CHEMICAL ENGINEERING TRANSACTIONS

VOL. 66, 2018

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Songying Zhao, Yougang Sun, Ye Zhou

ISBN 978-88-95608-63-1; **ISSN** 2283-9216

DOI: 10.3303/CET1866174

Anticorrosion MA Class Cast Asphalt Concrete Experimental Study of Flow Characteristics

Hongliu Rong[a,b,*], Yongjun Meng[b], Xiaoning Zhang[a], Jie Zhu[b]

[a]School of Civil Engineering and Transportation, South China University of Technology, Guangzhou 510640, China
[b]College of Civil Engineering and Architecture, Guangxi University, Nanning 530004, China
ronghongliu@sohu.com

GMA is a kind of brand-new anticorrosion MA class cast asphalt mixture mixing technology, and it will be used to solve the problem that steel deck plate paving of the Hongkong-Zhuhai-Macao bridge project is giant, the time limit for the project is tight and the environmental conditions can cause serious corrosion to steel deck. Using the EI fluidity test, evaluate its workability that is cast asphalt concrete of British system that simulated small cooker equipment and large cooker car to produce. Results show that small cooker equipment within 120min of mixing time and large cooker car within 270min of mixing time to produce GMA mixture fluidity are all less than 20s. This shows that large cooker car can extend the duration of mixing, and be advantageous to the organization construction. At the same time, it also shows that simulated small cooker equipment can also produce considerable liquidity of cast asphalt mixture as large cooker car and can reduce material consumption on the phase of the experimental study.

1. Instructions

Bridge steel deck plate paving area of Hongkong-Zhuhai-macao is 520000 square meters and is the largest steel bridge deck pavement engineering under construction in the world. After fully research, eventually we choose MA class cast asphalt mixture that has been successfully applied to Hongkong area as the recommendations of Hongkong-Zhuhai-Macao bridge. The structure of the upper is the SBS modified asphalt concrete that the thickness is 4cm, and the bottom is MA class cast asphalt concrete that the thickness is 3cm. Hongkong uses the traditional British MA class cast asphalt concrete technology (Yang et al., 2009), its manufacturing processes is that it first blend asphalt, mineral powder and fine aggregate to form asphalt mortar, then add the coarse aggregate to it, and last blend it to form the finished product. But the mixing time is too long (4 to 6 hours), and the production efficiency is low. It cannot very well meet the requirements of the huge amount of work and short construction time for the project. GA cast asphalt concrete technology which headed by Germany and Japan uses forced-mixing asphalt plant to blend all the raw materials of asphalt concrete (“RStO 01”, 2001; “ZTV Asphalt- StB”, 2001). The production efficiency of this kind of technology is high, but the performance of GA cast asphalt concrete is worse than the traditional English GA cast asphalt concrete(Chen et al., 2001).

In order to give full play to the advantages of stable performance of GA cast asphalt concrete and high efficiency of GA cast asphalt concrete, using GA cast asphalt concrete technology manufacture bituminous mixture which conforms to the traditional English MA cast asphalt concrete. The technology is referred to as "GMA”, and this paper calls it as new MA cast asphalt concrete. This new GMA technology will be used in the bottom structure of steel bridge deck of Hongkong-Zhuhai-Macao bridge. In order to guarantee the quality of pavement and prolong service life, it is necessary to conducted the thorough research about flow characteristics of GMA mixture.

