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# Implementation of a laboratory batching procedure with a correction for fines and moisture

*Implementación de un procedimiento de bacheo en laboratorio con correción por finos y humedad*

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## RESUMEN

La selección de una estructura de agregados apropiada es un proceso clave durante el diseño de mezcla debido a que esta afecta directamente el desempeño de la mezcla y la cantidad de asfalto en la misma. Durante los procesos convencionales de dosificación de agregados en laboratorio, los agregados son secados y separados mediante tamizado en diferentes tamaños, para luego ser recombinados en proporciones apropiadas para reproducir la granulometría de diseño. Este tipo de procedimiento puede producir granulometrías con porcentajes pasando la malla No.200 que son substancialmente mayores con relación a la granulometría objetivo. Este artículo explora los efectos que los finos adheridos a partículas más grandes tienen sobre el bacheo de granulometrías, el porcentaje óptimo de asfalto resultante y la proporción polvo/asfalto. Un método modificado de bacheo que corrige por estos finos adheridos a partículas más grandes y además por la humedad atrapada en los agregados es presentado y además se muestra cómo este proceso permite replicar más de cerca la granulometría objetivo. El porcentaje óptimo de asfalto fue determinado por medio del método de diseño Superpave®, tanto para una granulometría obtenida mediante bacheo convencional como para la misma granulometría obtenida mediante el uso del procedimiento de corrección sugerido. Los resultados muestran que el porcentaje de asfalto óptimo y la volumetría obtenida en ambos casos son substancialmente distintas. El procedimiento desarrollado para corrección de finos es recomendado para los procesos rutinarios de bacheo con el objetivo de minimizar la inclusión de finos adicionales que pueden potencialmente afectar las características de desempeño de la mezcla.

**PALABRAS CLAVES**: Agregados, Bacheo, Finos, Humedad.

## ABSTRACT

*The selection of an appropriate aggregate structure is a key step during mix design since this directly affects mix performance and the amount of asphalt in the mix. During conventional batching procedures, the aggregates are dried and sieved into different sizes only to be recombined later into the appropriate proportions to reproduce the design gradation. This type of procedure can produce gradations with substantially larger percent passing the sieve No.200 relative to the target gradation. This paper explores the effects that fines adhered to larger particles have on the batch gradation, the resulting optimum binder content and dust proportion. An improved batching procedure that corrects for fines adhered to larger particles and trapped moisture is presented in detail and shown to replicate the target design gradation more closely. The optimum asphalt content was determined by means of the Superpave® design method for both, a gradation batched conventionally and a gradation batched with the suggested corrected procedure. The results show that the optimum asphalt content and volumetrics obtained in both cases are substantially different. The procedure developed for the fines correction is recommended for routine batching in order to minimize the inclusion of additional fines that can potentially affect the performance characteristics of the mix.*

***KEY WORDS:*** *Aggregates, Batching, Fines, Moisture.*

## INTRODUCTION

Asphalt design procedures (Marshall, Hveem and Superpave) use different criteria to determine the appropriate aggregate structure and the corresponding optimum asphalt binder content for Hot Mix Asphalt (HMA). All of these procedures attempt to balance cracking, rutting and durability performance of the mix through the control of mixture volumetrics parameters and gradation. In particular, the percent passing the No. 200 or 0.075 mm sieve (denoted herein as P200) can play a very important role in the mix performance.

In order to determine an appropriate aggregate structure, the design procedures and their specifications provide gradation bands or control points within which the design mix gradation must fall. This gradation is obtained by combining aggregates from different stockpiles by selecting the appropriate proportions based on the individual stockpile gradations obtained by performing a wet sieve analysis following AASHTO, ASTM or any local test procedure. The use of this procedure is intended to create a combined gradation that would represent a field gradation with the same stockpiles.

During common laboratory procedures, the aggregates are dried, sieved and separated into several sizes to be stored separately before batching. The aggregates are later recombined in the appropriate proportions to reproduce the design gradation. Depending on the gradation composition, sometimes three or four sizes per stockpile are enough to create an accurate gradation; however, it might be necessary to separate the aggregates into all the standard sieve sizes when finer gradations are designed. When coarser gradations are used, it is common to observe the addition of all material passing either the No.4 or No. 8 sieve as a single combination or separated into two fractions depending on the percentages of fines used. Another procedure followed by some labs is to do wet sieve analyses of samples taken from batches created at the plant using field equipment and appropriate sampling and mixing procedures. Then, the field batches are separated into bins and recombined in appropriate proportions to create the smaller batches used for mix design.

