Solid State Technology
Volume: 63 Issue: 6
Publication Year: 2020

Effect of Iron Powder as Filler Material on Characteristics of Asphalt

Winsyahputra Ritonga, Eddyanto, Muhammad Aswin Rangkuti
Departement of Phyisic, Universitas Negeri Medan, Jl. Willem Iskandar Psr V Medan 20221
E-mail : winsyahputra@unimed.ac.id

Abstract. The purpose of this study was to determine the effect of iron powder as filler material on the characteristics of asphalt. The research was begun by testing the physical properties of pure asphalt. These tests provided the necessary information needed in order to establish a baseline for further research, as well as to produce materials for testing. The next step was making a specimen of pure asphalt by mixing the bitumen, soft aggregate and coarse aggregate to an optimal asphalt content of 6%. From the specimen, six samples of asphalt were prepared. No modifications were made to the first sample. The remaining samples of asphalt were modified by adding iron powder as a filler in increasing percentages, as follows: 0,5%, 1%, 1,5%, 2%, and 2,5%. A Marshall Test was conducted on each sample to determine the characteristics of the asphalt samples, including stability, density, flow, VIM, VMA, and VFA. Based on the test results, it can be concluded that the addition of iron powder affected the physical properties of asphalt.

Keywords: *Asphalt Modified, Iron Powder, Marshall Test, Asphalt Characteristics, Physical Properties*

INTRODUCTION

One of the factors affecting the quality of the asphalt mixture is the cavity (pore) of the asphalt mixture. Cavities on asphalt and aggregate mixtures are one cause of road damage. Large asphalt cavities will cause water to easily enter through the pores of modified asphalt and aggregate which causes the bonds of asphalt and aggregate to become weak. The weakness of these asphalt bonds leads to rapidly damaged roads (Ghuzlan and Carpenter 2006, Netterberg and De Beer 2012).

Various modifications of asphalt are done to reduce asphalt cavity. Some researchers have used rubber as a material to modify asphalt (Chiu 2008, Fontes et al. 2010, Liang et al. 2015, Liu et al. 2009). The addition of rubber aims to improve the quality of asphalt by reducing asphalt cavity in the mixture. The addition of resin as a binder is another alternative to improving the quality of asphalt (Jeong et al. 2010). Asphalt modification with chemical has also been carried out (Cubuk et al. 2009, Ouyang et al. 2005, Song et al. 2006). However, the results showed that there were still weaknesses in modified asphalt.

A breakthrough in reducing the asphalt cavity has been achieved by putting filler into the asphalt mixture and the aggregate (Navarro et al. 2009). The development of modified asphalt currently utilizes cement as a filler to improve the quality of the asphalt (Aksoy et al. 2005, Lu et al. 2009). One alternative material that has the potential to be filler in modified asphalt is iron powder. A test to determine whether iron powder can efficiently be used as an asphalt filler is required. Chemically, iron powder has excellent potential as a filler because it contains carbon element that allows interacting with Asphalt which is predominantly composed of also dominated by carbon. The interaction of carbon elements in the iron powder and asphalt is expected to produce strong bonds and increase asphalt quality.

METHODOLOGY

Materials used in this study include sand, gravel and iron powder as filler materials while the equipment included the following: thermometer, water bath, ring (made of brass material), steel ball, heater, brass ductility mold, ductility testing machine, pycnometer, glass vessel, Erlenmeyer flask, analytical balance, and mixer oven. The first sample is pure asphalt, while samples 2, 3, 4, 5, and 6 are mixtures of asphalt and iron powder. The primary methodologies used to test the samples were the penetration test and the Marshall test. These tests were conducted by penetration asphalt 60/70 standard.