2. Effects Profile of Mixing Process on Ma Class Asphalt Mixture

The construction temperature of MA class cast asphalt mixture is between 180 ℃ and 240 ℃(Luo et al., 2013). And comparing to the construction temperature of ordinary asphalt mixture which is about 150 ℃, the maximum temperature difference is up to 90 ℃. So the construction temperature of cast asphalt mixture is defined as super hot temperature. While cast asphalt concrete was added into large cooker car to mix, the relationship between flow characteristics with mixing time was shown in Figure 1. As shown in Figure 1, according to the change of temperature, flow characteristics can be divided into two areas, and there are heating area and isothermal area respectively. The area I is heating area, and because the temperature sensitive of this area is strong, viscosity will decrease with the increase of temperature. Isothermal area also can be divided into the thixotropic area and aging area. During the time of this process, asphalt mixture will lead to aging and thixotropy under the condition of the super hot oxidation. The area II shows that viscosity will decrease with the increase of time, and the thixotropy is main performance. The area III shows that viscosity will increase with the increase of time, and the aging is main performance. In order to illustrate easily, the area II and area III are respectively called the aging area and the thixotropic area. In the thixotropic area, when mixing time is too short, it will lead to high viscosity due to absence of thixotropy, bad for paving, and it is also easy to cause deep rut deformation. In the aging area, when mixing time is too long, although it can significantly improve the high temperature stability, it will lead to too high viscosity to construct in actual construction. Meanwhile, it will greatly decrease the fatigue cracking resistance of concrete, and it is not conducive to achieve the purpose of long-term durability of the steel bridge deck pavement design.

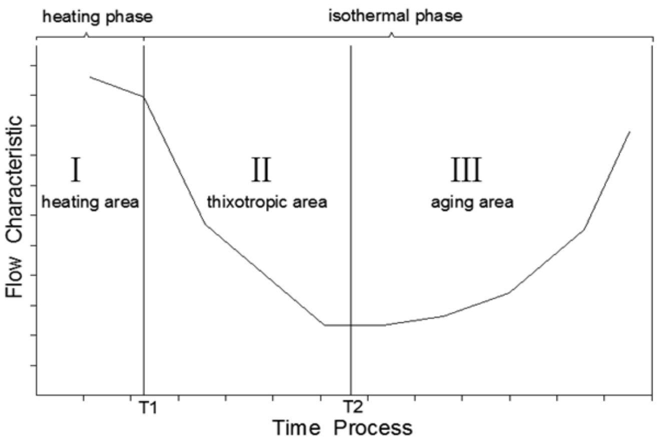

Figure 1: Flow Characteristics of Cast Asphalt Mixture with the Changing of Mixing Time

3. Mixing equipment of ma class asphalt mixture

The premise of the research on the flow characteristics of the mixture is to determine the proper mixing equipment. Larger cooker car which has the function of mixing, transportation and preservation in engineering can produce cast asphalt mixture, as shown in Figure 2. Due to the less demand of the mixtures that produce by large cooker car, it is high cost and low efficiency to use the mixtures by studying the indoor experimental performance of MA mixture. Liwen Zeng and his partner have developed the small cooker blending equipment that simulates production conditions of MA mixture, as shown in Figure 3.

Figure 2: Larger Cooker Car

Figure 3: Simulated Small Cooker Equipment

Small cooker mixing equipment is divided three parts:

(1) Mixing Pot. The mixing pot is similar to forced cement concrete mixing system. The one-time maximum mixture amount of the mixing pot can be up to 200 kilograms, and the best amount which lets mixture fully contact to the mixing blade is about 100 kilograms.

(2) Heating System. Small cooker mixing device contains heating sheet on wall which heats up mixtures and temperature control equipment that monitors and adjusts to the mixing temperature at any time.

(3) Mixing Frequency Control System. This small cooker equipment can well simulate the mixing situation which uses the large cooker car to mix in the actual construction process.

4. Ma Asphalt Mixture and Its Construction Performance Evaluation Method

The asphalt cementing material is comprised of 70% natural lake asphalt(TLA) and 30% ordinary Esso A-70 asphalt. The coarse aggregates use granite from Guangdong Zhaoqing Guitian quarry, and both fine aggregates and mineral power use limestone. All raw materials performance indicators are qualified after testing (“EN 13108-6”, 2006). The research believed that the British MA can obtain excellent performance which has great relationship with the MA preparation method from many successful cases. The preparation of MA fillers and fine aggregates is very meticulous, and it is divided into into four class materials that is A(0.075~2.36mm), B(0.075~0.6mm), C(0.075~0.212mm) and D(equal to or less than 0.075mm) for quality control. MA preparation method has great difference from GA and other asphalt mixtures preparation methods, so the quality stability of the MA mixture is very good. MA class cast asphalt concrete gradation composition are shown in Table 1.

