States of Washington, Oregon and Idaho have in recent years started using specific tests to determine the durability of aggregates. Many other public and private

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agencies are concerned with this problem and have considered or taken steps to assure more durable aggregates.

Considerable work has been done throughout the world in an attempt to develop a test method which will evaluate the resistance of aggregates to mechanical degradation. This work has led to the development of the Deval Abrasion Test, Los Angeles Rattler, various piston-type crush tests, particle impact-strength tests and crushing roller type tests to mention a few. Although these various methods were successful in breaking down the rock particles under test, we have felt that the fine material produced often differs in character from the fines resulting from normal degradation. The most successful attempts in producing characteristic types of fines in the laboratory have been through the use of the kneading compactor and methods where the degradation is accomplished by the action of interparticle abrasion in the presence of water.

We have had a few examples of failures or serious distress in roadways in California that could be attributed to deterioration or lack of durability of aggregates. There have been other cases of distress where the durability of the aggregates was suspected.

Probably everyone of you can cite an example of aggregates that have been stockpiled that met specifications and when these aggregates were incorporated in construction weeks or months later they would not meet the specifications. Two suspicions always arise i.e., whether the aggregates really

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met the specifications initially and was degradation the cause i.e., did the aggregate lack the necessary durability to withstand the weathering and handling encountered.

The first four figures illustrate degradation or breakdown that can take place in the production and handling of aggregate. Figure 1 shows 1½" x 3/4" aggregate as it left the plant, and it met the cleanness specifications for concrete aggregate. The next three figures show successive steps in handling the aggregate. It would not meet the cleanness specifications in the condition shown on Figure No. 4.

The question of durability of aggregates has been emphasized in recent years in highway construction by the progress that has been made toward completion of the Interstate System. As a result of inquiries or investigations by various committees or agencies into highway construction practices, the question of durability or breakdown of aggregates has been increasingly emphasized. As you are well aware the activities of the Blatnik committee or other similar studies have generally evolved around the question of compliance with specifications in regard to aggregates. There have been numerous investigations concerning the quality or thicknesses of aggregate layers in place. If an investigation indicates a certain grading or other test characteristic for an aggregate in-place and previous tests indicate different characteristics prior to placing, a logical question is "What changes would normally take place as an aggregate is incorporated into a completed roadway?" We have been well aware of this question, and in order to answer it

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and at the same time move toward a more thorough knowledge of the characteristics of suitable aggregates we have developed a durability test that will be incorporated in our new standard specifications.

There is an attached tabulation that shows grading, sand equivalent, R-value and other data that we secured in our study of durability. One set of data was secured from construction control samples as the various components of the roadway section were constructed. The other set of data was secured from audit samples after the roadway had been completed. Perhaps a third evaluation that we need and may secure to a limited extent could be from tests after these roads have been in service for many years. The above data is not always conclusive since the frequency of sampling is too limited to get good statistical values. Generally the audit samples show a breakdown of the aggregate i.e., finer gradation and lower R-value and sand equivalent. The data also show that this breakdown can be related to results of the durability test that we have developed. Figure No. 5 shows some average values from the above data. This slide is for illustrative purposes since there is probably no realistic basis for averaging the results from the many sources and construction operations.

One of the early phases of our study of this problem was the compaction of aggregate samples and subsequent testing to determine the changes in test characteristics. We compacted aggregates using efforts that were far in excess of that required for normal compaction in order to accelerate the normal

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breakdown and then tested the resulting materials in order to compare the new characteristics with the former characteristics. This phase of the test research is illustrated by Figure No. 6 which shows the change in R-value that resulted from excessive compaction of many aggregates.

In our study of the problem of durability of aggregates our investigation has covered many areas, and I will not burden you with some of the details or description of the avenues that we ultimately abandoned. While it is evident that the question of durability involves mechanical breakdown, natural weathering processes, chemical action, and probably other factors, the durability test that we have developed reflects primarily the mechanical breakdown of aggregates. We define the durability factor as a value indicating the resistance of an aggregate to producing detrimental clay-like fines when subjected to the prescribed mechanical methods of degradation.

The durability test procedure that we have developed utilizes for the most part equipment developed for other tests that we were already using, namely, sand equivalent and cleanness. A brief description of the test procedure follows:

The durability test for coarse aggregate is made by using the equipment for the cleanness test (Tyler sieve shaker and a stainless steel vessel) while the fine aggregate is tested in the sand equivalent apparatus using a motor driven shaker. The procedure is quite simple and takes only a short time. Briefly, clean washed samples of the aggregates are separated

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on the No. 4 sieve into coarse and fine fractions and are placed in the appropriate container and vigorously shaken or agitated for ten minutes. At the end of this time a representative sample of the wash water is mixed with the sand equivalent solution and the height of the sedimented "clay" column after twenty minutes is noted. Values for either coarse or fine aggregates may range from 80 for such hard materials as quartz down to 5 or less on clay bound sandstones and shales. In our new standard specifications durability factors above 30 will be required for subbases, above 35 for Class II and III bases, and above 40 for Class I bases and permeable materials. In aggregates containing both coarse and fine fractions we expect to require that the durability factor for both sizes must be above the required minimum. It should be emphasized that the durability test (by starting with a washed aggregate in the test sample) measures the quality of the product generated from interparticle abrasion during the agitation period. The fines in the original sample have no effect on the durability factor. It is not presently anticipated that the durability test will be regularly specified for concrete aggregates and aggregates for asphalt surfacing.

Figures 7 to 16 show the results of numerous durability tests that have been made on aggregate sources from the various Districts throughout the State. It will be noted that some Districts have many sources that are low or marginal. Many aggregates from District IV and V and to a lesser degree from District I are very low. These aggregates are primarily from

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sources along the coast range and usually have a high percentage of sandstone, serpentine and shale. On the other hand, the aggregates from some districts particularly Districts VII and VIII show consistently high durability factors.

Figure No. 17 shows a grouping of test results by types of mineral aggregate and their corresponding durability factors. It will be noted that some types of mineral aggregates generally show high test results where other types of mineral aggregates will show low test results. The higher test values were obtained on andesites, granites, and limestones; whereas, the lower test values were obtained on sandstones and weathered volcanics. It should be noted that many of our aggregates are of such a heterogeneous nature that it is difficult, if not impossible, to place them in the categories shown on this chart.

Figure No. 18 shows the relationship between the L.A. Rattler and the new durability test. The ordinate shows durability values for both coarse and fine aggregate, while the abscissa values show the L.A. Rattler loss at 500 revolutions for the coarse materials. It will be noted that the very soft materials show up adversely in both tests, but there are certain samples meeting the present L.A. Rattler requirements which breakdown when shaken in water for only ten minutes. It will be observed that there is little or no correlation between the L.A. Rattler and the durability test for the majority of materials shown on Figure 18. This is not surprising when you consider that the L.A. Rattler test results are indicative of the quantity of degradation produced by an abrasion process involving considerable impact while the durability test results reflect the nature

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of the degraded material that is produced as well as the quantity of degradation by an entirely different abrasion process.

The question will naturally arise as to what will be the effect of the introduction of this new durability test. Obviously, it will result in the rejection of some sources of aggregate that are presently being used. This is not surprising since some sources of aggregate have been trouble makers in the past and yet a test was not available that would eliminate these sources without the elimination of other known sources of good quality aggregate. It has been somewhat surprising to us to compare the known behavior of aggregate sources with the results of the durability test. The good correlation between behavior and test results has been most encouraging to us as we have completed the development of this test procedure.

The new durability test will be used in lieu of the L.A. Rattler test on certain materials such as permeable materials and aggregate bases. Since some aggregates would not pass our present specification for the L.A. Rattler and these same aggregates will pass the new durability specifications, this will result in a relaxation of our specifications in these instances. The relationship of R-value, grading, sand equivalent and durability in our new specifications for bases and subbases will permit the use of some materials under our new specifications that were not acceptable under the present specifications.

It is believed the introduction of this new durability test will result in two steps toward effective use of aggregates with low or marginal durability characteristics. The quality

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of these materials can be improved by adding cement, lime or asphalt treatment and in many instances this will be the net result. Obviously, this step will usually be taken at the design stage i.e., designers will propose to cement treat aggregates with low durability factors. Figure No. 19 shows the results of successive durability tests made on several aggregates. You will note that there is a tendency for each durability test to give a higher test value than the preceding test. This is particularly true on aggregates with a low initial durability factor. These results point to the beneficial effects of more vigorous washing and manipulating of the aggregates during production. Hence, if a given source has a low durability it may be possible to improve the durability of that particular aggregate source by more vigorous processing procedures.

As discussed earlier this new durability test procedure is primarily concerned with breakdown resulting from mechanical manipulation. We will continue to explore the effects of other types of degradation such as weathering, chemical action and others, and hope we can ultimately establish test procedures that will realistically take into account all processes affecting the performance of the material on the road.

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# Test Results
# Before and After Compaction

## Aggregate Base

| Contract No. | Location | Control or Audit Sample | % Passing Designated Sieve Size | | | | | Sand Equiv. | R-Value | Durability Factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1½" | 3/4" | No. 4 | No. 30 | No. 200 | | | Coarse | Fine |
| 61-3T13C15-F | 1 | C | 94 | 67 | 33 | 18 | 4 | 51 | 82 | 87 | 86 |
| | | A | 94 | 72 | 37 | 21 | 4 | 53 | 81 | | |
| | 2 | C | 94 | 70 | 36 | 21 | 5 | 48 | 79 | | |
| | | A | 92 | 73 | 39 | 22 | 5 | 48 | 82 | | |
| 61-7X13C15-P | 1 | C | 100 | 98 | 52 | 23 | 8 | 70 | 79 | 80 | 80 |
| | | A | 100 | 99 | 55 | 27 | 9 | 60 | 81 | | |
| | 2 | C | 100 | 98 | 55 | 25 | 8 | 60 | 80 | | |
| | | A | 100 | 98 | 57 | 27 | 10 | 55 | 83 | | |
| | 3 | C | 100 | 97 | 42 | 19 | 6 | 69 | 78 | | |
| | | A | 100 | 99 | 55 | 25 | 8 | 62 | 82 | | |
| 61-6X13C54-F | 1 | C | 100 | 94 | 43 | 22 | 6 | 50 | 76 | 87 | 78 |
| | | A | 100 | 96 | 50 | 28 | 8 | 55 | 82 | | |
| | 2 | C | 100 | 94 | 44 | 24 | 6 | 44 | 77 | | |
| | | A | 100 | 95 | 52 | 28 | 8 | 54 | 81 | | |
| 61-6X13C52-P | 1 | C | 99 | 70 | 36 | 21 | 5 | 63 | 81 | 85 | 70 |
| | | A | 100 | 72 | 40 | 24 | 6 | 64 | 80 | | |
| | 2 | C | 99 | 66 | 43 | 25 | 6 | 74 | 76 | | |
| | | A | 100 | 71 | 43 | 24 | 6 | 59 | 78 | | |
| | 3 | C | 100 | 72 | 41 | 27 | 7 | 58 | 79 | | |
| | | A | 99 | 71 | 43 | 29 | 8 | 58 | 80 | | |
| | 4 | C | 100 | 59 | 37 | 22 | 5 | 68 | 80 | | |
| | | A | 99 | 56 | 34 | 20 | 5 | 61 | 78 | | |
| | 5 | C | 99 | 69 | 44 | 27 | 6 | 68 | 84 | | |
| | | A | 100 | 74 | 48 | 29 | 8 | 50 | 81 | | |

