Warm Mix Asphalt with Plastic Recycle

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Abstract

In Thailand, asphalt is used in the construction of pavement and road maintenance work. As from the past years, many countries have tried to tackle with the Greenhouse effect. Greene-house gas causes include CO2 (Carbon dioxide), CH4 (methane), N2O (nitrous oxide), CFC8 (chlorine-fluorocarbon) and water and ozone. Production for which asphalt concrete is harmful with the heat aggregates producing CO2, NOx, VOC and dust through the blending process. One of the most popular waste materials use in the industry nowadays is waste plastic. This material is making the world warmer unless it is not recycled. One plastic bag takes about 450 years to decompose on average. If it is burned, it will form hydrocarbon compounds causing pollution. The use of recycled plastics can also reduce global warming, according to the US Association of Plastic Recyclers (APR). Compared to virgin plastics, HDPE plastic reduces energy consumption by 88% and 71% reduction in greenhouse gas emissions. In this study, the use of recycled plastic 2% and 4% of HDPE was added into asphalt concrete. Also, to reduce the higher heating mixing process of asphalt concrete, addition of warm mix additive (i.e. Sasobit) with 1.5%, 4%, and 6% was added. The objective is to determine viscosity of asphalt mixed with plastic and Sasobit additive.

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Chapter 1 Introduction

1.1 Background and Significance

Thailand uses asphalt o in the construction of pavement and road maintenance work throughout the country. Which the government has a road construction project to increase traffic routes and maintenance of asphalt slopes throughout the year the objective of this study was to study the use of Warm Mix Asphalt by using asphalt grade AC 60-70 mixed with recycled plastics (HDPE) and Sasobit reducing agent. Affecting from the past to the present as a result of global warming Part of the cause of greenhouse gases (Greenhouse Gases) are CO2 (Carbon Dioxide), CH4 (Methane), CFC8 (Chlorofluorocarbons), N2O (Nitrous Oxide), Steam and Ozone. manufacture or human activities, in which asphalt concrete mixing process Which uses fuel oil to burn to heat the aggregates This will generate CO2, NOx, VOC and dust particles in the plastic part. Plastic bags cause global warming. One plastic bag takes about 450 years to decompose on average. If burned, it will cause hydrocarbon compounds. Which causes pollution causing global warming and research from the University of Hawaii found that Degrading plastics can release new greenhouse gases that destroy the Earth's atmosphere. And the newly discovered gas is not included in the list of gases that destroy the Earth's atmosphere. Emissions of these gases are likely to increase. More plastics are produced and accumulated in the environment. And begins to decompose over time. Greenhouse gases have a direct impact on climate change. Affecting the rising sea level Rising global temperature Terrestrial and oceanic ecosystems, storms, floods, drought, and erosion Most of the plastic is made up of natural gas, thus releasing greenhouse gases from plastic waste. The use of recycled plastics can also reduce global warming, according to the US Association of Plastic Recyclers (APR), the latest report released by the US Association of Plastic Recyclers (APR) said the use of recycled plastics in the manufacture of new products can help reduce energy consumption and emissions. Greenhouse gases can be significant. Compared to virgin plastics, PET recycled plastics can help reduce energy consumption by 79% and reduce greenhouse gas emissions by 67%, while recycled HDPE plastic reduces energy consumption by 88% and 71% reduction in greenhouse gas emissions while recycled PP plastics can help reduce energy consumption by 8% and reduce greenhouse gas emissions by 71%.

1.2 Objective

1.2.1 To determine viscosity of asphalt mixed with plastic and Sasobit additive.

1.2.2 To determine the comparison of applications between Hot Mix Asphalt (HMA) and Warm Mix Asphalt

1.3 Research Scope

1.3.1 In this research, the viscosity properties of asphalt, plastic mixtures and reducing additive were studied. Temperatures are 135, 145, 150 and 155 degrees Celsius.

In this research, AC 60/70 is a recycled plastic HDPE plastic with 4% and 6% percentage of plastic, 1.5%, 4% and 6% reducing agents.

1.4 Benefits

1.4.1 Know the viscosity properties of asphalt, plastic mixtures and reducing agents 4%, 6% and 1.5%, 4%, 6% respectively.

1.4.2 As a guideline for further education. For those interested and provide information to agencies or persons involved in the construction of the road surface Both public and private sector

Chapter 2 Relevant document and Research

2.1 Relevant Research

This research's objective of studying and comparing applications between asphalt. Hot Mix Asphalt (HMA) concrete using asphalt grade AC 60/70 with WMA using technology. Different types of WMA to promote and protect the environment which in the current state. The world environment has changed a lot. As a result of global warming Part of the cause is from (Greenhouse Gases) including CO2 (carbon dioxide) CH4 (methane) CFC8 (chlorofluorocarbon)N2O (Nitrous Oxide), steam and ozone, especially CO2, are gases produced by the manufacturing process. Or activities of humans, which in the process of mixing asphalt concrete Which uses oil in the combustion furnace to heat the aggregates forms CO2, NOx, VOCs and environmental particulate matter.

Department of Highways by the Bureau of Analyst and Inspection as the main organization in the field of work realize these effects Therefore, the properties of Warm Mix Asphalt (WMA) were studied, both engineering and environment in order to be able to use properly, worthwhile and not damage the road work.

The Warm Mix Asphalt test project is a study of properties both engineering and environment by studying relevant information do laboratory experiments and lead to construction as a plot experiment and collect data on Warm Mix Asphalt pavement results to be used for drafting data Warm Mix Asphalt pavement standards for proper and proper use.

Warm Mix Asphalt using Sasobit as additive A trial plot was made on Highway 36 at km 21+592 (towards Chonburi District 2) - Rayong bypass.

คุณสมบัติของส่วนผสมแอสฟัลต์คอนกรีต	[๑]Hot Mix Asphalt ใช้ AC ๖๐/๗๐ (Binder Course)	[๒]Warm Mix Asphalt ใช้ Sasobit (๓%) (Wearing Course)
Asphalt Content (% by Mass of Aggregate)	๕.๐ (±๐.๓)	๔.๙ (±๐.๓)
Marshall density (g/ml)	๒.๓๘๔ (๒.๓๗๕ - ๒.๓๙๑)	๒.๖๙๑ (๒.๖๘๒ - ๒.๗๐๐)
Marshall Air Voids (%)	๔.๐ (๓.๓ – ๔.๗)	๔.๐ (๓.๒ – ๔.๘)
Voids in Mineral Aggregate (%)	๑๔.๕ (๑๓ min.)	๑๕.๑ (๑๔ min.)
Voids Filled with Bitumen (%)	๗๒.๐ (๖๘ – ๗๗)	๗๔.๐ (๖๘ – ๗๙)
Marshall Stability (lbs.)	๒๗๙๐ (๒๕๐๐ min.)	๓๙๓๐ (๓๕๐๐ min.)
Marshall Flow (๐.๐๑")	๑๒.๐ (๑๑ – ๑๓)	๑๐.๘ (๑๐ – ๑๒)
Marshall Stability/Marshall Flow (lb/๐.๐๑")	๒๓๒ (๑๖๐ min.)	๓๖๔ (๒๑๐ min.)
Strength Index (%)	๗๕.๓ (๗๕ min.)	๘๒.๑ (๗๕ min.)

