# How Good is Good Enough for Crushed Stone Specifications?

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When one realizes that in 1959 over $40 million out of $131 million of the total highway funds for Indiana was spent on the county road system of Indiana, and appreciates the enormous mileages involved in these county roads, it is clear that the problem of selecting materials that are good enough is one of major proportions. If a road is to function as its designer intended, the materials in that road should be of a quality good enough to carry the loads of traffic and to withstand the effects of weathering without excessive maintenance for the expected life of the facility. It is obvious in the broad concept that design, methods of construction, and quality of materials will each have an influence on the performance of a road.

The purpose of this paper is to discuss materials, or rather aggregates, and crushed stone in particular, as to how good is good enough. Instead of attempting to cover this subject from an all-inclusive point of view with the usual generalities, it will be confined to the major use of stone in county road construction, namely, traffic bound roads and base course construction. The Indiana State Highway Department permits Class B stone to be used for these types of construction with the essential specification requirements of a Los Angeles abrasion loss of not more than 45 per cent and a sodium sulfate soundness loss of not more than 20 per cent. This specification will now be discussed from three aspects: its development, its significance with respect to some research studies made by the National Crushed Stone Association, and its effect on the general economy.

All state highway departments have developed specifications for obtaining satisfactory aggregate which is economically available. Let it be emphasized that their effort is directed toward obtaining satisfactory or adequate quality aggregates and not the best material available, because no premium is placed on quality. For example, if a producer had stone with a Los Angeles abrasion loss of 20 per cent and a sodium sulfate soundness loss of zero per cent, he could not get one cent

more per ton over any other source of aggregate that was just within the specification limits for Class B stone. The State Highway Department of Indiana has been building more roads for more years with aggregates which are native to the state than any other agency.

The Highway Department has written specifications for materials that have been periodically revised and the latest revision is the 1960 edition of the Standard Specifications. These specifications are the combination of many years of experience and an honest effort to describe materials that are available which will perform with reasonable satisfaction if the design is adequate and the methods of construction are good. It is particularly pertinent to observe that the 1960 specifications for aggregates are essentially the same as those published in 1946; in other words, there is apparently no evidence to indicate that these specifications should be changed by being more restrictive or less restrictive. They are adequate for the service expected of materials that are economically available.

The argument may be advanced that the state road system carries a larger volume of traffic, consequently its specifications for aggregates must be to a higher standard than that necessary for a county road system. The stone used in a base course must be able to resist the destructive effects of traffic, both with respect to volume and weight, and of repeated freezing and thawing. At the recent meeting of the Association of Asphalt Paving Technologists a talk was given describing the increase in the pressures used in airplane tires which are now approaching 300 psi and the prediction was made that road designers should be prepared for trucks to follow with increased tire pressures. About all that can be said about future traffic is that it will increase. However, the effects of weathering are probably as destructive as the effects of traffic and both road systems are subjected to the same forces of nature. Generally, county roads do not have as heavy bituminous surfacing courses as state roads; therefore, the stone is under more severe exposure with respect to repeated freezing and thawing, so any lowering of soundness requirements would be to greatly increase the risk of failure.

If one were to review the requirements of the various state highway specifications with respect to allowable loss in the Los Angeles abrasion test on aggregate for base course construction, he would find an extremely wide range in values. The thought occurs as to whether the limit of 45 per cent in the Indiana State Highway Department specification could be raised to possibly allow cheaper aggregate to be used. It is quite questionable whether the Los Angeles abrasion test

is sensitive to field performance. In other words, if all other properties of two aggregates were the same except that one had a Los Angeles loss of 45 per cent and the other a Los Angeles loss of 50 per cent, it is doubtful if any difference in performance could be observed. This condition does occur in the granite producing areas due to differences in grain structure of sound unweathered granite, and in those areas a stone with rather high Los Angeles abrasion loss is permitted.

In certain areas in the South, limerock, caliche, and shellrock are used in base courses with excellent results. Often these materials crush under the roller to develop a completely smooth dense surface. However, when such materials have been used in areas of heavy frost penetration, these bases fail badly. In Indiana, there are many formations of limestone with a wide range in quality as measured for road building purposes. While factual information does not seem to be available, it is quite probable that the limit of 45 per cent loss in Los Angeles abrasion does a fair job of preventing the use of thinly bedded, cherty, soft, poor quality limestone. In other words, it is very likely that to raise the Los Angeles limits would have the effect of permitting the use of stone with a wider range in quality from a given quarry, thereby allowing the use of larger quantities of inferior material. Moreover, this limit of 45 per cent does provide aggregate of sufficient hardness to prevent excessive degradation during construction with the creation of plastic fines.

