Abridgment

Use of Crushed Stone Screenings in Highway Construction

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Quarried crushed stone is a basic nonmetallic commodity that, according to U.S. Bureau of Mines' statistics for 1977 (1), was produced by 3177 quarries in the United States. The total output was 865 million Mg (954 million tons) valued at \$2.35 billion or an overall average of \$2.72/Mg (\$2.47/ton). The average value has increased by only \$1.54/Mg (\$1.40/ton) since 1927. The material indeed qualifies as a low-cost material.

A portion of total crushed stone production is crushed stone screenings. Crushed stone screenings are the finer fraction of stone products and normally contain particles that are 4-5 mm (0.15-0.19 in) in size and smaller. The particle size distribution, particle shape, and other physical properties may be somewhat different from one geographical location to another and depend primarily on the type of rock quarried, the equipment used for crushing, the ratio of reduction, and the method used for separation of the screenings from the coarse particles. The product at one location, because it has been crushed by the same equipment, is fairly uniform and consistent in physical properties.

The general terminology for stone screenings, stone dust, or crushed fines was established when quarried rock was processed to obtain the coarse aggregate only, and the fine portion of the total product was generated as a waste by-product. With advancement of the technology and with the availability of modern crushing and sizing equipment, crushed stone fine aggregates are being produced intentionally and used successfully wherever fine aggregates are needed.

Crushed stone sands can be produced to certain desired gradations. Manufactured sands are usually produced from crushing operations by using controlled one-size feed aggregates. Stone screenings can be processed in terms of gradation and used as stone sands, provided mix proportions are properly adjusted.

PRODUCTION

Ledge rock is blasted to reduce the size of stone to manageable pieces and then normally crushed by a primary crushing system to reduce the product to sizes less than 125-150 mm (5-6 in). The crushed material is transported directly to secondary crushers, or to a surge-pile and then passed through secondary crushers. Secondary crushers may be classified as one of the following types:

1. Cone and gyratory,
2. Jaw,
3. Roll,
4. Impact,
5. Hammermill, and
6. Cage mill.

Each type has been used, and a certain portion of the resulting product can and usually is crushed for further reduction in size through tertiary or even fourth-state crushing, as described by McLean (2) in detailed comparative analyses of secondary crusher types.

The accumulated fine particles produced during the blasting, transportation, and primary and secondary crushing, if separated on the 4.75-mm (No. 4) mesh sieve, would compose a product that may generally be described as screenings. Screenings may be in the range of 10-20 percent of the total production. During tertiary reduction, the -4.75-mm mesh sieve material ranges from 20 to 60 percent or more of the feed. Tertiary and fourth-state crushing, however, produce fines that have special uses. The cost of these fines is greater due to the added cost in additional crushing, handling, and screening.

Assuming that screenings constitute about 12 percent of total stone production at U.S. quarries, the total amount of screenings produced in the United States during 1977 would have been approximately 104 million Mg (115 million tons). If used only as a subbase for a 3.66-m (12-ft) wide roadway with a thickness of 152 mm (6 in), 86 886 km (54 000 miles) of subbase could have been constructed.

PROPERTIES OF STONE SCREENINGS

Crushed stone screenings, because of the processes involved, may vary in size distribution, but in all cases consist of broken particles that have sharp corners. They may contain weathered rock from the quarry or overburdened material but, generally speaking, do not contain large quantities of plastic fines. In an extreme case, the plasticity index could be around 6 percent, in which case the screenings would be called dirty screenings. The largest quantity of the screenings produced are nonplastic and are the product of crushing rock from sound stone ledges. Studies reported by Shergold (3) indicate that the grading of crushed fines produced from different rock types by use of different types of crushers can be slightly different, but the products are uniform.

Two advantages of stone screenings for highway construction are their uniform grading and crushed faces. The particles provide great shear resistance when compacted. Such products are available and are suitable for mixing with coarse aggregate in a variety of aggregate mixes or for use in upgrading weak soils. They are very effective for stabilization since their nonplastic nature and clean particle surfaces permit full use of the stabilizing agent.

MECHANICAL STABILIZATION OF WEAK SUBGRADES WITH STONE SCREENINGS

Studies reported by Thompson (4) indicate that many typical fine-grained soils do not develop California bearing ratios (CBRs) in excess of 6-8 when compacted at or above the AASHTO T99 optimum water content, which is the minimum required during construction. Load support properties of weak subgrade therefore must be increased.

