USE OF RUBBER AGGREGATE IN SLURRY SEAL AS A STRAIN RELIEVING INTERLAYER FOR ARRESTING REFLECTION CRACKS

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VERMONT DEPARTMENT OF HIGHWAYS

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INTRODUCTION

During the fall of 1971, the Bituminous Concrete Subdivision initiated a memorandum relative to reflective cracking in which it was stated that:

> "Reducing reflection cracking in bituminous overlays is a national concern (see FHWA CMPB 16-70 and HO-31 of October 13, 1970) as well as a State concern (observe the condition of overlays placed in 1969 and 1970)".

It was also pointed out that the application of a slurry seal does little to rectify this particular problem as our overlays using slurry showed reflection cracks the first winter to a large degree.

In January 1973, a follow up memorandum was sent from the Bituminous Concrete Subdivision which stated:

> "The need for some means of preventing or reducing the reflection of cracks through our overlays is evident. Each year miles of cracked pavement is covered with up to two inches of new mix and after the first winter, it is sometimes difficult to know which section of the highway has or has not been repaved. This problem is not unique to Vermont and various agencies have worked on this problem over a span of years. The use of wire or fabric reinforcing has been used, along with a multitude of others. Basically, however, these other ideas did not provide for a stable bond breaker. They provided for a definite bond between the two layers and even though concepts such as softer asphalts were used in the new layer on top, it was bonded in such a manner that as the old pavement moved, the new material was not sufficiently elastic to absorb the movement.

In March of 1972, this section researched what we called 'Investigation of Recovered Ground Rubber as a Sandwich Course to Prevent Reflection Cracking'. Rubber shreds from a local tire recapping firm were mixed approximately 50/50 with asphalt cement to which slabs of hot mix were secured. With the slabs secured at one end, the lateral displacement of the base containing the rubber-asphalt blend was attempted prior to the cracking of the asphalt slab. However, as so many physical problems occurred, this research was suspended. The concept was considered valuable and while attending the Slurry Seal Seminar on November 10, 1972 at Concord, New Hampshire, it was mentioned that Massachusetts was working on this same concept. Subsequent contact with Mr. Gene Bastanza, Chief of Laboratory, Massachusetts Department of Public Works, has provided us with their proposed specification and a back up paper titled 'Use of Rubber Aggregate in a Strain Relieving Interlayer for Arresting Reflection Cracks in Pavements' by Gallaway and LaGrone.

This paper was prepared for presentation at the International Symposium on "The Use of Rubber in Asphalt Pavements" at Salt Lake City, Utah in May of 1971. Briefly stated, this paper indicated:

"A most troublesome problem encountered in design and maintenance of asphalt concrete pavements is that of reflection cracking caused by some type of foundation movement or shrinkage problem. These reflection cracks reduce the effectiveness of the pavement by loss of structural strength, by allowing intrusion of water into the pavement and down into the supporting structure, and/or by reducing the long-lasting smooth-riding quality of the surface.

It has been demonstrated that a 'Strain Relieving Interlayer' composed of approximately equal parts by volume of vulcanized rubber aggregate, mineral aggregate, and residual asphalt emulsion will produce a waterproof membrane that can accommodate substantial base movement without transmitting excessive strain to the surface course and will, thus, alleviate reflection cracks.

Laboratory data developed using an analog of a layered highway system has shown that allowable foundation movement before cracks reflected to the surface course would be 300% greater for a pavement system utilizing a 1/8 inch layer of the SRI composition and 440% greater for a 1/4 inch layer of the SRI composition. Strain relieving interlayers of more than 1/2 inch are not recommended due to possible stability problems".

With this background, a slurry seal company was contacted for materials so that experimentation could be conducted in our own laboratory.

PROCEDURE

In the manufacture and testing of these slurry seals, certain steps were laid down and adhered to. To begin with, all apparatus and materials were kept at room temperature (approximately 75°F). Also, each series of five samples were based around a 210 gram sample with slight variations due to varying the amount of one component of mix within that series. The weighing apparatus (Mettler P 11 N) has a range of 10 kg. with a precision of 0.1 gm. The hand mixing apparatus consisted of a cylindrical tin 2" deep and 3 1/2" in diameter and standard spatula.

First, air dry aggregate was placed in the mixing tin. Cement (Type I) was then added and mixed thoroughly with the aggregate. The shredded rubber was then added and also mixed thoroughly. After this, the desired water content was added and mixed to completely cover the dry material, thus being used as a carrying agent for the asphalt emulsion. Finally, the emulsion was added and the mixing time was set at two minutes to duplicate field mixing.

