NCAT Report No. 91-4

EVALUATION OF ASPHALT ABSORPTION BY MINERAL AGGREGATES

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OBJECTIVES

This research work was undertaken to achieve the following objectives:

1. Evaluate the various methods currently available to determine the amount of asphalt absorbed by the mineral aggregates, and recommend the most realistic and suitable method based on the test data obtained.

2. Study the time-dependent phenomenon of asphalt absorption especially in view of the storage of HMA in silos and/or transportation over long distances to the paving site, and develop asphalt absorption predictive techniques.

REVIEW OF LITERATURE

Many investigators in the past have attempted to evaluate asphalt absorption of aggregates through correlations with absorption using other liquids of which kerosene has been the most commonly used. Hveem (4) devised the centrifuge kerosene equivalent test (CKE) in 1942. The CKE is defined as the quantity of kerosene absorbed by 100-g of aggregate under specified conditions of soaking and centrifuging. It has been shown to be a function of the surface area and absorptive capacity of the aggregate and has been used as a part of the design of bituminous mixtures by Hveem method. Lohn (5) also used a similar approach and correlated asphalt absorption of an aggregate with kerosene absorption. He studied the effects of factors such as saturation time, centrifuge force and centrifuge time as well and finally adopted 10-minutes of saturation and 8-minutes of centrifuging at a force of 400 times gravity. Donaldson et al (6) further proposed some modifications to the Hveem CKE method by increasing the soaking time to 30-minutes and by testing a non-absorptive aggregate of the same gradation for the purpose of comparison. Since kerosene has wetting properties similar to that of asphalt, it has been believed to give a better representation as an absorption agent as compared to water (6, 7). A modified CKE procedure was developed by Cechetini (8), which can determine the surface areas and evaluate absorptive behavior of crushed aggregate mixes. Together with this information and the data characterizing the asphalt to be used, the amount of asphalt needed by an aggregate can be determined from a nomograph. Some other investigators (9, 10) have tried to use oils to evaluate the absorptive capacity of coarse aggregates. However, because of the differences in wetting properties and viscosities of these liquids and asphalts, only approximate estimations could be made of the asphalt absorption of the aggregates.

In 1936, a procedure was described by Reagel (n) for determination of relative absorption of water and liquid bituminous material by the coarse aggregate using a water displacement method. It was recommended that absorption of liquid bituminous material be estimated at 75 percent of the water absorption.

In 1942, Goshorn and Williams (12) developed the immersion method which is described later. Since the aggregate is in contact with an unlimited supply of asphalt at relatively low viscosity for an extended period of time in this method, the absorption is much higher than would be expected in actual HMA mixtures (1,3). However, the values can be taken as the absorptive potential of the aggregates used for HMA mixtures. Accuracy of this method is limited by the homogeneity of the aggregate and accuracy of the bulk specific gravity.

Rice (14, 15) proposed a vacuum procedure to determine the maximum specific gravity of the voidless HMA mixture. In this method, the absorption of asphalt by aggregates is calculated from the maximum specific gravity of the mixture, the asphalt content, and the bulk specific gravity of the aggregate used in the HMA mixture. This method is now standardized as ASTM D2041. If aggregates are not thoroughly coated, erroneous results may be obtained because of possible absorption of water by the aggregate during vacuum saturation. The ASTM test method D2041, however, allows the use of a supplemental (dry back) procedure to correct for the water absorption problem. The method can be applied to actual mixes and is not too time consuming. The accuracy of this method is also dependent upon the accuracy of bulk specific gravity of the aggregates used in the HMA mixture.

A different approach was used by Larsen (16) who conducted a high pressure test instead of vacuum saturation to determine the effective specific gravity of the aggregate. Asphalt absorption was calculated as percent of the volume of aggregate and ranged from 26 to 88 percent of the water absorption.

The U.S. Army Corps of Engineers (I-7, 18) developed and has used the bulk impregnated specific gravity in the design and control of bituminous mixtures. It is a function of the ratio of asphalt to water absorption, which varies widely but follows a definite pattern with different types of aggregates. The asphalt absorption can be found knowing the bulk impregnated specific gravity of the mixture, the bulk specific gravity of the aggregate and the specific gravity of the asphalt used in the HMA mixture. McLeod (19) has recommended the use of this method to determine the maximum or upper limit of asphalt absorption for an aggregate. Lee (13) has , however , compared the data obtained thus with other methods and concluded that these absorption values were by no means the absolute maximum absorption values for a particular aggregate, but can be considered as the “realistic” maximum absorption values aggregates will have in HMA mixtures. One serious limitation of this method is the removal of air bubbles entrapped in asphalt when both coarse and fine aggregates are added to the asphalt cement.

Absorption of asphalt by aggregates has also been determined by calorimetric analysis with photometer (13). The basic principle is that the amount of light absorbed by a given solution is proportional to the intensity of the incident light and to the concentration of the absorbing species in the path of the light beam. However, only solutions of light concentration can be used and the mechanism of absorption of asphalt in solution is likely to be different from that in an HMA mixture.

Cross-sectional measurements have also been employed to evaluate asphalt absorption (13). Compacted specimen of the HMA mixture is cut in halves by a diamond saw to expose the inner surface of the aggregates. The sample is then placed in an opaque projector and from its image projected on a screen, tracings are made of the external contours of the rock particles and lines of deepest asphalt penetration. The total area of a particle and area penetrated by the asphalt are measured by a planimeter, and the percentage of asphalt absorption is calculated. Limitations of this method are selective absorption of asphalt and different sizes of aggregate in a mixture.

More recently the Methylene Blue test has been used in Europe to indirectly measure the absorption/adsorption, surface area, cationic exchange capacity, soundness, and overall clay characteristics of aggregates. This test, first developed in France (20), uses Methylene Blue to quantify the absorption/adsorption of an aggregate. The method has serious limitations: (a) a powdered aggregate is used, and (b) no asphalt cement is used.

Franco and Lee (21) have recently evaluated the viability of using an air meter for determining the maximum specific gravity of HMA mixtures. The air meter normally has been used for determining the percent of air entrained in Portland cement concrete. The so-called pressure method works on the principle of Boyle's law. A weighed sample of HMA mix is introduced into the bowl of the air meter (Type B air meter as specified in AASHTO T152) and water is introduced to fill the meter to the capacity (no attempt is made to remove the entrapped air) . The filled air meter is weighed and the weight of water obtained. The air content of the meter is then determined in accordance with AASHTO T152. Back calculations are then performed and the volume of the HMA mix is determined. Further work is needed to improve the design of the air meter so that its consistency and sensitivity is acceptable.

The following is the summary of conclusions based on the review of literature concerning asphalt absorption as affected by the methods of determination.

1. No single standard method is currently in use for evaluating and specifying the absorptive characteristics of aggregates with respect to asphalt cement.