The addition of filler was carried out from a concentration of 0 - 2.5% by weight of bitumen (USDT 2008). The composition of the asphalt, showing the addition of iron powder, can be seen in [Insert Table 1] below:

Table 1. Mixed composition of sample

Sample	Asphalt		Iron Powder
	gr	phr	%
1	2000	100	0
2	2000	100	0,5
3	2000	100	1
4	2000	100	1,5
5	2000	100	2
6	2000	100	2,5

This research began by testing the physical properties of pure asphalt, the base material under investigation. Subsequently, the preparation of each sample was completed by mixing bitumen, aggregate and iron powder at optimum bitumen content of 6%. The final stage of the research is marshall testing to discover the characteristics of the modified asphalt. All the tests in this study referred to American Society for Testing and Materials (ASTM) –D Standards .

RESULTS AND DISCUSSION

Testing of physical properties

The first phase of this research was testing the physical properties of asphalt (sample 1). The physical properties of asphalt included penetration, softening point, ductilit, specific gravity, weight reduction, penetration after weight loss and ductility after weight loss (ASTM-D6927–15, ASTM-D346-14, ASTM-D5/D5M–13, ASTM-D113–17). The results of physical properties test can be seen in [Insert Table 2] below:

Table 2. Test result of physical properties of pure asphalt

No	Type of Test	Pure Asphalt (Sample 1)	Standard	Result
1	Penetration (mm)	72,50	60-79	Fulfilled
2	Softening Point (^{0}C),	35,00	30-50	Fulfilled
3	Ductility (cm)	110,00	Min 100	Fulfilled
4	Specific Gravity	1,01	Min 1,0	Fulfilled
6	Weight Reduction (%)	1,00	Min 1,0	Fulfilled
7	Penetration After Weight Loss (%)	70,20	Min 45	Fulfilled
8	Ductility Reduction (%)	55,00	Min 50	Fulfilled

[Insert Table 2] shows the tests results across eight criteria. The tests verified that the pure asphalt specimen reached standard penetration 60/70. Therefore, the asphalt specimen is a proper base material for this research.

Physical properties of aggregate

The aggregate is an integral part of asphalt testing. Tests on aggregate included water absorption, density, and abrasion with los angles machine. Test results of aggregate physical properties can be shown in [Insert Table 3] below.

Table 3. Physical properties of aggregates testing results

No	Characteristics	Conditions	Result	Note
Coarse Aggregate				
1	Water Absorption	max. 3%	0.751	Reached
2	Bulk Specific Gravity	min. 2.5 gr/ml	2,669	Reached
3	Effective density	min. 2.5 gr/ml	2,697	Reached
4	Abrasion machine Los Angels	max. 40%	15,54	Reached
Fine Aggregate				
1	Water Absorption	max. 3%	3,00	Reached
2	Bulk Specific Gravity	min. 2.5 gr/ml	2,502	Reached
3	Effective density	min. 2.5 gr/cc	2,621	Reached
4	Abrasion machine Los Angles	max. 40%	15,54	Reached

From the overall aggregate physical properties, four parameters have been implemented. Based on the results, it can be shown that the aggregate has fulfilled the requirements and can be used as a mixture of highway construction.

Testing of the characterization of modified asphalt

The asphalt characterization test was performed by Marshall Method (ASTM-D6927–15, Kandhal and Parker 1998). Test results with marshall method resulted in density, stability, flow, VIM, VFA and VMA values that describe the quality of asphalt.

Density test

The density value shows the density of a compacted mixture. High-density values are better able to withstand heavier loads than low-density mixtures (Altamzwi 2011). [Insert Figure 1] showed that the addition of iron powder has an effect on the modified asphalt density value. The effect that occurs was the addition of iron powder caused smaller density value. The overall value of modified asphalt density reached standard value.

