Comparison of Hot Mix Asphalt Mixture Design between Japan and the U.S.

Nagaoka University of Technology Member Osamu Takahashi

Introduction

For an year through 2005, the author have had the opportunity of staying at National Center for Asphalt Technology (NCAT) for studying the present situation of hot mix asphalt (HMA) design procedure in the U.S. This paper intends 1) to introduce the current mix design practice in the U.S. 2) to make clear the difference of mix design procedure between Japan and the U.S., and 3) to try to activate the study for HMA mixture design in our paving society.

Prior to SHRP project taking place, most of State Highway Departments in the U.S. had used to depend on Marshall design method for HMA, although some states had taken up Hveem method instead. Near the end of SHRP project, research efforts were integrated to Superpave and since then, most of HMA projects in the U.S. have been designed by means of Superpave mix design procedure. In this paper, permissible limits of aggregate gradation in the U.S. are shown comparatively with Japanese limits. Also, it is demonstrated that the design criteria for determining optimum binder content even for Marshall mix are not same between Japan and the U.S. and the differences are illustrated. Lastly, on-going study about performance evaluation between Marshall mix and Superpave mix in the U.S. is introduced to facilitate understanding of a leading research work being carried out in the U.S. This paper is only dealt with dense-graded HMA.

Comparison of Aggregate Gradation

Aggregate gradation is one of basic factors that control the physical properties of HMA mixtures. **Table 1** illustrates the standard proportion of 19.0 mm maximum aggregate size of dense-graded HMA mixture extracted from manuals by Asphalt Institute (AI)[1] and Japan Road Association (JRA)[2]. The standards are expressed by the upper and lower grading limits, namely, limiting some permissible ranges. Designer has to decide percentage of each aggregate so that the gradation line falls into inside of all specified ranges. In general, each median of the permissible range is taken as the target gradation value of the sieve size, yet the target gradation based on the medians of the range is not necessarily optimum. In any event, normal practice for selecting aggregate percentage is common for both countries.

Figure 1 illustrates all of these standard ranges and the median of those for 19.0 mm. The permissible boundary of U.S. standard is wider than that of Japanese standard. The permissible range of Japanese standard is almost included in that of U.S. standard and is located in the upper part. Judging from these features, the median line of Japanese standard is located at the upper part of U.S. line. When the maximum density line (MDL) is drawn on the 0.45 power chart, the median line of Japanese standard is located at upper than MDL and the median line of U.S. standard is located lower than MDL. It means that the target gradation in Japanese mix design is more biased to 'fine' proportion of gradation band compared with that in U.S. mix design.

Table 1 Comparison of aggregate gradation for 19.0 mm dense-graded HMA

Sieve size	The U.S.		Japan	
	Range	Median	Range	Median
25.0	100	100	100	100
19.0	90 – 100	95.0	95 – 100	97.5
12.5	***	***	75 – 90	82.5
9.5	56 – 80	68.0	***	***
4.75	35 – 65	50.0	45 – 65	55.0
2.36	23 – 49	36.0	35 – 50	42.5
0.6	***	***	18 – 30	24.0
0.3	5 – 19	12.0	10 – 21	15.5
0.15	***	***	6 – 16	11.0
0.074	2 – 8	5.0	4 – 8	6.0

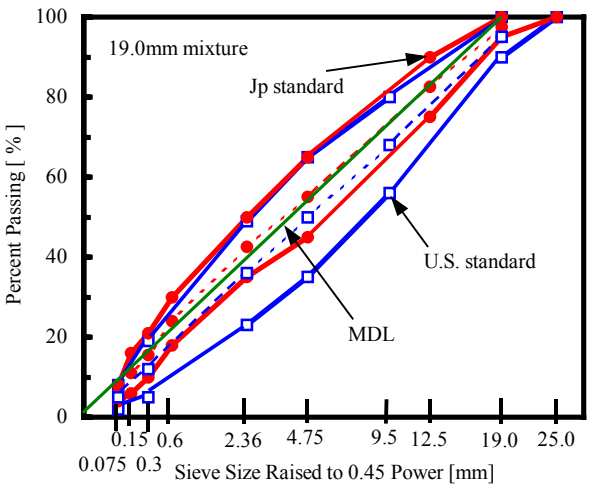

Figure 1 Comparison of gradation standard for 19.0mm HMA

KeyWords : hot mix asphalt, dense-graded, Marshall mix design, Superpave mix design

Adress : 1603-1, Kamitomiokamachi, Nagaoka, Niigata 940-2188 ***E-mail :*** roadman@vos.nagaokaut.ac.jp

Comparison of Marshall Mix Design between Japan and the U.S.