One procedure that may be employed to increase the CBR of fine-grained soils is to add stone screenings to the soil and compact after thorough mixing and moisture control. Such a remedy is suitable in place of the procedure known as "undercut and backfill" with other materials since 40-60 percent of that which would otherwise be undercut can be used again. The quantity of stone screenings needed will depend on the soils and the desired CBR. Test data reported by Kalcheff (5) provide guidance on how to estimate the quantity needed. For small projects when full laboratory preevaluation cost cannot be justified, one may consider the use of 50 percent screenings.

As one example of a project constructed with soil stabilization with stone screenings, Atlanta's downtown expressway can be cited. In the early 1950s, the Georgia Department of Transportation used 80 percent screenings and 20 percent bank clay—mixed in place as a subbase under the concrete pavement. This expressway, now Interstates 75 and 85, carries in excess of 140 000 vehicles/day. The pavement has performed well, no pumping has been noted, and it continues to be in excellent condition without resurfacing or overlays after almost 30 years.

CEMENT STABILIZATION

Stone screenings have been used combined with portland cement as cement-stabilized bases in many areas. When compacted, such products develop high rigidity with a small amount of portland cement. In comparison to soil-cement stabilization, stone screenings require less cement.

For the most efficient cement use in stabilizing, the screenings should have sufficient fines (material passing 0.075-mm sieve). Normally produced screenings, if not washed and if composed of nondeleterious fines, are best suited for cement stabilization.

USE OF STONE SCREENINGS IN ASPHALTIC CONCRETE

The superiority of crushed sand and stone screenings over uncrushed, smooth-surfaced, rounded aggregates for use in asphaltic concrete has been recognized for a long time. Research studies, such as those by Herrin and Goetz (6), present data from triaxial tests for dense and open-graded mixes and show that the ultimate triaxial strengths are always higher for combinations that use crushed fine aggregates. Research studies in the Asphalt Institute Laboratory by Griffith and Kallas (7) confirm the significant advantages of crushed stone screenings, particularly when larger quantities are used.

A recent study in the National Crushed Stone Association (NCSA) laboratory, reported by Nichols and Kalcheff (8), of asphalt-aggregate mixes under repetitive loading gives more information on the properties of mixtures that contain stone screenings. When the crushed particles are less cubical, the mixes exhibit higher voids in mineral aggregate (VMA) and thus a slightly greater asphalt content is required for meeting the void criteria for mix design—unless more dust of fracture is included as filler. In summary, the findings of the above study in which stone sand was a product of stone screenings were as follows:

1. All-crushed stone mixes had higher Marshall stability and considerably greater resistance to permanent deformation from repeated loads than did identically graded mixes that contained uncrushed sand;
2. Increases in the asphalt content by 0.5 percent above optimum in all-crushed stone mixes had little effect on the permanent deformation properties; mixes that contained uncrushed sand were quite sensitive to increased asphalt contents.
3. The deformation properties of all-crushed stone mixes were less affected by increased temperature during repeated loadings than those mixes that contained uncrushed sand; and
4. The deformation properties of all-crushed stone mixes were less affected by inadequate initial compaction than were those of uncrushed sand mixes, a finding that tends to counter the fact that all-stone mixes are somewhat more difficult to compact.

USE OF STONE SCREENINGS IN PORTLAND CEMENT CONCRETE

As suburbs continue to encroach on local natural sand deposits and as good sources of natural sand become further depleted, it is inevitable that the demand for manufactured sand will continue to increase. When screenings are produced for portland cement concrete, crushers are usually selected to produce bulky particles, and some of the material finer than 75 μm is removed.

Crushed fine aggregate has been used successfully for many years in mass concrete for dams, paving concrete for roadways, structural concrete for buildings, mortar for masonry, and a large number of special construction projects. An example of the extensive laboratory studies reported by Kalcheff (9) is presented in Table 1 for the purpose of giving the reader specifics on concrete properties with stone screenings. The fine aggregates that have shape indices 53 and 55 were stone screenings.

Table 1. Properties of portland cement concrete with crushed and uncrushed fine aggregates.