หมายเหตุ มวลรวมละเอียดเป็น (Limestone) จาก โรงโม่หินชลดา อ.บ้านบึง จ.ชลบุรี

[๑] มวลรวมหยาบเป็น Granite จากโรงโม่หิน บูรพาแอกกรีเกต อ.บ้านบึง จ.ชลบุรี

[๒] มวลรวมหยาบเป็น Steel Slag จาก โรงโม่ Slag บ่อวิน อ.ศรีราชา จ.ชลบุรี

Table 1. Property of asphalt concrete

2.2 Relevant Theory

2.2.1 Asphalt

The heaviest part of petroleum refining is black or brown, with a semi-solid and liquid characteristic, which is tough. It has a liquid status when heated. Before it is used, it must be heated to about 140-150 degrees Celsius. Once dried, it becomes solid, making it an interlocking material. Asphalt Cement is briefly called AC, which is classified by hardness by penetration measurement, which is checked by putting ac samples into a cylindrical cup with a diameter of about 5 cm, 3-5 cm high, tested at a temperature of 25 °C, and then using a needle on the mounting platform pressing the weight of 100 g. for 5 seconds on the surface of the rubber. The lower the amount of the needle, the less it becomes, the higher the penetration of the AC sample, which ranges from 10 to 350. We use this to determine which level of asphalt is suitable for each type of work. Set to 5 The level is AC 40/50, AC 60/70, AC 80/100, AC 120/150, AC 200/300. While the AC 40/50 is the hardest. In Thailand, ac 60/70 is used because it is suitable for the climate of Thailand. There are two types: asphalt cement and liquid asphalt. The use must be boiled before use asphalt cement in 3 types according to production.

- Penetration Grade can be obtained directly from crude oil refining.

-Blown Grade by removing the first asphalt to blow the air at high temperatures. About 250 - 300 degrees Celsius to make it harder and more heat resistant.

- Hard Grade obtained by asphalt removal The first type to continue distilling under a vacuum at high temperatures. To make the asphalt more hardened.

Liquid asphalt can be divided into 3 types:

- Asphalt cutback has liquid appearance in ordinary temperatures. After compaction and left, the solvent evaporates, leaving only the cement asphalt, from the asphalt cement to the melt in the oil type known as Dituent or Culter Stock, such as Neptha Kerosine and Diesel Oil, can be divided into three types of solvents: fast hardening, medium hardening, and slow hardening.

- Emulsified Asphalt is made from the removal of cement asphalt at a temperature of 250 °C. Mix with water at a temperature of about 170 ° C. Using a chemical called Emulsifier, a little fill up the asphalt particles and then is hit by the Colloidal Mill machine, allowing the asphalt to break into small particles scattered in the water.

- Polymer Modified Asphalt Polymer Modified Asphalt is a special grade asphalt rubber that is mixed between polymer and asphalt cement (ASPHALT CEMENT) under mixing processes performed in the factory using a mixer designed specifically for polymers used in the mix, including SBS (STYRENE BUTADIENE STYRENE STYRENE), EVA (YETH VINYL ACETATE) or other polymers. Hot mixed asphalt concrete provides superior properties on conventional asphalt surfaces.

2.2.2 Asphalt Concrete

A composite material made from the combination of asphalt cement and aggregate material for the purpose of road construction. The behavior of the concrete asphalt is Viscoelastic, where the stiffness varies according to the temperature by the time the weight is carried out for a short time. Asphalt concrete changes behavior to Viscous Material (Poel, 1954), a mixed material obtained from the hot mix between aggregate and asphalt cement at the mixing plant by controlling the ingredient rate and temperature as required. The purpose is for construction purposes. The restoration and maintenance work by paving or blending and crushing the hot mixing materials on any floor that have been prepared and properly inspected according to the level, slope, size, and cutting as described in the asphalt concrete mixture consists of aggregate material and cement asphalt. Part of the asphalt is absorbed into the aggregate material, while the rest of the asphalt, called effective asphalt, coats the aggregate granules. Figure 2. the air void between the aggregate material and the concrete asphalt.

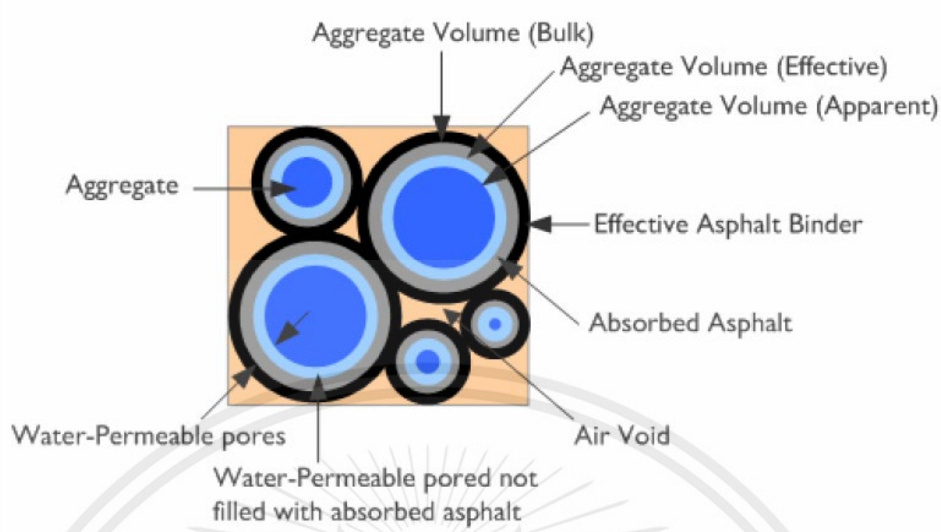

Figure 1. The air void between the aggregate material and the concrete asphalt

(Faculty of Engineering, Phayao University, 2016)

Physical variables influence the quality of concrete asphalt.

