Evaluation of Granular Overlays in Washington State

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Granular overlays have been used by the Washington State Department of Transportation (WSDOT) for about 30 years. Since the mid-1980s and along with the full implementation of the WSDOT Pavement Management System, WSDOT has been interested in examining the performance of granular overlays. It is believed by WSDOT that the performance of this rehabilitation treatment is better than might reasonably be expected. Further, past practice in Washington occasionally required that the preexisting surfacing (often several bituminous surface treatment layers) be scarified before placement of the crushed rock layer. The study and conclusions are reviewed.

The granular overlay system (hereafter referred to as "granular overlay") is an alternative type of overlay for rehabilitating mostly low-volume, rural roads. The overlay consists of a layer of densely compacted, crushed rock overlain by a generally thin surface layer. Figures 1a and 1b show typical granular and asphalt concrete (AC) overlays.

Granular overlays have been used throughout the world as a pavement rehabilitation treatment. The reasons for their use fall into four primary categories:

1. To reduce reflective cracking from a preexisting pavement structure,
2. To add extra pavement structure thickness to combat frost-related effects,
3. To improve the cross-slope road profile (and ride in general), and
4. To strengthen the pavement structure.

The last category will be the primary focus of this paper.

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One view of why the granular overlays have worked well structurally is that they take advantage of the stress stiffening behavior of granular materials. When a crushed rock layer is subjected to a confining pressure, its stiffness increases. Since the old pavement surface and the new surfacing confine the crushed rock layer in a granular overlay, traffic loads can provide high confining stresses, which, in effect, increase the stiffness of the crushed rock layer.

As the use of the granular overlay increased in Washington State, WSDOT realized that to improve and continue to use granular overlays, it needed to better understand how they worked, where they were appropriate, and how best to design and build them.

In cooperation with WSDOT, two initial studies were undertaken at the University of Washington (*1*,*2*). The results of these studies were encouraging. They led WSDOT and the associated Washington State Transportation Center (TRAC) at the University of Washington to enter into an agreement with the Federal Highway Administration to prepare a report on this topic, which was the source information for this paper (*3*).

METHODOLOGY

The study examined granular overlays in three ways. First, previous research on the behavior of confined crushed rock layers was reviewed. These studies provided information concerning the stiffnesses that have been found in crushed rock layers, the actions that can be taken to improve the crushed rock layer, and the problems that have been encountered in working with confined crushed rock layers. Next, the usable life of the granular overlay was compared with that of other types of pavement resurfacing, including AC overlays and BST. Finally, the granular overlays were field tested to determine their properties and to measure the effect of different designs on their performance.

LITERATURE REVIEW

The behavior of granular overlays depends on the condition of the crushed rock layer. Both the surface and the old pavement serve to protect this layer and to confine it. The crushed rock layer can provide much of the "strength" of the overlay. When crushed rock is used as a base course, it generally has a modulus of elasticity of about 15 to 30 ksi (100 to 200 MPa) (*4*). When it is subjected to a confining pressure of 125 psi (0.9 MPa), its modulus of elasticity can exceed 100 ksi (690 MPa) or more (*5*).

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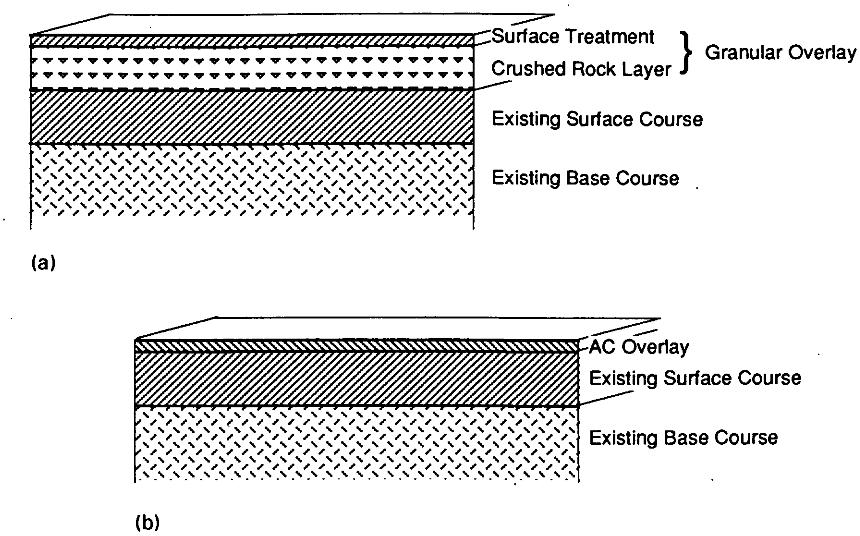