2. The indirect estimation of asphalt absorption using water, kerosene and oil is neither realistic nor reliable.

3. The immersion method may be used to quantify the potential maximum absorptive capacity of a coarse aggregate. However, it cannot be used for the whole HMA mix consisting of coarse and fine aggregates.

4. The bulk impregnated specific gravity method can be used to determine the realistic maximum absorptive capacity of an aggregate but it has limitations due to the problem of removal of air bubbles.

5. Rice method can be used for the whole HMA mix and is the most representative of all methods since it tests the actual HMA mix wherein asphalt is present only in thin films around the aggregate.

6. The phenomenon of asphalt absorption is very much time-dependent and needs to be evaluated as such.

7. The accurate determination of asphalt absorption by most methods is dependent on the accuracy of the determination of bulk specific gravity of the aggregates used in the HMA mixture.

8. There is an urgent need for adopting a realistic and suitable standard method for determining asphalt absorption so that reproducible results are obtained and the HMA mixes can be designed properly.

MATERIALS

The Materials Reference Library (MRL) for Strategic Highway Research Program (SHRP) has 11 different aggregates. Three aggregates were selected for use in the current study, based on the water absorption data for the MRL aggregates, covering a wide range of water absorption. These aggregates are:

1. RC - McAdam Limestone
2. RB - Watsonville Granite

3. RD - Frederick Limestone

These aggregates have high, medium and low water absorption, respectively. Detailed properties for the aggregates used are reported in Table 1. It was decided to use coarse aggregates only of uniform single size, namely, passing l/2-in sieve and retained on 3/8-in sieve. This was necessitated because one of the methods (immersion method) used in determining asphalt absorption can be used for coarse aggregate only, and, for bulk impregnated method, results are affected by the presence of fine aggregate. Use of a uniform gradation would give consistent results with different absorption methods. Although fine aggregate, which has a large surface area, is believed to have a pronounced influence on asphalt absorption, its asphalt absorption is not likely to be time-dependent. All aggregates were thoroughly washed and dried before use in order to exclude the effect of fines and moisture. In addition to the above, glass beads were also used in order to evaluate the operator and procedural errors associated with each method. The glass beads used were also of the same size.

The SHRP Materials Reference Library has several asphalts available of which the following were selected for use in the current phase of research:

1. AAM-1 - West Texas AC-20
2. AAB-2 - Wyoming Sour AC-5

The AC-20 asphalt was selected because it is the most commonly used viscosity grade in the U.S. Low viscosity AC-5 was chosen to study the effect of viscosity of asphalt on the amount of absorption. This is also the lowest viscosity graded asphalt available in the MRL, and is normally used for paving in Canada and Alaska. Various properties of the asphalt cements used in this study are given in Table 2.

TEST PROCEDURES

Three test methods were primarily used for determining the asphalt absorption. However, procedural variations were made within two test methods resulting in the following nine testing techniques:

1-2) Immersion method with immersion times of 1 and 3 hours.
3) Bulk impregnated specific gravity method
4-9) Rice method with mix aging times of O, 1, 2, 4, 6, and 8 hours.

The immersion method was first used in 1942 by Goshorn and Williams (12) and gives the maximum or potential absorptive capacity of an aggregate. The original procedure involved heating the aggregate to about 300°F and then suspending it by means of a wire basket in 85-100 penetration asphalt at 275°F for 2 hours. The sample was then cooled to room temperature while immersed and again reheated to and maintained at 275°F for 1 hour. The basket containing coated aggregate was then removed and suspended in an air bath at 275°F until all excess asphalt had drained off. The coated aggregate was removed from the basket, cooled to room temperature and weighed in both air and water to determine asphalt absorption. For this study a uniform temperature of 290°F was selected for all phases of this test since it approximates the average mixing temperature used by the HMA industry. Additionally, the aggregate was immersed only once for immersion times of either 1 or 3 hours to avoid any variations that might occur during the process of reheating. The baskets used were weighed both in air and under water to avoid removing the coated aggregate from the basket for weight determinations. The time used for draining excess asphalt was selected as 10 minutes to attain uniform draining for all samples.

The U.S. Army Corps of Engineers (17, 18) developed and uses the bulk impregnated specific gravity in the design and control of bituminous paving mixtures. The Corps' procedure involves heating about 1500 g of aggregate to constant weight at 230-290°F and weighing it. The asphalt is then separately heated to 280±5°F and poured into a gallon pail one-third full. A metal stirrer is inserted and asphalt is then allowed to cool to room temperature for a minimum of 8 hours. The pail with asphalt and stirrer is then weighed both in air and water. Asphalt pail and aggregate are then separately heated to 280±5°F until the temperature is stabilized. At this stage pail is removed from the oven and aggregate is slowly added to it while stirring with the stirrer. Stirring is continued till the elapsed time from start of mixing is 2 minutes. The contents are then cooled to room temperature and air bubbles, if any, removed using a flame. The pail with asphalt, aggregate and stirrer is then weighed both in air and water. The above five measurements allow the computation of the bulk impregnated specific gravity and hence the asphalt absorption. For the purpose of present study, some modifications to the test were done. The weight of aggregate used was 500 g instead of 1500 g because the aggregate had one uniform single size and thus was less variable. As a consequence the asphalt quantity was also reduced from one-third gallon to one-half quart. Additionally, a uniform temperature of 290°F was used at all stages of the test where use of oven was required.

The Rice method was originally proposed in 1956 (14, 15) to determine the maximum specific gravity of a bituminous mixture by using volumetric flasks. For this study trial mixes were prepared and heated in the oven at 290°F up to 8 hours to observe the available effective binder after aging at various asphalt contents. An asphalt content of 2.5 percent was selected for all three aggregates. Sufficient available effective asphalt binder was observed visually at this asphalt content even after 8 hours of aging in the oven. At higher asphalt contents the films were too thick and difficulties were experienced in handling the mixes. Mixes were prepared using the standard practice for preparing mixtures for the Marshall mix design method except that they were not compacted. Both asphalt cement and aggregate were heated to 290°F to maintain uniformity of temperature throughout the whole testing scheme. The mixes were aged in the oven at 290°F in covered containers for O, 1, 2, 4, 6, and 8 hours to study the effect of time on the absorption of asphalt. The theoretical maximum specific gravity of the mixtures was determined using ASTM standard procedure D2041 (Rice method) using a-4000 ml thick-walled glass pycnometer. Kandhal and Wenger (22) developed this large Pennsylvania pycnometer to determine the asphalt content of HMA mixes. It is still used by the Central Asphalt Laboratory of the Pennsylvania Department of Transportation to determine the Rice specific gravity. Accurate volumetric measurements are possible in this pycnometer because of a special capillary stopper and an overflow cap.

EXPERIMENT DESIGN

The experiment was divided into two phases. Phase I of the experiment was a 9x3x2 factorial design with 3 replicates for each combination giving a total of 9x3x2x3 = 162 tests. The three replicates were treated as blocks and tests within each block were completely randomized giving a blocked randomized design.