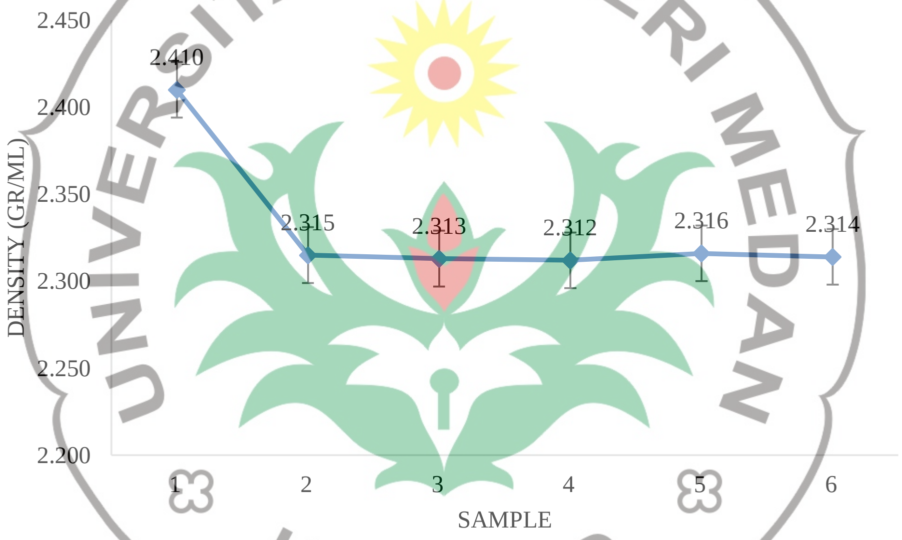

Figure 1. The relation between the addition of iron powder to the density value

Stability test

Stability is the ability of a road to receive a traffic load without permanent form changes such as wave, groove, and bleeding (Hicks 1991). [Insert Figure 2] showed that the addition of iron powder affected the stability value. The effect occurred was the addition of iron powder caused the greater stability value. The overall value of modified asphalt stability reached standard value.

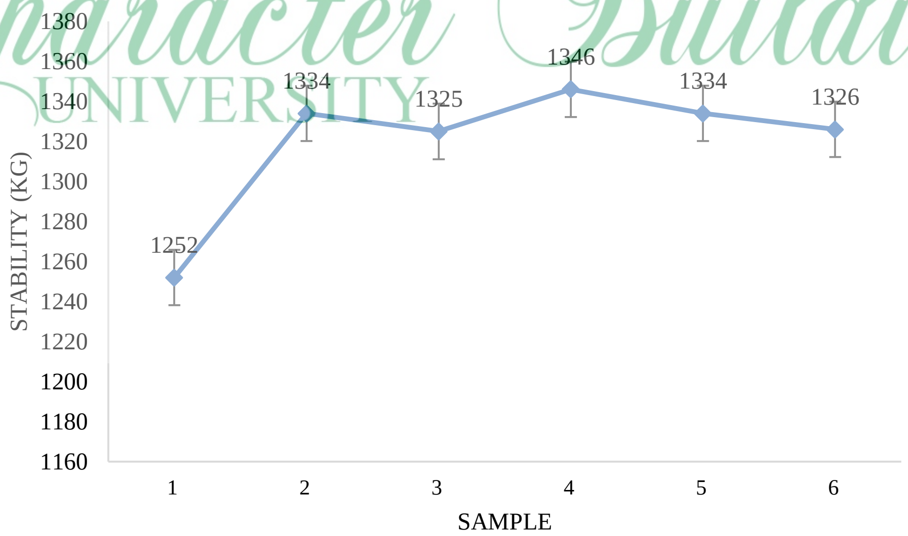

Figure 2. The relation between the addition of iron powder to the stability value

Flow test

The flow value was used to measure deformation occurring due to load (Hicks 1991). [Insert Figure 3] showed that the addition of iron powder influences the flow value. The effect occurred was the addition of iron powder caused the greater flow value. However, the overall value of the modified asphalt density reached standard value.

