Some Insight into the Mixture Design of Large-Stone Asphalt Mixture for Airport Pavement

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ABSTRACT: In Japan recently large-stone asphalt mixtures have been introduced into the airport asphalt pavement to reinforce the pavement structure. So far they have been used as the base layer and/or the subbase layer materials. To reduce the rutting damages further and to prevent stripping between layers, it is expected to use the large-stone asphalt mixtures as the surface-base layer material. However, the raveling and cracking durability have not been thoroughly clarified. Therefore in the study a series of laboratory tests were conducted on the large stone asphalt mixture to evaluate the raveling and cracking characteristics in detail. For example, raveling tests were conducted to measure the groove deformation. Atmospheric exposure tests were performed to evaluate the asphalt deterioration characteristic. Same tests were also carried out on the conventional type asphalt mixture. Based on the test results, this paper focuses the effects of air void ratio in the large asphalt mixture on the bending strength-deformation, the raveling characteristics and the asphalt deterioration. It is found that there are suitable ranges of air void ratio to match the bending and raveling resistance to those of the conventional type asphalt mixture. Then the paper also suggests the appropriate air void ratio in the large-stone asphalt mixture for the surface-base layer.

KEY WORDS: Large-stone asphalt mixture, air void, bending, raveling, deterioration

1 INTRODUCTION

Recently in Japan, airport maintenance cost, especially asphalt pavement maintenance cost has gradually increased due to severe damages induced by heavy traffics. To reduce the rehabilitation works and costs, the use of large-stone asphalt mixture is expected because of its high rutting durability (e.g. Davis, 1988) and its inexpensive cost. The large-stone asphalt mixture contains the aggregates, the maximum size of which is generally larger than 20mm in diameter. Its interlocking effects induced by the large particles increase the rutting resistance. Moreover, executed by the thick lift method, the large-stone asphalt mixture costs lower than the conventional type asphalt mixture to achieve the prescribed thickness (Beagle, 1972).

In Japan so far the airport asphalt pavement has used the large-stone asphalt mixture as the base layer and/or the subbase layer materials. The maximum aggregate particle size of the conventional type asphalt mixture is usually 13 or 20 mm in diameter for the surface layer. To enhance the pavement rutting resistance, it is desirable to introduce the large-stone asphalt mixture as the surface layer material. However the raveling and cracking durability have not been thoroughly clarified. The severe raveling and cracking damages also prevent airplanes from running safely on runways and taxiways. Therefore, the raveling and cracking characteristics in addition to the rutting characteristic should be investigated in detail to establish the appropriate mixture design for the airport asphalt pavement.

In view of the mentioned above, in the study a series of laboratory tests were conducted on the large-stone asphalt mixture. The tests were also carried out on the conventional type asphalt mixtures. Based on the test results, this paper focuses the effects of air void ratio in the large-stone asphalt mixture on the bending strength-deformation, the raveling characteristic and the asphalt deterioration. Then the paper also suggests the appropriate range of air void ratio in the large-stone asphalt mixture for the surface-base layer.

2 TESTED MARTERIALS

Rectangular specimens of four types of asphalt mixtures named as LG30, DG13, DG20 and CG20 were made for laboratory tests. LG30 is the large-stone asphalt mixture, maximum aggregate size of which is 30mm in diameter. DG13, DG20 and CG20 are the conventional type asphalt mixtures. DG13 and DG20 are the dense graded asphalt mixtures for the surface layer. The maximum aggregate size is 13 or 20mm in diameter respectively. CG20 is the coarse graded asphalt mixture for the base layer. The maximum aggregate size is 20mm. LG30, DG13, DG20 and CG20 had different aggregate gradations as shown in Fig. 1. The gradation LG30 shown in the figure satisfies the ASTM D3515 specification, while the gradations DG13, CG20 and CG20 satisfy the Japanese specifications (CAB, 1999) required for the airport pavement.