- Asphalt Cement is the most important variable in determining the properties of the elastic surface. The appropriate asphalt content per asphalt concrete depends on the properties of the aggregate: gradation, angularity.
- Air voids is the gap between the aggregates and coated with asphalt. The air gap is designed to support expansion when the temperature rises, preventing the groove of the wheel.
- Void in Mineral Aggregate, VMA is the total amount of space between the aggregates. In the concrete tarmac, where the gap between the partial aggregates is replaced by the tarmac. Asphalt concrete with high gap between aggregate materials has low durability.
- Density refers to the total amount of asphalt concrete per unit of volume. In asphalt concrete surface design, it must be designed with a density of at least 98% of the density obtained from the test chamber.

Engineering properties considered for the design of asphalt concrete.

- Durability elastic surfaces must have the ability to resist the disintegration of the road as a result of traffic conditions and seasonal variations throughout its lifecycle.
- Stability the elastic surface must be able to support the weight of traffic without deformation and cohesion between the granules of the aggregate.

If the surface of rough and rough aggregates results in asphalt, the concrete asphalt is stable and has good adhesion to the asphalt at normal temperatures. Therefore, it should be designed to asphalt content in the right ingredients If the asphalt content is higher than it should be, friction between the aggregates will be reduced.

- Workability the variable that defines workability is the mixed size of the aggregate. Opting for mixed sizes that are too large or using a mixed mass of not-so-good, such as excessive use of medium-sized aggregate particles, as well as the use of too low mixing temperatures. As a result, asphalt concrete cannot be well coated in aggregate.
- Fatigue Resistance cyclic loading due to the weight of traffic on the surface of the road. If the surface is badly compacted (the amount of air gap is too large or too low), or the use of low-quality asphalt will make the asphalt surface easy to fatigue.
- Skid Resistance the concrete asphalt surface requires enough resistance to prevent or reduce the rate of accidents due to slipping in. Unusual conditions such as rain, thick fog, etc., designs with excessive amounts of asphalt cement. This results in bleeding or the use of a smooth-skinned aggregate. As a result, the asphalt cement is poorly adhered to the gross surface. In addition, the improper mixed-sized design also affects the resistance to skid.

2.2.3 warm mix asphalt with Chemical additives' effects

Over the last few years asphalt industry has been looking for new strategies to improve energy performance, reducing costs, but simultaneously guaranteeing the quality of bituminous mixtures Bituminous mixtures produced at lower temperatures, designated as warm mix asphalt are one of the strategies most explored and evaluated for a long time; according to Kristjansdottir these technologies emerged, led by Professor Ladis Csanyi of the University of Iowa, in 1956, who developed a bituminous mixture introducing foam, taking the first step on foaming technologies. According to the EAPA, there are several techniques and products that reduce production and compaction temperatures, ensuring the full coating of the aggregates, and thus the workability and compatibility of the bituminous mixture. The most common division separates the warm technologies into chemical additives, organic additives and foaming techniques. Organic additives are usually waxing and fatty amides such as Sasobit, Asphaltan B and Licomont Bs 100. These products, at temperatures above bitumen's melting point, are able to reduce its viscosity. Chemical additives are often emulsifiers and surfactants, such as Cecabase, Rediset and Evotherm. These products are designed to improve the coating of aggregates, acting to reduce the internal friction between the aggregate and binder. Finally, the foaming techniques can be separated into injection foaming nozzles and minerals, both following the same base line: the introduction of small amounts of water into the hot bitumen that causes the expansion of the bitumen and the formation of a large quantity of foam, reducing the bitumen viscosity to achieve proper coating of the aggregates. The present research about additive–binder interaction was aimed at searching for the effects of chemical additives on the rheological properties of bitumen, evaluating the compatibility between different additives and binders. Since the literature, namely Oliveira et al. indicates that these additives do not change the bitumen properties, including its viscosity, in fact they seem to act at microscopic interface between aggregates and bitumen, reducing friction between these, this study aims to demonstrate that the performance of binders in the bituminous mixtures will not be affected, but that the bitumen–aggregate interaction will be improved. For this purpose, a hard bitumen, conventional bitumen and crumb rubber modified bitumen were characterized before and after the application of additives. In the second phase of the study, one of the chemical additives studied was selected to be tested on the mixture proving the capability of this product to reduce the production and compaction temperatures of bituminous mixtures.

Table 2 Results for storage stability of bitumen B35/50 with Cecabase

Table 4
Results for storage stability of bitumen B35/50 with Cecabase®.

% of Cecabase®	Storage stability			
	Top part		Bottom part	
	Pen. (1/10 mm)	R&B (°C)	Pen. (1/10 mm)	R&B (°C)
0.10	41.0	53.7	40.1	53.7
0.15	37.9	53.4	37.5	54.4
0.20	40.7	55.1	41.0	56.3
0.30	37.0	53.4	36.2	53.4

Figure 2. Comparation the viscosity from different percentage of Cecabase.

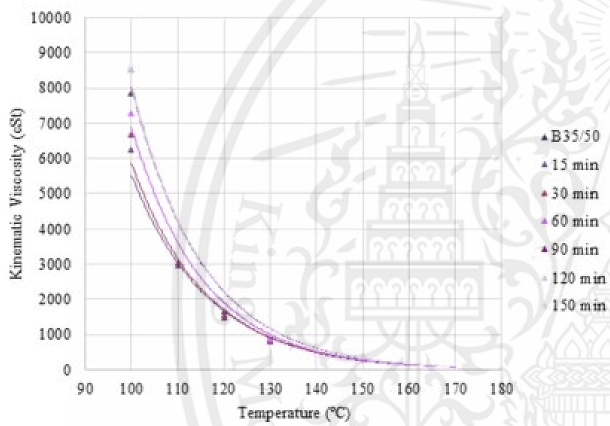

Fig. 4. Viscosity analysis of the bitumen specimen B35/50 with 0.10% of Cecabase®.

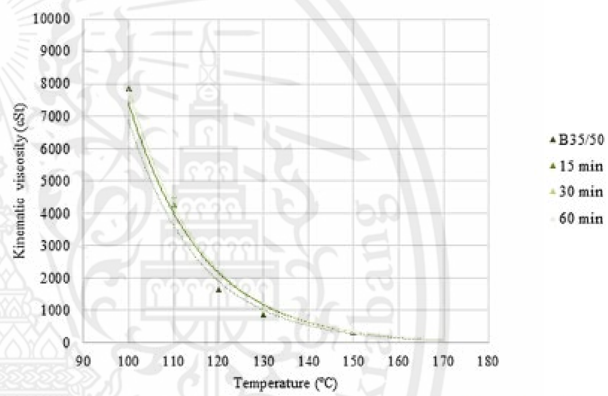

Fig. 6. Viscosity analysis of the bitumen specimen B35/50 with 0.20% of Cecabase®.

