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PRETREATMENT OF AGGREGATES

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U.S. Department of Transportation
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16. Abstract

It is thought that the coated aggregates of recycled pavements help to improve the material properties of the new mixes in which they are used. For this report, marginal and low quality virgin aggregate was precoated with seven different treatments to simulate the beneficial effects of recycled pavements. The laboratory test results varied. Two of the treatments improved all three of the material properties monitored. These treatments were retested with different aggregate. Improvements in material properties were again observed. These improvements, however, did not seem great enough to justify the added cost. Other more traditional methods of improving pavement quality are recommended.

Implementation

Since pretreatment of aggregates was not found to be cost effective, it is recommended that the current CDOH procedures of selecting better aggregates, adding anti-stripping additives, or adding hydrated lime be continued. The information in this report may be more useful if a better method of remixing the treated aggregate can be established.

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I. Introduction

For a number of years, the Colorado Department of Highways has been making asphalt pavement mixes by combining virgin aggregate with old asphalt pavement that has been recycled. This process has produced hot bituminous pavements that exhibit fairly high stability values and good resistance to stripping and raveling. Credit for the improved pavement qualities in these pavements has been given to the aggregates in the old mix.

The theory is, that in a new mix, the virgin aggregate absorbs and is coated with asphalt. Because some of the asphalt is lost due to absorption of the light ends (maltene resins, etc.), the pavement hardens early. This hardening is reduced when pavements are recycled. The recycled aggregates do not absorb as much new asphalt, and the existing asphalt coating helps create a much better aggregate-asphalt bond resulting in a better performing pavement. The above theory initiated this research study to determine if the characteristics of the recycled aggregates could be reproduced by pre-treating or pre-coating virgin aggregates.

The idea of this research study was to produce a high-quality pavement by using a marginal or low-quality virgin aggregate source. If this were done on a paving project, the contractor or construction agency would treat the aggregate and then stockpile it for curing before using it.

This was simulated in the laboratory for the study. Once the source was chosen, the aggregate was treated with several different materials and stored for a period of ten months. After ten months, design mixes were prepared using the pre-treated aggregate. These mixes were compared to similar mixes containing the same marginal or low-quality aggregate that was untreated.

If the treated aggregate improved the properties of the pavement as compared to the untreated aggregate, test sites were to be chosen and evaluated for a three-year period. This report documents the test results of each mix design using the pretreated aggregates and the untreated aggregates.

Laboratory testing was performed in two phases. In phase I, seven different treatments were used on the aggregate. Two of these treatments showed promise, therefore a second phase of testing was initiated using these two treatments with two different aggregate sources.

II. Phase I: Testing of Seven Methods of Pretreatment

A. Procedure

Pretreating and storing:

Samples of aggregate were chosen from two pits: the Hedges Pit east of Sterling, and the Wolf Pit near Colorado Springs. Both sources have been used in mix designs for approximately 15 years. These pits were determined to contain marginal or low quality aggregate, based on past performance of pavements using this material. However, pavements using aggregate from the Hedges Pit have shown improvement when lime treatment was used.

Before being treated, the aggregate from both sources was mixed together in equal amounts to ensure uniformity.

Seven bags of aggregate were pretreated; one for each of the seven treatments listed:

1.0% Kerosene

2.0% Gilsabind (mined asphalt in a Naptha cut-back)

3.0% AC-10

1.5% CSS-1h (asphalt emulsion)

2.0% MC-70 (cut-back)

1.5% Reclamite (asphalt rejuvenator)