Table 1: MA Class Cast Asphalt Concrete Gradation Composition

Material Specification	10~14 mm	5~10 mm	2.36~5 mm	Fine Aggregate A	Fine Aggregate B	Fine Aggregate C	Mineral Powder	Soluble Asphalt	
								TLA	A-70
Quality Percentage (%)	5.40	36.44	3.16	7.34	1.72	19.44	14.44	8.44	3.62

In China, the fluidity of the cast asphalt concrete is tested by the El fluidity test method. The test method is as follows: place the mixing of the sample into the barrel along the edge of the barrel, then put the hammer into the positive center perpendicular to the surface of the sample through the support of the inverted hole when the sample reaches the target temperature, finally drop down 995 grams of copper hammer and record the time “T” that the hammer falls through two scale lines by its weight, and record the sample temperature at this time. And the “T” is the fluidity. Usually the same set of tests need to be carry out in three parallel experiments. According to the provisions of the “highway steel bridge deck pavement design and technical guide for the construction” in our country, the fluidity should be less than 20s when its temperature is controlled at 240℃ (“JTG E20-2011”, 2001).

5. The Fluidity Performance Analysis of Cast Asphalt Mixture Which Use Simulated Small Cooker Equipment to Manufacture

5.1 The Influence of Blending Time on Flow Performance

In order to measure the influence of the blending time to the fluidity of MA asphalt mixture in details and quantity, we adopted the target gradation composition as said previously and mixed asphalt, mineral powder and fine aggregate proportionally to put them in the small cooker equipment. After stirring for ten minutes, we added coarse aggregate to stir 30 minutes again, then we started to record time. Under 220℃ and 240℃ temperature conditions, the test for the fluidity of GMA showed different results according the gradual changing stirring time. And the results are showed in the table 2.

Table 2: Results of the Fluidity Test

Blending Time (min)		30	60	90	120	150
Fluidity (s)	220℃	11.6	5.7	9.5	18.8	36.5
	240℃	6.2	4.2	5.4	15.1	55.9

As showed in the figure 4, the values of cast asphalt mixture fluidity which is manufactured by simulated small cooker equipment are all less than 20s during 120 minutes of stirring. The value is minimal in the interval of

45~90 minutes, after more than 90 minutes the value increases dramatically. It also shows that the relationship between the fluidity of cast asphalt mixture and stirring time is a U-shaped curve. In the early stage of the mixing, it exists strong thixotropy phenomenon, the structure of mixture is damaged by shearing action. And the shear failure rate was faster than its structure generation rate, thus the values of cast asphalt mixture fluidity reduces constantly with the increasing of blending time. But in the later stage of mixing, because the influence of the aging effect increases gradually, molecule in the asphalt volatilizes and polymerizes into macro molecular substances, and it can increase the micro-force between the molecule and particle. Therefore, the viscosity and the fluidity of asphalt mixture increase, and flow performance decreases gradually.

5.2 The Influence of Mixing Temperature on Flow Performance

MA asphalt mixture is rheological materials, theoretically, with the raising of temperature, the fluidity of MA asphalt mixture should increase. At the same time, at a high temperature, the fluidity would be affected by the aging action of asphalt mixture. It means that stirring temperature is a significant factor that will affect the fluidity of MA asphalt mixture (Tian et al., 2012). As illustrated in the figure 5, in the early stage of stirring, MA asphalt mixture workability shows sheared dilution behavior and the EL value decreases gradually. In contrast, in the late stage, affected by the aging action of asphalt mixture, the fluidity decreases and the EL value increases. On the whole, the relationship between the fluidity and blending time is a U-shaped curve. In the early stage, the fluidity of MA asphalt mixture which stirs at 240℃ is better than its that stirs at 220℃. But the higher stirring temperature is, the faster aging rate is. Affected by rapid aging, the fluidity of MA asphalt mixture which stirs at 240℃ is worse than its that stirs at 220℃ in the later stage.