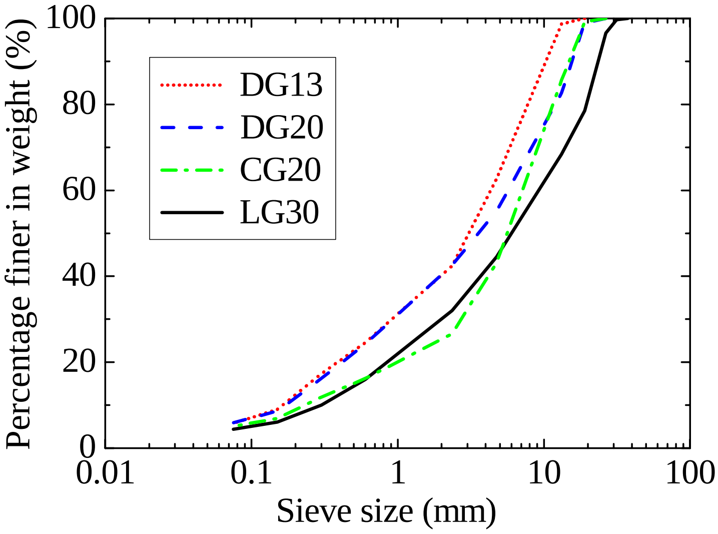

Figure 1: Aggregate gradations of LG30, DG13, DG20 and CG20

The LG30 rectangular specimens 300*300 mm in width and 100 mm in thickness were made in the following way. First, the aggregates were mixed well with straight asphalt 60/80 at the temperature range 150-160 degrees in centigrade. Various contents of the straight asphalt were attempted for the mixtures. Then each mixture was compacted with a roller inside a stiff box. The compaction was performed until the mixtures achieved desired air void ratios. The desired air void ratios were in advance determined based on the asphalt content – air void ratio relationship as shown in Fig. 2. The relationship was able to be derived from the compaction tests in which specimens 152 mm in diameter and 95 mm in height were made by 112 blows of a 10.2 kgf weight rammer fallen from the constant height 45.7 cm. The compaction energy per unit volume E_c calculated by the following equation is equal to that given for the traditional Marshal specimen.

$$E_c = \frac{W_R \cdot H \cdot N_B}{V} \qquad (1)$$

where W_R: rammer weight
H: falling height
N_B: blowing numbers
V: specimen volume

The rectangular specimens 300*300 mm in width and 50 mm in thickness were also made for DG13, DG20 and CG20. The specimens were made in a similar way as those of LG30, but the aggregates were mixed with the straight asphalt 60/80 at the optimum content. The optimum asphalt contents for DG13, DG20 and CG20 were determined by conducting Marshal-stability tests according to Japanese specification (CAB, 1999). The targeted air void ratios required for the roller compaction were also obtained from the Marshal specimens having the optimum asphalt contents.

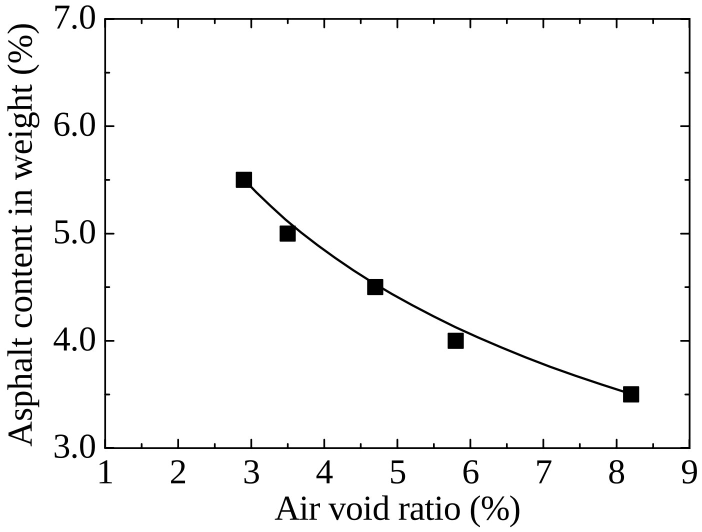

Figure 2: Asphalt content – air void ratio relationship of LG30 obtained from the compaction tests

