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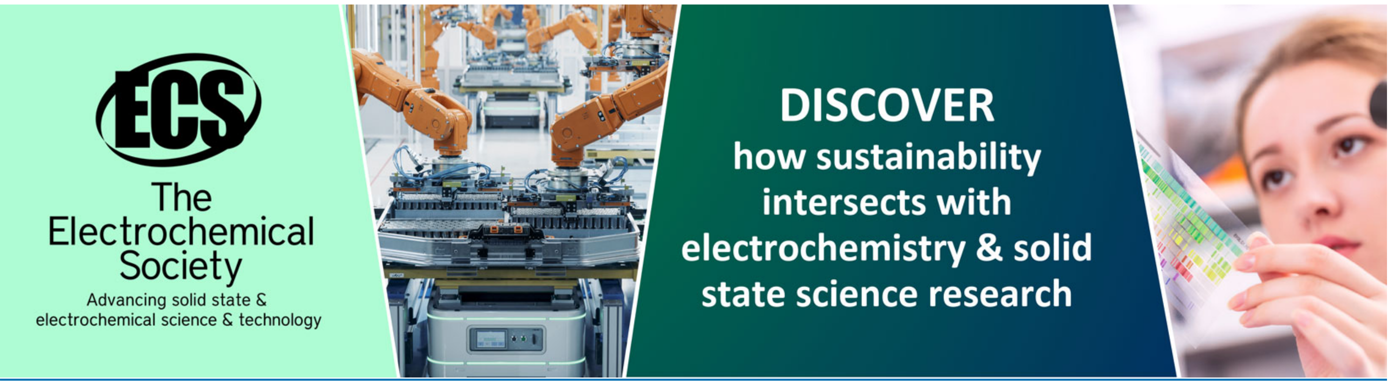

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Improving the properties of asphalt mixture using fiber materials

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Abstract. In Iraq, the increasing in number of vehicles and trucks with their heavy traffic loading under high temperature can led to different types of failures in pavements. Various types of fibbers in asphalt mixtures have been used to improve the paving properties to resist the developed distresses form the applied stresses. The main objective of this research is to find the effect of using two types of fibbers (Steel Fiber and Polypropylene Fiber) on the performance of asphalt mixture grade (40-50) from Al-Daurah refinery. In this work, four percentages of steel fibber and Polypropylene Fiber are used as combinations which are (0.4-0, 0.3-0.1, 0.2-0.2, 0.1-0.3 and 0-0.4) % by total weight of asphalt mixture. Three types of tests are carried out (stability, indirect tensile strength and flow tests) to investigate the influence of using the fibbers on hot mix asphalt. The tests are conducted in two different temperatures (40 and 60). The results show that using the combination of 0.3 steel fibber and 0.1 of Polypropylene fibber can improve the stability and flow by 34.9% and 67.7% respectively at temperature of 40c. In addition, the result shows that using the combination of 0.3 steel fibber and 0.1 of Polypropylene fibber can reduced temperature susceptibility. Finally, the use of double fibbers does not improve the stability and flow at 60c.

1. Introduction

Globally, there are many transport activities are operated through roads and highways. The components of the asphalt mixture (bitumen and aggregate) can be considered as sensitive materials particularly sensitive to temperature and repeated load, which can reduce the service life of the pavement (KÖFTECİ 2018). Thus, enhancing the pavement using additives is required to overcome any potential effects. One of the additives that are used for such purpose is Fibers (Thomas & Haiming, 1999). The use of fibers is traced back to 5000 years ago; it was used by Egyptian to reinforced clay pots (Mehta & Monteiro, 2006). However, the using fibers for reinforcing in modern ways started in 1950s (Saeed & Ali, 2000).