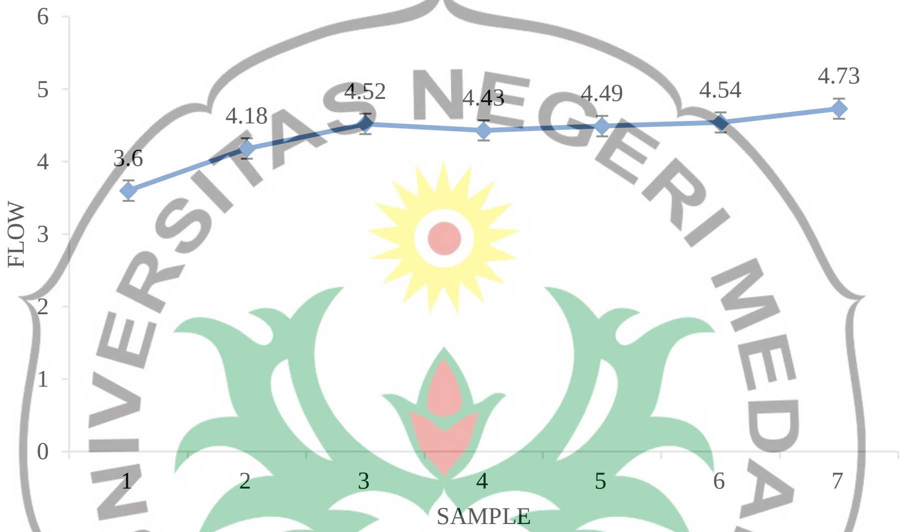

Figure 3. The relation between the addition of iron powder to the flow value

VIM (void in the mix) test

VIM (void in the mix) is the remaining pore volume after the asphalt concrete mixture is compacted. VIM is required for shifting aggregate grains due to additional compaction occurring by the repetition of the traffic load or where the asphalt becomes soft / expands due to rising temperatures. VIMs that are too big will result in asphalt concrete is less waterproof resulting in increased asphalt oxidation process that can accelerate the aging of asphalt and decrease the nature of durability. Conversely, too small VIM will result in pavement experiencing bleeding if temperature increases (Gaus et al. 2015).

[Insert Figure 4] shows that the addition of iron powder has an effect on the modified asphalt VIM value. The effect occurred was the addition of iron powder caused the greater VIM value. However, the overall value of the modified asphalt VIM reached standard value.

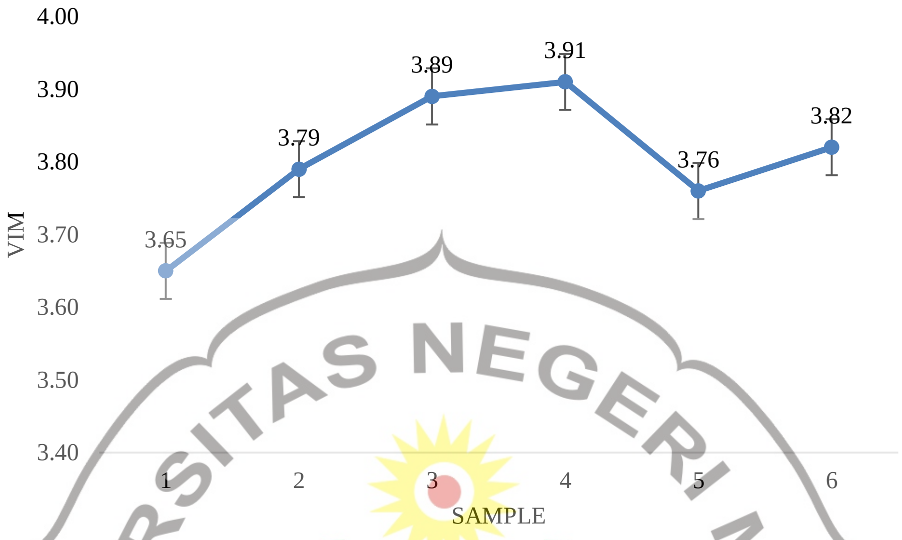

Figure 4. The relation between the addition of iron powder to the VIM value

VMA (void mix asphalt) test

VMA is the intergranular space occupied by asphalt and air in a compacted asphalt mixture (Hicks 1991). The addition of iron powder affected the VMA value. [Insert Figure 5] showed that the addition of iron powder has an effect on the VMA value. However, the overall value of the modified asphalt VMA reached standard value.