3 RUTTING AND BENDING CHARACTERISTCS

Effects of air void ratio on the rutting characteristic of LG30 were investigated by conducting the wheel tracking tests. The wheel tracking tests were also conducted on DG13 and DG20 based on the test specification JRA, 1988. The test results provided the dynamic stabilities *DS* of LG30 having three different asphalt contents as well as those of DG13 and DG20 having the optimum asphalt contents. Fig. 3 shows the relationship between *DS* and the air void ratio in the three kinds of asphalt mixtures. It is found in the figure that *DS* of LG30 increases with the increase of the air void ratio. It is also found that even though the specimen LG30 is thicker than the specimens DG13 and DG20, *DS* of LG30 is larger than those of DG13

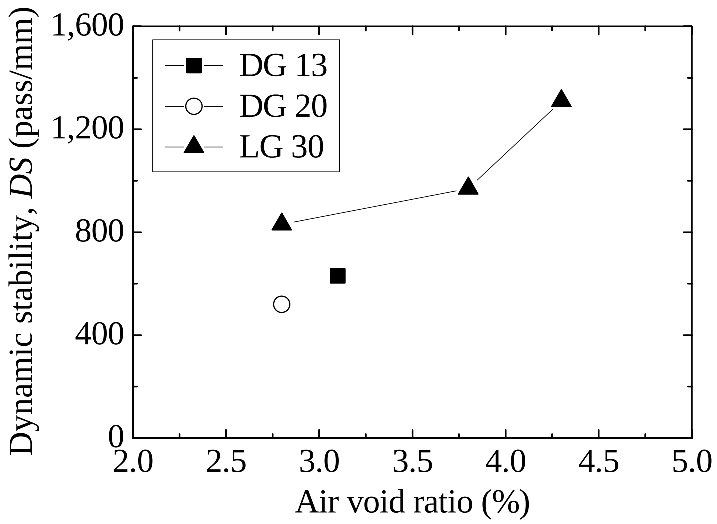

Figure 3: Dynamic stability–air void ratio relationships of DG13, DG20 and LG30.