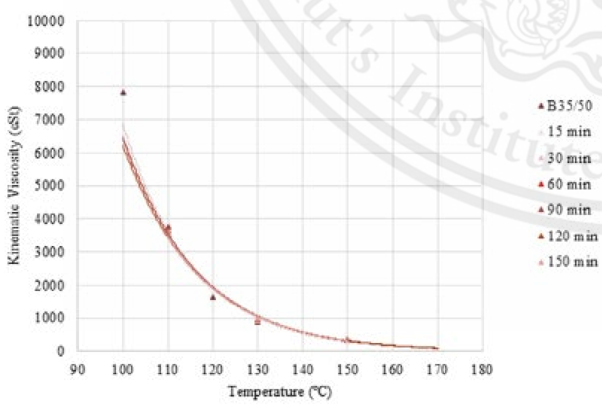

Fig. 5. Viscosity analysis of the bitumen specimen B35/50 with 0.15% of Cecabase®.

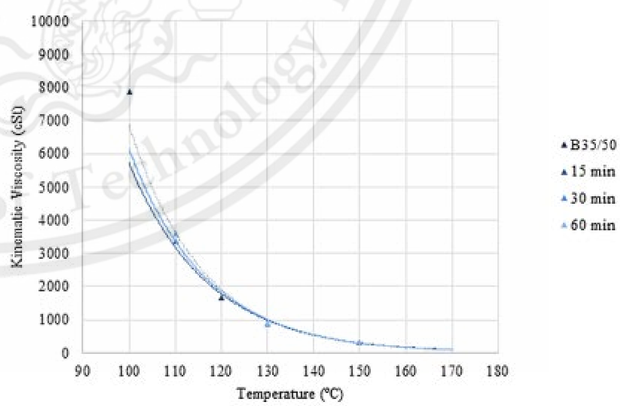

Fig. 7. Viscosity analysis of the bitumen specimen B35/50 with 0.30% of Cecabase®.

Table 2.1 presents the results for storage stability. This test is very important to predict the behavior of bitumen after modification during storage and transport. The results demonstrated that the additive remained homogeneous. The variations of needle penetration and softening point between the upper part and lower part of all the specimens were very small. Regarding viscosity, at 100 C, the samples with 0.10% of additive, taken with 15 and 30 min of stirring, showed a decrease in viscosity; however, for higher temperatures their trendlines approached the trendline of the standard bitumen. The trendline of the sample with 60 min of stirring overlapped with the trendline of the standard bitumen, and the samples with 90, 120 and 150 min of stirring showed an increase in viscosity throughout their trendlines. For samples with 0.15% of additive at 100 C, a decrease was verified of nearly 900 cSt against the viscosity of the reference bitumen. At 120 C the trendlines were overlapped, but at 165 C the situation was reversed, with an increase of approximately 32 cSt compared to the reference bitumen. For the samples with 0.20% of additive, at 100 C, an increase was verified of nearly 900 cSt, whereas at 165 C the increase was only about 30 cSt. Finally, for all samples with 0.30% of additive, at 100 C, a decrease in viscosity was observed of approximately 900 cSt compared to the reference bitumen and, once again, it was noted that the longer the stirring time, the greater the decrease in viscosity. At 130 C the trendlines were overlapped and, at 165 C, the contrary to the forementioned was noted, i.e., the longer the stirring time, the greater the increase in viscosity.

Table 3. Result of storage stability of bitumen B35/50 with Rediset

Table 8
Results of storage stability of bitumen B35/50 with Rediset®.

% Rediset®	Storage stability			
	Top part		Bottom part	
	Pen (1/10 mm)	R&B (°C)	Pen (1/10 mm)	R&B (°C)
1.00	38.2	54.4	35.9	54.3
1.50	39.3	53.2	37.1	54.1
2.00	45.1	52.7	41.9	53.5
3.00	48.0	54.5	46.0	54.6

Figure 3. Comparation the viscosity from different percentage of Rediset

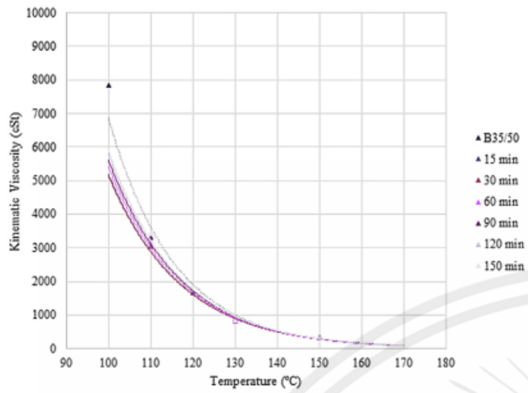

Fig. 10. Viscosity analysis of the bitumen specimens of B35/50 with 1.0% of Rediset®.

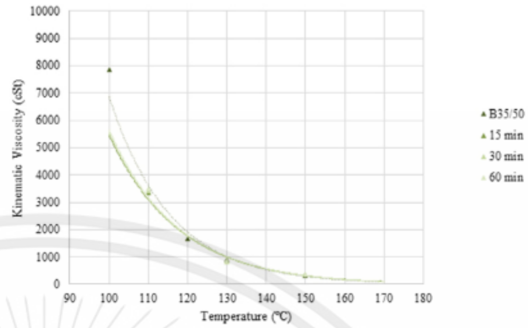

Fig. 12. Viscosity analysis of the bitumen specimens of B35/50 with 2.0% of Rediset®.

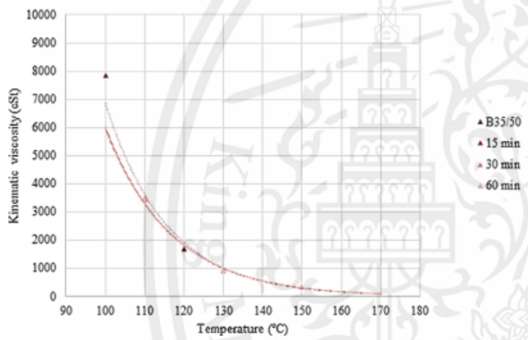

Fig. 11. Viscosity analysis of the bitumen specimens of B35/50 with 1.5% of Rediset®.