After the mixing was completed, the material was spread on a piece of 6"x8" sheet metal flashing with the sample being enclosed by a template of rectangular shape (4"x6" interior dimensions) and a depth of 3/16 of an inch. It was then allowed to cure at room temperature for a period of 18 hours. At the end of this time, the enclosing template was carefully removed and the supporting metal and specimen were placed in a freezer at 0°F for four hours.

To test the elasticity and rebound qualities of the mix, each sample was removed from the freezer and immediately bent over a 4" diameter mandrel. Pictures were taken and descriptions were noted of the results of bending the samples to an angle of 90°

After each series was tested, the specimen displaying the best overall qualities was noted and the following series were run using this as a standard and using some other ingredient of the mix as the variable.

MATERIALS

Preliminary tests were started with materials submitted by a Massachusetts slurry seal company. However, we were unable to combine the aggregate and CSS-1h emulsion in any reasonable proportions even though the materials were basically the same as were used on the Westminster-Rockingham overlay of 1972.

Sieve Size	Brox "A" 1972	Brox "B" 1973	Average 1972
4	100	100	100
8	95	96	91
16	70	71	64
30	47	52	47
50	31	37	30
200	10	13	12

Brox "A"	Original gradation submitted in 1972 as preliminary samples to be used on the Westminster-Rockingham overlay.
Brox "B"	Submitted for use with rubberized slurry seals.
Average 1972	This is the average grading of materials used on Westminster-Rockingham overlay.

During this period of preliminary testing, all materials were checked against the specifications and were found to be within reasonable compliance. Nothing was found that would indicate poor compatibility. The slurry seal company had duplicate samples of these materials and checked the results of our testing at their laboratory. Our results were substantiated by their people. It was determined by the emulsion supplier that a change in the gradation of Brox's aggregate was the source of trouble regarding the incompatibility of the materials. The emulsion supplier indicated the particular problem was due to a change in gradation on the No. 325 sieve.

New materials supplied by the slurry seal company were delivered to our laboratory in late January. These materials came from West Sand and Gravel, Walpole, Massachusetts.

CRUSHED STONE AGGREGATE

Sieve Size	Fine Aggregate "A"	Coarse Aggregate "B"	As Supplied Blend Used in Tests	Slurry Spec. General
4		100	100	90-100
8		78	85	65-90
16	100	39	61	45-70
30	96	20	48	30-50
50	56	9	26	18-30
200	16	2	7	5-15

Preliminary tests were made on these new materials and they were found to be compatible with the CSS-1h emulsion.

The vulcanized rubber shreds supplied were number 4 buffings without metal or fiber cord. This material passes the #4 sieve 100 percent.

DISCUSSION

Four preliminary samples were made to familiarize ourselves with a rubberized slurry seal. These four samples were made as follows (all weights in grams).

Sample No.	Aggregate	Cement	Rubber	Water	Emulsion	Original Appearance
101	100	4	40	20	36	ok
102	110	4	40	10	36	ok
103	120	4	40	0	36	dry
201	110	4	40	15	40	wet

After curing these materials at room temperature for two days, we decided to establish a basic mix formula and revolve our testing around it. The basic sample that was decided upon is indicated by the sample marked 201. This was due to its appearance after it had cured. During the initial curing period, it was felt this sample was too wet to be used but after it had set up, it gave a better overall appearance.

The "A" series was formulated around sample #201, varying the water content for A-1 through A-4 and can be found in Table I. A-5 was made by increasing the emulsion content. The A-5 sample appears to be the best in regards to tensile quality and for recovering to normal appearance. However, it starts out as a very fluid and wet mix and might cause problems during lay down operations.

The "B" series was formulated with a varying emulsion content (Table I), but not run. This was because the "A" series indicated emulsion contents less than 40 grams would not be worthwhile to run.

The "C" series was tried by varying the rubber content around the A-5 sample (Table I). The "C" series samples did not prove to give the exact results that were expected. C-3, which should have equaled A-5 in recovery, broke straight and it appeared that C-1 was more equal to A-5, although it had more rubber in it. However, it was decided to continue with the A-5 formulation and vary the water content for the "D" series. At this time, a series of photographs was returned which proved to be inadequate to show the failures for the "A" series.