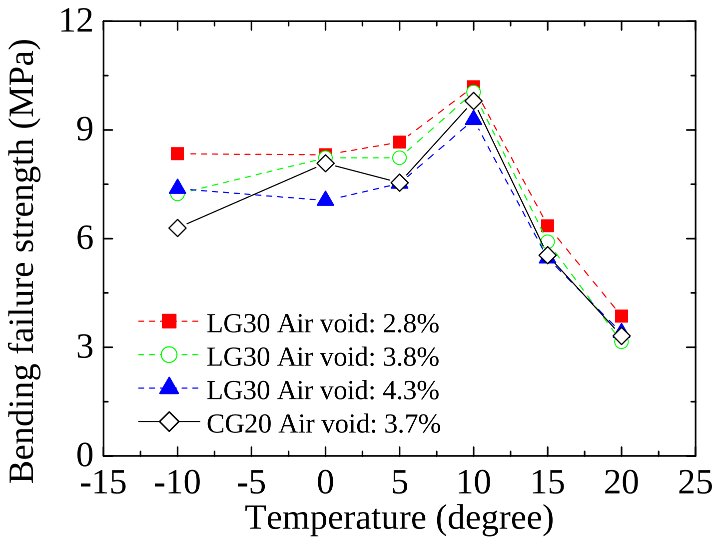

Figure 4: Bending failure strength-temperature relationships of LG30 and CG20

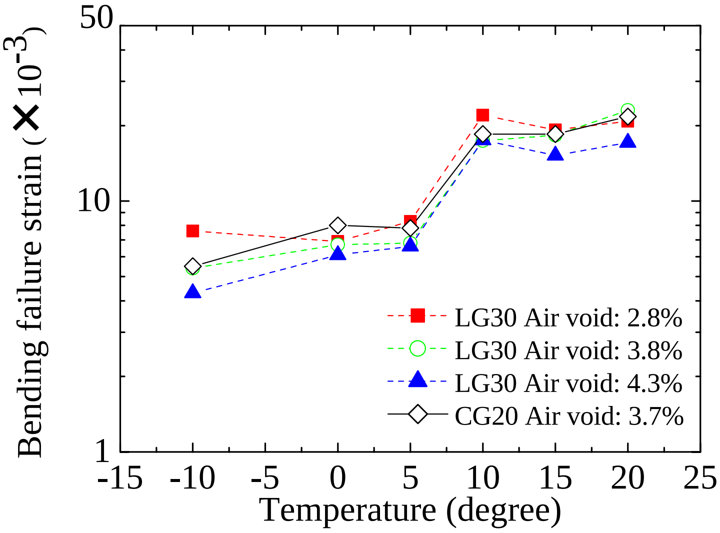

Figure 5: Bending failure strain-temperature relationships of LG30 and CG20

and DG20 at the same air void ratio. The fact indicates that the rutting durability of the large-stone asphalt mixture is still higher than those of the conventional dense graded asphalt mixtures even if the large-stone asphalt mixture is designed to have the same air void as that of the conventional dense graded asphalt mixture having the optimum asphalt content.

Effects of the air void ratio on the bending characteristic of LG30 were investigated by conducting the static bending tests. The specimens 50mm in width, 50mm in thickness and 300mm in length were obtained by cutting the roller compacted specimens into several pieces. The tests were performed at the temperatures of -10, 0, 5, 10, 15 and 20 degrees in centigrade. The loading displacement rate was 50mm per a minute. The bending tests were also performed on CG20 having the optimum asphalt content.

Fig. 4 shows the bending failure strength - temperature relationships of LG30 and CG20, while Fig. 5 shows the bending failure strain - temperature relationships. The effects of air void ratio are found in the figures on the failure strength and the strain of LG30. The effects become significant at the low temperatures. The failure strength and strain of LG30 tend to decrease with the increase of air void at the temperatures lower than 10 degrees in centigrade. It is also found in the Fig. 5 that the failure strains of LG30 having the air void 4.3% are significantly smaller than those of CG30. The fact indicates that the crack durability of the large-stone asphalt mixture might be inferior to that of the conventional coarse graded asphalt mixture if the large-stone asphalt mixture was designed to have the air void ratio larger than that of the conventional coarse graded asphalt mixture.

4 RAVAELING AND DETERIORATION CHARACTERISTCS

In Japan, grooving is usually formed on the top surface of runway to enhance the friction between the tire and the asphalt mixture. If the grooves were damaged by the effect of raveling, the friction decreased so that the airplane could not run safely especially at rainfall. Then the raveling durability becomes more important for the large-stone asphalt mixture of the surface-base layer. Therefore raveling tests were performed to measure the groove deformation of LG30. The grooving was performed as shown in Fig. 6 on the surface of the roller compacted specimens. There were seven grooves in total and each groove was 6mm in width, 300mm in length and 6mm in depth. Each raveling test was performed for an hour at the temperature of zero degree in centigrade. The chain wheel shown in the Fig. 6 made 200 rotations per a minute. The groove deformation was measured with the non-contact displacement transducer along the specimen centerline as 0, 2, 5, 10, 30 and 60 minutes had passed since the start of the raveling test. The typical groove deformation measured just before and after the test was shown in Fig. 7. Same raveling tests were also conducted on DG13 and DG20 having the optimum asphalt contents.

The raveling tests provided the change of the groove depth against the elapsed test time. Fig. 8 shows the relationship between the average loss of the groove depths and the elapsed time. It is found in the figure that the average groove depth of LG30 decreases with the increase of the elapsed time, that is, with the increase of the wheel rotation numbers. It is also found that LG30 having the air void ratio 4.3% shows the rapid loss of the groove depth compared with DG13 and DG20. The groove depth of LG30 having the air void ratio 3.8% also decreases rapidly at the early stage. The air void ratios 4.3% and 3.8% are larger than that of CG20 (see Figs. 4 and 5). Therefore it should be noted that the air void ratio in the large-stone asphalt mixture for the surface-base layer should be carefully designed not to exceed the air void ratio of the conventional coarse graded asphalt mixture from the point of the raveling durability.