A current manner of Marshall mix design is roughly divided into the following procedures: source acceptance test, specimen preparation, stability and flow test, density and voids analysis, and interpretation of test data. The flow of design procedures used Marshall mix design is basically same in both countries. However, the tests required for source acceptance evaluation, analysis of test result, and interpretation of test data are different.

All of test results are to be analyzed for obtaining most suitable design asphalt content. **Table 2** shows Marshall mix design criteria recommended by AI and JRA, respectively. Neither VMA requirement nor classification for lighter traffic is provided in JRA, but the requirements for medium and heavy traffic are almost identical for both criteria. The acceptance range of VFA by AI depends on the traffic classification and all the ranges are somewhat lower than that by JRA. Moreover the acceptance ranges of air voids and VFA by JRA show slightly wider than those by AI.

The difference of mix design may be said as a different approach in seeking the design asphalt content. In other words, the design asphalt content is determined on the basis of the design criteria and the field condition of the project, which is common for both procedures. The design asphalt content is established at 4.0 percent of air void in the U.S., whereas the design asphalt content is determined mainly on the basis of air void and VFA, occasionally adding with results of wheel tracking test and bending test in Japan. In any case, the design asphalt content depends deeply on the experience of design engineer.

When the design asphalt content is decided, sample specimens are prepared with the design asphalt content and evaluated whether all requirements are fully satisfied. Water susceptibility evaluation by indirect tensile test is usually performed in the U.S., but it is not conducted in Japan. According to mix design practice in Japan, bulk specific density of replicated sample is usually calculated from dry weight and submerged weight based on the assumption that the surface of sample by dense-graded HMA mixtures is smooth. Theoretical maximum density of mixture is derived from ‘theoretical calculation’ using percentage and specific gravities of individual ingredients, and not from actual measurement. The accuracy of volumetric properties calculated from the bulk specific density and the theoretical maximum density need to be assessed and discussed further. Currently in Japan, air voids and VMA are likely to be not prime concern during mix design. In comparison with the situation in the U.S., more research should be conducted to prescribe these properties more strictly in the design specification in Japan.

Comparison between Marshall Mix and Superpave Mix

The significant difference of the mix design between Marshall and Superpave is regarded as the compaction method for making HMA samples. The field temperature should be specified as one of design conditions in Superpave mix design procedure. It is generally well known that the design asphalt content with Superpave mix tends to be lower than that with Marshall mix, even if the mix design is carried out under the same design conditions. An engineer’s great concern is either pavement by Marshall mix or Superpave mix will last longer on actual service road. According to the recent NCAT research[3], both mixes exhibit almost similar quality and the difference in rutting susceptibility and cracking resistance can not be found between them during four years’ actual service. This conclusion was brought by the test data obtained from exactly same traffic condition. Further investigation for longer period is expected with great interest.

References

1) Asphalt Institute : Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types, Manual Series No.2 (MS-2) Sixth Edition, 1993.
2) Japan Road Association : Manual for Asphalt Pavement, 1989.
3) D. E. Watson and E. R. Brown : Comparison of Superpave and Marshall Mix Performance in Alabama, TRB 2005 Annual Meeting CD-ROM, 2005.

Table 2 Comparison of Marshall mix design criteria between Japan and the U.S.

Item	The U.S.			Japan	
Traffic class	Light	Medium	Heavy	Medium	Heavy
No. of blows	35	50	75	50	75
Stability N	≧3336	≧5338	≧8006	≧4903	
Flow mm	2.03 – 4.57	2.03 – 4.06	2.03 – 3.56	2.0 – 4.0	
Air voids %	3 – 5			3 – 6	
VMA (19.0mm)	Vo=3%: ≧12.0	Vo=4%: ≧13.0	Vo=5%: ≧14.0	***	
VFA %	70 – 80	65 – 78	65 – 75	70 – 85	