Phase II involved the use of glass beads (absorption = O) as a control material to ascertain and quantify the errors associated with the test equipment, test procedure, and operator for each method. Since viscosity of the asphalt cement and immersion or aging times will not affect the results, only one asphalt AAM-1 (AC-20) was used during this phase. Obviously, methods 2 and 5-9 were not considered.

TEST DATA AND DISCUSSION

The results of the phase I experiments are presented in Table 3 and Figs. 1-4. The values reported in Table 3 are averages of three tests which were run at different times. The range of the results obtained for different methods is also indicated in Table 3. Because of very low asphalt absorption values obtained with RD aggregate, plotted data for this aggregate is not included in this paper. An ANOVA (analysis of variance) of the results obtained is shown in Table 4. The ANOVA indicates that all the factors, namely, methods (A), aggregates (B), and asphalts (C) are significant at $a = 0.01$. In other words, the values of asphalt absorption obtained greatly depend on the aggregate and asphalt properties as well as the method used for determining asphalt absorption. Moreover, the interactions: AxB (aggregates x methods) and BxC (aggregates x asphalts) are also found significant at $a = 0.01$. All this suggests that only a standard method of determining asphalt absorption for any particular set of aggregate and asphalt must be used by all agencies to reasonably reproduce that mix design.

Absorption by Immersion Method

As expected, the results reported in Table 3 and Figs. 1-4 indicate that immersion method yields the highest values of asphalt absorption for any aggregate-asphalt combination. Moreover, the 3-hour immersion absorption values are significantly higher than 1-hour immersion values. This again indicates the time-dependent nature of the absorption phenomenon. As seen in Figs. 1-4 and also in Table 3, the lower viscosity asphalt AAB-2 gives higher absorption values as expected. That means the higher the viscosity of asphalt used, the lower is the absorption for a particular aggregate. Obviously, the lowest absorption aggregate RD does not show any sensitivity either to the viscosity of asphalt or to the immersion time. The asphalt absorption values for l-hour immersion are found to be 28 to 48 percent of the water absorption values based on the test data reported in Tables 1 and 3. For 3-hour immersion this percentage varies from 27 to 61 percent.

Although this method yields the highest values of absorption, it cannot be termed as the most realistic method of determining asphalt absorption because asphalt is present in bulk quantity around the aggregate, which is unrealistic for a HMA mixture. Moreover, it has the limitation of using the coarse aggregate only whereas most commonly used dense graded HMA mixtures contain both coarse and fine aggregates.

Absorption by Bulk Impregnated Specific Gravity Method

In general, the asphalt absorption obtained by bulk impregnated specific gravity method is expected to be lower than that obtained using immersion method for the same aggregate-asphalt combination. This is due to the fact that although asphalt is still available in bulk around aggregate in the bulk impregnated specific gravity method, the exposure time with hot asphalt is reduced because in this method asphalt-aggregate mixture is allowed to cool immediately after mixing. This is confirmed by the data reported in Table 3 and Figs. 1-4. Low absorption aggregate RD, again, seems to have no sensitivity towards the aggregate-asphalt contact time while hot. The asphalt absorption by this method as a percentage of water absorption is found to range from 25 to 43 percent based on data in Tables 1 and 3.

The asphalt absorption obtained using the bulk impregnated specific gravity method can be considered to represent the realistic maximum value of asphalt absorption. Although this method can test the whole mix for absorption, one serious limitation of this method is the potential problem of removing air bubbles when both coarse and fine aggregates are immersed in hot asphalt.

Absorption by Rice Method

Most HMA mixes contain both coarse and fine aggregates, and asphalt is present in the form of thin films around the aggregate. This method, therefore, can be applied to actual HMA mixes. The data on asphalt absorption obtained using Rice method is reported in Table 3 and plotted in Figs. 1-4. The data for the least absorptive aggregate RD was not plotted because of very low absorption values. The data for all aggregates indicates that asphalt absorption increases with time. Viscosity of the asphalt also has an effect in that the lower viscosity asphalt invariably gives higher asphalt absorption.

The asphalt absorption values for 8 hours of aging in the oven at 290°F are generally quite close to the values obtained by the immersion method with l-hour immersion, as can be seen in Figs.1-3. For aggregate RB - asphalt AAB-2 combination, the 8-hour Rice absorption is somewhat less than the l-hour immersion method value. This indicates that l-hour immersion method indeed gives considerably high absorption values of asphalt absorption. Looking at Figs. 1-4, the absorption values obtained by bulk impregnated specific gravity method, which is the second most commonly used method for asphalt absorption after Rice method, appear to intersect the corresponding Rice absorption curves at about 4 hours (3 to 5 hours range) of aging time. Moreover, the curve for asphalt absorption appears to level off at about 4 hours aging time. Based on these observations from this study, determination of asphalt absorption values obtained after 4-hour aging of the mix at 290°F is recommended for use as a standard general practice when dealing with absorptive aggregates. This will in turn assure computation of realistic and consistent air voids content in the mix, which is one of the criteria in the Marshall mix design method. Aging time can be increased in exceptional cases if it is demonstrated that absorption continues substantially beyond 4 hours.

To verify the conclusions drawn above, Duncan's multiple range test was run on the average values of the absorption obtained by various methods. Since interaction: AxC (methods x asphalts) was significant, results for each asphalt were handled separately. This analysis resulted in the following groupings of methods:

1. <u>Asphalt AAM-1 (AC-20)</u>:

Method[b,c]	R0	RI	R2	R4	R6	BI	R8	11	13
Average Absorption	0.210	0.310	0.440	0.463	0.497	0.503	0.554	0.561	0.7s1
Groupings			———	———					
			———	———	———				
			———	———	———	———			
				———	———	———	———		
					———	———	———	———	

It can be seen that asphalt absorption values obtained using bulk impregnated method and the Rice method with 2, 4, and 6 hours of aging are not significantly different from each other at α = 0.05. Moreover, there is no significant difference in the asphalt absorption values obtained by the Rice method with 4 to 8 hours of aging.

2. <u>Asphalt AAB-2 (AC-5)</u>:

Method[b,c]	R0	R1	R2	R4	R6	BI	R8	11	13
Average Absorption	0.219	0.402	0.438	0.560	0.600	0.619	0.650	0.714	0.953
Groupings		———	———	———	———		———	———	
				———	———	———			
				———	———	———	———		

Again, it can be seen that the absorption values obtained using the Rice method with 4, 6, and 8 hours of aging in the oven are not significantly different from each other as well as those obtained using the bulk impregnated method. Combining the results of the Duncan's multiple range test for both the asphalts, we can state that the Rice method with 4-hours of aging in the oven results in asphalt absorption values that are not significantly different from those obtained using the bulk impregnated method.