Independently from the procedure chosen, there is an inconsistency in the batching process, since the aggregates are separated into bins by the use of dry sieving, and later used to target a gradation based on wet sieve analysis of the individual stockpiles. This procedure creates a potential presence on each bin of particles finer than the corresponding bin size range. This presence of finer materials in each bin is not taken into account during the batching procedures. These particles are always present in some proportion due to the inability of mechanical sieving to break the bond between them and the larger particles, even after following the corresponding procedures, which is the reason why wet sieve analysis is used in the first place to obtain accurate gradation for the field stockpiles.

The dimension of this problem can vary from one source of aggregate to the next. However, particularly for the finer stockpiles, the amount of fines adhered to larger particles can be significant, and the use of these stockpiles may affect the optimum asphalt binder content and the P200 of the design gradation. This in turn will result in volumetrics obtained in the lab that are not representative of field mixes, which can lead to necessary adjustments during plant mix production.

In addition to this problem, moisture absorbed by the aggregates in the lab requires some consideration. Even after the aggregates are dried before the sieving procedures, these tend to pick up moisture from the environment once they are placed into bins or any closed container. This moisture can reach an equilibrium in well controlled environments, however it is necessary to take it into account before performing batching procedures in order to guarantee the appropriate proportions and weights of the materials.

## OBJECTIVE

This paper explores the potential effects that fines adhered to larger particles may have on the batch gradation, the resulting optimum binder content and dust proportion. The Superpave mix design procedure is used to select an optimum binder content for a gradation put together following a typical batching procedure and a procedure that corrects for fines adhered to larger particles and for moisture absorbed by the aggregates on each bin.

## BACKGROUND

Since the start of the last century when pavement design methods started, the process of finding an appropriate aggregate gradation remains an iterative one where trial and error determines the usefulness of a given aggregate matrix and experience plays an important role in putting together these matrices (Anderson and Bahia 1997). The importance of the aggregate gradation and other properties lies in their ability to affect the stiffness, durability, workability, permeability, stability, fatigue, frictional resistance and moisture susceptibility of the asphalt mixtures (Buchanan and Brown 1999).

However, as pointed by Anderson and Bahia (1997), during the development on the Superpave Mix design method, most of the attention was placed on the development of test specifications for asphalt binders and the volumetrics of the mixture, limiting the tests for aggregates to consensus properties and a few basic guidelines and restrictions for the gradation curve.

The Superpave Mix design procedure (AASHTO 2012a) identifies control points, which conform the limited gradation requirements for the combination of aggregates. Anderson and Bahia (1997) point out that these control points are used basically for three purposes : a) to control the top size of the aggregate, b) to control the relative proportion of coarse and fine aggregate and c) to control the amount of dust. In relation with the latter use, the AASHTO standard only mentions the possibility of increasing the dust proportion limits when the aggregate gradation passes beneath the Primary Control Sieve (PCS) control points. However, it was pointed out by Green et al. (2011) that the gradation control points are actually limited in their ability to predict performance. Furthermore, the procedure for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor (AASHTO 2012b), indicates for a batching procedure, that "appropriate aggregate fractions" should be weigh into a pan to combine them to a desired batch weight, without providing any further detail on how to accurately select these fractions. The accuracy of this procedure is of great importance to avoid the adhesion of significant amounts of fines to larger aggregate particles.

Additionally, as indicated by the AASHTO T-27 (2011) standard procedure for Sieve Analysis of Fine and Coarse Aggregates, an accurate determination of the material passing the No.200 sieve cannot be achieved by the use of dry sieving alone and suggests the use of the test method for wet sieving AASHTO T-11, as a complement for this task. Therefore, a more accurate gradation of a stockpile will be determined by first performing a wet sieve analysis to quantify the P200 material and then a dry sieve analysis of the material that was retained in the No. 200 sieve.

While performing a study of unbound aggregate performance, Mishra et al. (2010) found that the actual fines content of a sample was always higher than the target content of the blend. Percentages of P200 of 4.7, 6.8 and 8.1, were found for an initial target of 4 percent for dolomite, uncrushed gravel and limestone, respectively, whereas percentages of 8.7, 10.6 and 11.8 where found for an initial target of 8 percent. This suggests that the differences can be substantial depending on the source of the material.

Another study that showed differences between the target gradation and the one obtained in the lab was performed by Buchanan et al. (1999). They found that when the amount of P200 material is low, the washed and dry sieving procedures often result in comparable results, however when the P200 material is high, the results can vary significantly. Epps et al. (2000) recommend to carry a mixture sensitivity analysis when performing Superpave mix design procedures since the poor control during production of variables such as P200 can potentially have negative effects on the performance of the mix. Their study showed plant production standard deviations for asphalt content and P200 of 0.3 and 0.9 percent respectively. The FHWA Demonstration project 74 (D'Angelo and Ferragut 1991) also showed differences between laboratory mix design and plant produced mixtures. These differences can lead to plant produced mixtures with different characteristics than the ones expected from laboratory testing and can in part be due to inadequate batching procedures.

