Upgrading Marginal Aggregates for Road Construction Along the Oregon Coast

Oregon State University
Extension Marine Advisory Program
A Land Grant / Sea Grant Cooperative
Special Report 615
October 1981

UPGRADING MARGINAL AGGREGATES FOR ROAD CONSTRUCTION

ALONG THE OREGON COAST

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Special Report 615 / October 1981

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Sea Grant/Marine Advisory Program
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INTRODUCTION

The task of obtaining good-quality aggregate for construction is a growing problem for most Oregon coastal communities. Current shortages have forced users to import quality aggregate from areas as far as the Willamette Valley. The practice of transporting aggregate over such long distances is both costly and energy-intensive.

One feasible solution to this problem is to use abundant local supplies of low-quality, "marginal" aggregates. However, engineers encounter numerous problems when they use marginal aggregates for construction. Characteristics of these aggregates that contribute to problems include low resistance to mechanical and chemical degradation and poor gradation. Although these materials are not of sufficient quality for conventional use, special design considerations can help obtain satisfactory performance.

The term beneficiate is used to describe a process by which marginal aggregates are upgraded or otherwise made suitable for construction purposes. Marginal aggregates available along the Oregon coast and considered good candidates for beneficiation include: marine basalts, sandstones, sand, and dredged materials.

This report briefly outlines the problems associated with the use of these aggregates (a more thorough examination can be found in Construction Aggregates Available Along the Oregon Coast, Oregon State University Extension Service Special Report 614, hereafter Available). This report also includes a discussion of some of the more promising methods of beneficiating marginal aggregates and design considerations for their use.

PROBLEMS WITH USE OF MARGINAL AGGREGATES

A summary of the types of aggregates available and their deficiencies is shown in Table 1. Basalts, especially marine basalts, are high in mechanical strength but are susceptible to chemical weathering. There are well documented accounts of road failures attributable to degrading basalts. The cause of these failures is generally thought to be related to the production of plastic fines in altered basalts. The presence of water greatly accelerates the degradation in altered basalts. Poor drainage conditions cause a much more rapid failure of a road section made of marine basalt than a section constructed of high-quality aggregate.

Sandstones have a low resistance to mechanical degradation. Significant reduction in the grain sizes of a sandstone can occur during manipulation or loading. Field compaction and traffic loading result in dense gradations and a subsequent loss of permeability. The presence of water will then cause instability and failure.

Beach and dune sands and dredged materials are normally poorly graded--that is, they lack the grain interlock required to provide good stability.

Table 1. Marginal coastal aggregates and associated problems

Type of aggregate	Problem
Marine basalt	Low resistance to chemical degradation
Sandstone and siltstone	Low resistance to mechanical degradation
Sand, beach and dune	Low stability because of poor gradation Environmental restrictions
Dredged materials	Poor gradation Possibility of high organic content

METHODS OF BENEFICIATION

Problems such as high plasticity, excessive degradation under repeated loading, or low strengths found in marginal aggregates can be mitigated by mixing the aggregates with small amounts of a second material. This process is referred to as admixture stabilization. It generally improves the performance of a road construction material by increasing its strength, increasing its volume stability, and/or altering its permeability.

Pretreatment of marginal aggregates for improvement of properties before use in portland cement concrete or bituminous concrete pavements is another method that has received much attention and research. Pretreatment involves internal and external aggregate coatings and aggregate impregnation.

Another method of improving marginal aggregates is to remove deleterious particles by mechanical means such as heavy media separation, jiggling, or elastic rebound for aggregates susceptible to such separation techniques.

Finally, blending marginal aggregates with higher-quality aggregates can provide satisfactory construction material. Aggregate blending to extend quality aggregate supplies is practiced frequently in many parts of Oregon. The proportions of aggregates to be blended depend on the properties of both aggregate supplies.