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b 11 and 13 refer to immersion method with 1 and 3 hours immersion, respectively; BI refers to bulk impregnated method; and RO through R8 refer to Rice method with O, 1, 2, 4, 6, and 8 hours of aging in the oven, respectively.

c Methods are arranged in ascending order of the magnitude of average asphalt absorption.

This point is further illustrated by considering an example. Assume that the bulk specific gravity of the compacted mix using RC aggregate and AAM-l asphalt is 2.325. The Rice specific gravity value at O hour (just after mixing) of 2.422 (0.17 percent asphalt absorption) will give an air void content of 4.0 percent in the compacted specimen. Whereas, the 4-hour aged Rice specific gravity value of 2.458 (0.72 percent asphalt absorption) will substantially increase the air void content to 5.4 percent.

Absorption using Glass Beads

Asphalt absorption was determined using glass beads (absorption = O) during phase II of this study and the results thus obtained are reported in Table 5. As mentioned earlier, glass beads were used to evaluate the errors associated with the test ‘equipment and test procedures used in the three absorption test methods. A t-test was conducted to check whether the asphalt absorption obtained was significantly different from zero. The methods were ranked accordingly and it was found that the bulk impregnated specific gravity method gave the best results, followed by the immersion method and then by the Rice method, as reported in Table 5. The results of this phase suggest a need for refining the Rice method which is currently being done at the National Center for Asphalt Technology (NCAT) under the SHRP **A-003B** contract.

Relationship of Asphalt Absorption with Time

As the absorption is a time-dependent phenomenon, data for absorption using the Rice method was regressed against aging time in the oven. As shown in Figs. 1-4, the average asphalt absorption values follow almost a hyperbolic curve when plotted against aging time. The coefficient of determination (R*) for the fit ranges from 0.81 to 0.97. This was further confirmed by plotting the asphalt absorption data reported by **Kandhal** and **Koehler** (23) for Pennsylvania mixes. Fig. 5 shows two curves obtained on HMA mixes containing absorptive gravel aggregates. Cross & Co. ‘s mix had 7.5 percent asphalt content and the water absorption of the combined aggregate was 1.92 percent. Interstate Amiesite Corp. ‘s mix also had 7.5 percent asphalt content, and the combined aggregate had 1.79 percent water absorption. Fig. 6 shows similar curves for two additional mixes used by these producers using absorptive gravel aggregates. In this case, Cross & **Co.'s** mix had 5.1 percent asphalt content, and the combined aggregate had 2.0 percent water absorption. The asphalt content for Interstate Amiesite **Corp.'s** mix was 7.5 percent. Information on water absorption of the aggregate used was not available. Again, the R^2 values range between 0.97 and 0.99. This means that the asphalt absorption at any time can be predicted if the absorption is determined at O time and two other times initially.

The equations for obtaining an estimate of asphalt absorption at any given aging time, based on this hyperbolic relationship, when asphalt absorption values at 0 aging time and any two additional times are known, is given below.

$$A = A_o + \frac{t}{a+bt}$$

where, A = asphalt absorption at any given time t
A_o = asphalt absorption at 0 aging time

and the constants a and b are obtained using

$$a = \frac{t_1 t_2}{t_2 - t_1}\left[\frac{1}{\Delta A_1} - \frac{1}{\Delta A_2}\right]$$

$$b = \frac{1}{t_2 - t_1}\left[\frac{t_2}{\Delta A_2} - \frac{t_1}{\Delta A_1}\right]$$

where, $\Delta A_1 = A_1 - A_o$ and
$\Delta A_2 = A_2 - A_o$ are differential absorption at any other aging times t_1 and t_2.

One more advantage of the hyperbolic relationship above is that the ultimate (or limiting) value of absorption at infinite aging time, A_l, may also be estimated using

$$A_l = A_o + \frac{1}{b}$$

The values of the limiting absorption for the present study as well as for the data for Pennsylvania mixes (23) are indicated in Figs. 1-6.

It is worthwhile mentioning that although only three observations of asphalt absorption (at aging time 0 and any two additional times) are sufficient to determine the course of the whole hyperbolic relationship, it would be more appropriate to conduct more than one test at each of these points and use the average values in the above equations. Another approach would be to carry out several observations at different aging times and obtain a least squares estimate of the constants a and b to be used for prediction purposes.

It is believed that this predictive technique will especially be useful when dealing with some problem aggregates which have a history of continual asphalt absorption during construction and subsequently in service (3).

CONCLUSIONS AND RECOMMENDATIONS

Based on the asphalt absorption data obtained by 9 different methods/techniques using three aggregates and two asphalt cements the following conclusions are drawn and recommendations made.

1. The Rice method after 4 hours of aging in the oven at 290°F is believed to be the most realistic and suitable method for determining asphalt absorption. This recommended method will also ensure a realistic value of the Rice specific gravity for determination of the void properties of the mix for mix design purposes.

2. The asphalt absorption is found to follow a hyperbolic relationship with aging time. Based on this relationship the whole course of asphalt absorption with time can be determined if asphalt absorption values at aging time O and any other two aging times are known. The relationship can also be used to predict the ultimate (or limiting) value of asphalt absorption at infinite aging time. This will especially be useful when dealing with problem aggregates which have a history of continual asphalt absorption during construction and subsequently in service.

There is a need to improve the Rice method for better reproducibility of test results. This work is currently being conducted at NCAT as part of the SHRP A-003B project.

The methods for determining the bulk specific gravity of coarse and fine aggregates which are used in computing the amount of asphalt absorbed, also need to be improved. Establishing the saturated surface dry condition of the fine aggregates has been a serious problem in determining the bulk specific gravity. Improved techniques such as calorimetric procedures attempted by Kandhal and Lee (24) need to be explored.

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LIST OF TABLES

LIST OF FIGURES

TABLE 1 - PROPERTIES OF AGGREGATES USED

Property	RC - McAdam Limestone	RB - Watsonville Granite	RD - Frederick Limestone
Bulk Specific Gravity			
a) ASTM C127	2.485	2.692	2.713
b) ASTM C127 + Vacuum *	2.494	2.709	2.722
c) Hg Porosimetry **	2.467	2.759	2.899
Water Absorption (% Wt. of Aggregate)			
a) ASTM C127	2.88	1.68	0.38
b) ASTM C127 + Vacuum *	2.95	1.58	0.28
Median Pore Diameter, micron	0.178	0.054	0.013
Index of Particle Shape & Texture (ASTM D3398)	13.2	14.6	15.2

* Aggregate was vacuum saturated with water (vacuum level = 30 mm Hg, vacuum saturation time = 10 rein) and then kept immersed in water for 24 hours