During the same study, Epps et al. (2000) determined that voids in the mineral aggregate (VMA) are affected by the proportion of coarse and fine aggregate and the P200 in a blend, while it was noted that air voids are affected by the proportion of coarse and fines aggregate, the P200 and also the asphalt content in the mix. For each case studied, an air void reduction was found with an increase in the P200. When plotting the P200 against the air voids, a U shaped relationship was found, in which the air voids initially decrease due to the asphalt extender effect, and later increase due to the drying-up effect as the P200 increases. A more in depth discussion of this two effects can be found elsewhere (Khandal et al. 1998). This behavior suggests the possible existence of an optimum P200 percentage according to Epps et al. (2000). Additionally, this study found that for the mixtures evaluated, the optimum asphalt content to generate 4% air voids decrease 0.25 and 0.8 percent when the P200 was increased by 0.4 and 1.5 percent, respectively.

More recently, the Asphalt Institute MS-2 (2015), included in the batching section, a third method which deals with the problem of fines adhered to larger particles. However, even though the manual suggests that a procedure needs to be implemented to correct for these fines, there is no specific procedure explained. Furthermore, they encourage the reader to avoid this particular method and use any of the first two method explained in their manual. The discussion of the presence of additional fines in the MS-2 manual is another indication of its importance and that implementation of a more rational and repeatable procedure is necessary to address the issue, since the problem most likely will not be solved by the use of the first two methods described in MS-2, especially for certain types of aggregate sources.

Another issue that is commonly encountered in the laboratory is moisture absorbed by the aggregates from the environment. Independently from the aggregates being in covered bins or not, humidity is absorbed at a certain level, most likely depending of the absorption capacity of the rock. It is common to observe a 1-2 percent weight loss on the oven heated aggregate immediately before the mixing in comparison with the batched weight. This can be particularly problematic if the asphalt binder weight is not adjusted accordingly leading to inadequate binder-aggregate proportioning.

## METHODOLOGY

Two sets of batches were prepared in the laboratory to study the effect that fines adhered to larger particles can have on the gradation and the design optimum asphalt content. These batches were prepared using four different stockpiles of basaltic aggregates identified as 3Fine, Chips, 4Fine and C-33, These aggregates are of common use in the island of Oahu and were obtained from the Ameron, Kapaa Quarry. The gradation for each stockpile (resulting from a wet sieve analysis provided by the supplier), together with the appropriate proportions and the resulting job mix formula are shown in Table 1.

For the first set of batches, the common batching approach was followed in which the proportion from each bin of a stockpile with respect to the total mix is determined by multiplying the proportion in which the stockpile is added to the mix with the proportion within the stockpile that falls in the range of sizes stored in the bin. As an example, following Table 1, the proportion of 4Fine that passes the No. 8 sieve but is retained in the No.16 sieve should be computed as (0.627-0.418) x 0.38 = 7.94%. For this particular experiment, each stockpile aggregate was separated into each of the main sieve sizes that are commonly used to create gradation curves (25 mm (1 in), 19 mm (3/4 in), 12.5 mm (1/2 in), 9.5 mm (3/8 in), 4.75 mm (No.4), 2.36 mm (No.8), 1.18 mm (No.16), 0.600 mm (No.30), 0.300 mm (No.50), 0.150 mm (No.100) and 0.075 mm (No. 200)).

*Table 1. Stockpile and Job Mix Formula Gradations*

| Sieve | Percent Passing | | | | |
|---|---|---|---|---|---|
| | 3 Fine | Chips | 4 Fine | C-33 | Job Mix Formula |
| 3/4 | 100 | 100 | 100 | 100 | 100.00 |
| 1/2 | 54.1 | 100 | 100 | 100 | 89.90 |
| 3/8 | 18.3 | 96.4 | 100 | 100 | 81.31 |
| No.4 | 2.4 | 14.6 | 95.7 | 98.5 | 59.51 |
| No.8 | 1.4 | 2.3 | 62.7 | 91.8 | 42.95 |
| No.16 | 1.1 | 1.7 | 41.8 | 66.9 | 29.85 |
| No.30 | 1 | 1.5 | 27.8 | 34.7 | 18.02 |
| No.50 | 0.9 | 1.3 | 19.8 | 15.5 | 11.08 |
| No.100 | 0.8 | 1.3 | 14.3 | 5.9 | 7.05 |
| No.200 | 0.7 | 1.1 | 11.4 | 4.7 | 5.65 |
| Percentage | 22 | 20 | 38 | 20 | 100 |

A second set of batches were prepared by applying two corrections, the first correction is applied to the proportion from each bin of a stockpile and recognizes that for every material larger the No.200 sieve, there are particles finer than the lower bound of the bin's range adhered to the aggregates of each bin, which altogether contribute to a non-negligible proportion of P200 that is added to the batch. The second correction for the moisture absorbed by the aggregates is applied to obtain the correct batch weight after the aggregate has been in the oven prior to the mixing procedure.