Shape Index	Fine Aggregate Type	Grading[a]	Passing 0.075-mm Sieve (%)	Water-Cement Ratio	After 28 Days: Compressive Strength (MPa)	After 28 Days: Flexural Strength (MPa)	Shrinkage After 3 Years 0.01 Percent
47	Uncrushed	A	3 ±1	0.55	32.7	5.31	5.2
49	Crushed	A	3 ±1	0.56	35.2	5.69	5.4
		C	11 ±1	0.54	35.4	5.79	4.9
50	Crushed	A	3 ±1	0.57	31.4	5.31	7.0
		C	11 ±1	0.57	31.0	5.48	7.2
51	Crushed	A	3 ±1	0.57	60.8	5.38	5.6
		C	11 ±1	0.57	30.2	5.38	6.0
53	Crushed	A	3 ±1	0.61	28.3	4.83	6.9
		C	11 ±1	0.63	27.2	4.86	6.5
55	Crushed	A	3 ±1	0.67	29.0	4.75	7.1
		C	11 ±1	0.67	29.0	4.90	6.8

Notes: 1 MPa = 145 lbf/in^2.
Portland cement concrete mixes were proportioned with constant 279 kg of cement/m^3 of concrete (5 bags/yd^3) with coarse aggregate size No. 57 (ASTM D448) crushed limestone for 76 ±13 mm (3 ±0.5 in) slump and Vinsol resin for 5.5 ±0 percent entrained air.

[a]No results reported for uncrushed 47, graded only.

USE OF STONE SCREENINGS AS ROADBASE AGGREGATE

Stone screenings are used extensively in roadbase and subbase mixes and are used in combination with coarse aggregate. This type of use reduces the cost of the combined product because the screenings do not have to be separated and reblended. The Bureau of Mines' statistics (1) show that during 1977 more than 340 million Mg (375 million tons) of roadstone and roadbase aggregates were used in the United States. The reasons for that are basically two: (a) these combinations are lower-cost construction materials, and (b) the materials are exceptionally good and suitable for base construction without stabilizing additives.

Screenings have been used in roadbase construction ever since the first broken rock was produced by man. Due to modern technology available for mechanized construction, stone screenings for road construction are being used to an even greater extent. The past, present, and future role of unbound aggregates (a portion of which are stone screenings) in road construction are summed up in the proceedings (10) from a national conference in 1974. The subject of load-deformation characteristics, other fundamental properties, design procedures, production control systems, and quality assurance are extensively discussed in the proceedings.

NCSA staff, with the assistance of NCSA committee members, has prepared a number of manuals on the use of crushed stone products (including stone screenings) for specific purposes, such as construction of parking areas, streets, low-volume roads, highways, shoulders, and airports. Engineers and designers should consider the use of low-cost crushed stone materials for construction. These materials are available today, and the forecast for crushed stone by the year 2000 is on the order of 27 billion Mg (30 billion tons). Stone screenings account for 12 percent of that estimated total; therefore, more than 3 billion Mg (5 billion tons) of stone screenings will be used between now and then.

OTHER USES OF STONE SCREENINGS

Not all the uses of stone screenings for highway construction have been discussed here. The overall subject is very broad. Other applications of stone screenings include bedding materials, fillers, granulars for drain fields, fills, mixtures for de-icing, patches, slurry seals, surface treatment, and overlays.

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Sulphur-Asphalt Pavement Technology: A Review of Progress

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This paper briefly summarizes the current status of sulphur-asphalt pavement technology with emphasis on sulphur-extended asphalts. The various processes that are currently available are discussed and compared, and the various field trials are described. Performance observations and engineering properties are also considered. Finally, the future use, applications, and problems of sulphur-asphalt are reviewed. Based on experience, the use of sulphur-asphalt mixtures can be expected to increase during the next few years. This is especially true of sulphur-extended asphalt mixtures, which have greater applicability and conserve asphalt and produce a corresponding reduction in cost.

The accumulation of surplus sulphur, the need for improved paving mixtures, and the dwindling supply of asphalt and its rapidly increasing cost have provided the incentive to develop new uses for sulphur for the paving industry. One of the largest such applications is the use of sulphur in sulphur-asphalt mixtures.

Two basic approaches have been used. Either sulphur can be added to the mixture or it can replace a portion of the asphalt [sulphur-extended asphalt (SEA)]. Both processes have definite applications, and each has