THE RELIABILITY OF MARSHALL COMPACTOR FOR PREDICTING VOID AT REFUSAL DENSITY

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Summary

In Indonesia the use of Marshall compactor has been applied widely for predicting void at refusal density especially in the provincial PU because the proper equipment for this purpose is rarely available. The main problem of using this equipment is the possibility of segregation that occurs during compaction process because of impact loading of Marshall equipment. The research carried out is to see the reliability of using Marshall compactor for predicting void at refusal density especially for the ACWC mixture. The are two types of ACWC gradation taken i.e. upper Fuller line and crosses Fuller line. By limited number of samples it is concluded that the Marshall compactor is still possible to use for ACWC upper Fuller line as shown by the gradation after compaction process still falls into specification of ACWC.

Ringkasan

Di Indonesia penggunaan alat pemadat Marshall untuk memprediksi rongga pada kepadatan mutlak telah banyak digunakan khususnya di PU Daerah karena keterbatasan alat yang ada. Permasalahan utama dalam menggunakan alat pemadat Marshall untuk memprediksi rongga pada kepadatan mutlak ini adalah kemungkinan terjadinya segregasi pada benda uji akibat beban impact dari alat pemadat Marshall. Penelitian yang dilakukan adalah untuk melihat tingkat kepercayaan penggunaan alat pemadat Marshall untuk tujuan ini, khususnya untuk campuran ACWC. Penelitian ini mengambil dua tipe gradasi campuran ACWC yaitu diatas Fuller dan memotong Fuller. Walaupun jumlah benda uji sangat terbatas, didapat kesimpulan bahwa penggunaan alat pemadat Marshall untuk memprediksi rongga pada kepadatan mutlak hanya bisa dilakukan untuk ACWC yang mempunyai gradasi diatas Fuller seperti yang ditunjukkan oleh gradasi hasil ekstraksi dari benda uji yang telah mengalami pemadatan masih berada pada rentang spesifikasi untuk ACWC.

I. BACKGROUND

In mix design the compaction is one of main testing considered aiming to predict the condition of pavement performances both in the laying process and at the end of service life. This testing is used to predict the voids during the laying process and at the end of service life. These voids have been included in the Indonesian Specification (*Spesifikasi Umum Binamarga Volume 3*) under the parameters of Marshall void and the

void at the refusal density. Marshall void relates to the void required during the laying process while the void at the refusal density is the void required at the end of service life of a mixture used for pavement structure.

To measure the void at refusal density there are several equipment used such as Gyratory Compactor, Vibrating Hammer, and Marshall Compactor. Gyratory Compactor is the equipment recommended by the Strategic Highway Research Project (SHRP) based on years of research activity. This equipment tries to simulate the actual compacting mechanism such as stress applied, angle of compaction, and the condition of short term aging of bituminous material.

The vibrating hammer is mostly used in the United Kingdom and Australia. This type of compaction tool was proposed by the Transport Research Laboratory (TRL, UK). The compaction process was done by an equipment that vibrates at a certain level of stress. There were 8 points of compacting location at the surface of specimen.

The last choice of compacting tool is using the Marshall compactor. The specimen was compacted until a certain times of blows. The number of blows applied depends on the method used. The TRL suggests to take 600 times blows (TRL, 1998) while in Indonesia the number of blows applied usually is taken 400 times for each face of specimen (Darsana, 1999)

There are some limitations of using each type of compacting procedure mentioned above. In provincial highway authority in Indonesia (PU Daerah) the Marshall apparatus is still used for predicting the void at refusal density that is needed for mix design process.

This paper details the reliability of using Marshall Compactor for predicting void at refusal density. The analysis done is based on the aggregate segregation that is possibly occurred during the compacting process.

II. SPECIMEN PREPARATION

The first step in doing the research is to select the type of bituminous mixture used which is the ACWC. The gradation taken is both upper Fuller line and also crossing Fuller line. It is very common in doing research that is all the material properties should be in the range of specification. The aggregate is taken from a quarry near Subang of West Java, while the bitumen used is Ex Pertamina Pen 60. Table A-1 and A-2 in Appendix show that the aggregate and bitumen used meets the Indonesian specification.

Based on the gradation of each aggregate type (Coarse, Medium, and Stone Ash) and the specification of ACWC then the next step is to combine all the aggregate to perform

the ACWC mixture. The gradation chosen is above and cross the Fuller line. The combined gradation is shown in Figure 1. From Figure 1 it is shown that the aggregate combination of ACWC crosses the Fuller line between sieve sizes 2.36 mm and 4.75 mm.