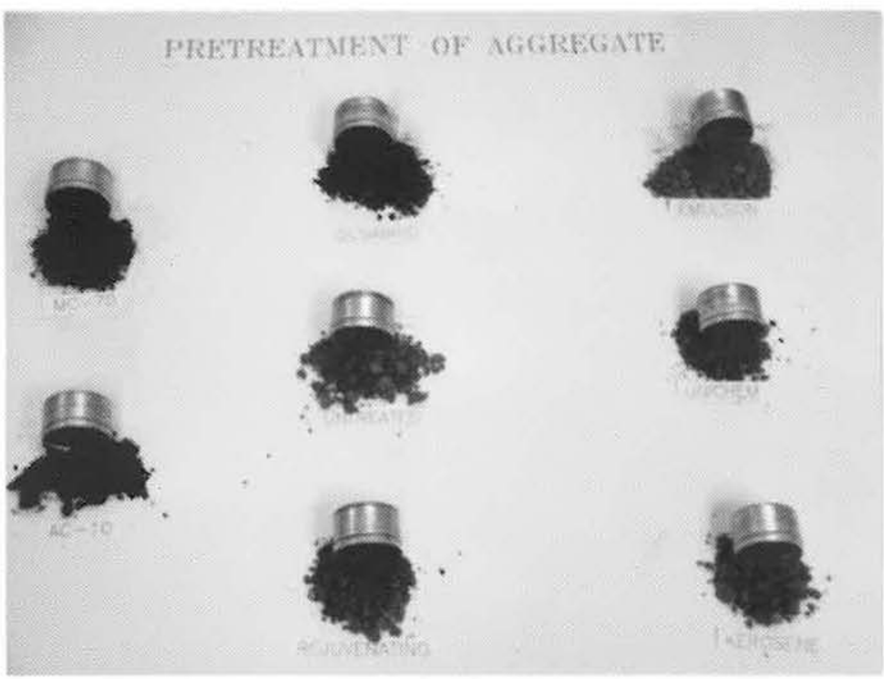
4.0% Unichem (mono calcium phosphate or MCP)

The process of treating the aggregate was fairly straight forward. All of the treatments, except the 3% AC-10, were mixed in the lab when the material and aggregate were cold. When treating the aggregate with 3% AC-10, the AC-10 and aggregate were heated before mixing.

The 1.5% CSS-1h required wet aggregate for mixing, since it is an emulsion.

The product designated "Unichem" is actually Mono Calcium Phosphate or MCP in a 1.75% solution. This solution was used at 4% of the dry weight of aggregate. The normal use of this material is to precoat the aggregate, much like lime, where it then reacts with asphalt nitrogen bases to form the bonding agent.

The aggregate was mixed in the laboratory, then stored outside in these bags as shown.



A general idea of the texture and color of each of the pretreated aggregates can be drawn from this photo. The untreated aggregate is in the middle.

Reclamite is an asphalt rejuvenating agent. Gilsabind is an asphalt cut-back made with Naptha. The asphalt used in Gilsabind is Gilsonite, a hard, mined asphalt composed of approximately 70% asphaltenes.

Once treated, the aggregate was stored in individual bags (approximately 30 lbs) outside the District 6 lab in Denver for approximately ten months. One bag of aggregate, to be used for a control, was left untreated. This bag was also stored with the treated bags of aggregate.

Laboratory testing:

When the storage time was completed, the aggregate was brought back to the central lab. 1200g samples from each bag were mixed with AC-10 and compacted into 2½" high by 4" diameter specimens. From these specimens, the optimum AC content, Hveem stability, Lottman (TSR), and resilient modulus values were determined.

The Hveem stability is an empirical measure which indicates the horizontal displacement under a 5000 lb. vertical load. The CDOH uses this value to help predict a pavement's resistance to rutting. The Colorado procedure for Hveem stability is CP L-5105. This is similar to AASHTO T 246.

The Lottman test is also called the tensile strength retained or TSR. A specimen is vacuum saturated in water, wrapped in plastic and frozen for 24 hours. It is then placed in a 140°F water bath for 24 hours, cooled down and loaded along the diameter to determine its split tensile strength. This value is divided by the strength of a dry specimen to give the strength retained as a percentage. This is Colorado Procedure CP L-5109, similar to AASHTO T 283.

The resilient modulus is obtained by loading a specimen cyclically on the vertical diametral plane, and measuring the resultant horizontal deformations and recovered deformations in microns. From this information and an assumed Poisson's ratio, the resilient modulus is calculated. For this experiment, a load of 75 lbs. was applied for one tenth of a second at a time with a resting period between loadings. Refer to ASTM D 4123 for a detailed description of the test.

B. Phase I Test Results

The same gradation was used for all of the pretreated and untreated samples. This gradation is shown in Table A. The test results on the optimum design mix for each bag of aggregate is shown in Table B. Some of the treatments improved the aggregate properties, while others had no effect.