FIGURE 1 ***(a)* Typical granular overlaid pavement and *(b)* typical AC overlaid pavement.**

The stress sensitivity of a granular material will, in general, follow Equation 1:

$$E = K_1 \theta^{K_2} \tag{1}$$

where

E = modulus of elasticity (psi),
K_1, K_2 = constants,
$\theta = \sigma_1 + \sigma_2 + \sigma_3$ = bulk stress, and
$\sigma_1, \sigma_2, \sigma_3$ = principal stresses.

A study by WSDOT and the University of Washington found that the crushed rock WSDOT normally uses (crushed surfacing top and base course) has the following "typical" constants (*6*): K_1, 8,500 (mean), 2,300 (standard deviation); K_2, 0.375 (mean), 0.067 (standard deviation). The laboratory tests used to obtain these constants were conducted at bulk stresses ranging from 4 to 28 psi.

In a traditional pavement system, the confining stresses on the crushed rock base depend on a number of factors, including the stiffness of the subgrade. Since the granular overlay is sandwiched between two stiff pavement layers, it will be subjected to higher confining pressures.

Equivalency Factors

The stiffness of a granular overlay is provided largely by the crushed rock layer (assuming that the surfacing is relatively thin). One method for comparing granular and AC overlays is to determine the thickness of a granular overlay that would provide the same life as a thickness of AC overlay. This is the technique used by Sibal (*2*) and Deoja (*1*) in their studies of granular overlays.

Sibal used two elastic layer programs to model the behaviors of AC and granular overlays: ELSYM5 and EVERSTR (*2*). The ELSYM5 program treats all layers as linearly elastic. EVERSTR treats the granular layers as nonlinear. Sibal determined the thicknesses of the crushed rock layer in a granular overlay that would provide the same pavement performance as different thicknesses of AC. In both the granular and AC overlay analyses, he varied the moduli of the subgrade and the granular overlay crushed rock layer.

Sibal considered three modes of failure: fatigue cracking of the surface, fatigue cracking of the preexisting pavement surface layer, and rutting. He determined which of the three modes of failure was critical for each model and used the corresponding number as the number of loads that would cause failure for the pavement. Finally, he compared the number of loads that would cause failure for each of the models to determine the equivalent thicknesses of granular overlays and AC overlays. The 1.0 in. of AC on top of the crushed rock layer was not calculated in the equivalency factor. For example, if a 4-in. AC overlay was to be converted to a granular overlay with an equivalency factor of 1.70, the conversion would be as follows: 4-in. AC = 1.0-in. AC + 3.0 in. of AC = 1.0-in. AC + 3.0 × 1.70 of crushed rock = 1.0-in. AC + 5.1 in. of crushed rock (or 6.1 in. total thickness).

Sibal's analyses are shown in Figure 2. His results suggest equivalency factors of about 2.0 for the stiffer crushed rock moduli.

Crushed Rock Layer in Inverted Pavements

A series of South African studies (*5,7–9*) and related data (*10*) investigated the effects of different parameters on the behavior of the crushed rock layer in inverted pavements. These studies verified that the modulus of the crushed rock layer can be high and offered insight into improved designs for this layer and optimum gradation.