A more in detailed explanation on how the corresponding equations for the fine correction procedure were developed can be found in Corrales-Azofeifa and Archilla (2015). The diagram shown herein presents the fines correction method through an example in order to illustrate the procedure for an easier implementation. It is important to point out that the correction needs to be performed just once for each stockpile, before a mix design or sample preparation procedure. When large stockpile variability is expected or measured through QA procedures, the necessary corrections should be applied on top of the batching correction shown herein.

### *Batching Correction Procedure*

The diagram in Figure 1 shows two tables interconnected by the calculations required to determine the necessary batching corrections. The upper table shows the results of a wet sieve analysis for one stockpile (4-Fine) and more specifically for each fraction of that stockpile smaller than the No. 8 Sieve size. Preliminary investigation indicated that for this particular aggregate source, the first particle size that retains a significant amount of finer material is the No. 16 sieve size. This can vary from one stockpile to another and should be evaluated. For this wet sieve analysis, approximately 500 grams of each bin size were wet sieved over a full set of sieves smaller than the bin's lower particle size in order to determine the real percentage of material that is included every time that a fraction is added to a batch. It was found that for this source of aggregate, as much as 20% of the material included as passing the No. 100 (150 μm) and retained on sieve No. 200 (75 μm) is actually material that passes the No. 200 sieve (P200). This tendency can also be observed (but to a lesser degree) in the bins for coarser materials.

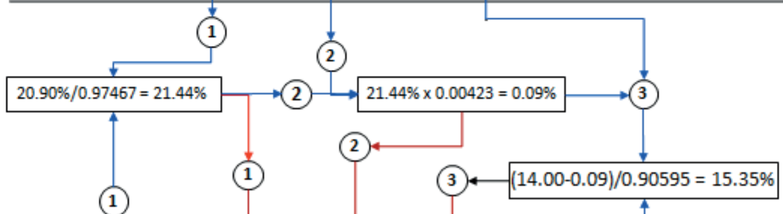
The lower table in Figure 1 illustrates for the 4-Fine stockpile how the corrected quantities to be added to the batch can be obtained based on the wet sieve analysis of the bins shown in the upper table. The boxes between the two tables illustrate, as mentioned before, some of the calculations needed for the correction. The lines in blue show the inputs to the calculations and the lines in red indicate the locations of the outputs. The flow of information for each calculation is identified with a circled number.

The first calculation (1) illustrates how to compute the percentage that actually needs to be batched in order to account for the adhered fine particles for the largest bin size for which a correction was deemed important (-No. 8 to +No 16 in this example). This calculation accounts for the fact that not all the material in this bin is in the intended bin's range. The second calculation (2) recognizes that the addition for this bin not only provides the needed mass contribution from this stockpile of material in this bin but also contributes material in the lower bin sizes. The same type of calculation is needed for all the cells below the underlined cells. The final calculation (3) is similar to the first but it recognizes the contribution to the desired bin's range by the larger bins. This contribution needs to be subtracted first.

The third calculation for other bins are similar except that the contributions from all larger bins need to be subtracted first. Clearly, since some –No. 200 material is contributed by all the bins, the actual percentage that needs to be added from this bin (8.24%) is substantially smaller than the target 11.40%. As shown in Corrales-Azofeifa and Archilla (2015), ignoring this correction can result in almost a 3% increase on the P200 of this stockpile material. Differences of this order in the finer stockpiles (such as the 4-Fine) have an important effect on the resulting mix gradation, giving as a result a laboratory gradation that differs from the target gradation.

Figure 2 shows the results of an experiment in which two samples of 2,500 g each were batched with and without the correction (labeled as corrected and uncorrected, respectively) and then they were subjected to a wet sieve analysis by washing over all sieves. Two curves are shown for each batch, one for the experimental results and the other for the theoretical results (see Corrales and Archilla 2015 for an explanation of the theoretical uncorrected gradation). These results demonstrate that by including the

| Size range | Bin size: -No.8 To +No. 16 | -No.16 To +No. 30 | -No. 30 To +No. 50 | -No 50 To +No. 100 | -No. 100 To +No. 200 |
|---|---|---|---|---|---|
| -No. 8 to +No. 16 | 97.467 | 0 | 0 | 0 | 0 |
| -No. 16 to +No. 30 | 0.423 | 90.595 | 0 | 0 | 0 |
| -No. 30 to +No. 50 | 0.101 | 2.499 | 87.177 | 0 | 0 |
| -No. 50 to +No. 100 | 0.181 | 1.149 | 3.004 | 86.097 | 0 |
| -No. 100 to +No. 200 | 0.181 | 0.907 | 1.331 | 2.662 | 78.592 |
| -No 200 | 1.646 | 4.851 | 8.488 | 11.240 | 21.408 |
| Total | 100 | 100 | 100 | 100 | 100 |