The stability values, the tensile strength retained (TSR) values, and the resilient modulus were compared for each mix, to determine the effect that the pre-treated aggregate had on each design. The current Colorado standard design requirement for the Hveem stability is 37 for roads with an ESAL greater than 375,000, 32 for roads with an ESAL between 175,000 and 375,000, and 28 for roads with an ESAL less than 175,000. The standard Colorado design requirement for TSR value is 70%. Currently, Colorado has no specification for resilient modulus, except for grading "F" mixes (minimum 400,000). The values for each treatment are shown in Table C.

TABLE A

Sieve Analysis for Phase I

% Passing for all mix designs

1	100
3/4"	100
5/8"	99
1/2"	98
3/8"	90
4	70
8	54
16	40
30	31
50	23
100	17
200	12.9

TABLE B
Laboratory Test Results
Pretreatment of Aggregates

Material Added	Untreated	1% Kerosene	2% Gilsabind	3% AC-10	1.5% CSS-1h	1.5% Reclamite	2% MC-70	4% Unichem
Percent Bitumen	6.8	7.0	5.5	3.0	6.0	4.5	5.0	7.2
Rice Value	2.363	2.363	2.371	2.372	2.373	2.356	2.373	2.352
Sp. Gr. of Specimen	2.249	2.237	2.263	2.272	2.265	2.249	2.260	2.256
Voids in Specimen	4.8	5.4	4.6	4.2	4.5	4.5	4.8	4.1
Stability Value	38.7	36.0	37.9	32.6	39.9	41.2	42.1	34.1
Cohesiometer value	188.	288.	401.	382.	308.	169.	214.	243.
R sub T Value	97.	101.	107.	104.	104.	97.	100.	98.
Resilient Mod(x 1000)	269.	288.	703.	506.	365.	229.	513.	223.
Strength Coefficient	.44	.44	.44	.44	.44	.44	.44	.44
Immersion - Compression								
% Bitumen	6.8	7.0	5.5	3.0	6.0	4.5	5.0	7.2
PSI Wet	208.	208.	300.	498.	349.	148.	367.	263.
PSI Dry	335.	353.	556.	575.	432.	254.	369.	275.
% Absorption	1.7	1.4	2.1	1.4	1.2	3.0	1.1	1.9
% Swell	.39	.38	.44	.59	.26	.71	.13	.53
% Ret. Strength	62.	59.	54.	87.	81.	58.	100.	95.
% Additive Used	.00	.00	.00	.00	.00	.00	.00	.00
TSR								
% Bitumen	6.8	7.0	5.5	3.0	6.0	4.5	5.0	7.2
Wet D.T. St	30	29.	31.	97.	44.	6.	61.	27.
Dry D.T. St	83	77.	169.	165.	106.	55.	115.	68.
% Voids	4.93	5.35	5.80	4.35	4.08	3.76	3.77	5.75
% Perm Vds	4.5	4.4	5.5	3.7	2.9	6.3	3.7	5.5
% T.S. Ret	36	37.	18.	59.	42.	10.	53.	40.
% Additive	.00	.00	.00	.00	.00	.00	.00	.00

TABLE C

Summary of Phase I Test Results

Material Added	Stability	Resilient Modulus	% TSR
		(X 1000)	
Untreated	37	269	36
1% Kerosene	36	288	37
2% Gilsabind	38	703	18
3% AC-10	33	506	59
1.5% CSS-1h	40	365	42
1.5% Reclamite	41	229	10
2% MC-70	42	513	53
4% Unichem Int'l	35	223	40

The stability values, as shown in Table C, varied from 33 to 42. The resilient modulus ranged from 223 to 703. The TSR varied from 10 to 59.

As compared to the mix design using the untreated aggregate, three of the methods (3% AC-10, 1.5% CSS-1h, and 2% MC-70) showed an increase in the resilient modulus and TSR value. However, only two of these three methods showed an increase in the stability value. The two methods which showed a significant increase over the mix design containing the untreated aggregate were CSS-1h and MC-70. In these mixes, the resilient modulus increased by 35.7% and 90.7%, the TSR value increased by 16.7% and 47.2%, and the stability value increased by 8.1% and 13.5% respectively.