## Aggregate Base

| Contract No. | Location | Control or Audit Sample | % Passing Designated Sieve Size | | | | | Sand Equiv. | R-Value | Durability Factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1½" | 3/4" | No. 4 | No. 30 | No. 200 | | | Coarse | Fine |
| 61-11V13C7-F | 1 | C | 95 | 74 | 47 | 22 | 11 | 30 | 81 | 66 | 68 |
| | | A | 96 | 72 | 45 | 20 | 10 | 33 | 79 | | |
| | 2 | C | 96 | 73 | 47 | 20 | 9 | 33 | 79 | | |
| | | A | 98 | 78 | 51 | 22 | 9 | 35 | 78 | | |
| | 3 | C | 97 | 77 | 48 | 23 | 11 | 30 | 79 | | |
| | | A | 96 | 69 | 41 | 21 | 9 | 30 | 80 | | |
| 61-10X13C32-P | 1 | C | 83 | 66 | 43 | 20 | 7 | 49 | 80 | 67 | 66 |
| | | A | 95 | 77 | 52 | 24 | 6 | 49 | 79 | | |
| | 2 | C | 90 | 77 | 52 | 23 | 8 | 50 | 82 | | |
| | | A | 93 | 77 | 53 | 24 | 5 | 48 | 80 | | |
| | 3 | C | 94 | 83 | 58 | 28 | 9 | 41 | 79 | | |
| | | A | 95 | 80 | 52 | 25 | 7 | 44 | 78 | | |
| | 4 | C | 93 | 77 | 53 | 25 | 8 | 46 | 78 | | |
| | | A | 91 | 80 | 56 | 27 | 7 | 50 | 80 | | |
| | 5 | C | 96 | 80 | 54 | 25 | 8 | 52 | 77 | | |
| | | A | 93 | 76 | 54 | 25 | 8 | 53 | 81 | | |
| 62-2T13C2 | 1 | C | 97 | 78 | 52 | 21 | 7 | 45 | 81 | 63 | 69 |
| | | A | 98 | 82 | 56 | 24 | 9 | 39 | 83 | | |
| | 2 | C | 95 | 76 | 52 | 22 | 8 | 42 | 81 | | |
| | | A | 97 | 85 | 58 | 26 | 10 | 40 | 82 | | |
| 62-10T13C1 | 1 | C | 100 | 95 | 47 | 24 | 7 | 32 | 80 | 59 | 65 |
| | | A | 100 | 92 | 42 | 23 | 6 | 32 | 79 | | |
| | 2 | C | 100 | 95 | 51 | 26 | 7 | 30 | 78 | | |
| | | A | 100 | 95 | 54 | 29 | 8 | 31 | 78 | | |
| | 3 | C | 100 | 96 | 50 | 27 | 8 | 28 | 78 | | |
| | | A | 100 | 95 | 52 | 28 | 8 | 31 | 80 | | |
| 61-4X13C38-P | 1 | C | 100 | 53 | 17 | 7 | 4 | 31 | 80 | 67 | 57 |
| | | A | 100 | 74 | 33 | 15 | 8 | 45 | 81 | | |
| | 2 | C | 100 | 71 | 30 | 14 | 8 | 24 | 80 | | |
| | | A | 100 | 88 | 36 | 17 | 9 | 27 | 80 | | |
| | 3 | C | 100 | 65 | 25 | 11 | 7 | 30 | 84 | | |
| | | A | 100 | 80 | 41 | 20 | 11 | 25 | 80 | | |



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# Aggregate Base

| Contract No. | Location | Control or Audit Sample | % Passing Designated Sieve Size | | | | | Sand Equiv. | R-Value | Durability Factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1½" | 3/4" | No. 4 | No. 30 | No. 200 | | | Coarse | Fine |
| 61-3TC3 | 1 | C | 98 | 69 | 38 | 20 | 6 | 41 | 80 | 62 | 57 |
| | | A | 99 | 74 | 43 | 23 | 9 | 38 | 81 | | |
| | 2 | C | 97 | 62 | 35 | 19 | 8 | 36 | 79 | | |
| | | A | 91 | 60 | 33 | 18 | 8 | 35 | 81 | | |
| | 3 | C | 97 | 66 | 37 | 19 | 7 | 42 | 78 | | |
| | | A | 95 | 65 | 38 | 21 | 7 | 43 | 81 | | |
| | 4 | C | 96 | 64 | 37 | 20 | 7 | 38 | 80 | | |
| | | A | 99 | 79 | 47 | 28 | 15 | 36 | 78 | | |
| | 5 | C | 99 | 73 | 41 | 20 | 7 | 41 | 78 | | |
| | | A | 99 | 77 | 43 | 22 | 9 | 46 | 82 | | |
| 62-6Y24C3 | 1 | C | 98 | 90 | 69 | 32 | 14 | 31 | 79 | 54 | 51 |
| | | A | 96 | 94 | 81 | 35 | 16 | 28 | 78 | | |
| | 2 | C | 94 | 79 | 57 | 24 | 10 | 32 | 80 | | |
| | | A | 98 | 88 | 67 | 28 | 12 | 34 | 80 | | |
| | 3 | C | 97 | 90 | 74 | 33 | 14 | 31 | 79 | | |
| | | A | 98 | 91 | 74 | 31 | 13 | 33 | 81 | | |
| 61-9X13C12-P | 1 | C | 100 | 97 | 54 | 32 | 15 | 37 | 82 | 59 | 48 |
| | | A | 100 | 96 | 56 | 30 | 11 | 48 | 78 | | |
| | 2 | C | 100 | 95 | 51 | 30 | 12 | 39 | 81 | | |
| | | A | 100 | 96 | 55 | 29 | 11 | 44 | 80 | | |
| | 3 | C | 100 | 95 | 48 | 28 | 10 | 35 | 80 | | |
| | | A | 100 | 98 | 59 | 34 | 13 | 43 | 78 | | |
| | 4 | C | 100 | 95 | 50 | 29 | 12 | 38 | 81 | | |
| | | A | 100 | 96 | 49 | 27 | 10 | 42 | 80 | | |
| 61-1TC6 | 1 | C | 99 | 77 | 41 | 18 | 8 | 30 | 79 | 52 | 40 |
| | | A | 98 | 83 | 51 | 22 | 10 | 26 | 72 | | |
| | 2 | C | 95 | 70 | 35 | 14 | 6 | 33 | 82 | | |
| | | A | 99 | 79 | 46 | 24 | 13 | 19 | 66 | | |
| | 3 | C | 95 | 74 | 39 | 14 | 5 | 37 | 83 | | |
| | | A | 100 | 83 | 49 | 22 | 11 | 27 | 77 | | |
| | 4 | C | 95 | 70 | 38 | 14 | 5 | 41 | 81 | | |
| | | A | 94 | 78 | 45 | 19 | 8 | 34 | 77 | | |

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## Aggregate Base

| Contract No. | Location | Control or Audit Sample | % Passing Designated Sieve Size | | | | | Sand Equiv. | R-Value | Durability Factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1½" | 3/4" | No. 4 | No. 30 | No. 200 | | | Coarse | Fine |
| 60-1DDC15-P | 1 | C | 96 | 74 | 34 | 19 | 8 | 24 | 78 | 40 | 43 |
| | | A | 97 | 83 | 47 | 28 | 12 | 23 | 80 | | |
| | 2 | C | 70 | 41 | 16 | 11 | 5 | 21 | 78 | | |
| | | A | 94 | 66 | 33 | 21 | 9 | 24 | 80 | | |
| | 3 | C | 95 | 70 | 28 | 16 | 7 | 23 | 78 | | |
| | | A | 99 | 81 | 42 | 25 | 11 | 25 | 76 | | |
| | 4 | C | 90 | 53 | 23 | 15 | 7 | 25 | 78 | | |
| | | A | 97 | 66 | 35 | 21 | 9 | 26 | 79 | | |
| 61-4X13C35-P | 1 | C | 99 | 81 | 39 | 20 | 5 | 38 | 78 | 35 | 28 |
| | | A | 99 | 85 | 45 | 25 | 9 | 27 | 82 | | |

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# Test Results
# Before and After Compaction

## AGGREGATE SUBBASE

| Contract No. | Location | Control or Audit Sample | % Passing Designated Sieve Size | | | | | Sand Equiv. | R-Value | Durability Factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1½" | 3/4" | No. 4 | No. 30 | No. 200 | | | Coarse | Fine |
| 60-3TC37-F | 1 | C | 90 | 73 | 45 | 27 | 4 | 75 | 78 | 86 | 85 |
| | | A | 91 | 69 | 39 | 23 | 4 | 66 | 82 | | |
| | 2 | C | 98 | 77 | 40 | 28 | 5 | 61 | 76 | | |
| | | A | 94 | 75 | 39 | 23 | 4 | 54 | 81 | | |
| 61-3T13C18 | 1 | C | 100 | 89 | 68 | 52 | 3 | 79 | 78 | 90 | 81 |
| | | A | 100 | 90 | 70 | 56 | 5 | 69 | 77 | | |
| | 2 | C | 100 | 95 | 83 | 72 | 8 | 71 | 76 | | |
| | | A | 100 | 97 | 83 | 74 | 11 | 68 | 71 | | |
| 61-1T13C16 | 1 | C | 83 | 62 | 36 | 14 | 2 | 46 | 80 | 73 | 67 |
| | | A | 88 | 69 | 40 | 17 | 4 | 40 | 85 | | |
| | 2 | C | 82 | 61 | 33 | 13 | 4 | 39 | 80 | | |
| | | A | 88 | 69 | 39 | 16 | 5 | 32 | 81 | | |
| 61-4X13C39-P | 1 | C | 100 | 82 | 38 | 17 | 7 | 41 | 81 | 66 | 52 |
| | | A | 100 | 83 | 39 | 17 | 9 | 34 | 82 | | |
| | 2 | C | 100 | 81 | 39 | 20 | 8 | 36 | 78 | | |
| | | A | 100 | 90 | 58 | 25 | 12 | 37 | 83 | | |
| 60-5VC11-F | 1 | C | 100 | 100 | 100 | 100 | 12 | 30 | 63 | - | 49 |
| | | A | 100 | 100 | 100 | 100 | 13 | 27 | 73 | | |
| | 2 | C | 100 | 100 | 100 | 100 | 12 | 29 | 74 | | |
| | | A | 100 | 100 | 100 | 100 | 13 | 27 | 72 | | |
| | 3 | C | 100 | 100 | 100 | 100 | 11 | 29 | 72 | | |
| | | A | 100 | 100 | 100 | 100 | 12 | 27 | 72 | | |
| 62-10T13C1 | 1 | C | 99 | 92 | 67 | 37 | 7 | 35 | 74 | 48 | 63 |
| | | A | 100 | 93 | 67 | 39 | 9 | 33 | 69 | | |
| | 2 | C | 99 | 93 | 68 | 35 | 5 | 40 | 76 | | |
| | | A | 99 | 93 | 65 | 34 | 4 | 38 | 68 | | |
| 62-11V13C4-F | 1 | C | 100 | 98 | 85 | 34 | 11 | 54 | 77 | - | 45 |
| | | A | 100 | 100 | 97 | 46 | 16 | 39 | 74 | | |