| Sieve Size (1) | Stockpile Wet Sieve Gradation (% Retained) (2) | Bin Correction Values: -No. 8 To +No. 16 (3) | -No 16 To +No. 30 (4) | -No. 30 To +No. 50 (5) | -No 50 To +No. 100 (6) | -No 100 To +No. 200 (7) | Stockpile Percentages Corrected for Fines (8) | Stockpile % Corrected for Fines and Moisture (9) |
|---|---|---|---|---|---|---|---|---|
| 3/4 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 1/2 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 3/8 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| #4 | 4.30 | 0 | 0 | 0 | 0 | 0 | 4.30 | 4.33 |
| #8 | 33.00 | 0 | 0 | 0 | 0 | 0 | 33.00 | 33.22 |
| #16 | 20.90 | ***21.44*** | 0 | 0 | 0 | 0 | 21.44 | 21.61 |
| #30 | 14.00 | 0.09 | ***15.35*** | 0 | 0 | 0 | 15.35 | 15.47 |
| #50 | 8.00 | 0.02 | 0.38 | ***8.71*** | 0 | 0 | 8.71 | 8.78 |
| #100 | 5.50 | 0.04 | 0.18 | 0.26 | ***5.83*** | 0 | 5.83 | 5.88 |
| #200 | 2.90 | 0.04 | 0.14 | 0.12 | 0.16 | ***3.12*** | 3.12 | 3.15 |
| Pan | 11.40 | 0.35 | 0.74 | 0.74 | 0.66 | 0.67 | 8.24 | 8.31 |

Figure 1. Diagram for the fines correction method (4-Fine stockpile)

correction, the P200 in the batch (5.89%) is much closer to the target 5.65% than the P200 in the uncorrected batch (7.58%). In both cases, the laboratory gradations are close to the theoretical predictions. The difference of 1.66% between the two theoretical curves, show that not performing the correction for fines results in an additional amount of fines that will substantially change the optimum binder content (OBC) of the mixture, as discussed later.

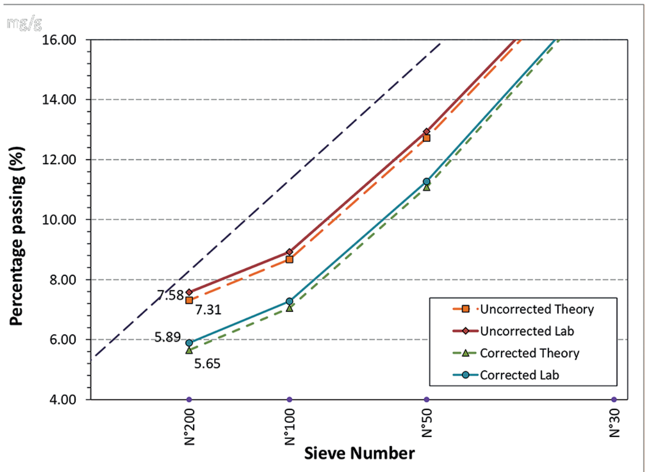



Figure 2. Differences due to fines on the mix design gradation curve

### *Correction for Moisture*

A simpler but necessary correction for moisture must be performed in order to recognize that part of the material added to a batch is water absorbed by the aggregate. This is noticeable once the batch is heated prior to mixing. Ignoring this correction can lead to an inadequate asphalt binder content added to the mix, if the percentage is not recalculated after the batch is placed inside the mixing bowl or drum, leading to an additional percentage of asphalt added to the mix due to the lower weight of the aggregate batch. Also, it would be possible to fall short on material to achieve a certain target air voids every time a batch is prepared with the exact necessary weight.

In order to perform this correction, samples of 500 grams of material per bin size were oven dried for 16 hours at 110°C (230°F), after several days of being in the laboratory inside their containers. The final weights were determined and the difference was therefore taken as moisture absorbed. Table 2 shows the correction for each material. Each of these percentages need to be included after the fines correction to adjust the weight of every fraction. Details of the correction procedure are presented in Corrales-Azofeifa and Archilla (2015).