Horak et al. noted that the gradation specifications are important for achieving the high densities required for optimal performance of confined crushed rock layers (*8*) and published a paper that dealt with the effects of tightening the

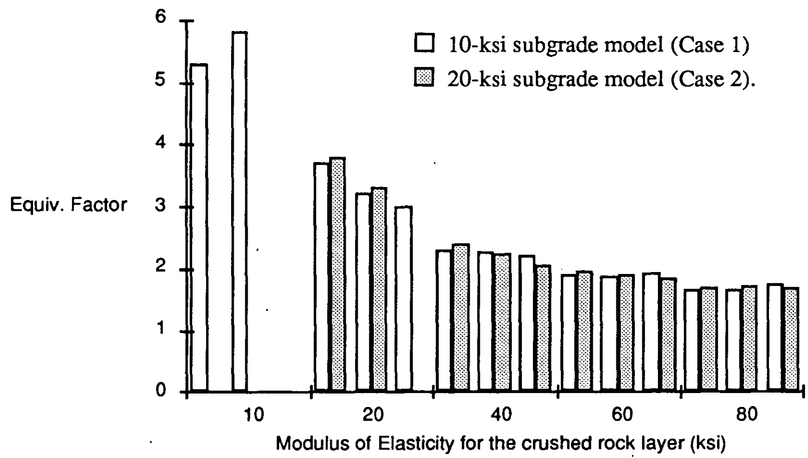

FIGURE 2 Equivalency factors versus the modulus of elasticity for the crushed-rock layer based on Sibal's calculations (*2*).

grading specifications beyond those normally required for the G1 (South African) base (*9*). Although the importance of the strength, durability, shape, and Atterberg limits of the aggregate was mentioned, the report focused on changes to the specifications to produce a better compacted base.

For convenience, the gradation bands for the South African G1 material, as well as somewhat similar gradations from AASHTO M147 (Gradings A and B) and WSDOT (Crushed Surfacing Top Course and Base Course), are given in Table 1. The gradation band for the G1 material was obtained directly from a figure in Horak et al. (*9*). It appears that the most similar gradations to the G1 are AASHTO Grading B and the WSDOT Crushed Surfacing Base Course (*11*). (The majority of granular overlays constructed by WSDOT to date have used the Crushed Surfacing Top Course grading.)

The base course on which Horak et al. reported was compacted with 99 to 103 percent of modified AASHTO and had a gradation that fell within the specifications for a G1 base, but with a few additional requirements (*9*). They found that the greater effort required to set up the crusher and obtain the correct gradation was more than offset by the increased ease in compacting the material to a higher density.

As was previously stated, the crushed rock layer is stiffer and more durable if it is well constructed. The compaction and integrity of the crushed rock layer is very important. The material for the crushed rock layer must be durable. As was mentioned by Horak et al., the easiest way to obtain the highest compaction is to use an optimum gradation (*8*). Interviews during 1990 with WSDOT project engineers on granular overlay construction projects indicated that the moisture content is also important (*12–14*). Because the crushed rock is spread in a thin layer, the moisture from the rock tends to evaporate rapidly.

A significant problem that WSDOT has encountered in the construction of the granular overlay is traffic. When there is no possible diversion, the traffic has to pass over the crushed

TABLE 1 Gradation Bands for Various Crushed Rock Specifications

Sieve Designation		Percent Passing				
		South African G1*	AASHTO M147-65		WSDOT 9-03.9 (3) Crushed Surfacing	
Standard	mm		Grading A	Grading B	Top Course	Base Course
2 in.	50	100	100	100		
1 1/4 in.	32	93 - 97				100
1 in.	25	82 - 92		75 - 95		
3/4 in.	19	72 - 85				
5/8 in.	15.9	64 - 78			100	50 - 80
3/8 in.	9.5	50 - 67	30 - 65	40 - 75		
1/4 in.	6.35	40 - 57			55 - 75	30 - 50
No. 4	4.75	35 - 52	25 - 55	30 - 60		
No. 10	2.00	23 - 39	15 - 40	20 - 45		
No. 30	0.600	14 - 26				
No. 40	0.425	11 - 24	8 - 20	15 - 30	8 - 24	3 - 18
No. 200	0.075	5 - 12	2 - 8	5 - 20	10 max	7.5 max.

* South African G1 grading taken from plotted gradation band (10)

rock layer during construction. This frequently causes washboarding. Therefore, the granular surface must be rebladed immediately before the surface layer is placed.

Improvement in BST Construction

A recent WSDOT study examined the effects that construction practices have on the problems associated with BSTs (*15*). The main problems that were investigated included flushing of excess asphalt, windshield damage due to loose rock, and aggregate loss due to poor embedment. Through a review of the use of BSTs in other western states and an examination of BST construction projects, a series of design and construction guidelines was developed.