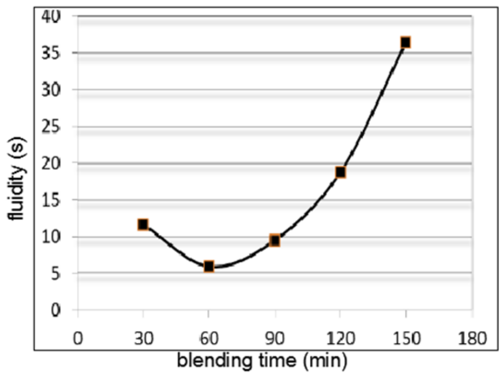

Figure 4: The Relational Graph of the Fluidity and Blending Time

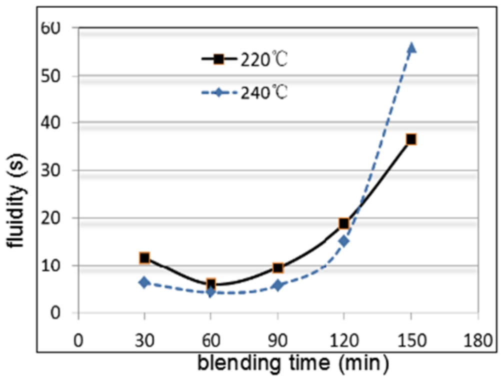

Figure 5: The Relational Graph of the Fluidity and Blending Temperature

6. The Fluidity of Cast Asphalt Mixture Impact Analysis Based on Large Cooker Car

6.1 The Influence of The Blending Time on Flow Performance

In order to quantitatively analyze blending time effects on the fluidity of MA asphalt mixture, we adopted the aforementioned target gradation composition, and put the asphalt, mineral powder, fine aggregate and coarse aggregate one after another into the large mixture plant by GMA process at the beginning of the blend, then added the mixture into the large cooker car, stirring and timing simultaneously. Every 30 minutes took samples to test the fluidity value after stirring 60 minutes. The test results are shown in Table 3.

Table 3: Results of the Fluidity Test

Blending Time (min)		60	90	120	150	180	210	240	270
Fluidity (s)	220℃	7	7	4	6	6	8	9	15
	240℃	3	6	5	4	5	6	15	18

As shown in Figure 6, the values of cast asphalt mixture fluidity which is manufactured by large cooker car equipment are all less than 15s during 270 minutes of stirring, meeting the requirements of construction. The value is minimal in about 120 minutes, after more than 240 minutes the value increases dramatically. The relationship of the fluidity of cast asphalt mixture and blending time is basically the same as the simulated small cooker equipment, which changes in a U-shaped curve roughly. In the early stage of the mixing, it exists strong thixotropy phenomenon, the structure of mixture is damaged by shearing action. And shear failure rate was faster than its structure generation rate, thus the values of cast asphalt mixture fluidity reduces constantly with the increasing of blending time. But in the later stage of mixing, because the influence of the aging effect increases gradually, molecule in the asphalt volatilizes and polymerizes into macro molecular substances, and macro molecular substances again polymerizes into molecular chain, and it can increase the micro-force between the molecule and particle. Therefore, the viscosity and the fluidity of asphalt mixture increase, and flow performance decreases gradually (Chen et al., 2011).