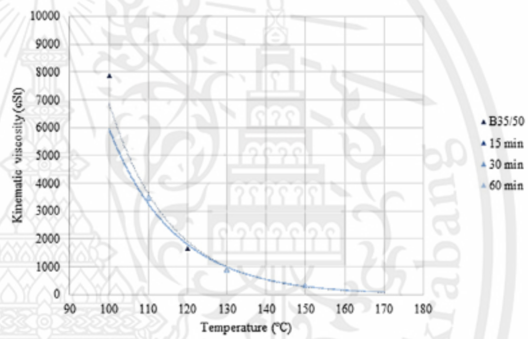

Fig. 13. Viscosity analysis of the bitumen specimens of B35/50 with 3.0% of Rediset®.

According to Table 2.2, the increase in additive caused a decrease in the penetration and this behavior reached a peak for 2.00% of Rediset. This result may be related to an execution error during the test, or most likely the exposure of the bitumen to air caused it to harden. The modified samples showed higher softening point values than the reference bitumen and it was verified that the higher the percentage of additive, the lower the softening point variation. The elastic recovery declined for almost all percentages of additive, except for 3.0%. After the accelerated ageing test, no significant differences were revealed in the mass variation and softening point, but the penetration decreased considerably.

Regarding the storage stability test (Table 2.2), there were some small differences between the top and bottom parts of specimens. The top part showed lower hardness than the bottom part, and the softening point only showed differences in the two intermediate parts; however, the differences allow us to confirm the homogeneity after storage.

Regarding the viscosity analysis, all samples, at 100 C showed lower viscosity than the reference samples; however, at 165 C, their viscosity exceeded the viscosity of the reference bitumen. For the remaining samples, modified with 1.50, 2.00 and 3.00% of additive, in general, this additive did not change substantially their viscosities.

Chapter 3 Methodology

This research was to study the percentage of plastic when mixed with asphalt.

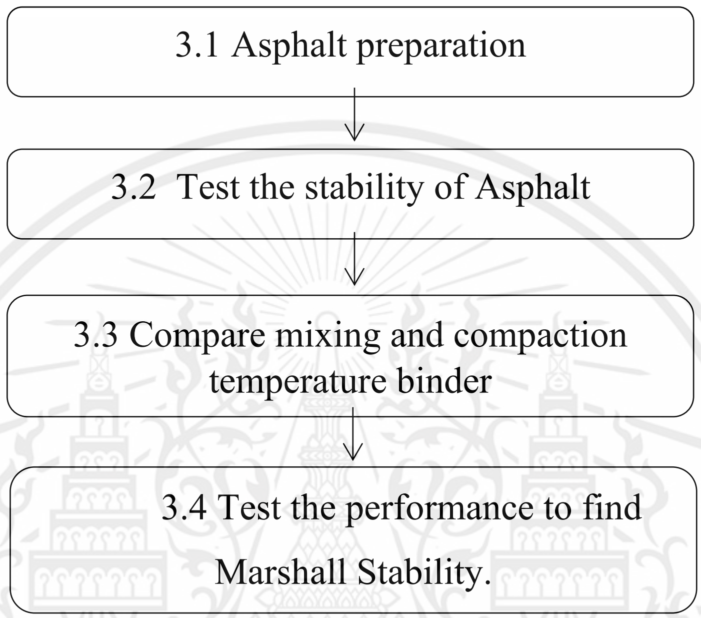

Figure 4. Procedure

Type & Percentage					
Plastic	%	Asphalt	%	Additives	%
HDPE	1.5	AC60/70	Base	Sasobit	2
	4				4
	6				6

Table 4. Type & Percentage of plastic, asphalt, additive

3.1 Asphalt Preparation Process

1. Bring the Asphalt AC 60/70 fill in each can then weight it too closely together.
2. Put the can into oven for 90 minutes at 150 C.
3. Set the blender rotate to 1000 RPM and prepare hot plate.
4. Put the can on the hot plate to heat and set up a digital thermometer to measure asphalt temperature to 160 C then drop the sasobit and plastic after finishing wait 120 minutes to blend the asphalt.

Figure 5. Heating asphalt binder

Figure 6. Mix asphalt binder with plastic.

Figure 7. Experiment samples

3.2 Study of viscosity properties

Viscosity of asphalt binder Mode Rotational Viscosity (RV)

1. Bring the sample that prepared put in an oven 90 minutes at 150 C.
2. Prepare a Brookfield Viscometer and set the temperature controller at the temperature at 170 C and use spindles 21 for samples of asphalt mixed with plastics, use spindles 27 for asphalt binder.

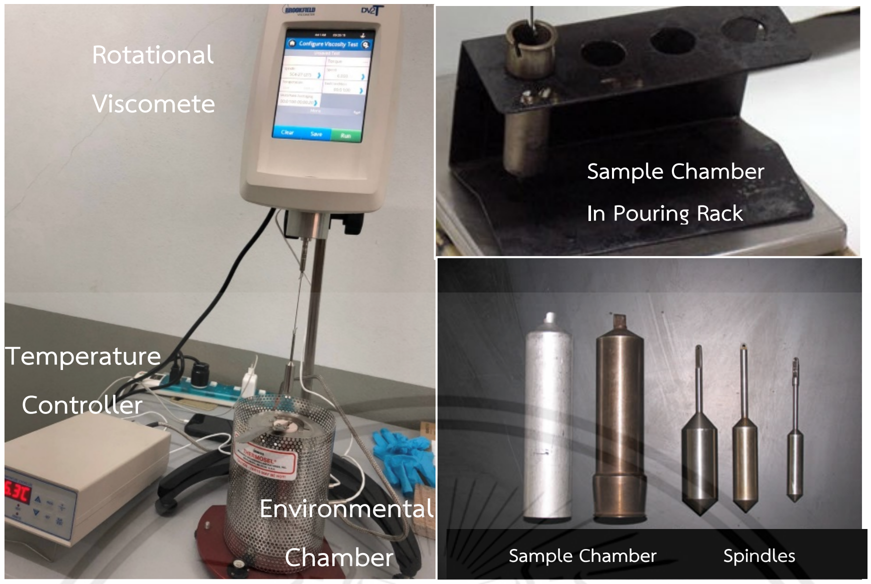

Figure 8. Brookfield Viscometer and another instrument

3. Set Brookfield Viscometer speed 20 RPM.
4. Bring the sample from oven and pour into tube 10 g then put the tube to a Brookfield Viscometer and left for at least 10 minutes before starting the test.
5. Follow the steps 2,3,4 by changing the temperature to 160 C, 165 C, 160 C , 155 C, 150 C and 145 C.