The study also recommended several guidelines for the proper choice of roads to be overlaid with BSTs. The report suggested that the BST be applied only to roads that were not considered a high traffic risk [i.e., roads with average daily traffic (ADT) counts in excess of 5,000]. If a BST surface was used on granular overlays, these same limitations were applicable. (WSDOT mostly requires BSTs on routes with ADTs of 2,000 or less and discourages the use of BSTs on routes with ADTs of 5,000 or more.)

Existing Pavement

Although granular overlays reduce the rate of reflective cracking, they are also sensitive to moisture infiltration through breaks in the existing pavement surface. Infiltration of moisture lowers the stress sensitivity of the crushed rock layer (in terms of K_1, hence overall stiffness).

To circumvent the problem of an inconsistent base for the overlay, the highway department in Zimbabwe rips and spreads the existing base and shoulder, then stabilizes with 2 percent cement or lime (if required) and recompacts it. In this manner, the granular overlay is assured of having a solid base (*16*). Normally, all that is required is to patch any holes and seal any cracks in the existing pavement surface.

Other Advantages and Limitations

Insulation

An advantage of the granular overlay is that it protects the existing pavement from daily extremes in temperature. This is important during hot summer months and in tropical countries where pavement surface temperatures can approach and exceed 160°F (70°C) (*16*).

Increased Frost Resistance

Frost heave and thaw weakening problems are often a result of subgrade freezing, so if the subgrade is insulated from the cold, these problems are reduced. Several states, including Alaska, Iowa, Oregon, and Washington, use frost protection in their pavement thickness design calculations (*17*). Most of these states design the pavement thickness to be at least 50 percent of the total expected frost depth. In this manner, the subgrade is at least partially insulated against frost.

In Washington State, designing the overall pavement depth to be equal to 50 percent of the total frost depth has worked well for controlling all but the most severe frost problems (*18*). Unfortunately, many of the state's low-volume rural roads were built before this design procedure was adopted. These roads frequently consist of only a thin BST over 6 to 9 in. (150 to 225 mm) of base course when the frost design thicknesses are 15 to 24 in. (380 to 610 mm). Rehabilitating these roads typically means adding a granular overlay with a minimum of 4.2 in. (107 mm) of crushed rock.

To prevent the crushed rock layer from contributing to frost heave, the amount of material that passes the No. 200 sieve (0.075 mm) may have to be limited. Researchers have observed that the finest content of soils is an important indicator of frost-susceptible material (*19*). The pavement agencies surveyed specified that the maximum percentage of material that passed the No. 200 sieve be 5 to 15 percent. The lower range of this specification is lower than the range suggested by Horak et al. for obtaining the maximum compaction (*9*).

Change in Road Geometry

By adding 3 to 6 in. (75 to 150 mm) to the overall pavement structure, the granular overlay can alter the road geometry. It can be used to increase drainage, improve the road profile, and level off inconsistencies in the pavement. The additional height makes it unusable in areas where the road geometry is restricted by curb height or other considerations.

Resistance to Shear

Little information could be found concerning the ability of confined crushed rock layers to resist shear. However, this is a potential problem. Although granular materials are very strong in compression, they have little resistance to tension. When subjected to a high confining pressure, the crushed rock particles can distort, be crushed, shift, roll, or slide. The amount of movement caused by any of these actions is directly proportional to the confining pressure. If the shear stress becomes sufficiently large, the combined movement from these actions will result in a shear failure (*20*).

Design of Granular Overlays

There are two basic techniques for designing granular overlays. One is based on mechanistic-empirical calculations. The studies done by Sibal (*2*) and Deoja (*1*) are examples. Another technique is based on practical construction considerations.

The second design approach is to use the maximum thickness of granular material that can be easily compacted in one lift. This suggestion was offered in a report by Maree et al., in which the authors found that a crushed rock layer 12.6 in. (320 mm) thick did not perform significantly better than one 5.5 in. (140 mm) thick (both crushed rock layers were on cement-stabilized subbases) (*7*). Maree et al. concluded that the crushed rock layer need not exceed the maximum thick-

ness that can be placed and compacted in one lift [6 in. (150 mm)].