The use of steel fiber and polypropylene as additive materials had been recommended for more than a two decades including for pavement applications due to the factors that affect asphalt mixture. A number of studies have recommended the technical merits of steel-fiber-pavements and polypropylene-pavement; however little work has been carried out on adding these two materials together for different percentage of adding to provide better evaluation to these additives on the stability and indirect tensile strength (ITS). For instance, (Al-Kaissi & Mashkoor, 2016) investigate the influence of adding polypropylene as additive material on the durability performance of open-graded asphalt materials. They found the strength and permeability of the mix can boost by adding only polymer modifier in the mix (a six percent by volume of total mix was the best percent of adding such polymer modifier). Similarly, (Al-Ridha et al., 2014) investigate the influence of adding steel fiber as additive material on stability of asphalt mixture. They used four percentages of steel fibers (0.1, 0.2, 0.3, 0.4) percent, three temperature degrees (50, 60, 70) and three compaction blows (50, 75,125).They found that higher stability when asphalt mixture that contains less than or equal two percent of steel fibers. As a result, asphalt modified with polymers and steel fibers is a common means of providing optimally performing pavement. One reasons of using two type of fiber materials is the other papers are studied the effect of one type of fiber materials while this paper study the effect of combination of two types of fiber material on asphalt mixture, so it can obtain better quality control on the outcome by changing the quantity of each type of fibber similar to a model. This work aims to determine the effect of using double fiber modified asphalt on the properties of hot mix asphalt.

2. Objective of Study

The objective is evaluating the effect of adding steel fiber and polypropylene fiber to Marshall Specimens. This paper used different percentage of adding to provide better evaluation to these additives on the stability and ITS.

3. Materials

In this study, the used materials such as asphalt and aggregate are locally available and extracted from Iraq, while steel fiber and polypropylene fiber are imported from overseas, also locally available.

3.1 Asphalt Cement

In this work, grade (40-50) of asphalt cement was used from Daureh refinery. The optimum asphalt content that used in this work is equal to (5.0) percentage by weight of total mix. This percentage is provided by the asphalt laboratory staff in Al-Mustansiriyah University- College of engineering. The physical properties of asphalt cement were (Penetration rate was 43 at 25°C, Kinematic Viscosity was 390 at135°C, Softening Point 51.5, Ductility was over100 mm, Flash Point was 335°C, Specific Gravity was 1.048 at 25°C, Loss on heat was 0.18. These physical properties of asphalt cement are determined based on ASTM specifications D-5, D-2170, D-36, D-113, D-92, D-70 and D-1754.

3.2 Aggregate

The aggregate source is from Al-Nibaay quarry. One gradation with a maximum size of (12.5 mm) was applied according to (SCRB, 2003). The selection of gradation is based on based on the Iraqi specification of aggregate; for Sieve no ½ selected gradation was 100, for Sieve no 3/8 selected gradation was 95, for Sieve no 4 selected gradation was 70, for Sieve no 8 selected gradation was 50, for Sieve no 50 selected gradation was 15,and for Sieve no 200 selected gradation was 7.

3.3 Mineral Filler

In this work, Portland cement which is obtained from cement factory of Tasluga, was used as a mineral filler. The physical properties of Portland; Specific Surface was 3372, Bulk Specific 3.4(gm/cm3), Passing sieve no 200 was 96%.

3.4 Steel Fiber

The utilized steel fibers in the current research are straight steel fibers which are manufactured by Bekaert Corporation. The properties of steel fibers, which is brought from China, It was straight with thirteen mm as length, 0.2 mm diameter,7800 Kg/m3 as density, 2600 Mpa Tensile Strength. The fibbers can be gold or silver; hence they are coated with a thin brass layer throughout the drawing process (Roux and Sanjuan, 1996). Figure (1) demonstrations the used steel fibers.

Figure 1. Steel Fiber

3.5 Polypropylene Fiber

Grace cemfiber is considered as a high-performance micro polypropylene fiber which is developed for cementitious materials as a crack controlling additive. It can be found in two grades based on its manufacturing length which are 6 mm as well as 12 mm. The 6 mm fibers is used for mortar while the 12 to 6mm fibers is used for concrete. This type of fiber has advantages in the textile applications field. This fiber is considered to be strong and resilient, and does not fibrillate like high-density polyethylene, because it has degree of crystallinity of 72 to 75%. The melting temperature of polypropylene is equal to 165°C, which can be considered high enough for using it in most textile applications. Finally, polypropylene fiber provides better coverage per pound than any other fiber. It can resist the chemical attack as well as mechanical abuse (Al-hadidy 2006).

Figure 2. Polypropylene Fiber

4. Work Plan

First, asphalt specimens prepared from selected grade of aggregate, asphalt content, mineral filler and different rate of steel fiber as well as polypropylene fiber.