3.3 Design of asphalt concrete mixture

Design gradation

Aggregate materials for mix in asphalt concrete include:

1. Coase Aggregates is material with a size of 4.75 mm (Sieve no 4) such as Crushed Rock.
2. Fine Aggregates is material with a size less than 4.75 mm (Sieve no 4) such as sand, Stone dust.
3. Mineral Filler is material with a size through a sieve size 0.0600 mm (Sieve no 30) such as Porland Cement, Silica cement.

The calculation of line 0.45 Power Maximum Density Curve uses the formula.

$$P = (d/D)^n$$

When P = % Finder than the sieve

d = aggregate size being considered

D = Maximum aggregate size to be used

n = parameter which adjusts curve for fineness or coarseness

In Design Gradation, this calculates the stone size 12.5 mm (1/2 inch) is the maximum aggregate size, so n = 0.45 to find the 45-degree square.

3.4 The Preparation of asphalt concrete mixture sample

After knowing the weight of the mixed as designed and sift the limestone through U.S Sieve is a square grid. The sieve used to measure the size of the stone, starting from number 1/2", 3/8" and for sieves sift the sand there are size 4,8,16,30,50,100 and 200. The number indicate the number of sieves per 1 inch for example sieve number 30 mean that for 1 inch is divided into 30 squares, so in 1 square inch there will be a total of 900 squares.

Material

1. Limestone.
2. Sieve number 1/2", 3/8",4,8,16,30,50,100 and 200.
3. Sieve Shaker.
4. Container for each size of stone.
5. Brush and air blower to clean the sieve.

Procedure

1. Sort the sieve as follows: 1/2 “, 3/8”, 4, 8, 16, 30, 50, 100, 200 and pan.
2. Pour the prepared limestone into the top sieve and then set the sieve in the Sieve Shaker.
3. Turn on the Sieve Shaker and set a time to shake 15 minutes.
4. After shaking then take the remaining stones from each sieve.

Figure 9. The Sieve Shaker

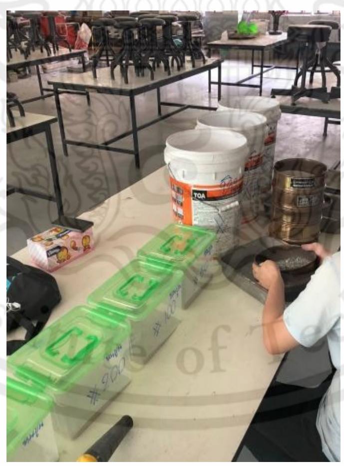

Figure 10. Stone container of each

Chapter 4 Result

The result of Viscosity of asphalt binder test with AC60/70(unmodified) and AC60/70 with plastic and sasobit mixed by plastic 2%, 4% and sasobit 1.5%, 4%, 6% proportion got the test result as follows:

4.1 The result of Viscosity of asphalt binders

Viscosity (Pa.s)			
Temperature	135	150	165
AC60/70	0.48	0.283	0.24
AC60/70+sasobit 1.5%	0.437	0.213	0.18
AC60/70+sasobit 4%	0.363	0.21	0.16
AC60/70+sasobit 6%	0.41	0.25	0.20
AC60/70+plastic 2%	0.47	0.38	0.17
AC60/70+plastic 4%	0.745	0.56	0.29
AC60/70+Plastic2%+sasobit4%	0.32	0.26	0.14
AC 60/70+Plastic 4%+sasobit 4 %	0.765	0.48	0.235
AC 60/70+Plastic 4%+sasobit 1.5 %	0.64	.51	0.28

Table 5. The viscosity of difference asphalt binders.

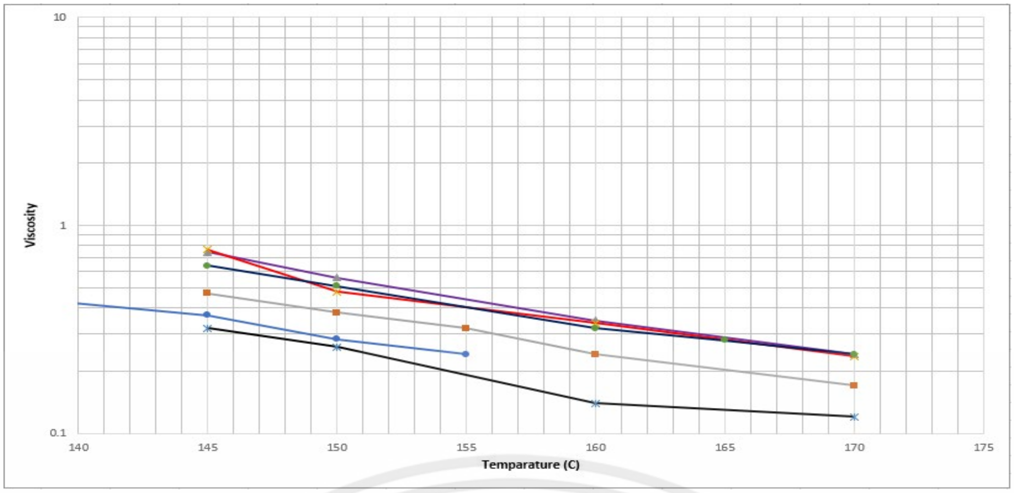

Figure11. Graph shows relationship between viscosity and temperature.

The equation for the relationship between temperature and the viscosity of asphalt concrete is obtained. 60/70 (unmodified) and asphalt type AC 60/70 with plastic2% and sasobit4% mixed.