** Obtained at 14.7 psi

TABLE 2 - PROPERTIES OF ASPHALTS USED

Property	Asphalt	
	AAM-1	AAB-2
Grade	AC-2 0	AC-5
<u>Original Asphalt</u>		
Viscosity at		
140 F, poise	1992	403
275 F, cSt	569	193
Penetration, 0.1 mm (77 F, 100 g, 5 see)	64	166
Ductility, cm (39.2 F, 1 cm/min)	4.6	81.0
Softening Point (R&B), F	125	115
Component Analysis		
Asphaltenes (n-heptane)	3.9	16.7
Polar Aromatics	50.3	35.7
Naphthene Aromatics	41.9	36.5
Saturates	1.9	10.8
Element Analysis		
Nitrogen, %	0.50	0.50
Sulfur, %	2.40	5.40
Vanadium, ppm	60	163
Nickel, ppm	29	36
<u>Thin Film Oven Test</u>		
Mass Change, %	0.00516	0.00149
Viscosity of TFOT Residue at		
140 F, poise	3947	1073
275 F, cSt	744	263
Viscosity Ratio (140 F)	1.98	2.66

TABLE 3 - ASPHALT ABSORPTION DATA FOR PHASE I (PERCENT BY WEIGHT OF AGGREGATE)

Method/Conditioning	RC - McAdam Limestone (Water Absorption = 2.88%)		RB - Watsonville Granite (Water Absorption = 1.68%)		RD - Frederick Limestone (Water Absorption = 0.45%)	
	AAM-1 (AC-20)	AAB-2 (AC-5)	AAM-1 (AC-20)	AAB-2 (AC-5)	AAM-1 (AC-20)	AAB-2 (AC-5)
1. Immersion Method (1 hr)	0.80	1.17	0.71	0.81	0.18	0.17
2. Immersion Method (3 hr)	1.23	1.63	0.91	1.02	0.12	0.21
3. Bulk-Impregnated Method	0.73	0.97	0.60	0.73	0.18	0.15
4. Rice with No Aging	0.17	0.26	0.35	0.36	0.10	0.04
5. Rice with 1 hour Aging	0.42	0.60	0.44	0.59	0.07	0.02
6. Rice with 2 hour Aging	0.62	0.65	0.56	0.57	0.14	0.09
7. Rice with 4 hour Aging	0.72	0.92	0.60	0.68	0.06	0.08
8. Rice with 6 hour Aging	0.73	0.96	0.75	0.72	0.01	0.12
9. Rice with 8 hour Aging	0.88	1.11	0.66	0.71	0.12	0.13

Notes:

1. Each reported value is an average of 3 test restults.

2. On the average, the range of values for the 3 replicates was:

Method	Range
Immersion method	0.17
Bulk impregnate method	0.13
Rice method	0.17 *
Overall	0.16

* The least average range was observed for Rice method with 4 hours of aging to be 0.09.

3. No outliers were observed.

TABLE 4 - ANOVA FOR PEASE I EXPERIMENTS

Source	df	Ss	MS	Fo
Total	161	23.5166		
Methods (A)	8	4.6830	0.5854	70.0 *
Aggregates (B)	2	14.5063	7.2531	867.2 *
AxB	16	2.3494	0.1468	17.6 *
Asphalts (C)	1	0.3746	0.3746	44.8 *
AxC	8	0.1452	0.0181	2.2
BxC	2	0.3244	0.1622	19.4 *
AxBxC	16	0.1162	0.0073	0.9
Blocks (Replicates)	2	0.1311		
Error	106	0.8865	0.0084	

*** significant at a = 0.01**

TABLE 5 - ASPHALT ABSORPTION DATA **FOR PHASE II**
(Absorption by Percent Weight of Beads)

Method	Individual Values (percent)	Average absorption (percent)	Standard Deviation (percent)	|t|	Ranking of t	Remarks
Immersion Method	0.02 0.03 0.06	0.04	0.02	1.76	2	Not Significant at a - 0.05
Bulk-Impregnated Method	0.01 *0.08* -0.02	0.02	0.05	0.45	1	Not Significant at a = 0.05
Rice Method	-0.08 -0.03 -0.04	-0.05	0.03	1.89	3	Not Significant at a - 0.05