Figure 6: Specimen and a chain wheel for raveling test

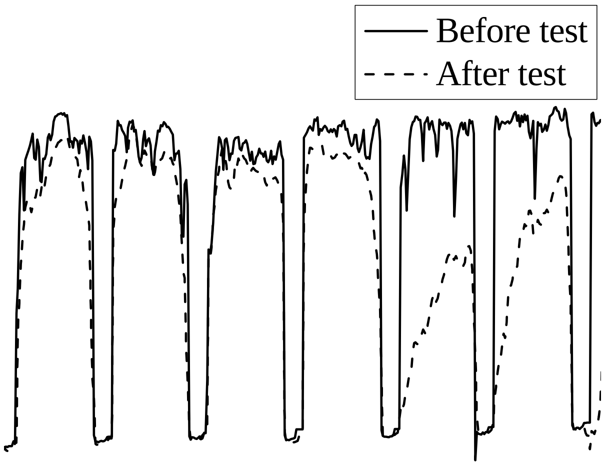

Figure 7: Example of the groove deformation measured with a non-contact displacement transducer

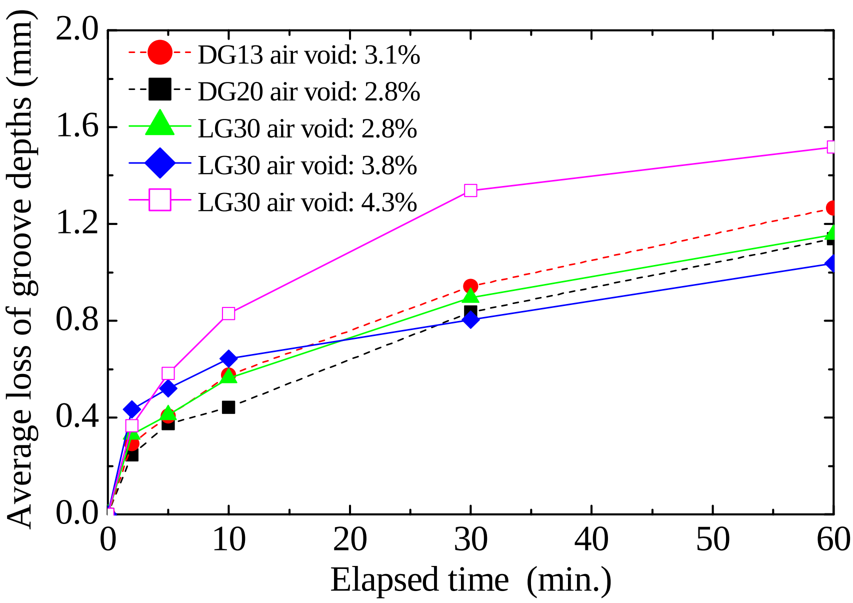

Figure 8: Average loss of the groove depths and the elapsed time relationships

Figure 9: Specimens for atmospheric exposure tests

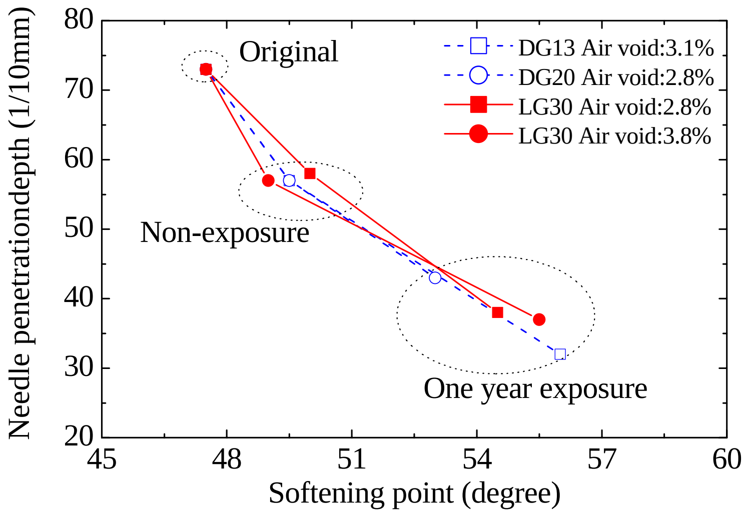

Figure 10: Needle penetration depth and softening point relationships

Atmospheric exposure tests as shown in Fig. 9 were carried out on the roller compacted specimens. The tests were performed on LG30, DG13 and DG20. When one year had passed since the start of the exposure test, the consistency of the asphalt in the exposure specimens was investigated as follows. First, the asphalt mixtures ranging from the exposure surface to 10mm depth of the specimens were retrieved. Then the asphalt in the mixtures was extracted with the Abson method. Needle penetration tests and softening point tests were conducted on the extracted asphalt. These two kinds of asphalt consistency tests were also carried out on the asphalt extracted from the non-exposure specimens. The asphalt in the non-exposed specimens was extracted soon after the specimens were prepared with the roller-compaction.

The relationships between the needle penetration depth and the softening point obtained from the above test results are shown in Fig. 10. The needle penetration depth - softening point relationship of the non-used asphalt is also plotted as “original” in the figure. It is seen that the needle penetration depths of LG30 decrease and the softening points increase by the effect of the atmospheric exposure. However the degree of the change of the asphalt consistency indices of LG30 is similar to those of the DG13 and DG20 regardless of the air void ratio values.