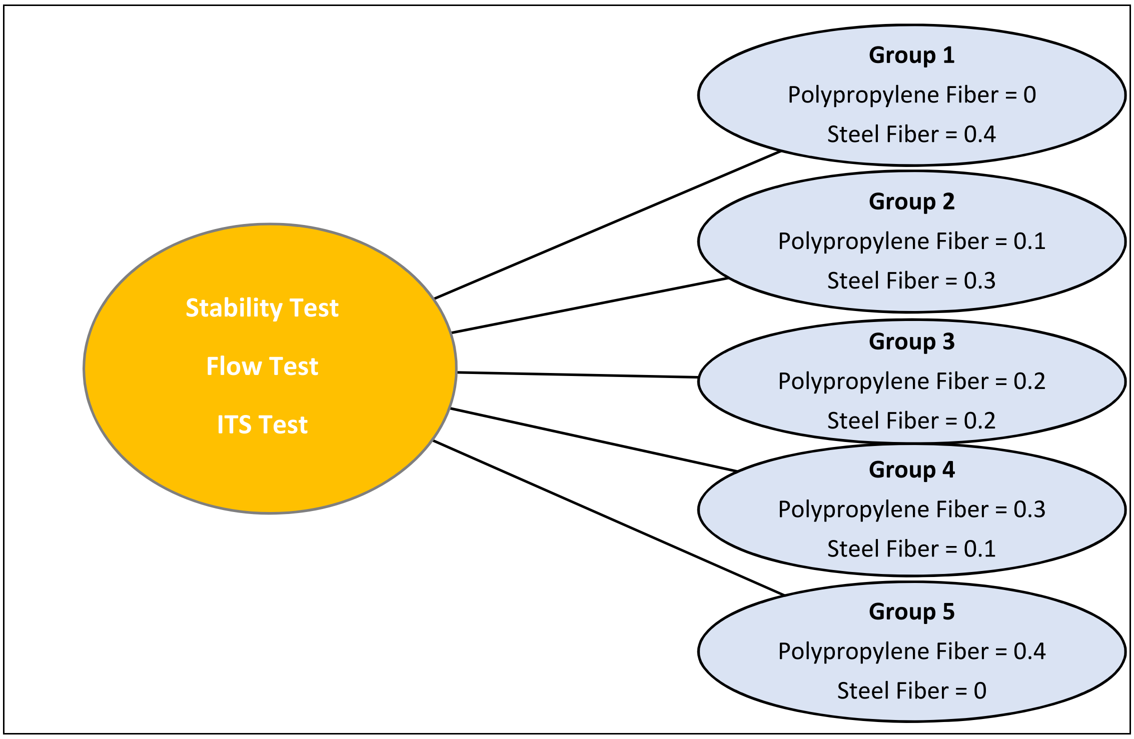

Figure 3. Work Plan

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Figure 4. Groups of Specimens

Figures 3 and 4 represent the work plan of study presents the specimens that had been tested in laboratory divided into 5 groups. There are two types of fibbers that used together in each sample. For example, group one includes Four percentages of steel fibber and no Polypropylene fiberFigures 3 and 4 represent the work plan of study presents the specimens that had been tested in laboratory divided into 5 groups. There are two

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types of fibbers that used together in each sample. For example, group one includes Four percentages of steel fibber and no Polypropylene fiber

5. Test Methods
The subsequent tests were implemented on specimens which prepared in laboratory to assess the performance of hot mixture of asphalt with different rates of steel fiber and polypropylene fiber:

5.1 The Marshall Stability and Flow Test
The stability and the flow of Marshall test presents the measure of performance estimation for the method of Marshall mix design. Stability which is considered the first part of the test compute the highest applied load carried by each test specimen within rate of 50.8 mm/min. essentially, the applied load is raised till it becomes maximum, at that point the applied load is ceased and the highest load is measured before the applied begins to reduce. During the loading process, the plastic flow of the specimen is measures using an attached dial gauge. At the same time that the highest applied load is computed, the flow value is measured in 0.25 mm increments. In this work the optimum asphalt content of the different samples found to be (5%).