Aggregate Subbase

| Contract No. | Location | Control or Audit Sample | % Passing Designated Sieve Size | | | | | Sand Equiv. | R-Value | Durability Factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1½" | 3/4" | No. 4 | No. 30 | No. 200 | | | Coarse | Fine |
| 61-6X13C51-F | 1 | C | 100 | 100 | 98 | 53 | 15 | 50 | 71 | - | 40 |
| | | A | 100 | 100 | 98 | 46 | 9 | 54 | 77 | | |
| | 2 | C | 100 | 100 | 96 | 48 | 12 | 35 | 68 | | |
| | | A | 100 | 100 | 97 | 49 | 14 | 42 | 70 | | |
| | 3 | C | 100 | 100 | 95 | 47 | 10 | 52 | 69 | | |
| | | A | 100 | 100 | 98 | 49 | 15 | 34 | 70 | | |
| | 4 | C | 100 | 99 | 96 | 48 | 12 | 45 | 77 | | |
| | | A | 100 | 98 | 96 | 56 | 18 | 29 | 62 | | |
| 60-5TC10 | 1 | C | 100 | 76 | 49 | 22 | 7 | 29 | 79 | 38 | 58 |
| | | A | 100 | 81 | 57 | 27 | 9 | 28 | 78 | | |
| | 2 | C | 100 | 76 | 50 | 21 | 6 | 35 | 73 | | |
| | | A | 98 | 80 | 47 | 22 | 8 | 33 | 80 | | |
| 61-5X13C26-P | 1 | C | 100 | 100 | 93 | 47 | 12 | 51 | 74 | - | 35 |
| | | A | 100 | 100 | 93 | 47 | 13 | 44 | 75 | | |
| | 2 | C | 100 | 99 | 91 | 44 | 11 | 54 | 74 | | |
| | | A | 100 | 99 | 91 | 44 | 12 | 44 | 78 | | |
| | 3 | C | 100 | 99 | 96 | 49 | 13 | 48 | 76 | | |
| | | A | 100 | 100 | 97 | 51 | 16 | 32 | 67 | | |
| | 4 | C | 100 | 99 | 92 | 43 | 11 | 48 | 77 | | |
| | | A | 100 | 100 | 97 | 48 | 13 | 40 | 77 | | |
| | 5 | C | 100 | 100 | 95 | 48 | 12 | 50 | 75 | | |
| | | A | 100 | 99 | 93 | 48 | 15 | 37 | 77 | | |
| 61-10T13C18 | 1 | C | 100 | 100 | 100 | 47 | 15 | 58 | 72 | - | 30 |
| | | A | 100 | 99 | 98 | 53 | 18 | 38 | 66 | | |
| | 2 | C | 100 | 100 | 100 | 47 | 14 | 60 | 67 | | |
| | | A | 100 | 100 | 99 | 49 | 15 | 50 | 70 | | |
| | 3 | C | 100 | 100 | 100 | 49 | 16 | 57 | 67 | | |
| | | A | 100 | 99 | 98 | 51 | 15 | 48 | 68 | | |



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## Aggregate Subbase

| Contract No. | Location | Control or Audit Sample | % Passing Designated Sieve Size | | | | | Sand Equiv. | R-Value | Durability Factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1½" | 3/4" | No. 4 | No. 30 | No. 200 | | | Coarse | Fine |
| 61-4MBC1 | 1 | C | 100 | 68 | 27 | 14 | 8 | 22 | 80 | 36 | 28 |
| | | A | 100 | 90 | 52 | 27 | 14 | 23 | 71 | | |
| 61-4X13C38-P | 1 | C | 89 | 55 | 33 | 25 | 9 | 39 | 79 | 13 | 21 |
| | | A | 97 | 81 | 57 | 42 | 16 | 26 | 75 | | |
| | 2 | C | 89 | 56 | 34 | 26 | 9 | 42 | 84 | | |
| | | A | 97 | 78 | 55 | 46 | 15 | 30 | 77 | | |
| 61-4T13C26-P | 1 | C | 100 | 92 | 56 | 27 | 11 | 31 | 78 | 12 | 26 |
| | | A | 100 | 92 | 56 | 29 | 11 | 31 | 79 | | |
| | 2 | C | 99 | 83 | 39 | 18 | 7 | 35 | 78* | | |
| | | A | 100 | 93 | 56 | 28 | 12 | 32 | 76 | | |
| | 3 | C | 100 | 89 | 50 | 24 | 10 | 35 | 78* | | |
| | | A | 100 | 96 | 62 | 30 | 12 | 34 | 78 | | |
| | 4 | C | 99 | 78 | 41 | 19 | 8 | 40 | 78* | | |
| | | A | 97 | 82 | 47 | 23 | 10 | 37 | 81 | | |
| | 5 | C | 100 | 94 | 60 | 25 | 10 | 35 | 77 | | |
| | | A | 100 | 93 | 63 | 32 | 13 | 20 | 71 | | |
| | 6 | C | 100 | 91 | 56 | 26 | 10 | 42 | 79 | | |
| | | A | 100 | 97 | 68 | 31 | 12 | 33 | 79 | | |
| 62-2Y24C05-P | 1 | C | 85 | 71 | 43 | 28 | 16 | 32 | 62 | 8 | 18 |
| | | A | 97 | 79 | 46 | 25 | 11 | 36 | 75 | | |
| | 2 | C | 96 | 83 | 47 | 31 | 15 | 31 | 56 | | |
| | | A | 99 | 83 | 53 | 33 | 15 | 18 | 56 | | |

*Estimated test results based upon tests run on other samples from same sources.



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1½" x 3/4" primary size of concrete aggregate sampled from truck after loading at producer's plant - Cleanness Value 82.

Material sampled from truck after hauling approximately 25 miles to concrete batch plant - Cleanness Value 77.

Material sampled from conveyor belt just prior to dropping into storage bin at batch plant.

Sample of same material as discharged from weigh hopper at batch plant - Cleanness Value 47.