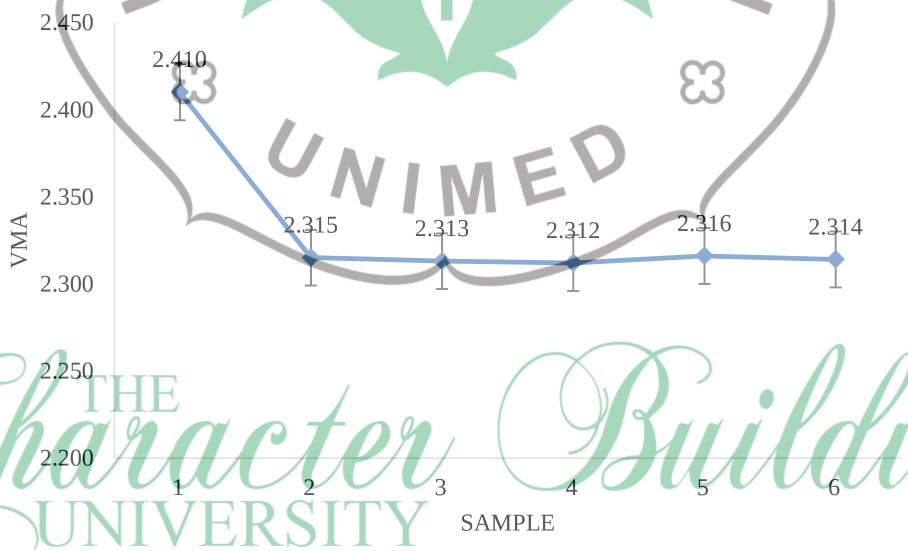

Figure 5. The relation between the addition of iron powder to the VMA value

VFA (void filled with asphalt) test

The volume filled with asphalt from VMA is named VFA. VFA (Void Filled with Asphalt) is the volume of cavities that can be filled by asphalt. Thus the VFA is part of the VMA filled with asphalt, not including the asphalt that absorbs into the pores of each aggregate item. Asphalt that fills VFAs is asphalt that serves to envelop aggregate grains in solid asphalt concrete i*nto film or asphalt blankets* (Hicks 1991).

The addition of iron powder affected the VFA value. [Insert Figure 6] showed that the addition of iron powder has an effect on the VFA value. However, the overall value of the modified asphalt VFA reached standard value.

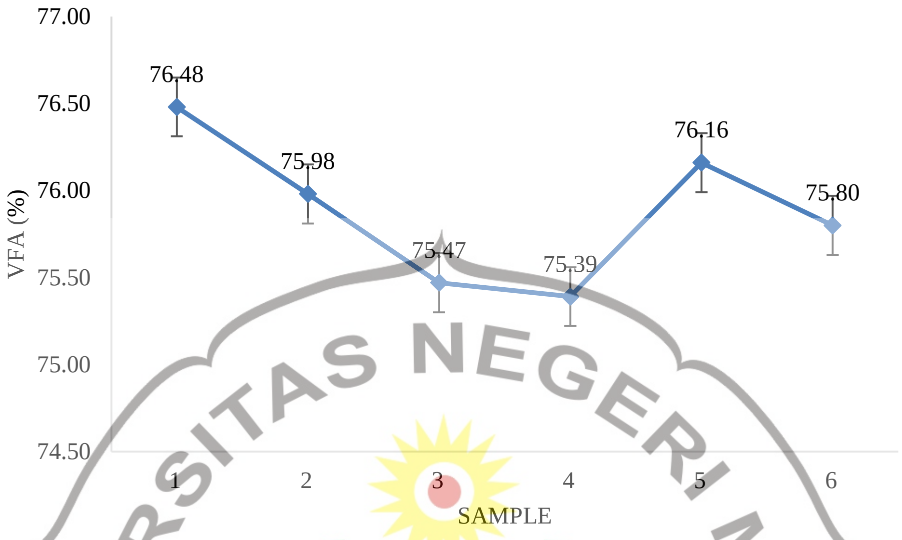

Figure 6. The relation between the addition of iron powder to the VFA value

DISCUSSION

The addition of iron powder to the asphalt mixture affected the asphalt density where the addition of iron powder resulted in decreasing asphalt density [Insert Figure 1]. The decrease in density in the modified asphalt system was due to the formation of larger chains. The formation of larger chains caused the higher the distance between the aggregate molecular chains and the asphalt.