5.2 Indirect Tensile Test
According to method illustrated in ASTM D-4123, the test of indirect tensile strength is typically utilized to find the tensile strength of compacted asphalt mixture specimen. The specimen are prepared using Marshall method, then left for 24 hours to cool and obtain the room temperature, after that put the specimens in a water bath at temperature of 20 C for 30 min to assess the fatigue cracking. In order to achieve the test, the specimens are placed into the loading apparatus immediately after removing them from the water bath. At a constant rate of (50.8mm/min) the compressive load is applied and the maximum load at failure is measured. The indirect tensile strength (I.T.S) is computed using the Eq 1:

$$I.T.S = {}^{2P_{ult}}/_{\pi.t.D} \qquad (1)$$

I.T.S = indirect tensile strength (MP).
P_ult = ultimate load at failure (N).
t = thickness of specimen (mm).
D = diameter of specimen (mm).

6. Presentation of Testing Results

The testing results represent by stability, flow and temperature susceptibility.
The results of the stability test are presented in figure (5, and 7). The test performed in two different temperature to find out the effect of temperature on the stability. The results show that there is an increase in the stability at 40 c.
The flow test results are presented in figure 6 and figure 8. The test also performed in two different temperatures to detect the influence of temperature on the flow. The results show that there is an improvement in the result at temperatures of 40 and 60.
The temperature susceptibility test results are presented in figure 9. The result shows that there is a decrease in temperature susceptibility. Temperature susceptibility can be calculated by equation 2.

$$T.S = I.T.S(t1) - I.T.S(t2)/(t2-t1) \qquad (2)$$

T.S = temperature susceptibility (Kpa/C▫).
I.T.S(t1) = indirect tensile strength at t1.
I.T.S (t2) = indirect tensile strength at t2.