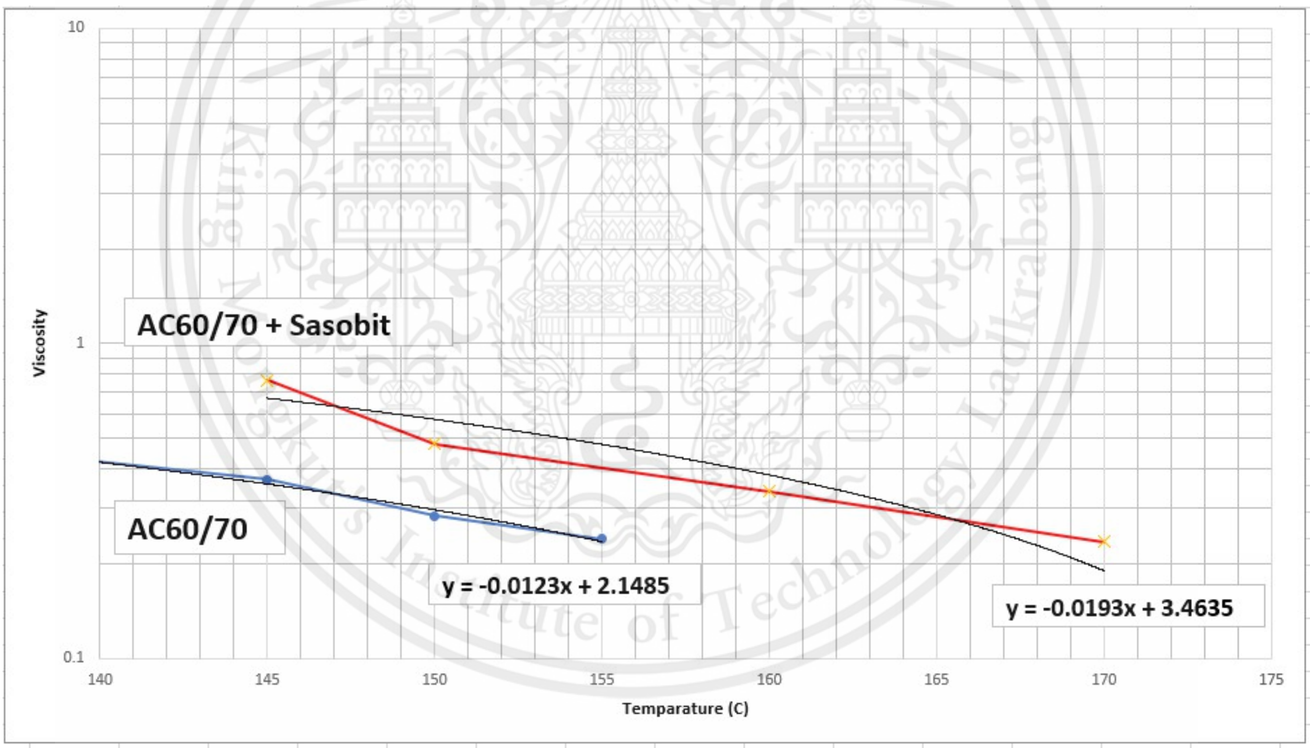

Figure 12. Graph shows relationship between viscosity and temperature.

From the equation we got, to find mixing temperature, which gives Y=0.17 and the compaction temperature is given to Y=0.28 by solving the equation for X which is asphalt type AC60/70 (unmodified) and asphalt AC60/70 with plastic2% and sasobit4% mixed.

	Mixing Temperature (℃)	Compaction Temperature (℃)
AC60/70	160.00	147.00
AC60/70+plastic2%+sasobit4%	161.15	153.77
AC 60/70 + Sasobit 6 %	162.638	153.747
AC 60/70 + Plastic 2 %	170.636	163.264
AC 60/70 + Plastic 4 %	177.296	170.578
AC 60/70 + Plastic 2 % + Sasobit 4 %	161.146	153.773
AC 60/70 + Plastic 4 % + Sasobit 4 %	177.742	170.872
AC 60/70 + Plastic 4 % + Sasobit 1.5 %	176.83	169.271

Table 6. Compaction & Mixing Temperature

Chapter 5 Conclusion

5.1 Conclusions

Summary of the results of the study according to the operating procedure in the study of properties of AC 60/70 (unmodified) asphalt and AC 60/70 mixed with plastic and sasobit additive by using plastic 2%, 4% and sasobit 1.5%, 4%, 6% proportion.

5.1.1 Viscosity of asphalt binders

The viscosity properties were analyzed using Ac60/70 (unmodified) asphalt and Ac60/70 mixed with plastic and sasobit additive by using plastic 2%, 4% and sasobit 1.5%, 4%, 6% portion by testing in the laboratory, the results of the research can be summarized as follows. It was found that Asphalt with 4% of plastic has too high viscosity to workability compare with 2% plastic that has more close value to Ac60/70 so that mean asphalt with a higher percentage of plastics will have a higher viscosity. In case of sasobit with 1.5%, 4% and 6% with Asphalt binder their have a lower viscosity than Ac60/70 so additive can reduce viscosity but it's not depended on higher percentage because viscosity at 1.5% is lower than 6%. And Ac60/70 mixed with plastic and sasobit has lower viscosity only in 2% of plastic and 4% of sasobit, the rests have greater viscosity so that are 4% of plastic + 1.5% and 4 % of sasobit. All of asphalt samples that tested at a higher temperature, the lower the viscosity.

5.1.2 Compaction and Mixing Temperature

The results of this viscosity test were used to design the mixing temperature and compaction temperature of asphalt concrete. It was found that high viscosity asphalt resulted in higher mixing temperature and compaction temperature of asphalt concrete. the results of the research can be summarized as follows.

- AC60/70 is the base of all sample that we tested so it has 160 Celsius of mixing temperature and 147 Celsius of compaction temperature.

- AC 60/70 + Sasobit 1.5% and 4% have 157 Celsius, 151 Celsius and 155 Celsius, 147 Celsius of mixing temperature and compaction temperature respectively. So that mean Sasobit is effective in reducing both temperatures.
- AC 60/70 + Sasobit 6% has lower compaction and mixing temperature too but not as much as it should be so that is 163 Celsius of mixing temperature and 154 Celsius of compaction temperature.
- AC 60/70 + Plastic 2 % and 4% have too higher of compaction and mixing temperature so that are around 170 and 177 Celsius so that can loss of its properties.
- AC 60/70 + Plastic 4 % + Sasobit 1.5% and 4 % can slightly reduce of temperature but not as much as it should be so that are around 177 Celsius and 170 Celsius of mixing and compaction temperature.
- AC 60/70 + Plastic 2 % + Sasobit 4 % has most effective in reducing of temperature so it's lower than pure 2% of plastic and it is similar to Ac60/70 so that is 161 Celsius and 154 Celsius. So, we use this sample to be a further study.

5.2 Future work

5.2.1 Determination of suitable asphalt cement content

To find a suitable amount of asphalt cement, the value of Percent air voids (Percent air voids) equal to 4 percent or the error can be + -0.2 percent according to the Department of Highways standards.