RECOMMENDED METHODS AND TREATMENTS

A research project aimed at providing the information necessary to use marginal aggregates found along the Oregon coast has been completed by Oregon State University's Transportation Research Institute (TRI). The project selected six distinct aggregates representative of those along the coast and studied their properties and performance under various conditions. The research focused mainly on using marginal aggregates in open-graded asphalt emulsion mixes (Evans) and in cement-treated bases (Chang). Table 2 summarizes the recommended methods of beneficiating these aggregate types.

Table 2. Summary of recommended stabilization methods for Oregon's coastal aggregates

Material	Stabilization method
Marine basalt	Asphalt emulsion Portland cement
Sandstone and siltstone	Portland cement
Sands	Asphalt emulsions Portland cement Lime-pozzolan
Dredged materials	Portland cement Lime, lime-pozzolan

ASPHALT-TREATED MATERIALS

Historically, emulsified asphalts have been used with marine basalts to produce open-graded asphalt emulsion mixes with good performance characteristics. An open-graded mix provides a thick film of asphalt to waterproof and allows room for minor degradation of the basalt. The Federal Highway Administration (FHWA) and the Bureau of Land Management (BLM) have constructed projects using this type of mix (1).

The FHWA-BLM Surfacing Study Team is also investigating the use of sandstones and basalts treated with portland cement, asphalt, asphalt emulsion, and lime in a number of test roads on the Oregon coast. They have found that several test sections comprised of open-graded, emulsion-treated basalts and dense-graded sandstones on top of sandstone bases have performed very well. Table 3 summarizes some of the test roads that this team is currently investigating.

Table 3. Summary of major SST test roads (1)

Project	Construction completed	No. of sections	Surfacing type	Surfacing depth	Basis of studies	Comments
Nestucca River Rd. BLM 10	Summer 1976	5	Std. bit. plant-mix; Rd. mix w/ seal coat; and open grd. marine basalt plant-mix w/seal coat.	Pave 3" on 4" base; pave 4" on 2" base; pave 3" on 4" base (existing subbase under all sections).	Deep, steep canyon with degrading aggregates and high maintenance cost. Determine a pavement structure that will be suitable. Possibly upgrade local aggregate.	During 1st fall road-mix showed distress. This has not spread, considered a construction defect. No other distress to date.
Moon Creek Rd. BLM 1672	Under contract	8 wedges	Local aggregate, marine basalts, and sandstone, emulsion mixes, w/seal coat.	3.5 to 9 inches, directly on subgrade (4 on level and 4 on grade).	Implement studies on degrading rock (microscopically identify bad-actors). Establish tentative equivalency factors. Compare wear, flat and steep grades.	Under construction.
		3 Std.	Emul. tr. plant-mix base w/seal coat and base w/soil binder.	2" treated on 2" of water bound on 12" of sandstone subbase. 4" on existing base.	Compare soil bound w/asphalt bound base material.	Binder provided misc. work, but contractor elected source contained binder quality, and none was added.

Table 3. Summary of major SST test roads (1) (continued)

Project	Construction completed	No. of sections	Surfacing type	Surfacing depth	Basis of studies	Comments
Elk Creek Rd. BLM 629	Fall 1972	3	Bit. open-graded water bound base lime treated base all w/seal coats.	10" (all on subgrade) 16" 10"	Upgrade local aggregate with an admixture to cut haul costs on good rock.	Microscopic examination of fragments recovered in the summer of 1977 showed: water bound slight degrading; asphalt tr. trace of degrading; lime treated still clear.
Berry Creek Rd. BLM 409	Summer 1975	9 steps	Base w/BST. Gravel wP.I. Quarry base w/ S.E.	2",4",6", and 8" on 6" of topping. 8" on topping. 8",10", and 13".	Confirm "R" value design method. Compare gravel (50% fractured river rock) w/ binder to quarry rock w/fracture for serviceability. Check for pattern of rock loss under traffic. Demonstrate maintenance type light emulsion mat.	Under designed sections are now failing under the mat; however, the unoiled sections are not? Shifting of material under traffic shows: crowns become supers, and supers go flat, etc. Data still being gathered.
Blue Ridge Rd. BLM	Summer 1975	2	Open-graded bit. treated base w/ seal coat.	2" on variable base and subbase according to "R" value design.	Can an open-graded mat of minimum depth serve with adequate base underneath? Does a light dust treatment retain fines and reduce maintenance?	The bituminous mat is in good condition and being monitored. Maintenance costs on the spur roads cannot be separated out, so this phase is lost.
		4	Base-treated and untreated w/dist. oil.	4" to 6" admin. des. spur roads.		