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# DEGRADATION OF AGGREGATES

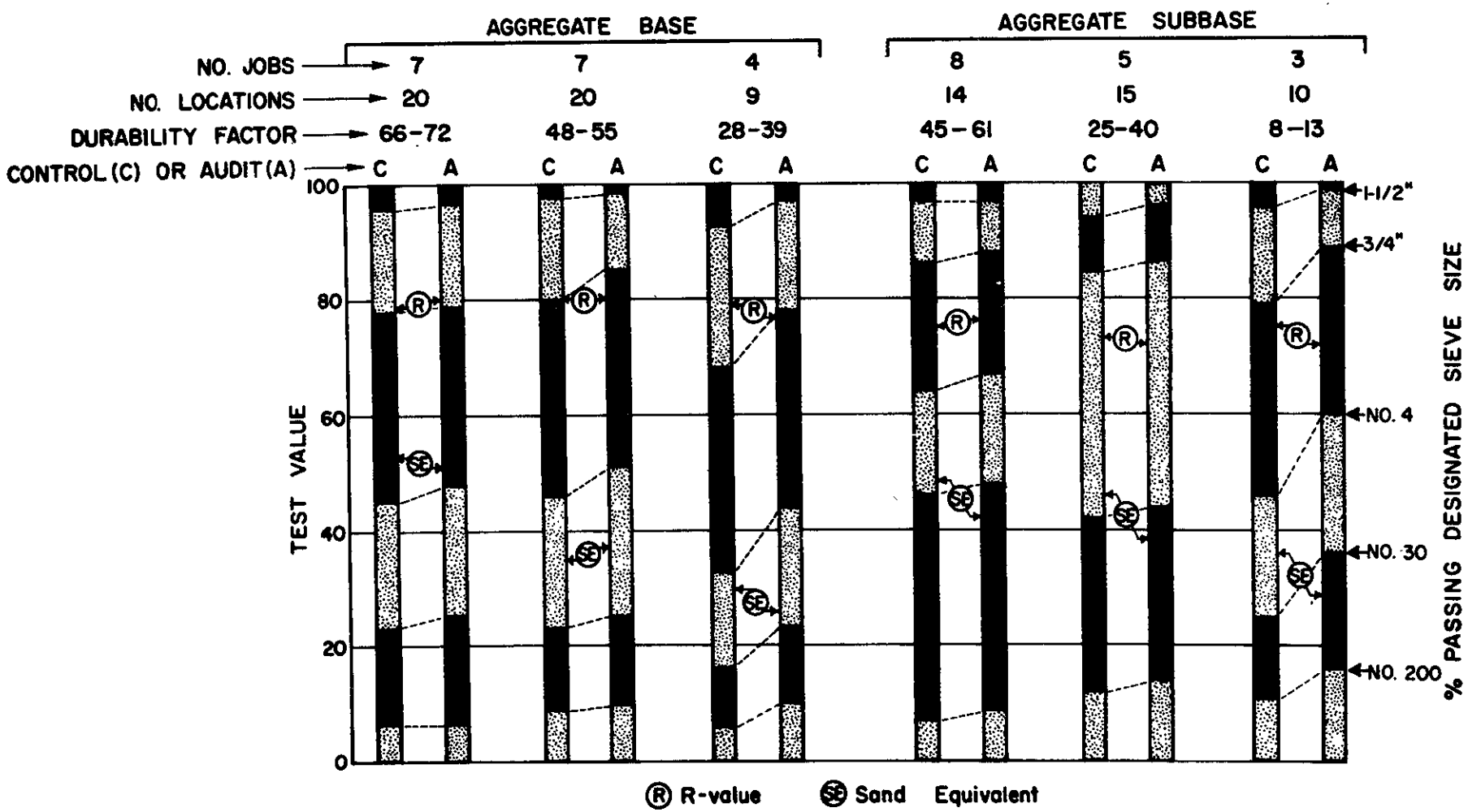


FIGURE 5

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FIGURE 6

# REDUCTION IN R-VALUE CAUSED FROM LABORATORY DEGRADATION

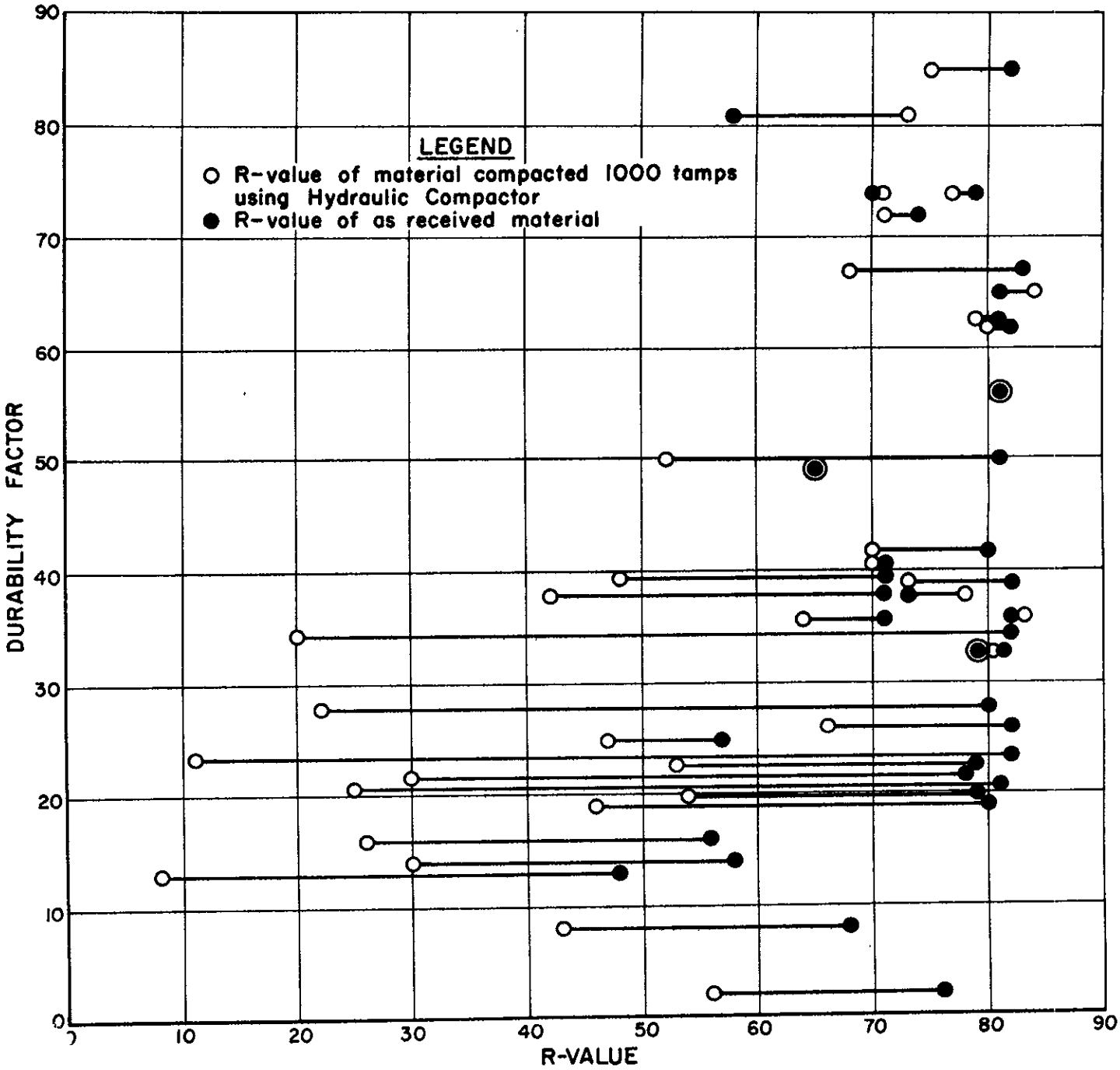


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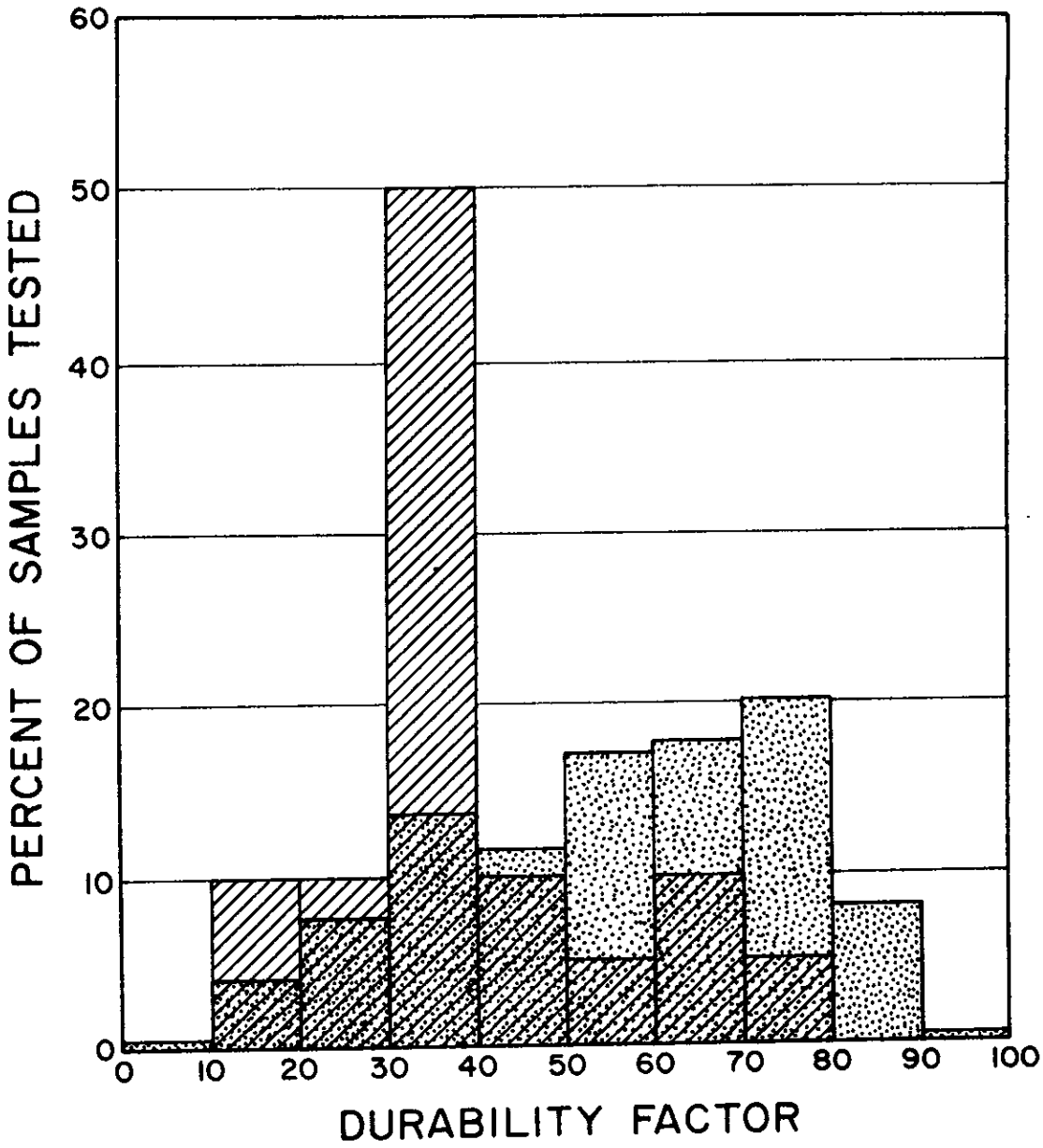
FIGURE 7