C. Analysis of Results for Phase I

The results indicated that five of the seven methods of pre-treating aggregate were not effective. None of these five design mixes met all of Colorado's asphalt design criteria. The pre-treated aggregates did not make a significant difference on the mix properties as compared to the untreated aggregate. Even if the design mixes for these methods could be altered enough to meet the criteria, the quality of the pavement would not increase enough to justify the cost of pre-treating aggregates. Some cost comparisons are made later in this report.

Although the two remaining design mixes did not meet our current design criteria, the results indicated that using CSS-1h and MC-70 showed some promise as being cost-effective with the aggregate tested. It was recommended that further lab testing be performed to determine if these improvements would hold for other aggregate sources. It is possible that both of these pretreatment methods could meet Colorado's design criteria and produce a high quality design mix by adding an additive to improve the tensile retained strength values.

In the procedure section, it was noted that the CSS-1h requires wetting of the aggregate prior to mixing. For the small amount of aggregate that was pretreated, this did not increase the preparation time by a significant amount. For a project, however, the process of pretreatment would entail a bit more. Larger quantities of aggregate would need to be treated and stored. This would require additional handling of the aggregate which, in turn, would add to the cost of the project. Even though the cost of the project would be increased by the pretreatment process, hauling quality aggregate to the project site can be more costly.

III. Phase II: Laboratory Testing with MC-70 and CSS-1h

A. Introduction

Further evaluations were performed using MC-70 and CSS-1h as treatments. Design mixes containing aggregate from the Wolf Pit alone were done and compared to design mixes prepared using aggregate from the Clark Pit, a marginal aggregate source located in the Denver area.

The aggregate samples were prepared in the same manner as the Phase I aggregate samples and stored for seven months. Design mixes were then run with this material (see Table D).

Once the test results were completed on the new design mixes, the results were evaluated and compared to those of some projects which had been built using aggregate from these pits. In these projects, the material property deficiencies were overcome with anti-strip additives (see Table E).

B. Phase II Results

TABLE D

Phase II Laboratory Test Results

PIT	PRETREATMENT	%AC	STABILITY*	RESILIENT* MODULUS (x1000)	%TSR*
Wolf	Untreated	5.5	36	619	
		5.8			39
		6.0	35	584	
Wolf	1.5% CSS-1H	5.5	38 (9%)	833 (43%)	63 (62%)
Wolf	2.0% MC70	4.0	41 (17%)	687 (18%)	
		4.1			50 (28%)
Clark	Untreated	5.5	33	318	46
Clark	1.5% CSS-1H	4.5	35 (6%)	485 (53%)	95 (107%)
Clark	2.0% MC70	3.5	37 (12%)	561 (76%)	
		3.6			81 (76%)

*The numbers in parentheses are the percent increases of pretreatment over untreated aggregate.

TABLE E

OTHER PROJECTS USING AGGREGATE
FROM THE WOLF OR CLARK PITS

Project IR 25-2(204) HBP Grading EX

The combination used was 50% sand and fines from the **Wolf** Pit, 30% -1/2" rock from the Black Canyon Pit, and 20% recycled asphalt pavement. The tests were performed in March of 1987. (The mix was rejected and another aggregate source used.)

%AC	Stability	Resilient Modulus(x1000)	%TSR	%IRS
6.1	37	771	47	69
			(.4% Unichem 8160)	

Project MP 11-0121-65 HBP Grading EX

The combination used 64% fines from the **Clark** Pit, and 36% rock from the Cooley Pit. The tests were performed in August of 1987. (Even though the design passed using B/A 2000, a different mix was used on the project. The combination actually used was 100% from the Clark Pit as used on Project FRU 470-1(65) (see below).)

%AC	Stability	Resilient Modulus(x1000)	%TSR
5.5%	39	225	43 (.4% 8160) 99 (.4% B/A 2000)

Project FRU 470-1(65) HBP Grading EX

100% **Clark** Pit. Mix design was done in July of 1987. Field samples were tested in August and September of 1987.

%AC	Stability	Resilient Modulus(x1000)	%TSR	
5.5	38	175	70	(Design Mix) (.4% 8160)
5.42	40	292	103	(Field Sample)
5.00	40	311	110	"
(From MP 11-0121-65)				
4.38	41	301	102	"
4.77	41	349	133	"

C. Analysis of Phase II Results

The stability, modulus and TSR improved in all cases of pretreatment. For the Wolf Pit, however, even with pretreatment the TSR did not meet the required 70% for Colorado. For the Clark Pit, the stability using CSS-1h did not reach the required 37.