Note : $t_{0.025,2}$ = 4.303

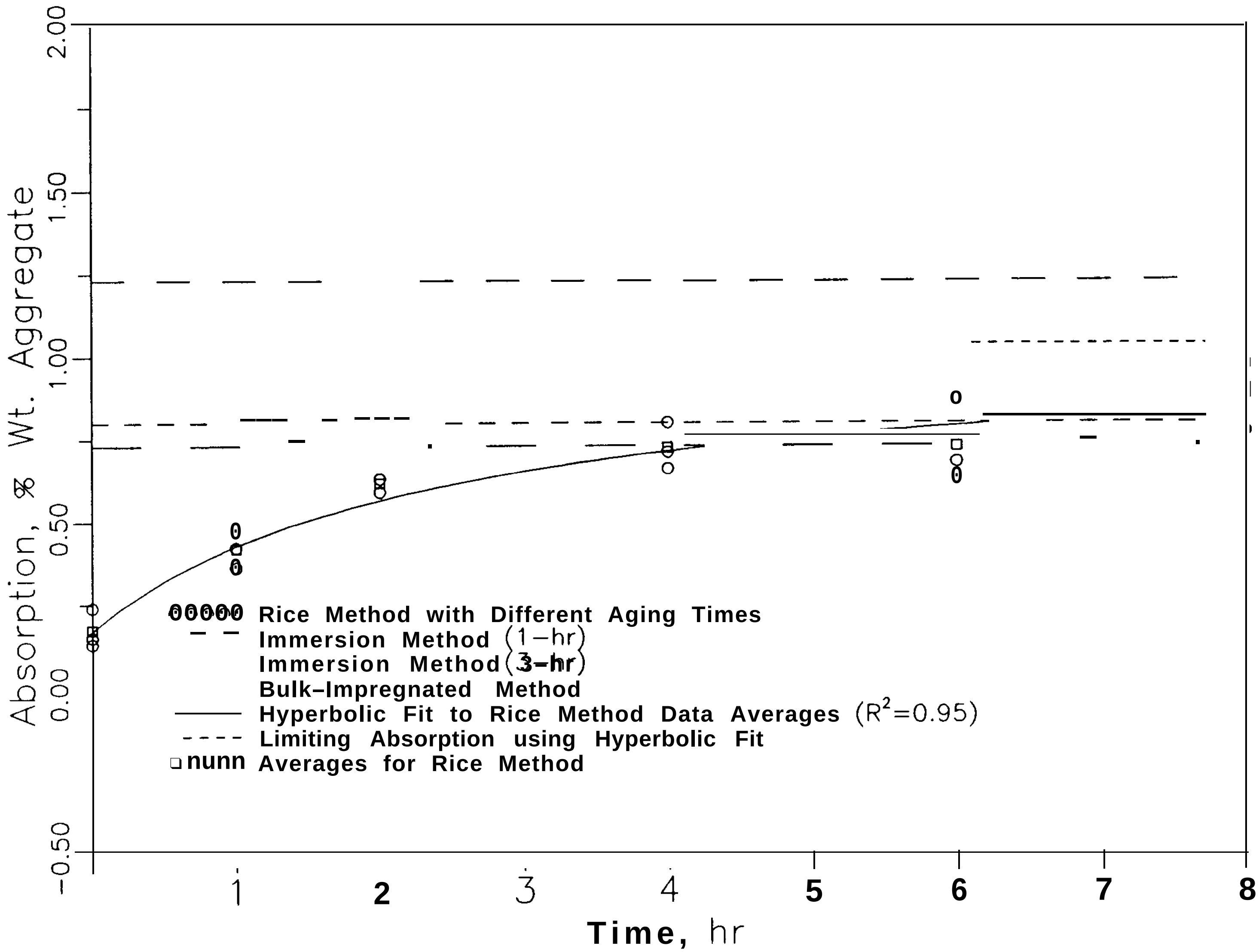


Fig. 1 – Asphalt Absorption vs. Aging Time for RC and AAM- I

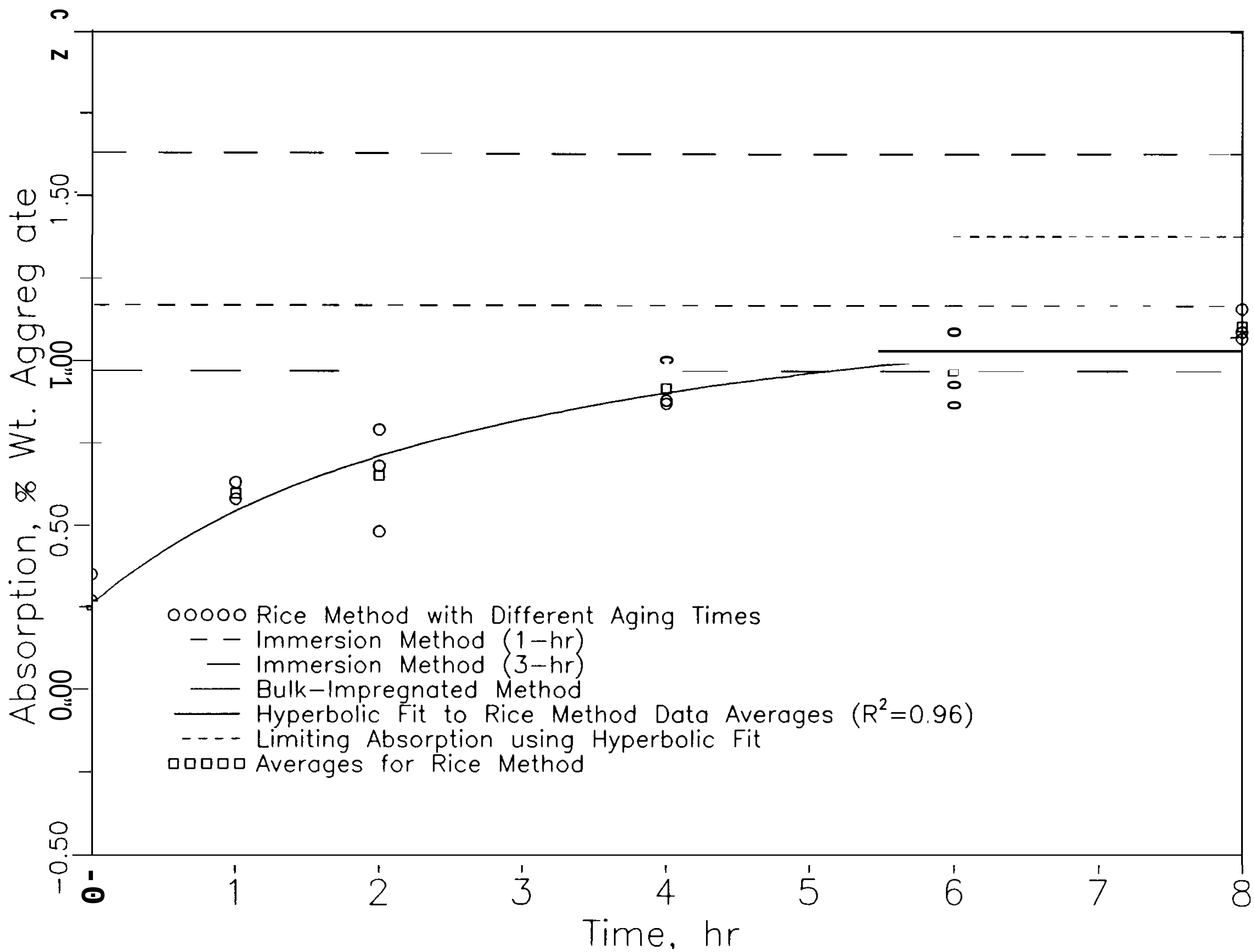
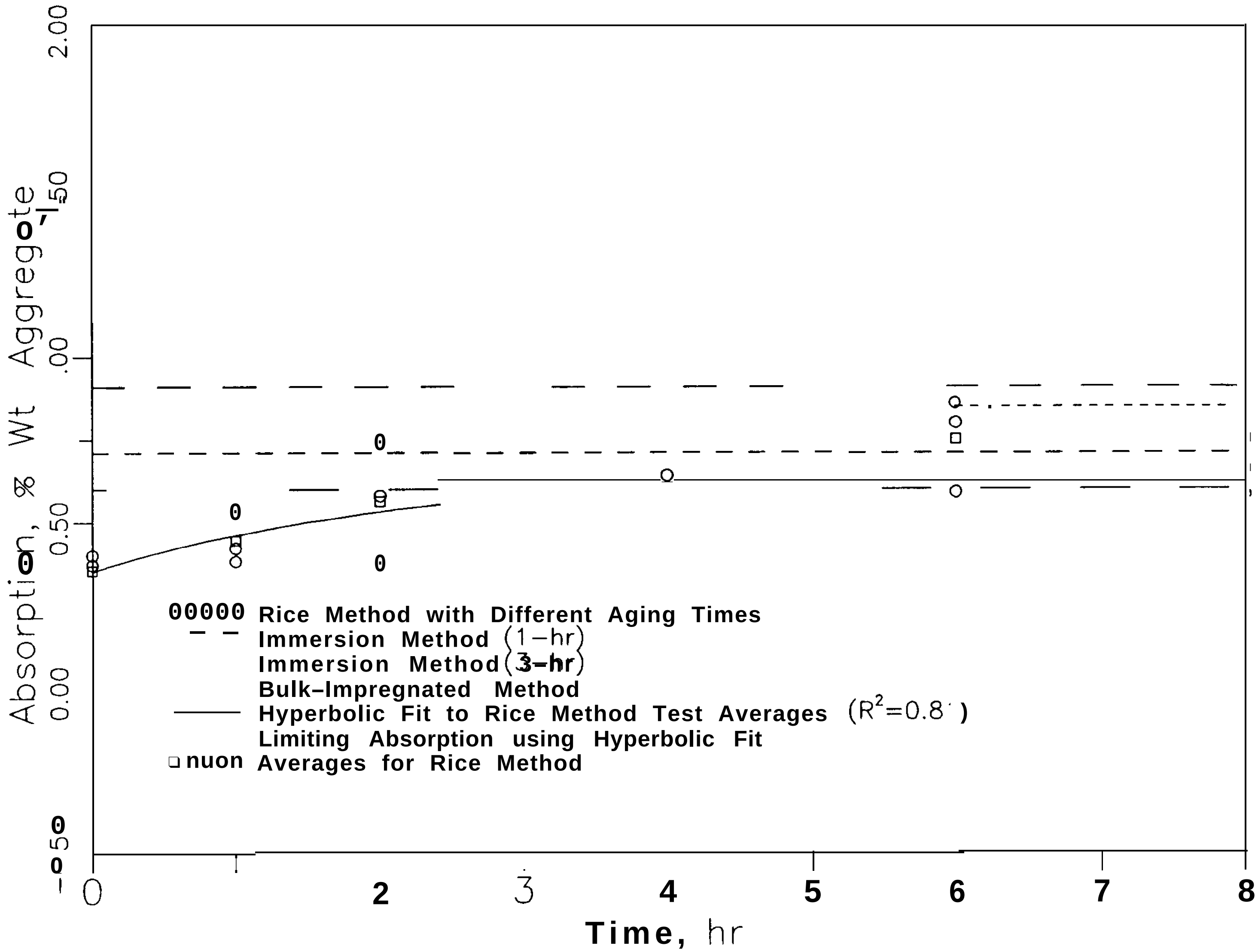