Table 3. Summary of major SST test roads (1) (continued)

Project	Construction completed	No. of sections	Surfacing type	Surfacing depth	Basis of studies	Comments
Whitcomb Creek	Summer 1974	none	Aggregate surfacing w/P.I.	Variable 4" to 8" on existing subbase.	An old specification was used because it fit the project needs: gravel surface, overburden on the listed source.	Maintenance was not as low as hoped, and rock loss appears excessive. More detailed study of other projects will be necessary.

1" = 25.4 mm.

Of particular interest here is the Nestucca River Road. A test section of this road that has performed exceptionally well was comprised of an open-graded, emulsion-treated marine basalt. The basalt typically met all of the aggregate specifications except for the dimethyl sulfoxide (DMSO) test, in which all 10 rocks would fracture (4 of 10 is acceptable). This condition is known to exist in many of the marine basalts found along the Oregon coast.

The Siuslaw National Forest has used pure blow sand in two projects, the Sand Beach Park south of Tillamook and the Sutton Creek Beach Park north of Florence. The sand was mixed with CSS-1 emulsion and used as a surfacing mix, covered by a chip seal. Both of the roads, constructed by slightly different methods, have proven to be quite successful (1). Douglas County has also reported good results using asphalt emulsion (CSS-1) and 1 to 2% portland cement with a sand aggregate in the construction of the Winchester Bay Road, County Road 252 (1). Other successful projects using asphalt emulsion and marginal aggregates, dune sands, beach sands, and alluvial sands, are documented by Chevron, USA, Inc. (discussed in Reference 1).

Evans (1) developed mix designs for three open-graded, asphalt-emulsion mixes that use marginal aggregates and one cement-modified, sand-emulsion mix. Table 4 shows the optimum emulsion contents determined for the aggregates

Table 4. Optimum emulsion contents (1)

Aggregate	Emulsion type	Emulsion content, %	Water content, %	Dry density, pcf
Quality basalt	CMS-2	5.0	0-1	123
Marginal basalt	CMS-2	6.0	2-4	123
Marginal basalt	CMS-2	6.0	3-4	130
Marginal sandstone	CMS-2s	12.0	12-14	114 (not recommended)
Dune sand	CSS-1	8.0	9-12	104 (not recommended)
Dune sand	CSS-1 + 1.5% portland cement	7.0	9	116

1 pcf = 16.02 kg/m^3

tested. Improved pavement design techniques were used to determine layer equivalencies compared with hot asphalt concrete. The recommended layer equivalencies, considering both open-graded emulsion mix and cement-modified emulsion mix, are shown in Table 5. These results compare well with those of other agencies.

Table 5. Recommended layer equivalencies* for hot mix thicknesses (1)

Design load applications, 18 kip EAL	Open-graded emulsion mixes	Cement-modified sand mix
10,000	1.27	1.82
50,000	1.27	1.51
100,000	1.27	1.41
500,000	1.27	1.20
1,000,000	1.27	1.18

*Layer equivalencies are in relation to hot mix asphalt. For example, one inch of hot mix asphalt is equivalent to 1.27 inches of open-graded emulsion mix.

CEMENT-STABILIZED MATERIALS

Cement stabilization can be used with a wide range of soil types and is the most common of conventional stabilization techniques. Best responses generally occur with materials ranging from silt size to coarse-grained aggregate.