6.2 Influence of Mixing Temperature on Flow Performance

As shown in Figure 7, mixing temperature has a significant effect on the fluidity of MA cast asphalt mixture. In two groups of mixing temperature, both flow performance meets the requirements of construction. In the early stage, the fluidity of MA asphalt mixture which stirs at 240℃ is better than its that stirs at 220℃. But the higher stirring temperature is, the faster aging rate is. Affected by rapid aging, the fluidity of MA asphalt mixture which stirs at 240℃ is worse than its that stirs at 220℃ in the later stage. The relationship of the fluidity of cast asphalt mixture and mixing temperature is basically the same as the simulated small cooker equipment. The higher mixing temperature is, the gentler the fluidity with the blending time variation curve is. The lower mixing temperature is, the sharper the fluidity with the blending time variation curve is.

It shows that thixotropic effect of low mixing temperature is obviously higher than that of the high mixing temperature.

In conclusion, when mixing temperature is at 220℃ and 240 ℃ and blending time is at 0.5~4.5h, the fluidity of GMA mixture which manufactures by large cooker car varies between 5s and 15s. It shows that flow performance of mixture is better and more appropriate to the construction. When the blending time is at 0.5~3.5h, the fluidity fluctuation is relatively small, which is basically between 6s and 8s. When the blending time is over 4h, the fluidity increases obviously, which indicates that the aging rate of the mixture is accelerated. Only thinking from the construction workability, because of aging of the mixture, paving construction at 2~4h is more appropriate.

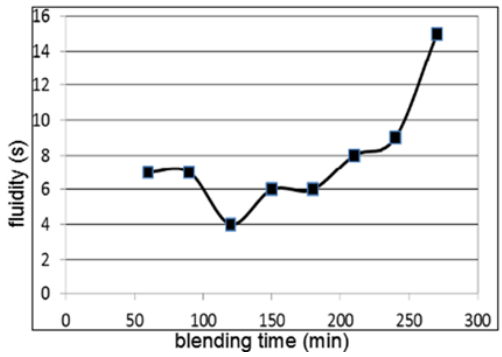

Figure 6: The Relational Graph of the Large Cooker Car's Fluidity and Blending Time

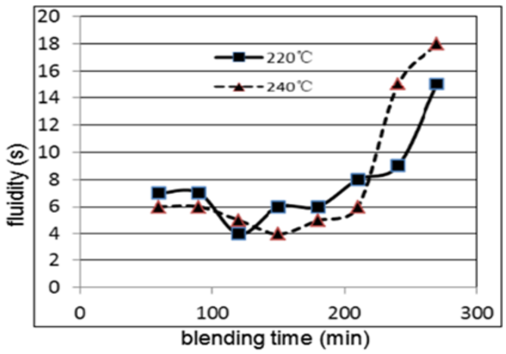

Figure 7: The Relational Graph of the Large Cooker Car's Fluidity and Blending Temperature Conclusion

The relationship of blending time and the fluidity of asphalt mixture which is respectively manufactured by larger cooker car and simulated small cooker equipment changes in a U-shaped curve roughly. In the early blending stage, affected by the thixotropy, flow performance becomes better gradually with the increasing of blending time. In the later blending stage, affected by aging effect, the viscosity increases gradually, therefore, flow performance decreases.

When comparing the degree affected by time, the fluidity of asphalt mixture which is manufactured by simulated small cooker equipment was significantly greater than that of larger cooker car. Simulated small cooker equipment and larger cooker car are significant differences in linear velocity, impermeability, capacity, etc, and it lead to different aging rate in the asphalt mixture. And it makes that the relationship of blending time and the fluidity of cast asphalt mixture which is manufactured by simulated small cooker equipment basically changes in a sharped U-shaped curve, however, the relationship of larger cooker car basically changes in a gentle U-shaped curve.