# FREQUENCY OF DURABILITY FACTORS

## DISTRICT I




DISTRICT I — 20 Samples

CALIFORNIA — 323 Samples

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FIGURE 8

# FREQUENCY OF DURABILITY FACTORS

## DISTRICT II

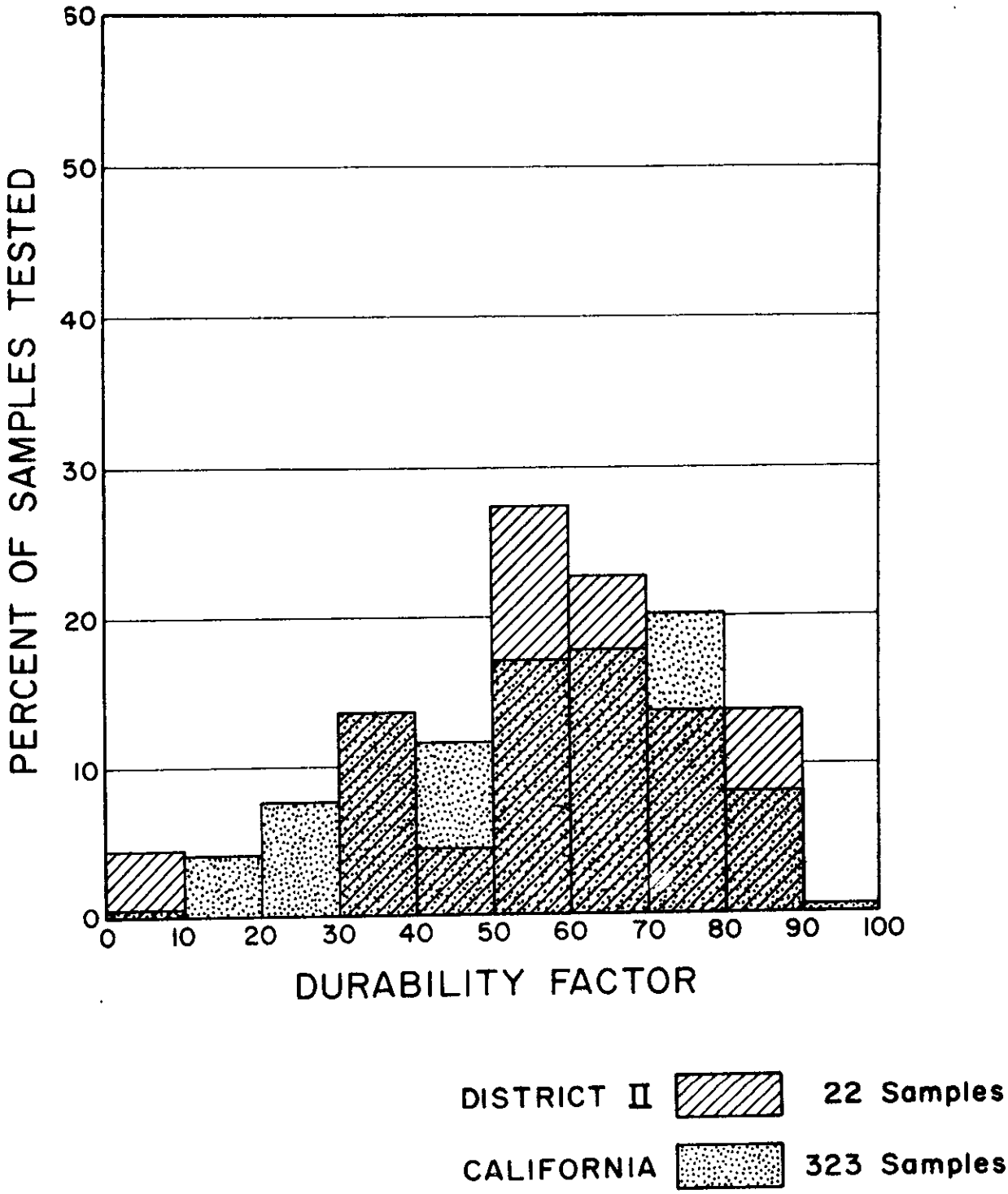


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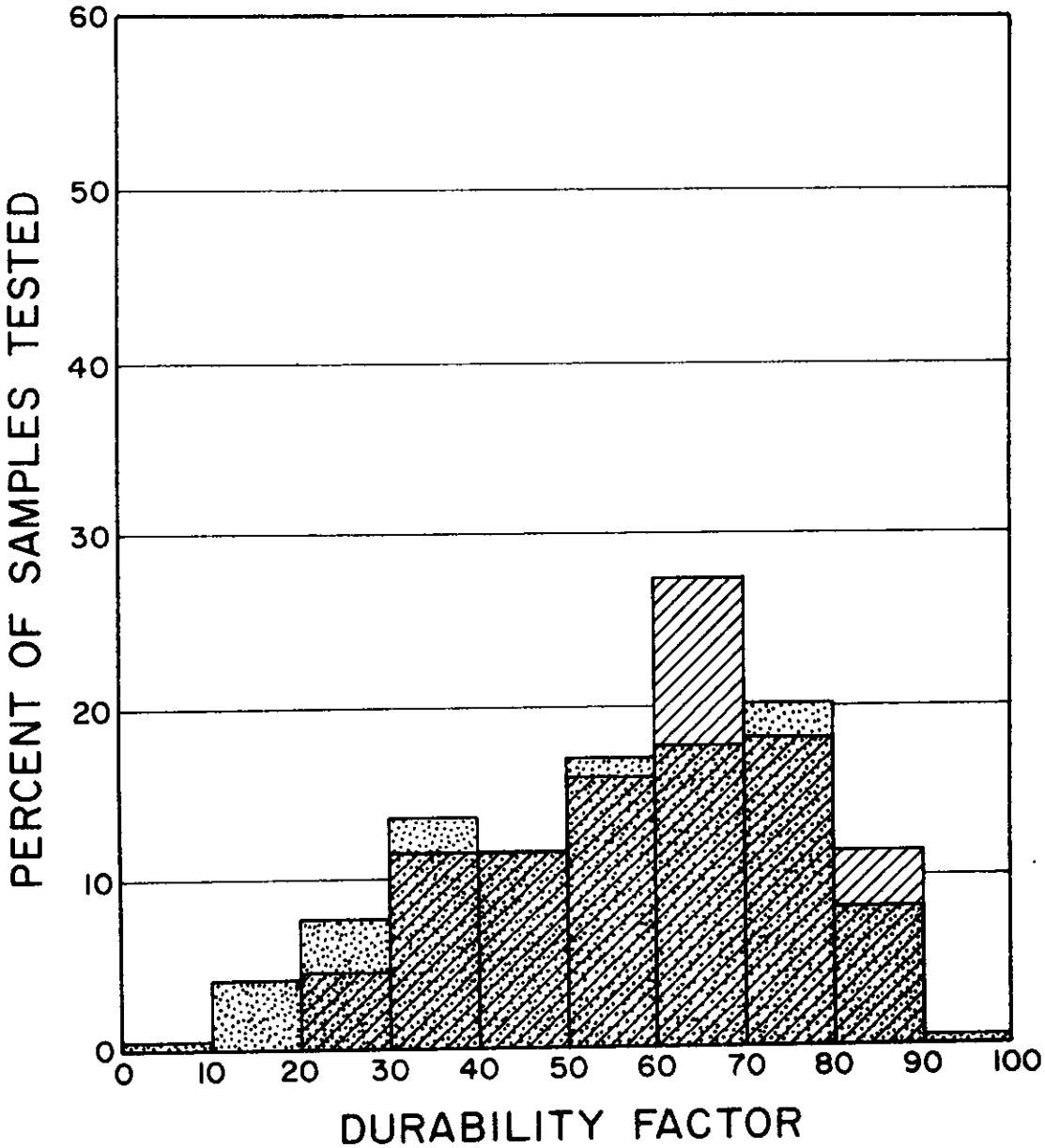
FIGURE 9

# FREQUENCY OF DURABILITY FACTORS

## DISTRICT III




DISTRICT III — 44 Samples

CALIFORNIA — 323 Samples

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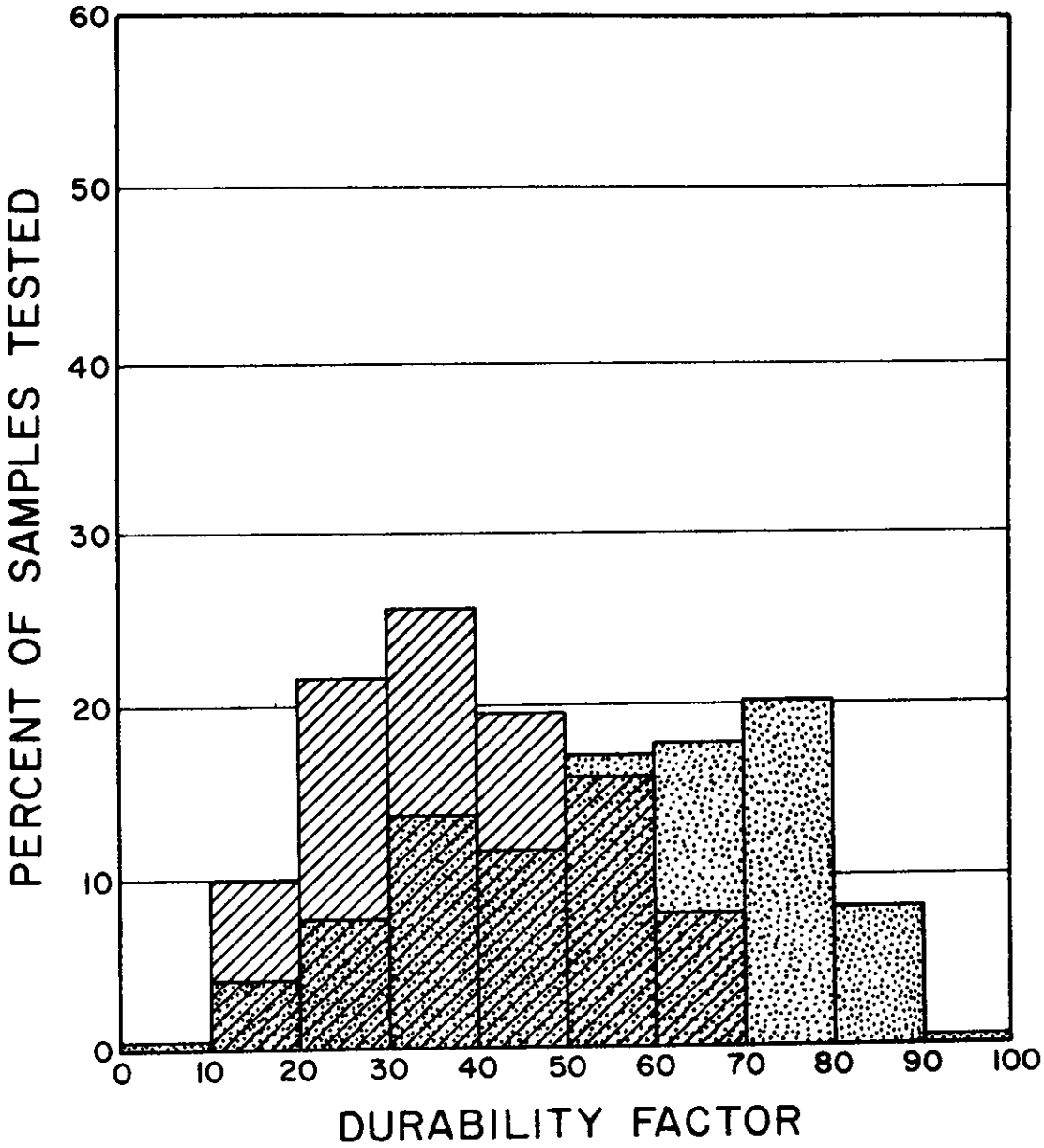
FIGURE 10

# FREQUENCY OF DURABILITY FACTORS

## DISTRICT IV




DISTRICT IV — 51 Samples

CALIFORNIA — 323 Samples

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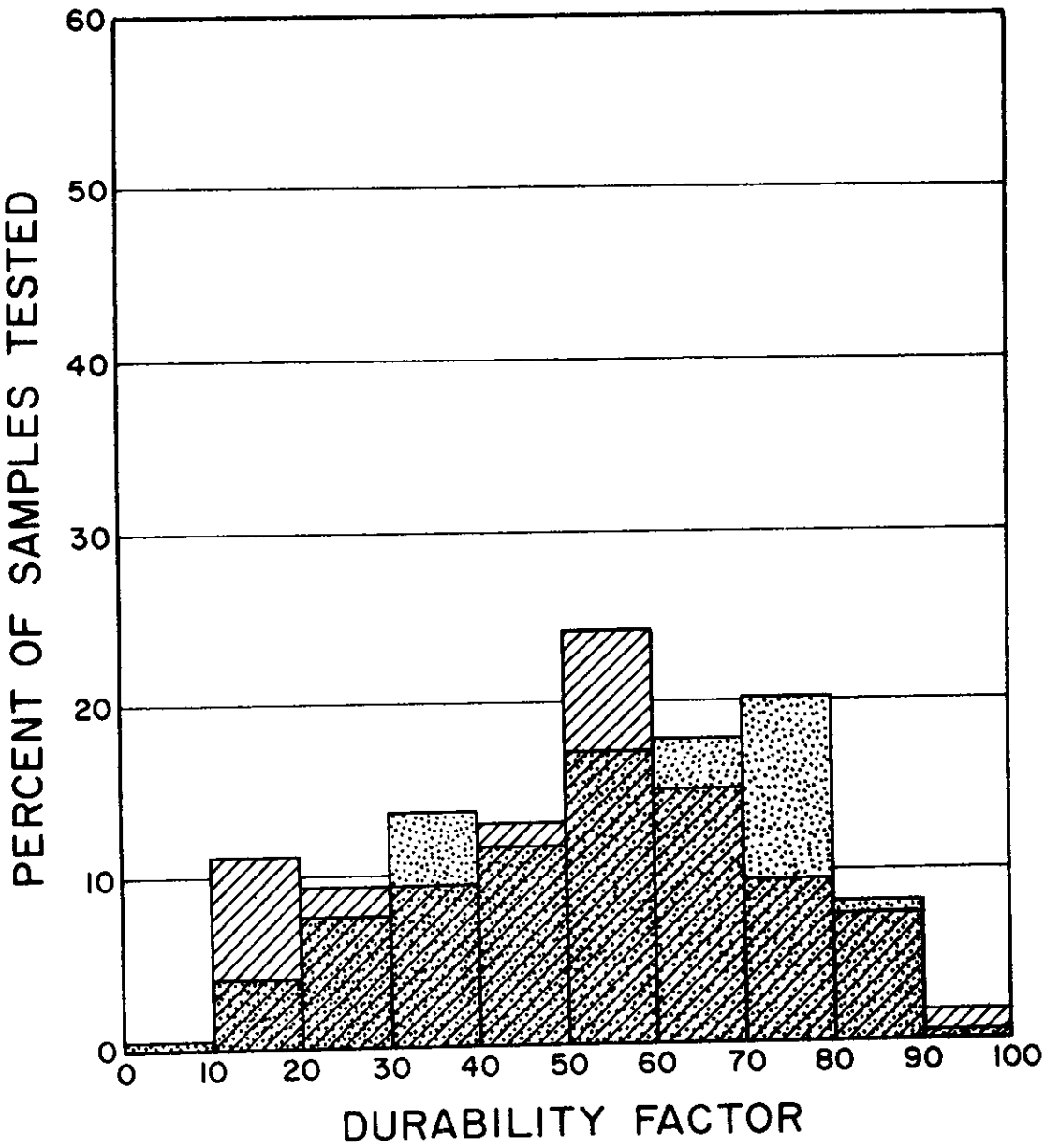
FIGURE 11