The "D" series (Table I) was, therefore, observed more astutely concerning setting times and failure performance. After four hours of curing, both D-1 and D-2 were still slightly tacky but D-3 and D-4 were set. After three hours, D-3 was slightly tacky and D-4 was firm but not completely set. This indicated that decreasing water contents shortens setting times. Following the 18 hour cure and the four hour freezer periods, D-3 and D-4 had a coarse texture and had definite breaks with no recovery. D-2 had a medium texture and cracked approximately halfway through the sample but closed when returned to a flat position. D-1 was fine textured and when bent 90° over the 4" mandrel, a fine hairline crack appeared which disappeared when the sample was returned to its original position. This series indicates that water in proper proportions is important as far as texture, mixability, spreading and flexibility of the mix.

The "E" series (Table I) was run changing the cement content. This particular series was started late in the day and observations on setting could only be made up to two hours. At the end of the two hour period, only E-5 was nearly set or cured. After removal from the freezer and bending over the 4" mandrel, E-1 cracked halfway through the sample and returned acceptably when flattened out. E-2 and E-3 responded similarly to E-1 except the crack was not as deep. E-4 had a fine crack with good rebound qualities while E-5 had a hairline crack with excellent rebound qualities. This showed that while using this type of aggregate, cement was not needed to retard setting of the material while mixing and that better results were achieved when no cement was used as far as setting time and quality of material after set up.

It should be mentioned here, that at the beginning of the experimentation, that the "A" series was bent 90° over a 1" bar after being removed from the freezer. However, as this proved to be too restrictive a test, the "A" series was duplicated and a 4" mandrel was used for bending all samples.

CONCLUSION

By starting with a basic mix and then varying one component of the mix throughout a series of slurry mixes, it was attempted to transcend from one series to the next, basing the new series on the most favorable findings of the latter. In this way, it was hoped to arrive at the most suitable mix, bearing the desired qualities, using specified percentages of materials used.

As mentioned in the text of the report (Series "D"), the amount of water used is very important as far as texture, mixability and spreading and also in the finished quality of the mix. In Series "E", it was found cement was not needed in lengthening the mixing time for suitable mixing. It was also noted that with the absence of cement, the set up time was reduced and a better quality product resulted. Before this, it had been assumed cement was needed to lengthen mixing time, but this did not prove true using this type of aggregate. However, other aggregate sources may need cement.

Our tests indicate that the materials submitted in 1972 and 1973 were basically the same and yet one set of aggregates were not good. This would indicate a grading problem could exist in an aggregate and not be found until being incorporated on a project without proper laboratory investigation.

In view of literature reviews as well as our own laboratory findings, we wholeheartedly endorse the SRI concept in theory, as well as the use of a rubberized emulsion slurry in particular. It is considered that this is possibly an exciting breakthrough in the solution of one of our major maintenance problems. The cost of the rubberized slurry will be approximately twice that of normal slurry that is presently used prior to overlays, but the crack filling process may hopefully be bypassed, thus equalizing the cost.

RECOMMENDATION

It is recommended that the Department investigate rubberized slurry seal from an economic standpoint based around the following proportioning of ingredients.

	Aggregate	Cement	Rubber	Water	Emulsion
% by weight	52	0	20	7	21
% by volume	38	0	35	7	20

TABLE I

	Aggregate	Cement	Rubber	Water	Emulsion
BASIC FORMULA (WEIGHTS IN GRAMS)					
	110	4	40	15	40
"A" SERIES					
A-1	110	4	40	15	40
A-2	110	4	40	10	40
A-3	110	4	40	5	40
A-4	110	4	40	0	40
A-5	110	4	40	15	45
"B" SERIES					
B-1	110	4	40	15	35
B-2	110	4	40	15	30
B-3	110	4	40	15	25
B-4	110	4	40	15	20
B-5	110	4	40	15	15
"C" SERIES					
C-1	110	4	50	15	45
C-2	110	4	45	15	45
C-3	110	4	40	15	45
C-4	110	4	35	15	45
C-5	110	4	30	15	45
"D" SERIES					
D-1	110	4	40	15	45
D-2	110	4	40	10	45
D-3	110	4	40	5	45
D-4	110	4	40	0	45
"E" SERIES					
E-1	110	4	40	15	45
E-2	110	3	40	15	45
E-3	110	2	40	15	45
E-4	110	1	40	15	45
E-5	110	0	40	15	45