A project design mix, which was 50% aggregate from the Wolf Pit, performed better in all three categories than the untreated aggregate of the laboratory experiment. It was modified with .4% Unichem 8160. This mix did not, however, pass the design criteria, so alternate material was used on the project.

The other projects, which used material from the Clark Pit, showed good material properties for the mix. They passed all Colorado design requirements when a good anti-strip additive was used. All of the field samples which used 100% Clark Pit aggregate had a higher stability and TSR than any of the laboratory pretreated samples. This seemed to indicate that pretreatment was not necessary to make this aggregate perform well.

IV. Cost Comparisons

Three Colorado contractors were contacted and asked to provide estimates for the final cost of in-place asphalt if the pretreatment process was used. These figures were compared to the costs of using a high quality anti-stripping additive or hydrated lime. The results of this survey are presented in Table F.

TABLE F

	Cost for Modification
Standard Mix	-
With Anti-Strip Additive	$.75-$1.00/Ton
With Hydrated Lime	$1.00-$2.00/Ton
Pretreated with CSS-1h	$2.00-$3.50/Ton

(Pretreating with MC70 does not appear to be feasible due to environmental concerns, however, the cost of this would be comparable to pretreating with CSS-1h)

These figures are likely to vary considerably. Some of the factors which would create fluctuations in the cost are: capital output for the aggregate which would not be recovered during storage time, availability of yard space for stockpiling, number of times the material must be rehandled, availability of needed equipment, distance to job site, length of job, thickness of mat, and the type of terrain being paved.

One of the major costs of the pretreatment process is the rehandling of the aggregate. Besides hauling it back and forth and mixing it twice, the aggregate must be wetted for the emulsion and then dried again for the final mix.

With pretreatment, there is an additional cost up front for the emulsion. Most of this is recovered by the need for less asphalt for the final mix.

V. Discussion

A number of difficulties would need to be resolved in order to use the pretreatment process in the field. If the treated aggregate was run through a regular hot-mix plant, the asphalt on it would be burned, thus decreasing the quality of the final product. A new process would need to be developed to make a mix of 100% pretreated aggregate. If the mix was made of 50% or more virgin aggregate, the pretreated aggregate could be added through a dual feed mixing plant and heated by the super-heated virgin aggregate, in the same manner as recycled pavement.

One suggestion was to pretreat only the large aggregate and add it to the fine aggregate in this manner. This would also reduce any segregation problems which may occur in the stockpiled aggregate.

Drying of the aggregate for final mixing would present some problems also. As in the mixing process mentioned above, it could not be exposed to open flames or heated at too high a temperature.

An additional concern was that the treated aggregate would clump together and make it difficult to work with. In this case, it might need to be heated some to break it apart before adding it to the mixing plant.

VI. Conclusions

The CSS-1h and MC-70 provided increased resistance to stripping (as indicated by the TSR), increased stability values, and increased resilient modulus values. However, project mix designs using the same material, without pretreatment, appeared to provide comparable test results at a lesser cost. These designs used anti-stripping additives. It is also likely that a mix with hydrated lime would perform well.

Aggregate taken from different parts of the pit may have different material properties. Whatever method is used, it is important to continually test the production samples to determine if the same material is being placed as designed.

Since there is already an abundance of recycled asphalt pavement (RAP) available, it would make more sense to use it, rather than simulate it with virgin aggregate. This would be cheaper in most cases, and would be less detrimental to the environment.

It was decided that a test section would not be established for this project. If a cost-effective method of pretreating aggregate on a scale large enough for production can be established, it is recommended that a test section be established and evaluated at a future date. This would be done to determine if pretreatment has a benefit which is more significant in the finished product than in the laboratory.

VII. Implementation

Since pretreatment of aggregates was not found to be cost-effective, it is recommended that the current CDOH procedures of selecting better aggregate, adding anti-stripping additives or adding hydrated lime be continued. The information in this report may be more useful if a better method of remixing the treated aggregate in the field can be established.