The addition of iron powder to the asphalt mixture affected asphalt stability [Insert Figure 2]. The addition of iron powder had an impact on the higher its asphalt stability value. It happened due to the increase of the hardness of the asphalt (penetration decreased) and the higher softening point. Also, it is possible that the iron powder could fill the cavity between the asphalt and the aggregate. The results of this study was similiar to the study that the addition of resin can improve the stability of the asphalt (Cubuk et al. 2009).

The addition of iron powder to the asphalt mixture affected to the asphalt flow value [Insert Figure 3]. The addition of iron powder resulted in the more significant value of the asphalt flow. This change corresponded to the changes that occur in the penetration value and softening point [Insert Table 2]. It happened due to the combination of asphalt, aggregate and iron powder which caused the mixture to become denser and thicker.

The addition of iron powder to the asphalt mixture affected the cavity values (VIM and VFA). The addition of iron powder caused the increasing of VIM value [Insert Figure 4]. This change also occurred in the VFA. The addition of iron powder to the asphalt mixture results in a smaller VFA value [Insert Figure 5]. Thus the addition of iron powder affects VIM and VFA with an almost inversely proportional pattern. It was probably due to the change in the heavy density of the asphalt mixture is getting bigger if iron powder were added.

From the discussion of Marshall properties test results obtained that the addition of iron powder decreases the VFA density value, and increases the value of stability, flow, and VIM. The increased value of stability and flow was the advantage of the asphalt-aggregate mix system. This excess was physically seen with the higher asphalt hardness indicated by decreasing penetration value and increasing softening point [Insert Table 2]. It was likely to be a mixture of two materials that have different physical violence.

The need for stability is proportional to the function of the road, and the traffic load to be served. Roads that serve a high traffic volume and dominantly consist of heavy vehicles require high-stability road pavement. Conversely, road pavement intended to serve light vehicle traffic certainly does not require high stability value. Therefore, the addition of iron powder as a filler on the asphalt mixture and the aggregate results in better quality of asphalt and can withstand heavier loads.

The decreasing of density and VFA values and the increasing of VIM value are the weaknesses in the asphalt-aggregate system. The higher the concentration of iron powder added in the asphalt-powder system the density decreases, the VFA decreases, and the VIM increases. The decrease in density (density between molecules) in the modified asphalt system is due to the formation of larger chains. The formation of larger chains causes the higher the distance between the aggregate molecular chains and the asphalt. The occurrence of this bond between the asphalt-Aggregate, on the one hand, increases the softening point of the asphalt but causes the enlargement of the pores between the chain/molecule shown by the increasing of VIM and the decreasing VFA.

CONCLUSION AND RECOMMENDATIONS

Based on the results and discussion of research results, it can show that iron powder was potentially used as a filler to modify the mixture of bitumen and aggregate. The addition of iron powder can affect the quality of modified asphalt. One of this was the increase of stability and flow rate of asphalt. The high value of stability and flow affected that asphalt can withstand heavier loads. Other influences that occur were the decrease in the density and VFA values and the decreasing value of VIM. This condition affected the presence of cavities in asphalt mixtures and aggregates. It was feared that the existing cavity would decrease the quality of modified asphalt.

ACKNOWLEDGMENT

We would like to deliver our deep sense of gratitude and profound thanks to Ministry of Research and Higher Education of Indonesia who funded this research.