The static bending tests were performed on the specimens 50*50*300mm obtained from the one-year exposure specimens. The tests were done at the temperatures of -10, 0 and 10 degrees in centigrade. Each bending specimen was set on the apparatus so that the exposure surface was subjected to tension force.

Fig. 11 shows the bending failure strain - temperature relationship obtained from the bending tests. It is found that the bending strains of the exposed specimens shown in the Fig. 11 are smaller than those of the non-exposed specimens shown in the Fig. 5. This is mainly due to the effects of the asphalt deterioration described above. However, it is also found in the Fig. 11 the bending failure strains of LG30 are similar to those of the DG13 and DG20. Therefore it can be concluded that the atmospheric exposure damages on the large-stone asphalt mixture are no greater than those on the conventional type asphalt mixture.

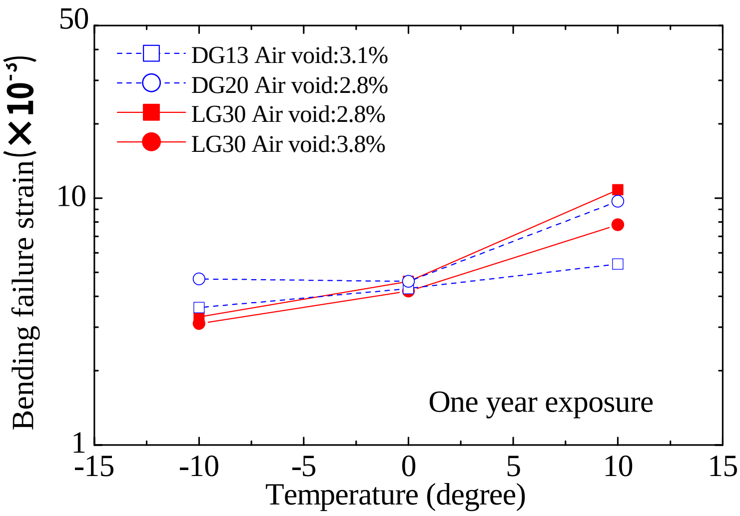

Figure 11: Bending failure strain-temperature relationships of the exposure specimens

5 SUMMARY

In this study, raveling, bending, atmospheric exposure tests in addition to wheel tracking tests were conducted to investigate the large-stone asphalt mixture durability for airport pavement. Then the effects of air void ratio on the raveling, bending and asphalt deterioration characteristics as well as the rutting characteristic were clarified. It is found that the bending and raveling durability become important rather than the asphalt deterioration characteristics for the surface-base layer. Then the raveling and bending test results suggest that the large-stone asphalt mixture for the surface-base layer should be designed to have the air void ratio no greater than that of the conventional coarse graded asphalt mixture having the optimum content.

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