A study by Otte and Monismith produced similar conclusions (*21*). They used a layer elastic program, PSAD2A, to model the behavior of several inverted pavement structures. The computations were made for 9.0-kip (40-kN) dual wheels, 13.0 in. (330 mm) apart. The pavement that was simulated was an inverted pavement with a 1.4-in. (35-mm) BST surface. The thicknesses of the crushed rock layer and the cement-stabilized base and subbase were varied over a wide range of thicknesses.

The authors found that the primary stresses in an inverted pavement were on the surface course and cement-stabilized layers. They found that because of stress stiffening, as the thickness of the crushed rock layer increased from 5 to 20 in. (125 to 500 mm), the equivalent elastic modulus of the granular base declined about 30 percent. Otte and Monismith recommended the following (*21*):

1. The bituminous surfacing for inverted pavement designs should not exceed 1.2 to 1.4 in. (30 to 35 mm).
2. For typical highway traffic loads, the granular layer should have a thickness of about 5.0 to 6.0 in. (125 to 150 mm).
3. The cement stabilized layers supporting the granular layer should be (*a*) two layers, each 6 in. (150 mm) thick, if the subgrade has a CBR of 15 or better, or (*b*) one layer, 6 in. (150 mm) thick, for light traffic (rural).

The one thickness approach is also used in Zimbabwe (*16*). The highway department in Zimbabwe has found that the practical range for the construction of the crushed rock layer in an overlay is 5 to 6 in. (120 to 150 mm). Thinner layers tend to shear under a roller. If a thicker layer is needed, the road probably needs to be reconstructed.

In Washington State, granular overlays are generally built with thicknesses of 3 to 6 in. [most with a 4.2-in. (107-mm) thickness].

Costs

Typical WSDOT project specific costs for granular overlays with both AC and BST surfaces were estimated. In general, granular overlays surfaced with AC are about twice as expensive as those surfaced with a BST (about $7.00/yd² for AC versus $3.50/yd² for BST).

SURVIVAL AND PERFORMANCE STATISTICS

One definition of the survival life of a pavement is the amount of time between a pavement's construction and its resurfacing. The performance period is the amount of time from its initial construction to the time it reaches a minimally acceptable level. Both survival lives and performance periods provide valuable estimates of pavement life. In this portion of the report, the survival lives and performance periods of AC overlays, BST resurfacings, and granular overlays are estimated and compared.

This part of the study considered only the ages of the different types of surfaces. Other factors, such as traffic loadings, weather conditions, and soil support, affect the amount of time that a pavement lasts, but these were not directly considered. Since the study was conducted within a small geographic area, the weather and subgrade effects were assumed to be constant for all roads. The effects of higher traffic loadings were expected to be somewhat canceled by the thickness of the resurfacing.

Roads overlaid by the different techniques had different characteristics. In general, roads with AC surfaces had higher traffic counts than roads with BST surfaces. In addition, granular overlays were often used as a method for repairing badly distressed roads. Most roads that received a granular overlay had suffered from either thermal cracking or roughness problems and therefore had required special treatment.

In comparing the survival times and performance periods, note that the sets of data did not come from the same time period. Since the performance life equations were only calculated for the present road surface, they represented only resurfacings built since the late 1970s. The data for calculating the survival lives, on the other hand, were equally spread from the 1980s to the 1960s, with some dating as far back as the 1940s. Because of the problems previously mentioned with the "old" survival life data, the old information tended to increase the average survival life slightly.

Source of Data

The source of data for this analysis was the WSPMS (*22*). The WSPMS contains records of work done on the roads and the pavement condition analyses. Data from the WSPMS were spot checked against as-built plans and pavement conditions and were found to be accurate.

The estimation of survival lives and performance periods was restricted to WSDOT Districts 2 and 6 (eastern Washington). These two districts are generally rural areas where the topography ranges from mountainous to rolling hills. The average annual precipitation is about 17 in. (432 mm) in Spokane (*23*), but the area has severe frost in the winter. These are also the two districts that contain the majority of roads with granular overlays.