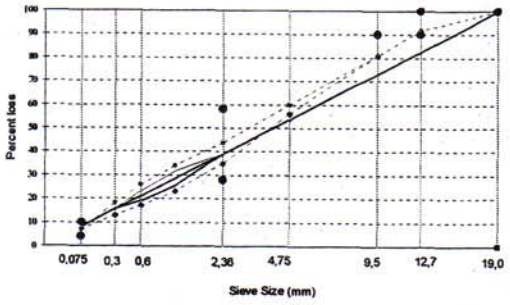

Figure 1 Aggregate Combination for ACWC upper and cross Fuller line

From Figure 1 it can be seen that the combined aggregate of both ACWC upper Fuller line and ACWC cross Fuller line fall in the range of ACWC specification. This would result that two types of combined aggregate can be used for the testing.

The next step is to prepare the specimens for compacting. The variation of blows is taken 100, 200, 300, 400, 500, and 600 times for each specimen face. The size of specimen is taken as same as recommended by Marshall sample. This means that there are 12 samples prepared i.e. 6 samples for the ACWC upper Fuller line and the same amount for the ACWC with the gradation cross the Fuller line. All of activities follow the Indonesian National Standard (SNI) for preparation of Marshall specimen.

III. ACWC UPPER FULLER LINE

For the type of ACWC upper Fuller line the relation between the number of blows using Marshall compactor and void occurred is shown in Figure 2.

When it is assumed that the void at refusal density is obtained at the condition where the sample cannot be condensed anymore, so it can be said that for ACWC upper fuller line the void at refusal density is 2.50%. This value seems quite true because in Indonesian Specification this value is minimum 2.50% (Spesifikasi Umum Bina Marga Volume 3, 2002).

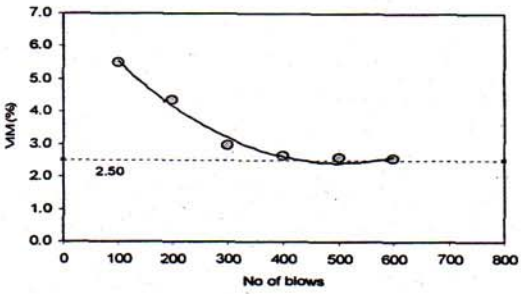

Figure 2 VIM vs No of Blows for ACWC upper Fuller line

In the point of view of the value of void generated at the condition of refusal density ones can say that the use of Marshall compactor to predict this can be accepted for the number

of blows 400 or 500 as shown in Figure 2. However this finding should be evaluated by looking at the possibility of segregation occurred during the compaction process. This is based on the common sense when a bituminous mixture sample gets many times blows it can possibly also break the aggregates on it. To prove this, the 400 blow Marshall sample is extracted to see the gradation of its aggregates. Table 1 shows the extraction result compared to its original gradation. This is also illustrated in the Figure 3.

Table 1
The result of extraction of ACWC upper Fuller line

Sieve Size		Original	Extraction	Unit
Inch	mm			
3/4 "	19	100.0	100.0	% loss
1/2 "	12.7	92.0	93.3	% loss
3/8 "	9.5	81.0	78.7	% loss
# 4	4.75	60.0	60.8	% loss
# 8	2.36	44.0	43.9	% loss
# 16	1.18	34.0	32.3	% loss
# 30	0.6	26.0	20.7	% loss
# 50	0.3	18.0	15.8	% loss
# 200	0.075	7.0	10.0	% loss

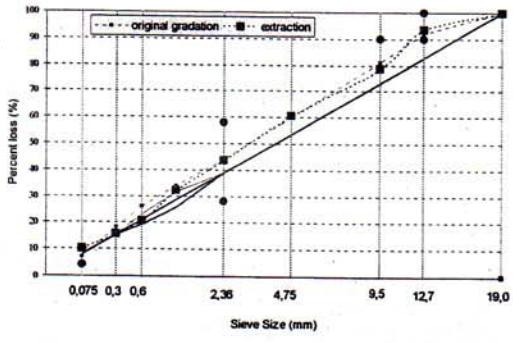

Figure 3 The gradation of original and extraction of ACWC upper Fuller line

From Table 1 it can be seen that for the ACWC upper Fuller line, the Marshall compaction process results a little bit segregation as shown by the percentage of the material passing the sieve # 200.The original design is 7% while the result of extraction gives 10%. This means that the tiny segregation of aggregate in mixture has occurred during the compaction process. When the extraction result is plotted into the gradation curve it can be seen that it still falls into the specification for the ACWC as shown in the Figure 3. These two findings may bring us into a fact that the use of Marshall compactor to predict the void at refusal density for the ACWC upper Fuller line should take 400 – 500 blows for each face of specimen.

IV. ACWC CROSSES FULLER LINE

For ACWC crosses the Fuller line, the relationship between number of blows and the void generated is shown in Figure 4. It can be seen that the value of void at the refusal density comes to 2.60%. When compared to the specification used in Indonesia where the minimum void at the refusal density, this value is something acceptable.