Materials and equipment

1. Limestone prepared from sizing.
2. Prepared Asphalt AC60/70 and Asphalt mixed with plastic and sasobit additive by using plastic 2%, 4% and sasobit 1.5%, 4%, 6%.
3. Compaction mold consists of base plate, mold, and collar extension mold.
4. Compaction Hammer used as a manual release handle. It consists of a 1.27 cm thick round steel plate with a diameter of 9.84 cm attached to a steel rod which weighs 4.54 kg (10 lb) for throwing weight on the round iron plate in the process of crushing to have a falling distance of the iron bar equal to 45.72 cm (18 inches)
5. Compaction pedestal and Mold holder.
6. Oven and water bath
7. Mixing machines
8. Weighing machine

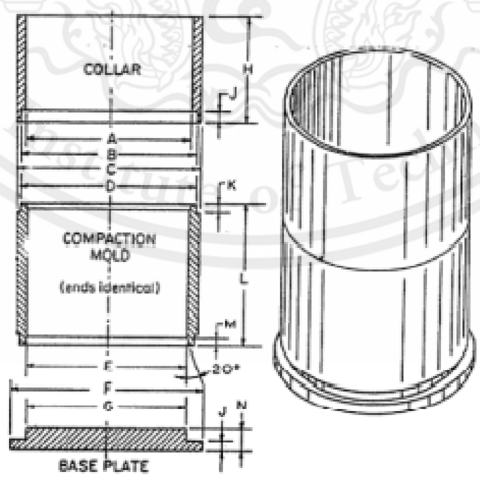

Figure 13. Compaction Mole

Methodology of Future Work

Determination of suitable asphalt cement content

Percent air voids

G_{mm} = Weigh in air/ (Weigh in air - Weigh in water)

G_{mb} = Weigh in air / (Weight sat. dry skin - Weigh in water)

Percent air voids = $[(G_{mm} - G_{mb})/ G_{mm})] - 100$

1. Bring AC60 / 70 asphalt and the prepared aggregate materials into an oven at 160 ° C, (mixing temperature) for 90 minutes.

Figure 14. Aggregate before oven

Figure 15. Pour aggregate

2. After oven, the aggregate material is weighed then add the asphalt by trying to put 5% Of gross material weight.
3. Mix the asphalt to coat aggregate materials. Which is called asphalt concrete.
4. When mixing the asphalt, coat the aggregate material until it is fully integrated the put it into the oven at 147 ° C, which is the compaction temperature for 90 minutes.
5. After oven, spread the asphalt concrete on the paper and leaves it at least 16 hours to reduce the temperature and then the asphalt concrete was put into moles for compaction by using 75 hammering times.

Figure 16. Smoothing asphalt concrete

Figure 17. Compaction of asphalt concrete

6. When the compaction is done, let the asphalt concrete temperature be lower by leaving for at least 16 hours to remove the asphalt concrete from the mole.
7. Separated the spread-out asphalt concrete into 4 parts, then combine the two opposite parts together and then weighed to find the weight by weighing in the air and weighed in the water to find the G_{mm} value.
8. Take the Asphalt lump to weight by weighting in the air, saturated dry skin and in the water to find G_{mb}.

9. G_{mm} and G_{mb} values are used to determine the amount of air voids (Percent air voids).
10. Take the steps from the beginning to increase or decrease the percentage of asphalt added to the aggregate material if the air voids value (Percent air voids) is not yet 4%.

5.2.2 Test the performance to find Marshall Stability.

1. Weigh each size of the aggregate to 1200 grams.
2. Prepare asphalt cement.
3. Bring the aggregate sample put in a mold and put asphalt cement into an oven for 150 C and 120 minutes.
4. Mix aggregate and asphalt together.
5. Place a sheet of circular paper in the base of the Marshall mold.
6. Hold the Marshall mold and base pieces into Holding platform then compacted with a Marshall hammer.
7. Remove the Marshall mold and flip the mold and then do step 6 again.
8. Peeling the circular paper from the sample and wait sample to cool down.
9. Then test the sample to find Marshall Stability.

5.2.3 Moisture damage in asphalt mixture

1. After compaction until get a couple mole of asphalt concrete and leave them 16 hours to cooldown the temperature.
2. Remove the asphalt concrete from the mole. Then leave them for 24 hours.
3. Bring a dry asphalt concrete to find TSR value by using Marshall stability testing machine.
4. Bring the another to soak in a water at 60 degree Celsius for 24 hours. Then immersed in water at room temperature for another 2 hours (Wet), then tested for TSR.
5. The test was performed by using asphalt type AC60 / 70 and asphalt AC60 / 70 mixed with plastic 2% and sasobit 4%.

- TSR Formula = $\frac{Wet}{Dry} \times 100$

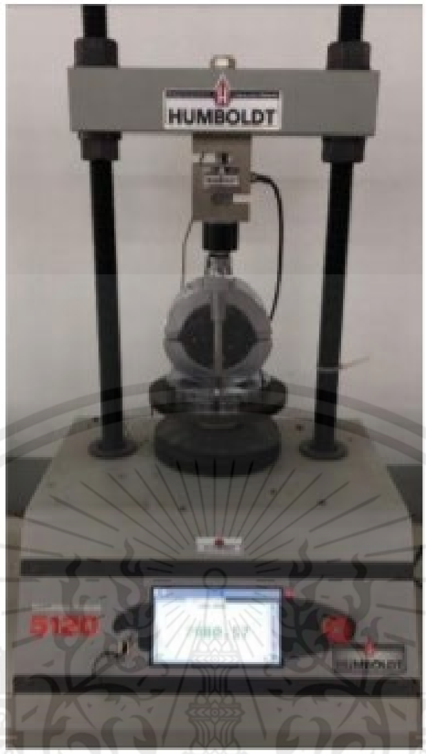

Figure 18. TSR determination by Marshall Stability Testing Machine

Reference

- Warm mix asphalt: Chemical additives' effects on bitumen properties and limestone aggregates mixture compactibility a Civil Engineering Department, University of Aveiro, University Campus of Santiago, 3810-193 Aveiro, Portugal b Galp Energia, SGPS, S.A., Rua Toma´s Fonseca – Torre C, 1600-209 Lisboa, Portugal c RISCO – Aveiro Research Centre of Risks and Sustainability in Construction – University of Aveiro, University Campus of Santiago, 3810-193 Aveiro, Portugal.
- ดร.มนตรี เดชาสกุลสม,พรหมมา เทพศรีหา,เรืองฤทธิ์ ทิพย์วังเมฆ,กิตติชัย ศรีโยธา,ถาวร ตะไก่แก้ว. *Warm mix asphalt,2010.*
- Mr. Thanawat Sangsuriyothai ,Mr. Piyawat Thonginta ,Mr. Poom Wannawichate*,A STUDY OF INCREASING THE RHEOLOGICAL AND PERFORMANCE PROPERTIES FOR PARA – ASPHALT, 2019.* 28 May 2020.