The Oregon State Highway Department has constructed several projects in which marine basalts were treated with cement to form a cement-treated base (2). The pavement section for the projects consisted of a granular base varying in thickness from 12 to 16.5 inches underlying an 8-inch treated base layer. An asphalt concrete surface course was used in each case. Cores removed from these projects were tested for strength, and they exhibited acceptable results. The pavements have been in service since the late 1960's, and the performance of all sections has been satisfactory.

Dune and beach sands can be stabilized with cement to achieve satisfactory results. However, uniformly graded materials (sands and some dredged materials) have high void ratios and require more cement to fill the voids than well-graded materials. Oregon's first cement-stabilized dune-sand base was constructed on the coast highway south of North Bend, Oregon, between 1939 and 1941 (3). The section proved to be uneconomical because of the high cement content required. Another problem that may be encountered when stabilizing dune and beach sand with cement is the acidic condition characteristic of coastal sand. The acid acts as an inhibitor to chemical reactions that take place during hydration.

Chang (4) determined recommended cement contents for the aggregate evaluated in the TRI study. These recommendations are shown in Table 6. Chang also

Table 6. Recommended cement contents (4)

Aggregate	Cement content %
Quality basalt	5
Marginal basalt	6
Marginal sandstone	5
Dredged spoil	9

used advanced pavement design techniques to determine layer equivalencies for cement-treated base. Table 7 lists the recommended layer equivalencies.

Table 7. Recommended layer equivalency for CTB (4)

Aggregate	Layer Equivalency*	
	Calculated value	Recommended value
Quality basalt	1.0	1.0
Marginal basalt	1.05	1.05
Marginal sandstone	0.9-1.09**	1.05
Dredged spoil	1.15-1.40**	1.25

*Layer equivalencies are in relation to a quality cement-treated material. For example, one inch of cement-treated quality aggregate is equivalent to 1.05 to 1.25 inches of cement-treated marginal aggregate.

**Depending on the AC thickness and subgrade modulus.

LIME-POZZOLAN STABILIZED MATERIALS

Lime and pozzolan treatment can improve the properties of fine-grained soils and soil aggregate mixtures. Fly ash (or volacnic ash) is commonly used as the pozzolan in lime-pozzolan treatments.

The Port of Portland constructed a high-standard pavement for the John M. Fulton container yard using a pavement section with base layers consisting of lime, cement, pozzolan, filler, stone, and dredged sand (LCPF) (5). Specifications are shown in Table 8. The project achieved a good-quality

Table 8. Specifications for LCPF base, Port of Portland (5)

Pavement thickness and composition
Total 22 inches
2" asphaltic concrete
8" type "A" LCPF (lime, cement, pozzolan, and filler)
6" type "B" LCPF
6" type "C" LCPF

	LCPF composition % by dry weight		
Material	Type A	Type B	Type C
Lime	3.3	3.0	3.0
Cement	1.1	1.0	1.0
Pozzolan	6.6	6.0	6.0
Stone	25	10	0
Silt filler	8	10	10
Onsite sand (dredged material)	56	70	80

	LCPF properties (approximate)		
Property	Type A	Type B	Type C
Modulus	1×10^6	5×10^5	2.5×10^5
Compressive strength ultimate	2000 psi+	1500 psi+	800 psi+

pavement at minimum cost by incorporating onsite dredged materials in the design. Lime-pozzolan stabilization is not suited for small projects as a central plant is required to mix the admixtures with the aggregate.

SUMMARY

A feasible solution to the Oregon coasts's quality aggregate shortage is to utilize marginal aggregates that are in good supply. These aggregates have performed satisfactorily when used in open-graded asphalt-emulsion mixes, cement-treated bases, and with lime-pozzolan stabilization. Attempts to use marginal aggregates should be encouraged. Information contained in this publication should aid in the selection of a suitable method of beneficiation and proper treatment levels for these aggregates. For detailed information, see the articles in the reference list.

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