*Table 2. Moisture Content of the Different Stockpile Fractions*

| Sieve | Moisture Content, % | | | |
|---|---|---|---|---|
| | *3 Fine* | *Chips* | *4 Fine* | *C-33* |
| 1/2 | 0.501 | – | – | – |
| 3/8 | 0.534 | 0.467 | – | – |
| No.4 | 0.567 | 0.700 | 0.633 | 0.467 |
| No.8 | 0.600 | 0.700 | 0.667 | 0.500 |
| No.16 | 0.488 | 0.621 | 0.767 | 0.533 |
| No.30 | 0.252 | 0.386 | 0.767 | 0.667 |
| No.50 | 0.325 | Not used | 0.800 | 0.700 |
| No.100 | 0.541 | 0.528 | 0.833 | 0.667 |
| No.200 | 0.702 | 0.713 | 0.867 | 0.667 |
| Pan | 0.800 | 0.800 | 0.800 | 0.800 |

### *Effects on Mix Design and Volumetrics*

A job mix formula (JMF) and other gradation information was obtained from a full Marshall mix design performed by a private company in the island of Oahu for an airport job. The same gradation information was used to determine the OBC of two different sets of specimens using Superpave® for airfields (Rushing et al. 2010). From the two sets of batches, one was batched with the conventional batching procedure (without the fines correction) and the other applying the correction for fines. However, the moisture correction was applied in both cases to obtain batches of appropriate masses. Essentially, the differences in actual gradations are the same as those observed between the corrected and uncorrected curves in Figure 2.

Three sets of replicates were compacted for each gradation with 85 gyrations using a ServoPac gyratory compactor. In order to obtain the %Gmm @ Nmax, two additional specimens were compacted for each gradation to 130 gyrations.

*Table 3. Mix Design Results for the Corrected and Uncorrected Mixtures*

| Test property | Design Criteria 12.5mm NMAS | Corrected Mix | Uncorrected Mix |
|---|---|---|---|
| Air Voids @ $N_{design}$ | 4.0 | 4.0 | 4.0 |
| VMA @ $N_{design}$ % | 14 | 15.72 | 14.06 |
| VFA @ $N_{design}$ % | 65-78 | 74.56 | 71.69 |
| Dust proportion | 0.6-1.2 | 1.11 | 1.73 |
| $\%G_{mm}$ @ $N_{initial}$ | ≤ 90.5 | 86.12 | 86.01 |
| $\%G_{mm}$ @ $N_{max}$ | ≤ 98.0 | 96.36 | 96.41 |
| Optimum AC% | - | 6.48 | 5.76 |
| $G_{mm}$ @Optimum AC | - | 2.477 | 2.507 |

Table 3 shows the results of the two mix designs. In this example, the OBC is 6.48% for a corrected gradation and 5.76% for an uncorrected gradation. These results imply that performing a mix design with a traditional batching procedure may result in a substantial deficiency on the OBC (0.72% in this example.)