# FREQUENCY OF DURABILITY FACTORS

## DISTRICT V




DISTRICT V — 54 Samples

CALIFORNIA — 323 Samples

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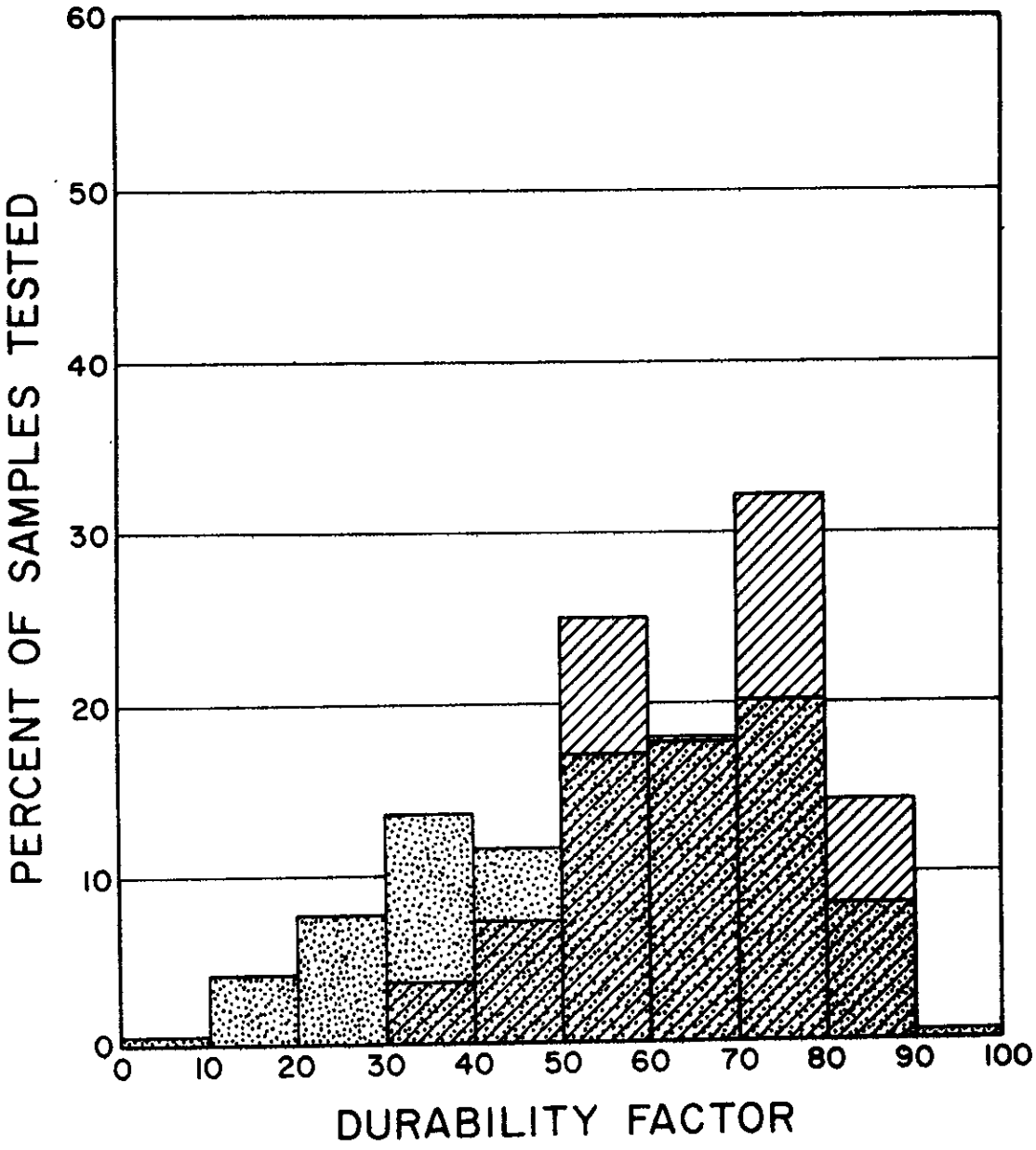
FIGURE 12

# FREQUENCY OF DURABILITY FACTORS

## DISTRICT VI




DISTRICT VI — 28 Samples

CALIFORNIA — 323 Samples

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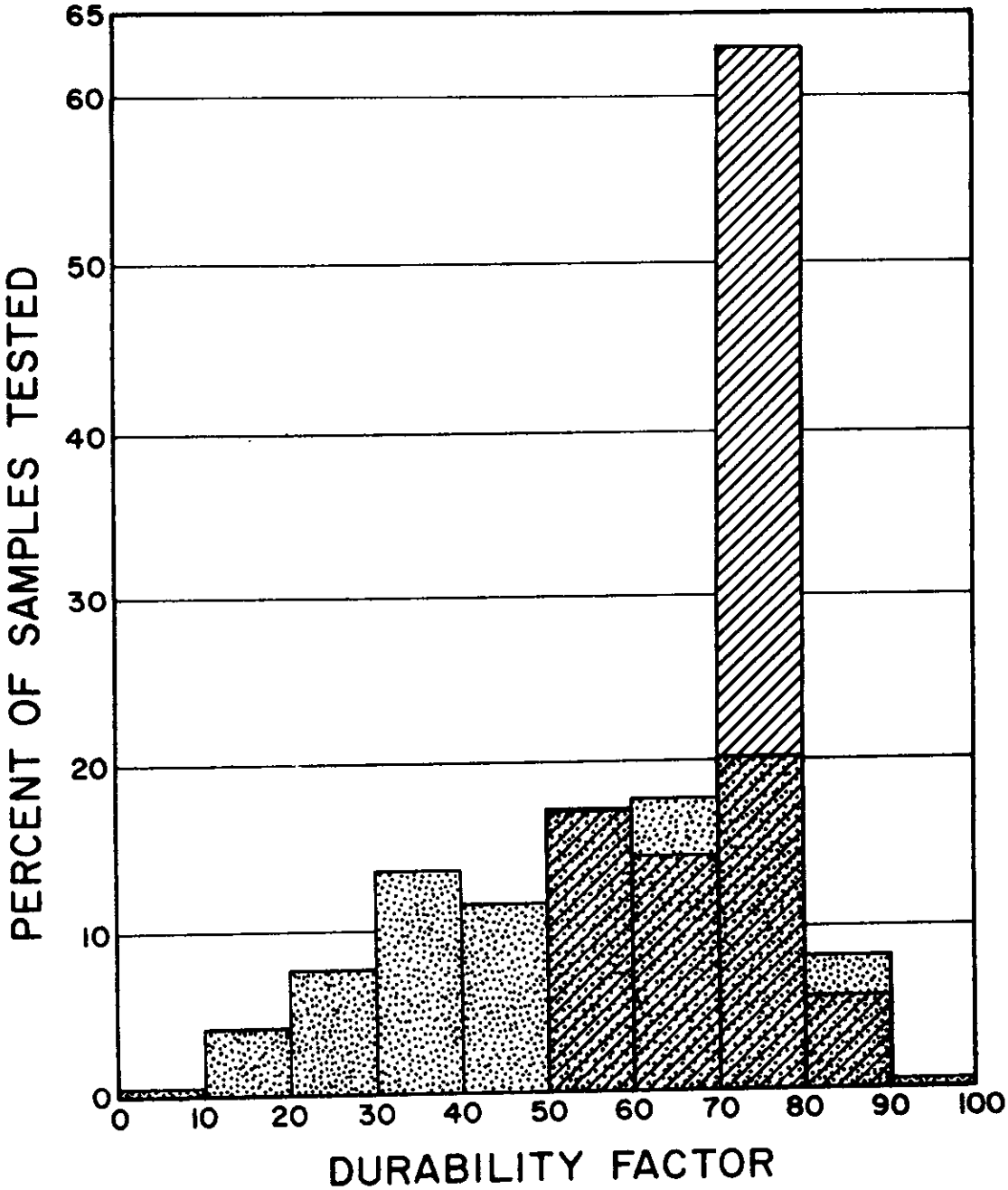
FIGURE 13