The values of cast asphalt mixture fluidity which is manufactured by simulated small cooker equipment during 120 minutes of stirring and by larger cooker car during 270 minutes of stirring are all less than 20s. Because the suitable blending time of larger cooker car is far longer than that of simulated small cooker equipment, it is convenient for construction. Adjust the preparation technology parameters properly and simulated small cooker equipment also can manufacture the cast asphalt mixture which construction workability is almost same with the larger cooker car.

Acknowledgments

This research was supported by Guangxi Natural Science Foundation (serial number: 2014jjBA60003).

References

Agostinho B., Cátia D., Ana A.C., Tiago C., Raul P., 2015, Design and performance of a warm high-modulus asphalt concrete, Journal of Cleaner Production, 95, 55-65, DOI: 10.1016/j.jclepro.2015.02.057

Ambika B.S., Chandra., 2017, Aging Characteristics of Warm-Mix Asphalt Binders, Journal of Materials in Civil Engineering, 29(10), DOI: 10.1061/(ASCE)MT.1943-5533.0002013

Bražiūnas J., Sivilevičius H., 2010, The bitumen batching system's modernization and its effective analysis at the asphalt mixing plant, Transport, 25(3), 325-335.

Chang F.Q., Xia W.C., Jen Y.J., Ping Z.Z., Min Z., Sheng Z.S., 2013, Aging properties and mechanism of the modified asphalt by packaging waste polyethylene and waste rubber powder, Polymers for Advanced Technologies, 24(1), 51-55, DOI: 10.1002/pat.3048

Chen J.S., Liao M.C., Huang C.C., 2011, Evaluation of Guss Asphalt Applied to Steel Deck Surfacing, T&DI Congress 2011 © ASCE, 462-471.

Chen J.S., Liao M.C., Huang C.C., Wang C.H., 2011, Fundamental Characterization of Engineering Properties of Gussasphalt Mixtures, Journal of Materials in Civil Engineering, 23(12), 1719-1726.

Hisham Q., Ibrahim A., 2016, Effect of bitumen grade on hot asphalt mixes properties prepared using recycled course concrete aggregate, Construction and Building Materials, 121, 18-24, DOI: 10.1016/j.conbuildmat.2016.05.101

Jian Y.O., Yan L.H., Guo H.B., 2017, The rheological properties and mechanisms of cement asphalt emulsion paste with different charge types of emulsion, Construction and Building Materials, 147, 566-575, DOI: 10.1016/j.conbuildmat.2017.04.201

JTG E20-2011, Standard Test Methods of Bitiumen and Bituminous Mixtures for Highway Engineering, Beijing: China Communications Press.

Justas B., Henrikas S., 2010, The bitumen batching system's modernization and its effective analysis at the asphalt mixing plant, Transport, 25(3), 325-335, DOI: 10.3846/transport.2010.40

Luo S., Zhong K., Qian Z.D., 2013, Permanent Deformation Prediction of Steel Deck Pavements with Different ombinations, Journal of Tongji University (Natural Science), 41 (03), 397-401.

RStO 01(2001) Richtlinie fuer die Standardisierung des Oberbaues von Verkehrsflaechen (German Guideline for Pavement Design).

Sargın S., Saltan M., Morova N., Serin S., Terzi S., 2013, Evaluation of rice husk ash as filler in hot mix asphalt concrete, Construction and Building Materials, 48, 390-397, DOI: 10.1016/j.conbuildmat.2013.06.029

Tian Z.F., Fan X.H., Liu Y.Q., 2012, Introduction of full scale accelerated pavement test on asphalt practice, Shenyang: Northeastern University Press.

Yang J., Cong L., Zhu H.R., 2009, Analysis on Rutting Potential of Asphalt Pavement on The Steel Deck by Finite Element Method, Engineering Mechanics, 26(5), 110-115.

ZTV Asphalt- StB 01 (2001) Zusaetzliche Technische Vertragsbedingungen and Richtlinien fuer den Bau von Fahrbahndecken aus Asphalt (German Guideline for the Creation of Asphalt Layers).