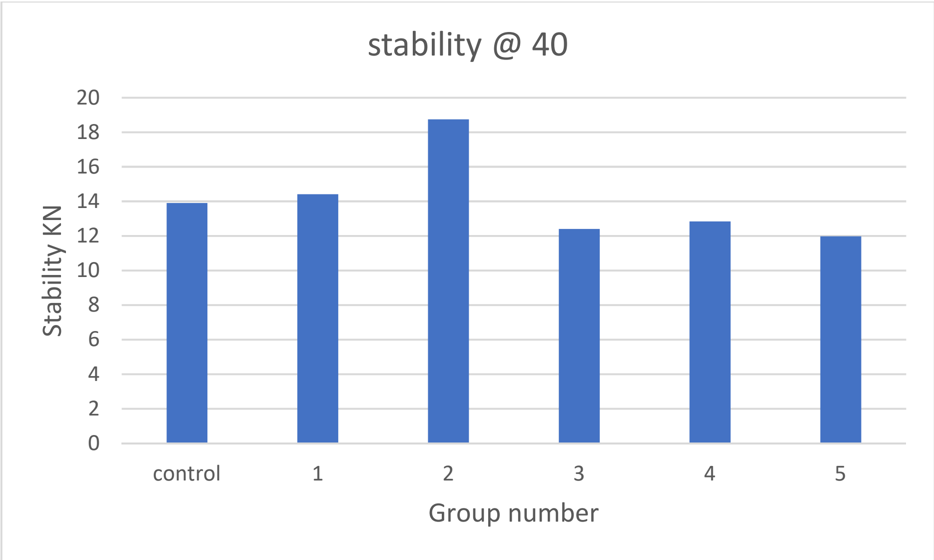

Figure 5. Effect of fibers on stability at 40c

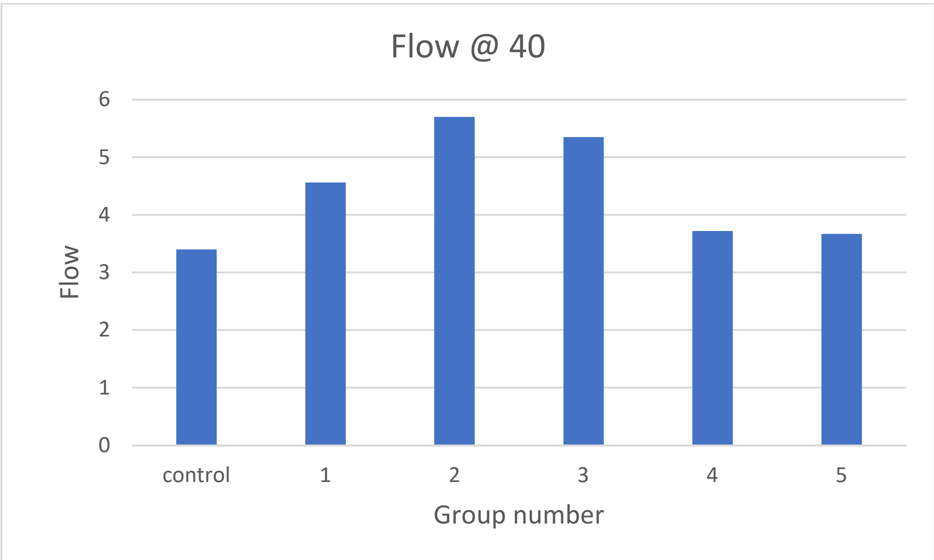

Figure 6. Effect of fibers on flow at 40c

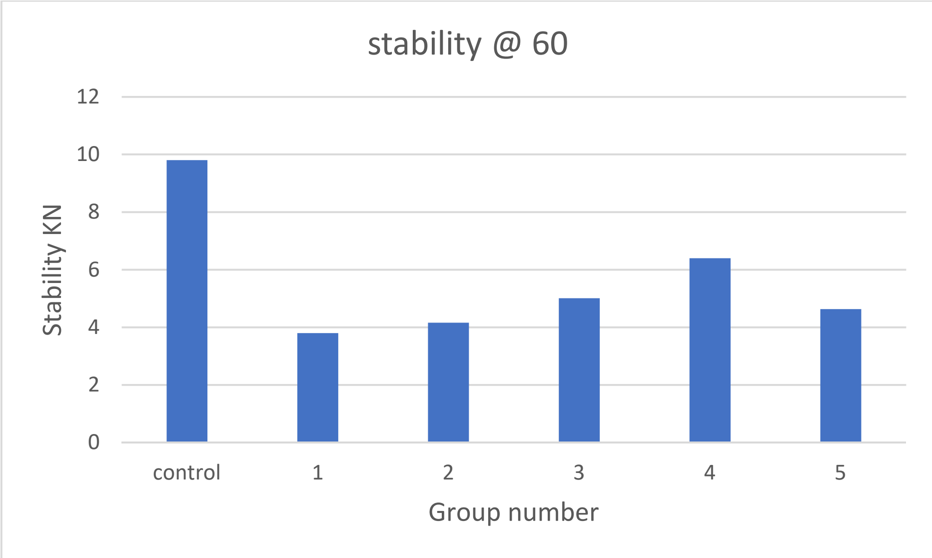

Figure 7. Effect of fibers on stability at 60c

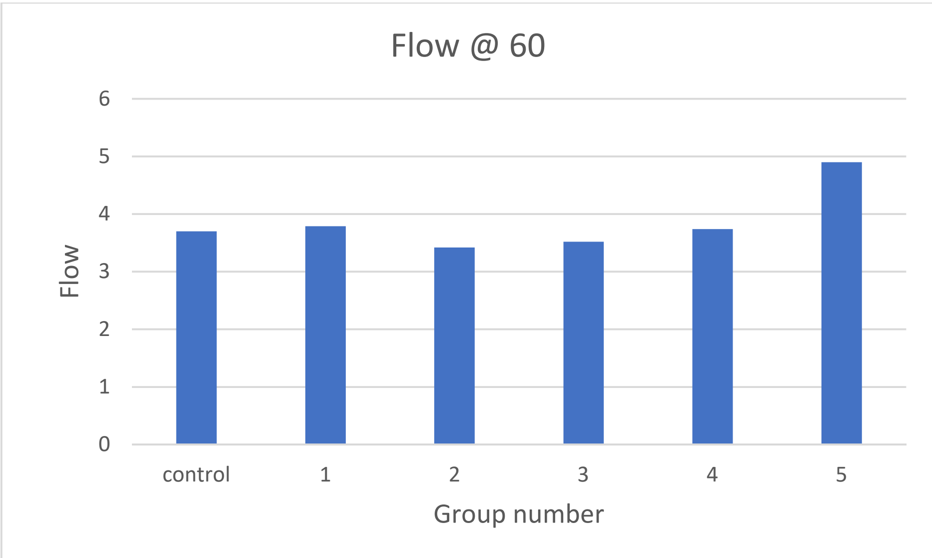

Figure 8. Effect of fibers on flow at 60c

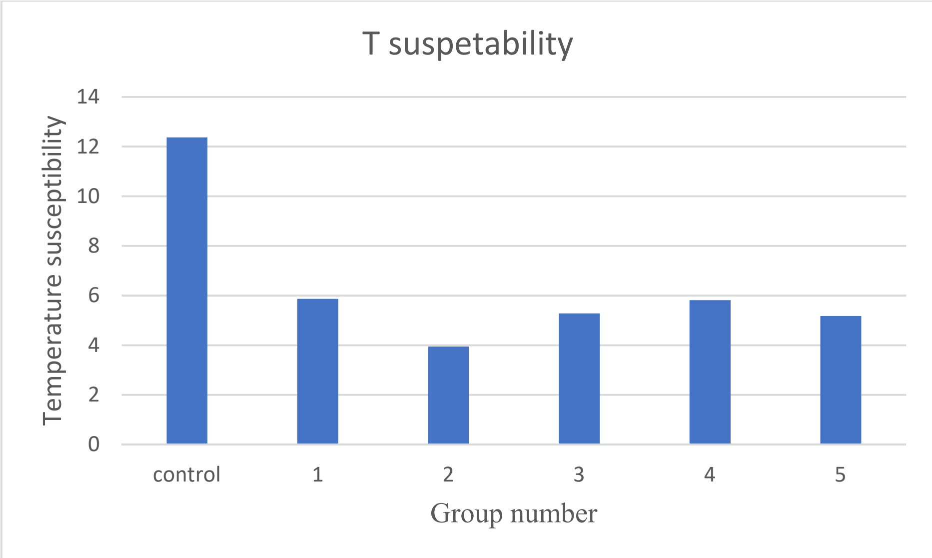

Figure 9. Effect of fibers on Temperature susceptibility

7. Result discussion

- Based on the results presented in the figures (5 – 9), the following points show the influences of adding steel and polypropylene fibers in different combinations to Marshall Specimens.
- Stability values of specimens modified with fibers show improvement at temperature of 40c. The specimen that improved with group 2 of fibers (0.3% of steel fibber and 0% of Polypropylene fiber by total weight of mixture) has the highest stability. It is higher than the control one by 34.87%. While with temperature of 60c, adding fibers did not make any improvement.
- Flow values of specimens modified with fibers show improvement at temperature of 40c. The enhanced specimen with group 2 of fibers (0.3% of steel fibber and 0% of Polypropylene fiber by total weight of mixture) has highest flow. It is higher than the control one by 67.65%. In addition, they show improvement in flow values at temperature of 60c. The highest value of flow at 60c is the improved specimen with group 5 of fibers (0.3% of steel fibber and 0% of Polypropylene fiber by total weight of mixture). It is higher than the control one by 32.4%.
- Temperature susceptibility of specimens modified with fibers show improvement. The specimen that enhanced with group 2 of fibers (0.3% of steel fibber and 0% of Polypropylene fiber by total weight of mixture) has the least effect to temperature change. It has less effect to temperature by 67.5% than the control specimen.