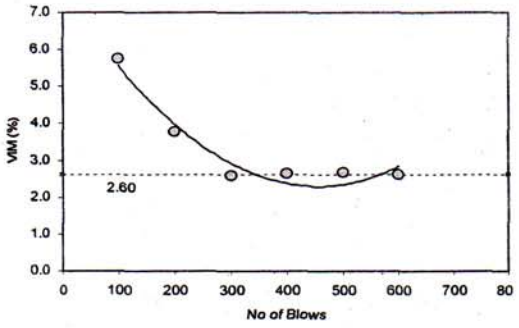

Figure 4 VIM vs No of Blows for ACWC upper Fuller line

Figure 4 also shows that the number of blows resulting void of 2.60% is started from 300. This means that from the point of view of void itself, 300–400 times of blows for each face of specimen using Marshall equipment can be used to predict void at refusal density. To accept this number of blows for predicting the void at refusal density, the further testing is to do extraction to see the possibility of sample gets segregation. The sample taken is the one which has been compacted for 400 blows of each face. The result is shown in Table 2 and illustrated in Figure 5.

Table 2
The result of extraction of ACWC upper Fuller line

Sieve Size		Original	Extraction	Unit
Inch	mm			
1"	25.4	100.0	100.0	% loss
3/4 "	19	100.0	93.9	% loss
1/2 "	12.7	93.1	91.7	% loss
3/8 "	9.5	83.9	80.1	% loss
# 4	4.75	53.1	69.9	% loss
# 8	2.36	32.6	58.0	% loss
# 16	1.18	22.2	41.9	% loss
# 30	0.6	15.4	25.8	% loss
# 50	0.3	11.2	19.1	% loss
# 200	0.075	7.4	10.7	% loss

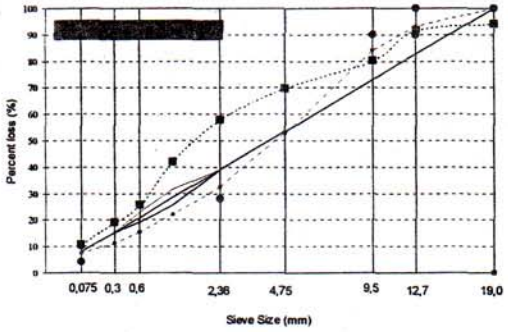

Figure 5. The gradation of original and extraction of ACWC crosses Fuller line

Table 2 shows that the segregation happens for nearly all of the aggregate sizes. For example at the size # 4 sieve the original gradation is 53.1% loss while after the extraction it is 69.9% loss. The same pattern is also occurred for sieves of #8, #16, #30, #50, and #200.

When compared it to the specification especially for gradation needed for the ACWC, it can be analyzed from Figure 5. It is seen that the gradation after extraction falls out of the control points. This means that the gradation of ACWC specimen after gets compacted cannot be accepted.

These two points would bring us to the fact that for ACWC crosses the Fuller line, the use of Marshall compactor to predict the void at the refusal density cannot be accepted.

V. DISCUSSION

The use of Marshall compactor for predicting void at refusal density is not proper decision even thought some institutions still allow it. The research has shown that by using this type equipment the void can be reached

but in the same time the segregation of aggregate is also occurred. If this equipment is still used for that purpose, it would result the bias prediction and furthermore the inaccurate design.

When using the specimen that gets segregation (in this case using Marshall compactor) for design, the prediction of bitumen content seems to be higher. This probably result the plastic deformation in its service life. As we know that plastic deformation is one of the main failures of bituminous mixture.

The segregation that is occurred during the compaction process is the result of excessive impact of Marshall blows. Based on the actual mechanism of compaction, it may be better to use the other type of compactor, for example gyratory compactor that tries to imitate the actual compaction of vehicle tires. Some parameters considered in this sort of compactor are compaction angle and also the stress generated that is about 580 kPa – 600 kPa for standard load. These two parameters are accommodated by gyratory compactor especially the one which is recommended by SHRP.

One interesting point that is drawn from the testing above is that the possibility of segregation on the coarser mixture is higher than that of finer one as shown by Figure 5 (ACWC crosses Fuller line, the coarser mixture) and Figure 3 (ACWC upper Fuller line, the finer mixture).

VI. CONCLUSIONS

Even though the samples are very limited, at least the trend of using the Marshall compactor can be concluded as follows:

a. The prediction of void at the refusal density for ACWC upper Fuller line can use the Marshall compactor by applying 400 – 500 blows for each face of specimen. However care should be taken especially the segregation that might happen during the compaction process. This has to be controlled by evaluating the gradation after compaction.
b. It is not reliable to use the Marshall compactor to predict the void at refusal density for ACWC crosses Fuller line, because the gradation after compaction is out of the specification.
c. Using Marshall compactor the segregation of coarser mixture is higher than that of finer one.

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