Fig. 2 — Aspha t Absorption vs. Aging Time or RC on AA 2



F g. 3 — Aspha t Absorpt on vs. Aging Time for RB and AAM- I

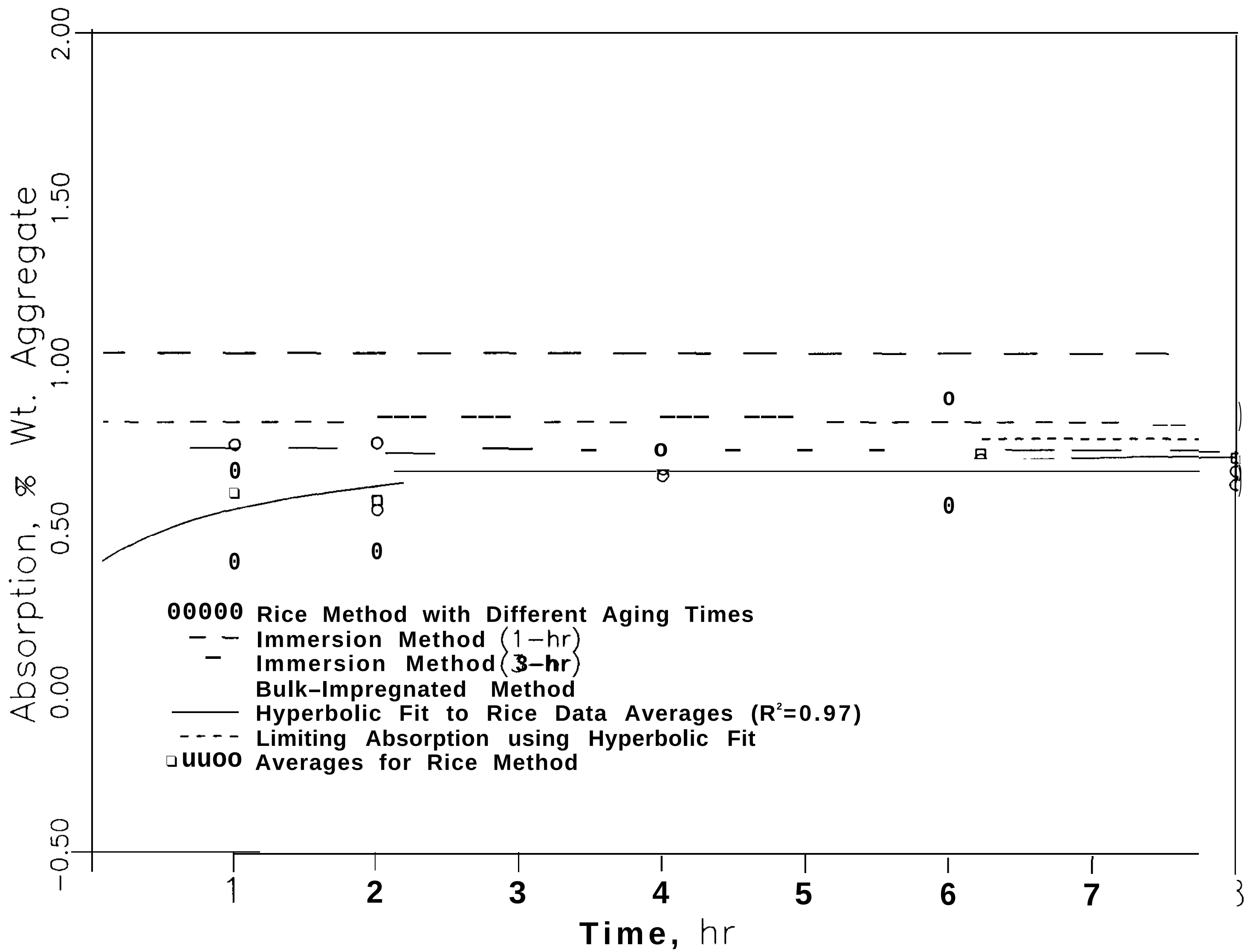


Fig. 4 – Asphalt Absorption vs. Aging Time for RB and AAB–2