# FREQUENCY OF DURABILITY FACTORS

## DISTRICT VII




DISTRICT VII 35 Samples

CALIFORNIA 323 Samples

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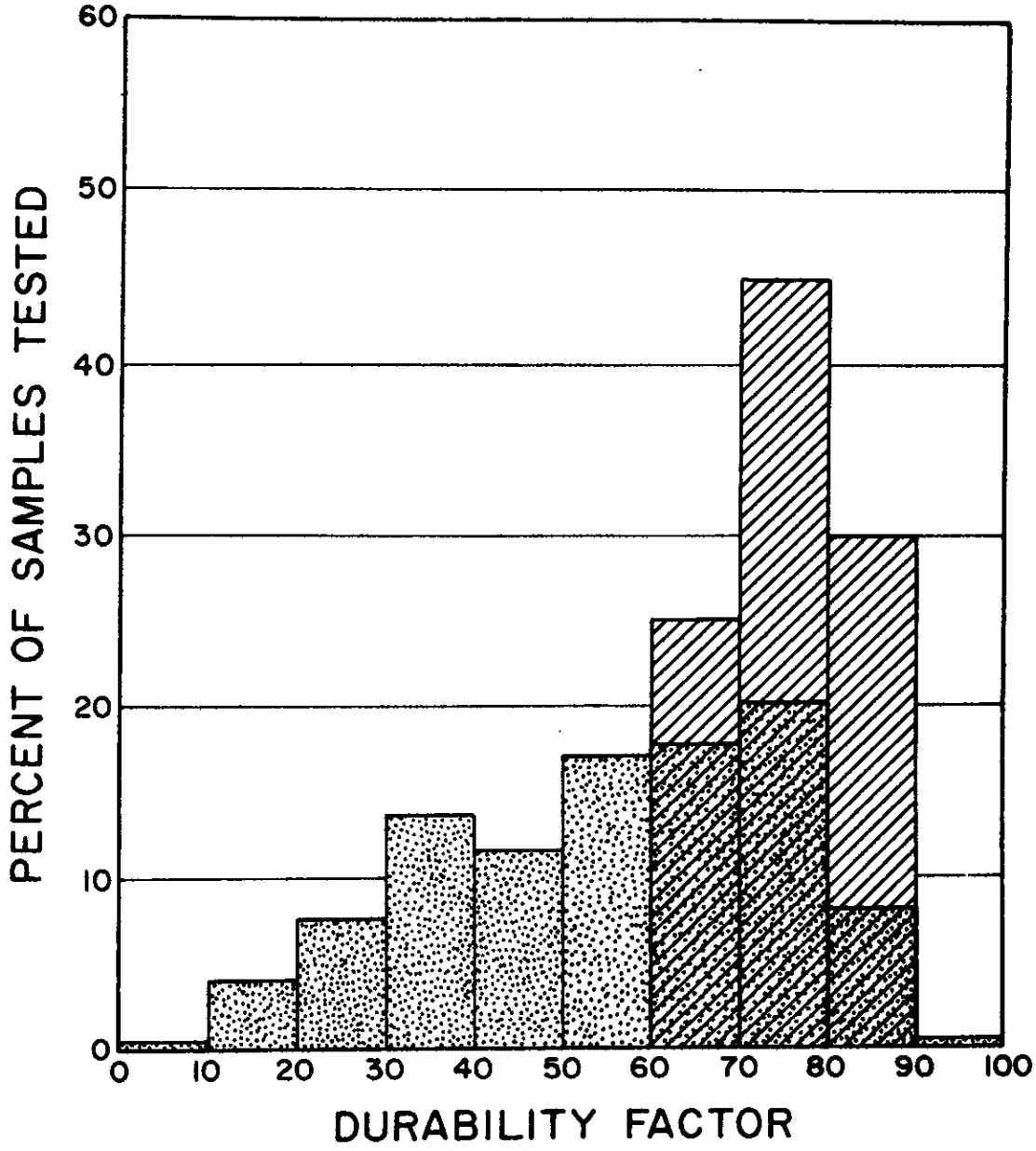
FIGURE 14

# FREQUENCY OF DURABILITY FACTORS

## DISTRICT VIII




DISTRICT VIII 20 Samples

CALIFORNIA 323 Samples

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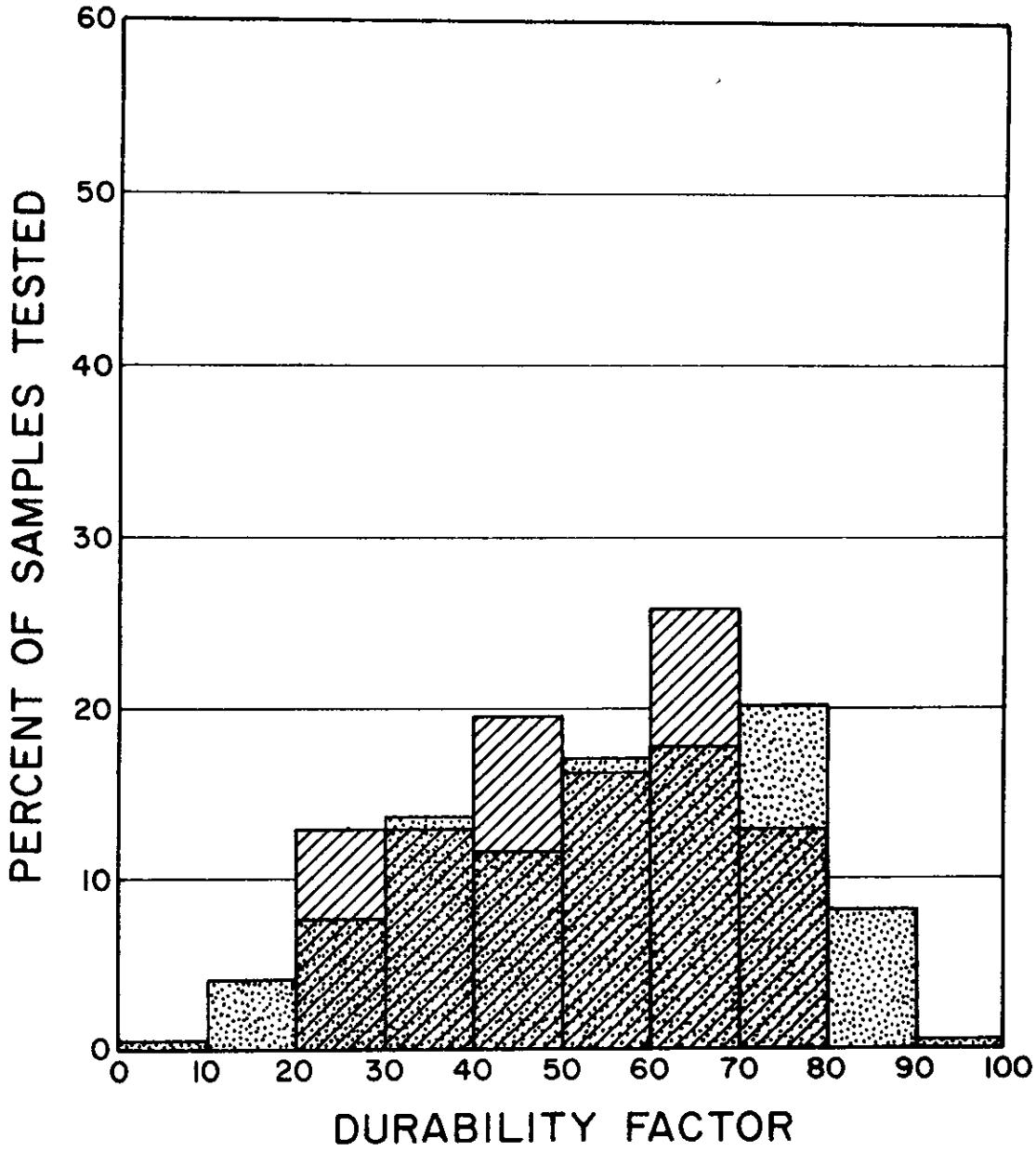
FIGURE 15

# FREQUENCY OF DURABILITY FACTORS

## DISTRICT X




DISTRICT X — 31 Samples

CALIFORNIA — 323 Samples

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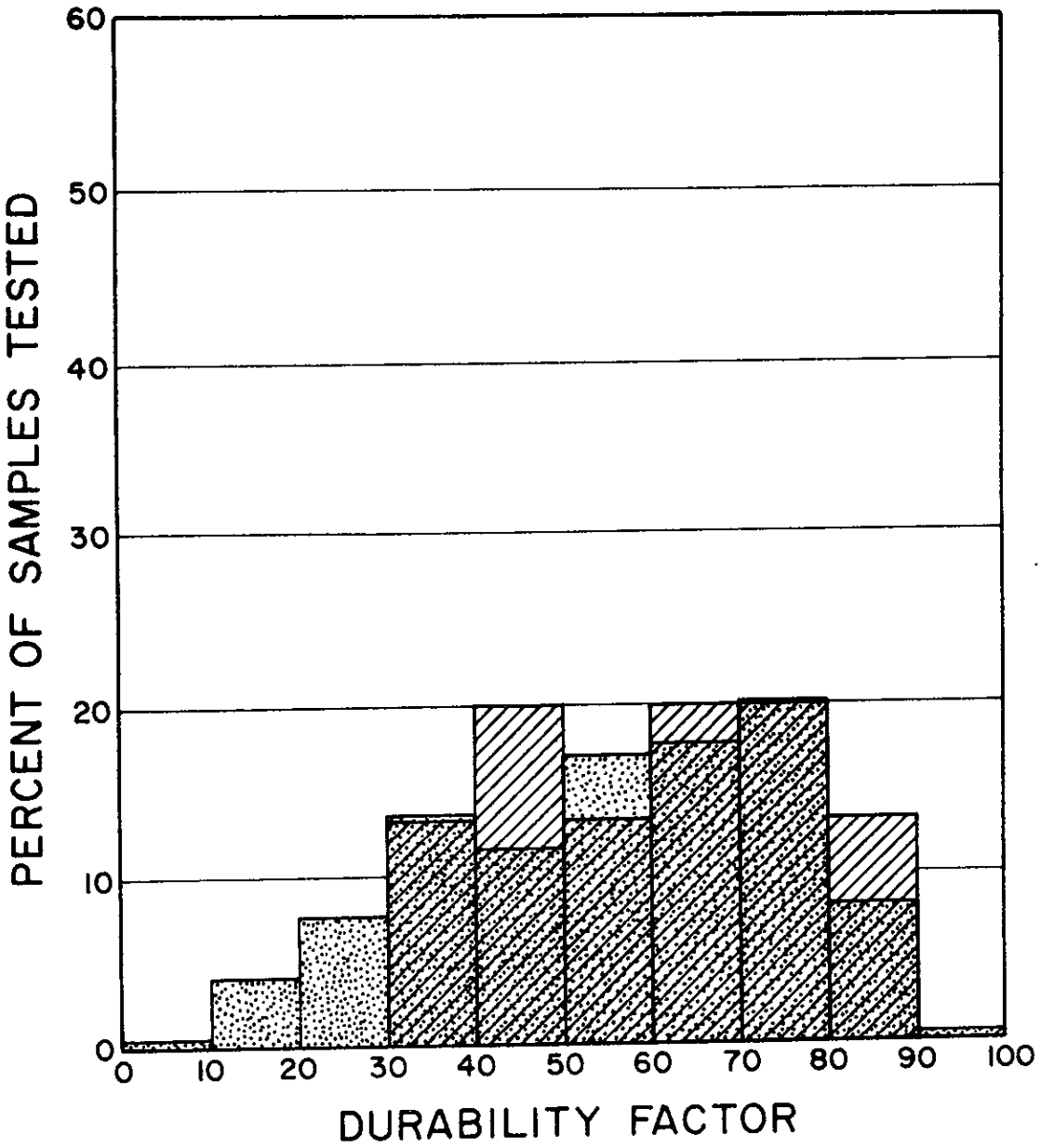
FIGURE 16