REFERENCES

1. Aksoy, A., Şamlioglu, K., Tayfur, S. & Özen, H 2005. Effects of various additives on the moisture damage sensitivity of asphalt mixtures. *Construction and building materials,* 19: 11-18.
2. Altamzwi, W. S. A 2011. *The Effect Of Crumb Rubber Additive Into Hot Mix Asphalt Performance.* magister teknik sipil.
3. ASTM-D5/D5M–13. Standard Test Method for Penetration of Bituminous Materials.
4. ASTM-D113–17. Standard Test Method for Ductility of Asphalt Materials.
5. ASTM-D346-14. Standard Test Method for SofteningPoint of Asphalt and Pitch (Mettler Cup and Ball Method).
6. ASTM-D6927–15. Standard Test Method for Marshall Stability and Flow of Asphalt Mixtures.
7. Chiu, C.-T 2008. Use of ground tire rubber in asphalt pavements: field trial and evaluation in Taiwan. *Resources, Conservation and Recycling,* 52: 522-532.
8. Cubuk, M., Gürü, M. & Çubuk, M. K 2009. Improvement of bitumen performance with epoxy resin. *Fuel,* 88: 1324-1328.

9. Fontes, L. P., Triches, G., Pais, J. C. & Pereira, P. A 2010. Evaluating permanent deformation in asphalt rubber mixtures. *Construction and Building Materials*, 24: 1193-1200.
10. Gaus, A., Tjaronge, M., Ali, N. & Djamaluddin, R 2015. Compressive strength of asphalt concrete binder course (AC-BC) mixture using buton granular asphalt (BGA). *Procedia Engineering*, 125: 657-662.
11. Ghuzlan, K. A. & Carpenter, S. H 2006. Fatigue damage analysis in asphalt concrete mixtures using the dissipated energy approach. *Canadian Journal of Civil Engineering*, 33: 890-901.
12. Hicks, R. G. 1991 *Moisture damage in asphalt concrete*, Transportation Research Board.
13. Jeong, K.-D., Lee, S.-J., Amirkhanian, S. N. & Kim, K. W 2010. Interaction effects of crumb rubber modified asphalt binders. *Construction and Building Materials*, 24: 824-831.
14. Kandhal, P. S. & Parker, F 1998. *Aggregate tests related to asphalt concrete performance in pavements*, Transportation Research Board.
15. Liang, M., Xin, X., Fan, W., Sun, H., Yao, Y. & Xing, B 2015. Viscous properties, storage stability and their relationships with microstructure of tire scrap rubber modified asphalt. *Construction and Building Materials*, 74: 124-131.
16. Liu, S., Cao, W., Fang, J. & Shang, S 2009. Variance analysis and performance evaluation of different crumb rubber modified (CRM) asphalt. *Construction and Building Materials*, 23: 2701-2708.
17. Lu, C.-T., Kuo, M.-F. & Shen, D.-H 2009. Composition and reaction mechanism of cement–asphalt mastic. *Construction and Building Materials*, 23: 2580-2585.
18. Navarro, F., Partal, P., García-Morales, M., Martín-Alfonso, M., Martinez-Boza, F., Gallegos, C., Bordado, J. & Diogo, A 2009. Bitumen modification with reactive and non-reactive (virgin and recycled) polymers: a comparative analysis. *Journal of Industrial and Engineering Chemistry*, 15: 458-464.
19. Netterberg, F. & De Beer, M 2012. Weak interlayers in flexible and semi-flexible road pavements: Part 1. *Journal of the South African Institution of Civil Engineering*, 54: 31-42.
20. Ouyang, C., Wang, S., Zhang, Y. & Zhang, Y 2005. Preparation and properties of styrene–butadiene–styrene copolymer/kaolinite clay compound and asphalt modified with the compound. *Polymer degradation and stability*, 87: 309-317.
21. Song, H., Do, J. & Soh, Y 2006. Feasibility study of asphalt-modified mortars using asphalt emulsion. *Construction and Building Materials*, 20: 332-337.
22. USDT 2008. Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects. United States Department of Transportation.