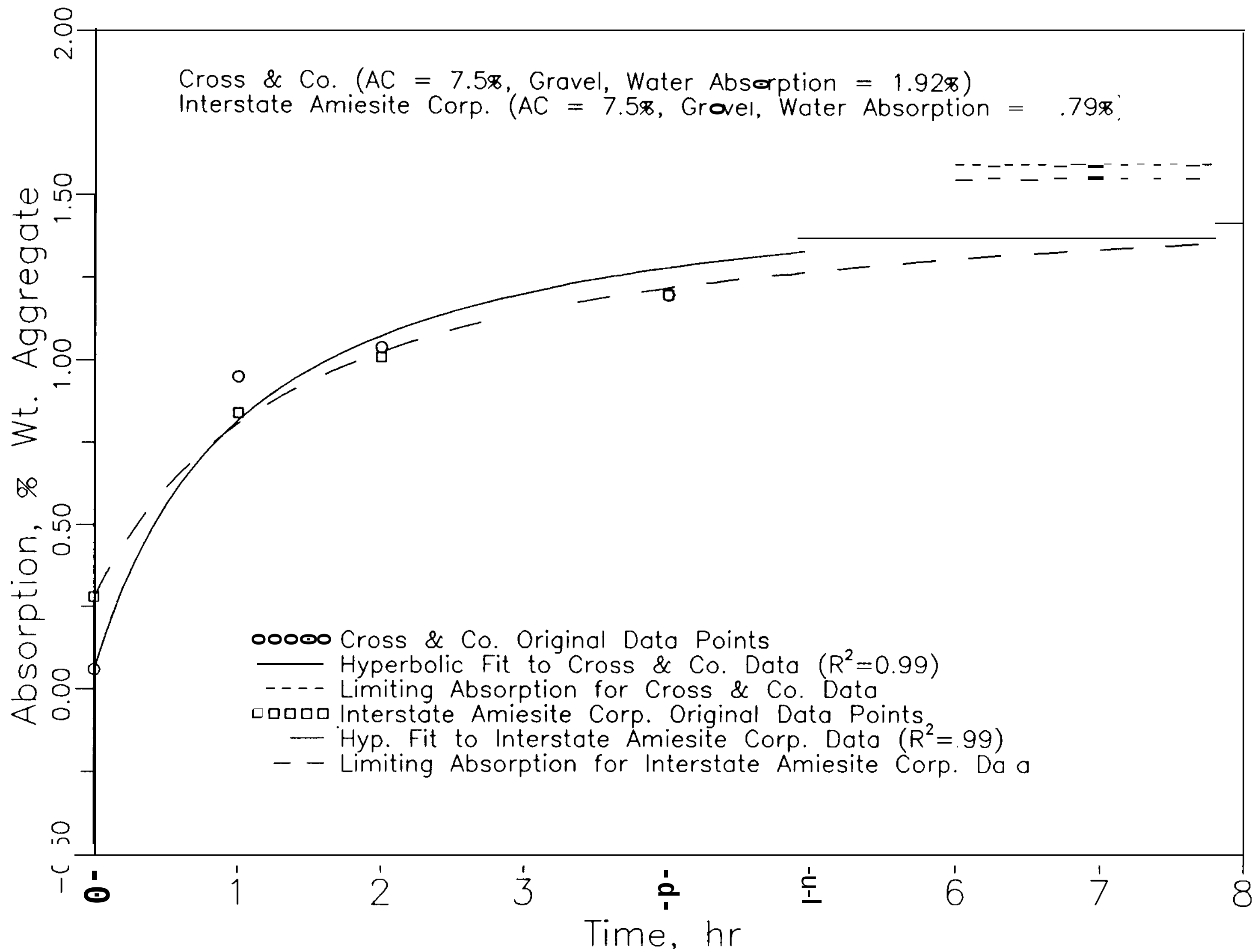


Fig. 5 – Asphalt Absorption vs. Aging Time (Pennsylvania Data)

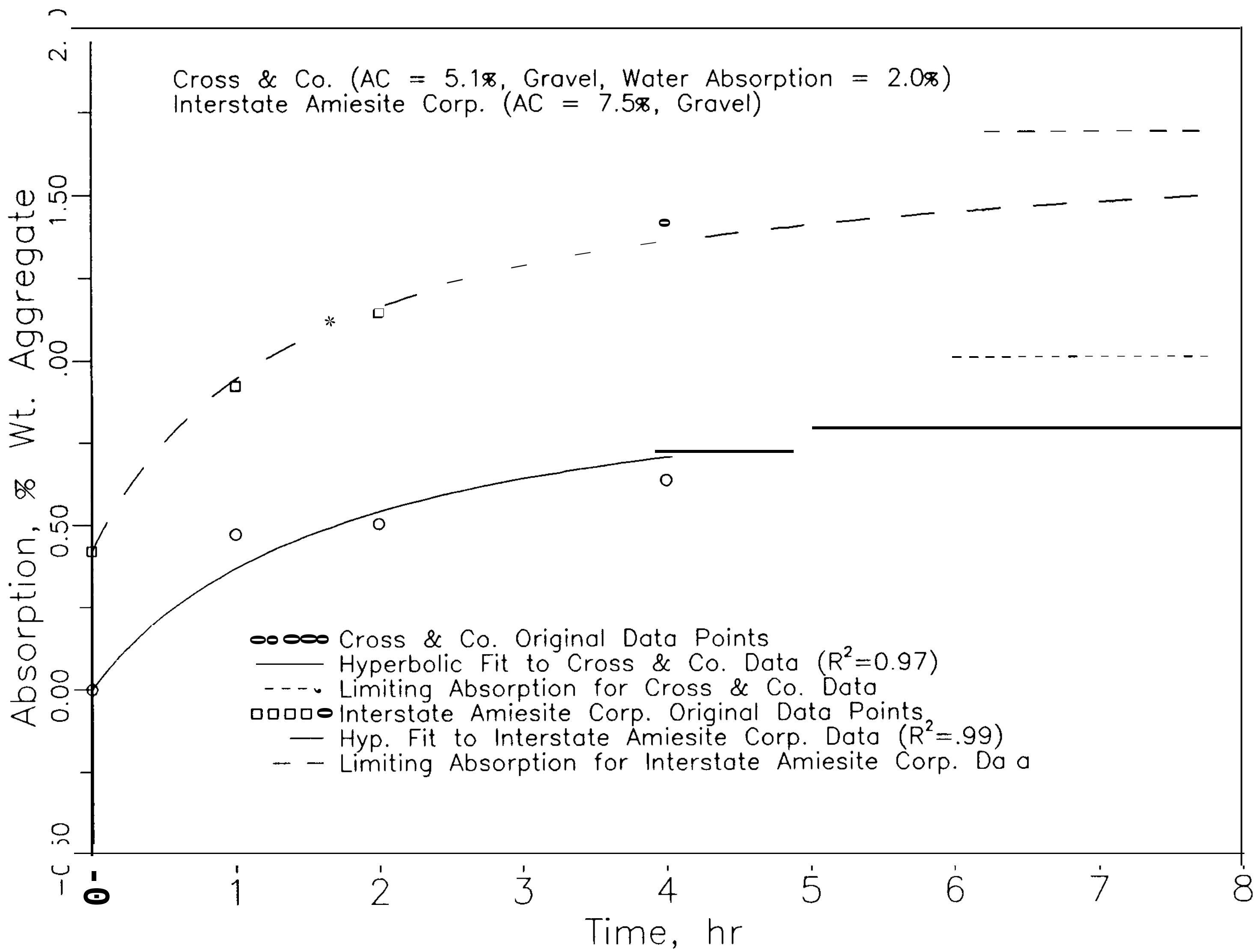


Fig. 6 – Asphalt Absorption vs. Aging Time (Pennsylvania Data)