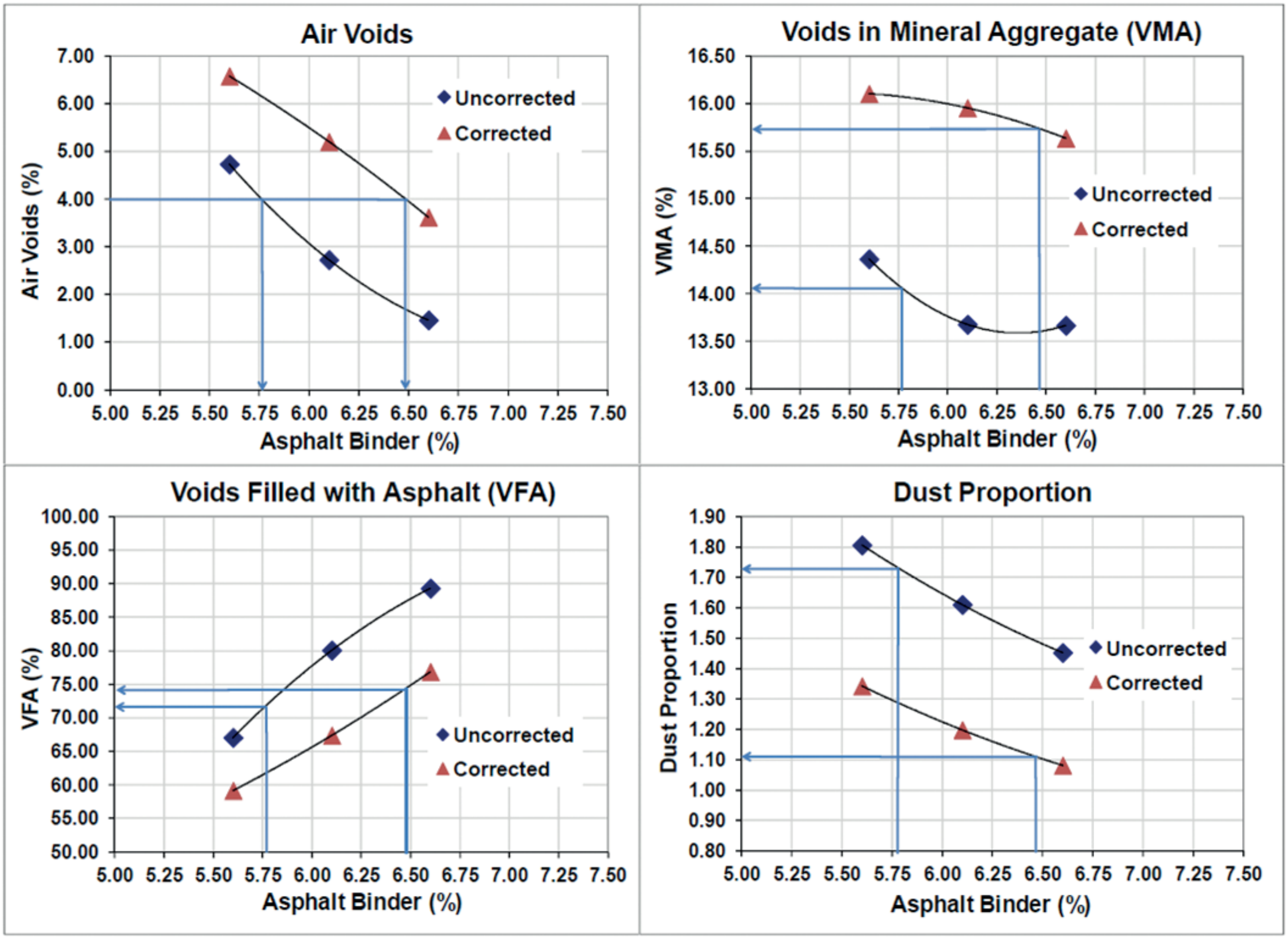



Figure 3. Mix design results for the corrected and uncorrected mixtures

The volumetric plots from which the results in Table 2 are obtained are shown in Figure 3. The lower OBC resulting from the unaccounted additional fines introduced in the uncorrected batching procedure translates into a smaller asphalt film thickness of the field mix (which barring field variations should have a gradation similar to the corrected one). This, in turn, may result in durability problems such as raveling, potholes, and asphalt striping. The development of these early distresses may have a direct impact on the optimum timing to apply preservation treatments.

The fact that the dust proportion for the uncorrected mix is not met is to be expected due to the excess of P200 material that is unintentionally added using the conventional batching procedure. It is important to point out that without noticing that additional fines are being added with the conventional batching procedure, the computed dust proportion would have been 1.21. Although this is just slightly higher than the normal 1.2 limit, it is lower than the 1.6 limit that is sometimes allowed for mixes that pass below the restricted zone. Thus, in practice, the exceedance of this limit in laboratory batched specimens would go unnoticed.

A larger amount of P200 included in the uncorrected mix affects not only the dust proportion of the mixture, but also the rest of the volumetrics and most importantly the OBC of the mixture. In this particular case, an increase of 1.66% in the P200 of the uncorrected mix with respect to the corrected mix, lowered the OBC for the uncorrected mix relative to the corrected mix by 0.72%, which is consistent with the findings by Epps et al. (2000). The additional fines included with the uncorrected batching procedure seem to act as filler and leave less space for the binder. Another point worth noticing is the substantially higher voids in the mineral aggregates (VMA) of the corrected mix since this volumetric target is often not easy to achieve.

Currently, in the United States most of the state specification tolerances for the job mix formula (including Hawaii), specify a ±2.0% for the material passing No.200 sieve and ±0.4% on the asphalt binder content. Although for this particular example the difference found on the material passing No.200 sieve after the correction is still lower than the allowable range (1.66% over the required value), the error in the material percentage is introducing a change (0.72%) on the OBC during the mixture design which in this particular case is close to twice the allowable tolerance for asphalt content. Based on these results, it is believed that gradations produced in the laboratory carrying conventional batching procedures may not always be representative of the field gradations. Furthermore, this problem will potentially determine very different asphalt contents than the necessary ones (even outside of the allowable tolerances, as shown), giving as a result the use of a field OBC that does not match the gradation it was obtained from. The proposed batching procedure seems to address all these issues, and therefore it is believe to be a great improvement from the conventional batching procedures. It is believed, however, that parameter thresholds for mix design procedures, should be adjusted accordingly to account for potential differences in the resulting mix volumetrics and OBC.

### *Simplified Corrected Batching Procedure*

It can be seen from Figure 1 that for a given bin, the largest of the proportions of fine particles that do not belong to that bin size, are typically those that pass the No. 200 sieve. Even though the proportions for other particle sizes are not negligible, those passing the No. 200 sieve are likely to have the most significant effect. If only the P200 fines adhered to larger particles are considered, the corrected batching procedure can be largely simplified. By following this approach, only the bold underlined values and the cells in the last row from the lower table in Figure 1 need to be computed, making the implementation of the procedure in a spreadsheet much simpler since for a given stockpile all the calculations can be concentrated in a given column. A comparison between the OBC resulting from the simplified corrected batching procedure and the full correction procedure needs to be developed. Incidentally, this simplified procedure has been used for some time at the University of Hawaii Pavement Laboratory.