While this discussion of the Los Angeles test is essentially theoretical, the experience of the Indiana Highway Department is practical. It, therefore, would seem to be a sound policy to accept the limits of the State Highway Department of 45 per cent Los Angeles abrasion loss until data were presented which proved that satisfactory results could be obtained in Indiana with Indiana aggregate of a higher Los Angeles loss.

In the laboratories of the National Crushed Stone Association investigations have been made of the properties of dense-graded aggregate base course material by means of the triaxial compression test. A laboratory test to be meaningful should be made under conditions approaching the worst that will occur in service. Accordingly, all of our tests were made on carefully molded specimens that had been subjected to capillary saturation which probably is similar to field conditions in the early spring. One phase of this investigation was to develop data on the effect of plasticity on the load-carrying capacity of these base courses. Without going into any detail, our studies indicate that the lower the plasticity index, the stronger the base course and

also it shows less deformation under a given load. Under dry or damp conditions plastic fines appear to be beneficial in binding or cementing the aggregate particles together, but under conditions of high moisture these same fines become a lubricant which is conducive to rutting, instability, and poor load-carrying capacity of the base. While most specifications limit the plasticity index for base course aggregate to not more than six, these data show that not only should it be not more than six, but also that the lower the plasticity index which can be economically obtained, the better.

A couple of years ago at a meeting of the Highway Research Board, failure of base courses due to "degradation" of the aggregate was reported by several of the far western states. In the laboratories of the National Crushed Stone Association it was decided to study this problem to determine if this were a characteristic of stone being produced from commercial quarries in other areas of the country. As reported, the term "degradation" meant material that broke down into plastic fines which was clay-like material, all of which passed the 200 mesh sieve. Spot check tests were made on stone from a number of quarries and in no case did the stone degrade into plastic fines. It was concluded that most of the commercial sources of crushed stone in the eastern half of the country provided satisfactory material in this respect.

Later, we were asked to make some evaluation studies of sandstones which were to be proposed for base course construction for the purpose of developing a suitable specification. Our investigation showed that some of these sandstones did break down into objectionable plastic fines. Those standstones which were bad were all shaly sandstones and the sodium sulfate soundness test would readily detect them. It was the shale component that degraded into plastic fines. On the basis of these investigations, it would seem that the Indiana Highway Department's specifications requiring not more than 20 per cent loss in the sodium sulfate soundness test is a reasonable and necessary limitation in order to exclude aggregate which may break down in service into plastic fines and be the cause of failure of a base course.

Let us conclude with a short discussion of the economics of this specification. Since the Indiana Highway Department specification has been in effect for many years, a large number of plants have been built with the idea that they would have a large and continuing market for their product. The local crushed stone plant with which you are familiar requires a capital investment of $25-$35 thousand per man employed. It is a segment of a national industry consisting of 1,466 limestone quarries, in 1958 employing 30,700 workers with a payroll of

over $137 million, and this does not include quarries operated as a part of cement or lime manufacturing. These quarries purchased close to $39 million worth of machinery made and distributed by workers in other branches of our economy. As you know, the local quarry and the people employed by it return large sums of money in taxes to the state and the county.

The aggregate industry is essential to the economic life of the community, for there is not a road, bridge, home, school, church, or factory that does not have aggregate in it. Any proposal for aggregate of a lower quality than that of the State Highway Department invites transient operators to come in and take the business away from the established producer. While a few cents per ton may be saved on the original cost by allowing a low grade of aggregate to be used, hardly anyone will concede that such a practice is a sound business policy, irrespective of the great risk of failure involved. There is no fear or objection on the part of the established aggregate industry to the opening up of new deposits as long as the same standards of quality are maintained, but to have one set of standards for a roadside operation and a higher one for the regular producer is decidedly unfair.

In light of present technical knowledge, of past experience, and of sound economic considerations, it would seem that the 1960 Standard Specifications of the Indiana State Highway Department provides for the procurement of aggregate of satisfactory quality on a fair competitive basis.