# FREQUENCY OF DURABILITY FACTORS

## DISTRICT XI




DISTRICT XI — 15 Samples

CALIFORNIA — 323 Samples

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FIGURE 17

# DURABILITY VERSUS TYPE OF MATERIAL

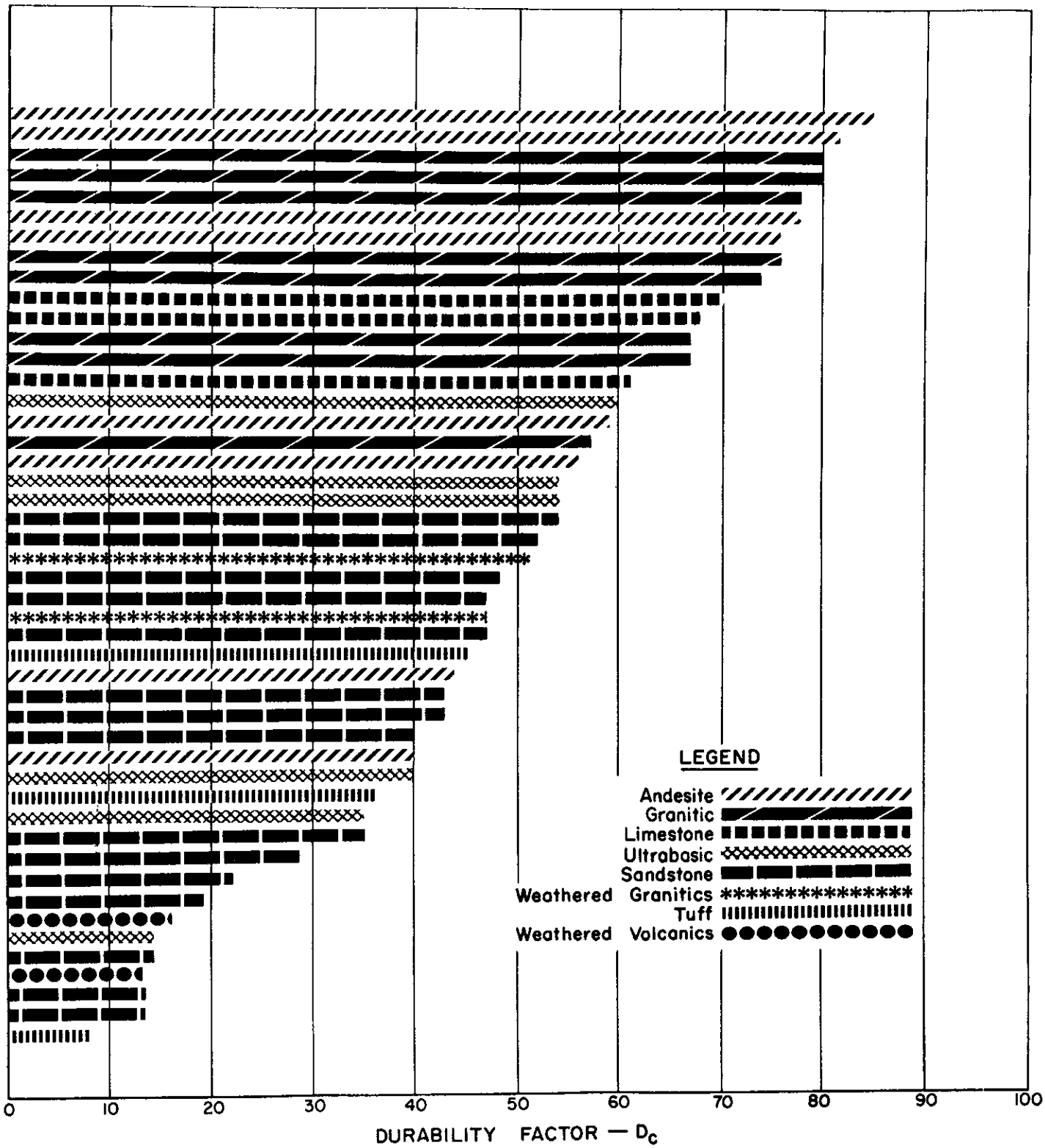


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FIGURE 18

# CHART SHOWING COMPARISON BETWEEN LOSS AT 500 REVOLUTIONS IN L.A. RATTLER AND DURABILITY VALUES ON COARSE AND FINE AGGREGATES

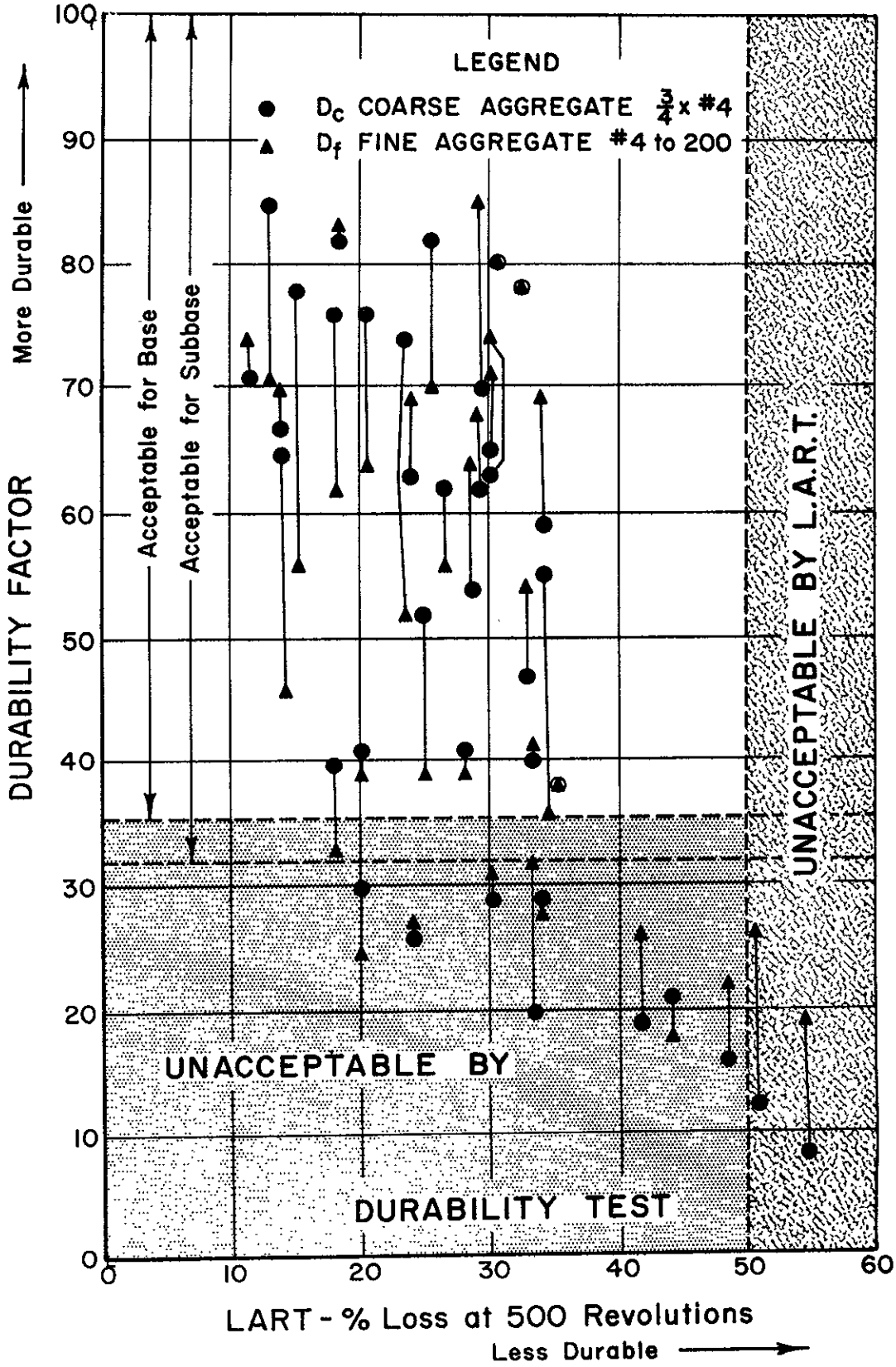


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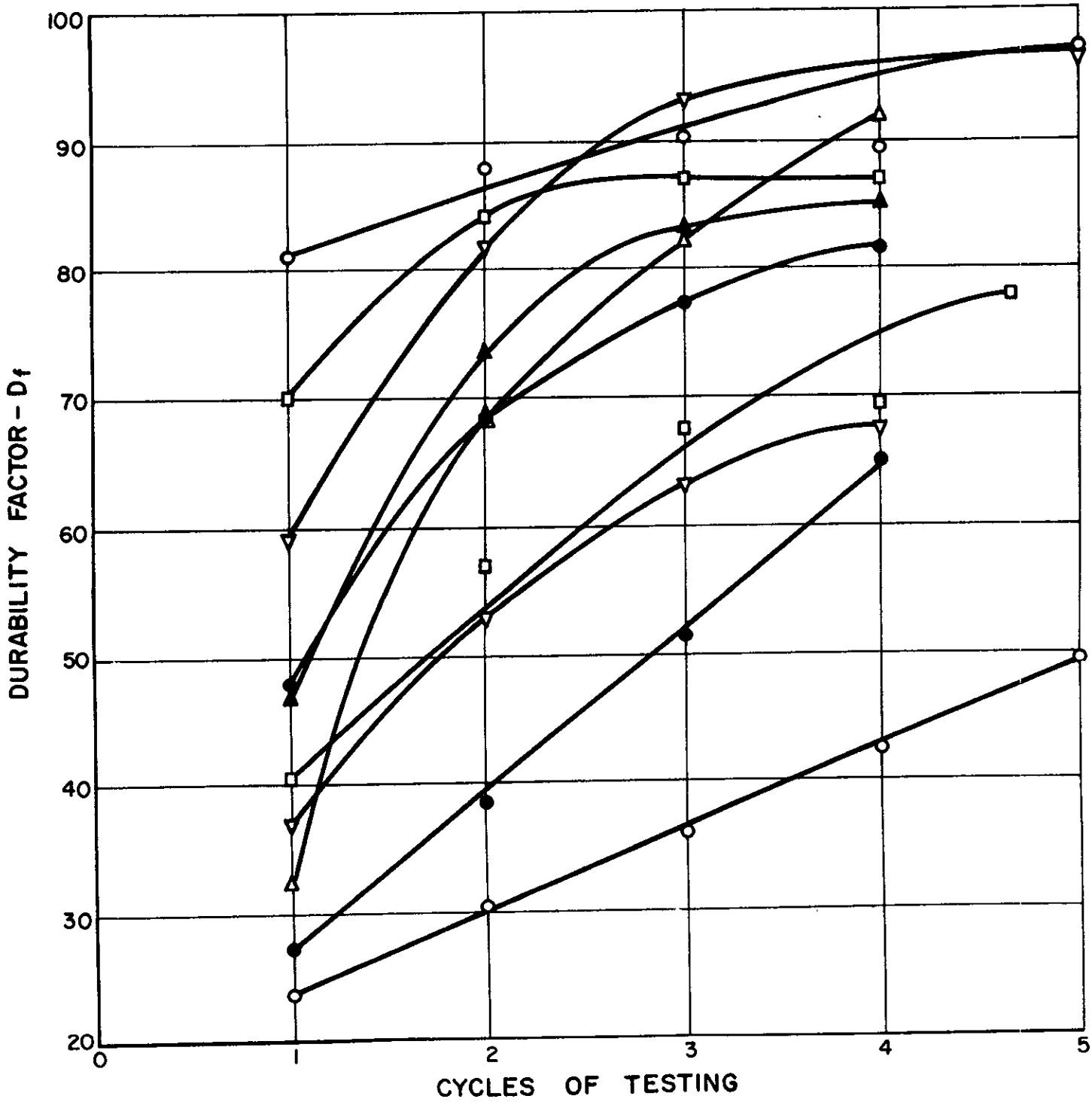
FIGURE 19

# INCREASE IN DURABILITY FACTOR CAUSED BY REPEATED WASHING

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