## CONCLUSIONS AND RECOMMENDATIONS

A new procedure for batching aggregates that accounts for fines adhered to larger particle sizes and for moisture trapped in aggregate bins has been developed and introduced. Based on laboratory results, the following conclusions and recommendations are made:

1) Conventional batching procedures that do not account for fines adhered to larger particles for some aggregate sources, can potentially produce gradations that deviate substantially from the target gradation particularly for small sieve sizes. For this particular study, it was shown that using the conventional batching procedure produced a P200 that was off by 1.66% from the target gradation. Therefore, it is possible to produce gradations in the lab with conventional batching procedures that may not always represent field gradations.

2) The proposed corrected batching procedure seems to replicate very accurately the target gradations based on wet sieve analysis. More in depth, batches prepared with the corrected and uncorrected procedures and subjected to wet sieve analysis, produced a gradation which followed the target JMF for the batch prepared with the corrected procedure and a gradation obtained with theoretically computed deviations from the job mix formula (calculated through the same procedure) for the batch prepared with the uncorrected procedure.

3) For this particular experiment, the differences in gradations obtained with the corrected and uncorrected batching procedures lead to mixture designs with substantially different volumetrics and asphalt contents. A more in depth study would be necessary to assess the changes, if any, in mix design criteria and also the effects on performance tests, for this and other aggregate sources.

4) The use of the corrected batching procedure developed in this study can serve as a standardized procedure for the production of aggregate batches that could be implemented in every laboratory and agency. Even though it is possible that the differences are not that significant for some aggregate sources, it is recommended to always determine the corrections a priori in order to make a decision.

5) Further study is necessary to determine the implications of using the simplified corrected procedure which accounts only for fines that pass the sieve No. 200 adhered to larger particles.

## REFERENCES


1. Anderson R.M., and Bahia, H.U. (1997). "Evaluation and Selection of Aggregate Gradation for Asphalt Mixtures Using Superpave." Transportation Research Record No.1583, Transportation Research Board, Washington, DC, 91-97.

2. Buchanan, M.S. and Brown E.R. (1999). "Development and Potential Use of an Automated Aggregate Gradation Device." Transportation Research Record No.1673, Transportation Research Board, Washington, DC, 81-88.

3. Corrales-Azofeifa, J. and Archilla, A. (2015)."Laboratory Batching Procedure Corrected for Fines and Moisture." J. Mater. Civ. Eng., 10.1061/(ASCE)MT. 1943-5533.0001384, 04015102.

4. D'Angelo, J.A., and Ferragut, T. (1991). "Summary of Simulation Studies from Demonstration Project No.74, Field Management of Asphalt Mixes." Journal of the Association of Asphalt Pavement Technologies, Vol. 60, 287-309.

5. Epps, A.L., and Hand, A.J. (2000). "Coarse Superpave Mixture Sensitivity." Transportation Research Record No.1712, Transportation Research Board, Washington, DC, 35-43.

6. Greene, J., Kim, S. and Choubane, B. (2011). "Accelerated Pavement Testing and Gradation-Based Performance Evaluation Method." Transportation Research Record No.2225, Transportation Research Board, Washington, DC, 119-127.

7. Kandhal, P.S., Lynn, C.Y. and Parker F. (1998). "Characterization Tests for Mineral Fillers Related to Performance of Asphalt Paving Mixtures." Transportation Research Record No.1638, Transportation Research Board, Washington, DC, 101-110.

8. Mishra, D., Tutumluer, E. and Butt, A. (2010). "Quantifying Effects of Particle Shape and Type and Amount of Fines on Unbound Aggregate Performance Through Controlled Gradation." Transportation Research Record No.2167, Transportation Research Board, Washington, DC, 61-71.

9. Rushing, J.F., Mejias, M., and Brown, E.R. (2010). "Development of Criteria for Using the Superpave Gyratory Compactor to Design Airport Pavement Mixtures." Proc., 2010 FAA Worldwide Airport Technology Transfer Conference, Atlantic City, NJ, 2010.

10. AASHTO (American Association of State Highway and Transportation Officials). (2012a). "Standard Test Method for Superpave Volumetric Mix Design (M 323-12)." Washington, DC.

11. AASHTO (American Association of State Highway and Transportation Officials). (2012b). "Standard Test Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor (T 312-12)." Washington, DC.

12. AASHTO (American Association of State Highway and Transportation Officials). (2011). "Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates (T 27-11)." Washington, DC

13. The Asphalt Institute. (2015). "Asphalt Mix Design Methods (MS-2)", Seventh Edition. Lexington, KY.