The WSPMS was searched to locate all roads containing BST, AC, and granular overlay resurfacings. First, the actual survival time for the different layers of pavement surfaces was calculated by subtracting consecutive resurfacing construction years from the previous years. Next, pavement condition rating (PCR) (100 = no distress, 0 = extensive distress) data on the most recent resurfacing were examined to determine whether the regression equation in the model represented a "true" regression equation. Finally, the survival lives and the performance periods were compared for each type of resurfacing and among the types of resurfacings.

Bituminous Surface Treatments

The survival times for BST resurfacings are approximately normally distributed with a median survival time of 8.0 years and a mean of 9.2 years (standard deviation = 5.1 years for a sample size of 1,310).

Next, the PCR equations were examined to determine the performance periods. Although more than 200 road sections

TABLE 2 Statistics on Performance Periods

	PCR Level	Median	Mean	Std. Dev
BSTs[1]	PCR 40	6.1	7.0	2.5
	PCR 20	7.4	8.2	2.4
	PCR 0	8.7	9.3	2.4
AC Overlays[2]	PCR 40	10.6	10.2	1.7
	PCR 20	11.4	11.3	1.7
	PCR 0	12.2	12.1	1.8
Granular Overlays[3] (All Surfaces)	PCR 40	8.7	9.2	1.8
	PCR 20	10.7	10.8	2.1
	PCR 0	12.2	12.2	2.6
Granular Overlays (BST Surfaces)	PCR 40		7.5	
	PCR 20		8.3	
	PCR 0		11.0	
Granular Overlays (AC Surfaces)	PCR 40		9.5	
	PCR 20		11.3	
	PCR 0		11.8	

[1]Based on 21 data points
[2]Based on 29 data points
[3]Based on 17 data points

were analyzed, only 21 had usable regression equations (sections less than 5 years since last resurfacing were not used). These results are summarized in Table 2.

A comparison of the values for the actual survival times and the performance periods reveals that WSDOT resurfaces BST roads when their PCR is between 20 and 0.

AC Overlays

The survival times for AC overlays were essentially normally distributed. The survival times based on AC overlays with thicknesses of less than 1.2 in. (30 mm) were separated out. According to the 1988 WSDOT specifications, only AC overlays thicker than 1.2 in. (30 mm) are subject to compaction control. The survival times for AC overlays less than 1.2 in. (30 mm) were, again, normally distributed with a median survival time of 8.0 years and a mean of 8.7 years (standard deviation = 2.8 years). For AC overlays greater than 1.2 in. (30 mm), these times were 10.0, 9.7, and 4.5 years, respectively.

There were also a significant number of survival times of 5 years and less. If only the survival times of AC overlays thicker than 1.2 in. (30 mm) and lasting more than 5 years are considered (thus eliminating construction-related and underdesigned factors), the average survival life increases to 11.5 years.

The predicted performance periods are summarized in Table 2.

Granular Overlay

Unlike the other two resurfacings (or overlays) that were examined, there are not a large number of granular overlays on the WSDOT route system; however, projects tend to have long lengths (thus a large amount of mileage). In addition, because granular overlays had only been used with greater frequency since the mid-1980s, few data were available concerning survival times. Therefore, survival times were not analyzed. This left the examination of the performance periods. The data are summarized in Table 2.

Performance Summary

Although both methods used for calculating the usable life of the resurfacings have uncertainties, the two methods together provide reasonable estimates of usable life.

A comparison of BST resurfacings with granular overlays with BST surfaces shows that the difference in predicted performance is relatively small (7 percent) at a PCR of 40 but increases (18 percent) at a PCR of 0 (the granular overlays in both cases last longer than a simple BST). However, for AC, the granular overlays surfaced with AC do not last as long as a conventional AC overlay (7 percent less at a PCR of 40 and 2 percent less at a PCR of 0).

These comparisons show that the BST-surfaced granular overlay performs better than simple BST resurfacings (without the crushed-rock layer) and AC-surfaced granular overlays not quite as well as plain AC overlays. Granular overlays are generally used to repair pavement structures with significant distresses. BST and AC overlay resurfacings are normally placed on pavements early in the distress cycle (usually due to fatigue cracking). If the granular overlays had been used on pavements in better condition, these comparisons would have probably been different.

NDT TESTING AND EVALUATION

To assess the actual performance of roads with granular overlays more than 50 centerline mi (80 km) of roads were tested with a Dynatest falling weight deflectometer (FWD) Model 8000. These roads were located throughout WSDOT Districts 2 and 6 and had a variety of structures, ages, and conditions. The tests were designed to provide evidence about the comparative performance and stiffness of granular overlays.

All of the selected roads were in rural eastern Washington. Traffic on these roads is mostly local, with occasional long-haul trucks. The topography of eastern Washington ranges from mountainous to rolling hills, and most of the land is either dry land wheat farms or scrub fields.

A sample of roads with enough different characteristics to be representative of all the other roads in these two districts was sought. Characteristics that were considered included age, pavement structure, traffic flow, and road location. The roads that were selected are summarized in Table 3. Where more than one section was tested on a specific road, each section was designated by a letter.

The analysis of these test sections was done in two fundamental ways. First, basic deflection parameters were calculated for each test section (subgrade modulus, D_0, and area parameter). These measured parameters were then compared with calculated parameters for typical AC-surfaced sections with similar subgrade moduli (modeled with the ELSYM5 linear elastic program). Second, the layer moduli were backcalculated using the program EVERCALC 3.0. The overall goal of this second effort was to estimate granular overlay moduli by use of FWD deflection data. The backcalculation process was difficult and the results contain uncertainties; however, reasonable convergence errors of 1.5 percent or less were used (RMS basis).

On the basis of the analyses of test sections on SR28A and SR17, the modulus of elasticity for the crushed rock layer of the granular overlay was estimated to be approximately 80 ksi (551.2 MPa) under a 9.0-kip load. The South African studies showed elastic moduli ranging from 29.0 to 75.4 (and higher). Presumably, one of the reasons for the higher modulus of elasticity was that the bulk stress in the crushed rock layer in the granular overlay was higher than in the inverted pavement.

CONCLUSIONS

The following conclusions are based on the entire study of granular overlays (including reviewed literature).

1. Granular overlays are effective at reducing reflection cracking, insulating the old pavement surface against extremes in temperature, and improving the road geometry.
2. BSTs are more appropriate surfacings for granular overlays than are AC overlays (on the basis of observed performance).
3. The crushed rock layer should have a maximum recommended thickness of 6 in. (150 mm) (on the basis of structural considerations only) and a minimum value of 3.0 in. (75 mm).
4. The AC equivalency factor for the confined crushed-rock layer that is properly constructed and well protected can be about 2.0 (refer to Figure 2), but in-service WSDOT pavements suggest this value is probably higher (i.e., less support).
5. Consideration should be given by WSDOT to using crushed surfacing base course (maximum aggregate size = 1¼ in.) for the crushed rock portion of the granular overlay on some projects and evaluating its performance. The gradation is similar to (but not the same as) the South African G1 material specification.
6. The pavement surfacing (before granular overlay) should be left in place if project conditions permit. This enhances the stress stiffening of the crushed-rock layer in the granular overlay system.

The full study documentation is contained in the report by O'Neil et al. (*3*).

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TABLE 3 Road Sections Tested with FWD

Location	Surfacing Type	Granular Thickness in.	Granular Thickness mm	Age at testing (years)	Test Length miles	Test Length km	Average Daily Traffic[1]	Annual 18kip (80 kN) ESAL[2]
District 2								
SR17	BST	2.4-12[3]	60-300	6	8.0	12.8	960	107,000
SR 24	BST	3.6	90	4	11.0	17.6	920	26,000
SR 28A	AC	3.0	75	6	5.0	8.0	4,700	180,000
SR 28B	BST	3.6	90	6	5.8	9.3	640	29,000
District 6								
SR21A	AC	4.2	107	11	5.0	8.0	330	28,000
SR21B	BST	3.0	75	10	5.0	8.0	280	13,000
SR231A	BST/AC	4.2	107	11	5.0	8.0	180	5,700
SR231B	BST/AC	4.8	122	8	5.0	8.0	230	6,400

[1]WSPMS, 1990 [2]Calculation is based on WSDOT's estimate of truck count (MIDAL, 1990)
[3]Thickness varies

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