- Comparing the outcomes with previous studies, it can be noticed that the previous studies investigated one type of fibber wither steel or Polypropylene fiber. However, it can be noticed that the best group for this study is no.2, 0.3 steel fiber which is almost similar with previous studies and 0.1 Polypropylene fiber which is different from previous studies and the reason is the combination of the two fibers.
- Using these two fibers can be considered as economically efficient, hence they are locally available and they are relatively cheaper than other fibers.

Conclusions

- The main objective of this work is to evaluate the effect of adding steel and polypropylene fibers to Marshall specimens. The following points can be concluded:
- Using steel and polypropylene fibers in different combination improves the stability of Marshall at temperature of 40c. The best combination is group 2 (0.3% of steel fibber and 0% of Polypropylene fiber by total weight of mixture). It gives improvement to stability by 34.87%. While at 60c, it did not add any improvement.
- Using steel and polypropylene fibers in different combinations improves the flow of Marshall at temperature of 40c as well as 60c. The best combination at temperature of 40c is group 2 (0.3% of steel fibber and 0% of Polypropylene fiber by total weight of mixture). It has improvement of 67.65%. While the best combination at temperature of 60 is group 5 of fibers (0.3% of steel fibber and 0% of Polypropylene fiber by total weight of mixture). It has improvement of 32.4%.
- Using steel and polypropylene fibers in different combinations improves the temperature susceptibility. The best combination is group 2 (0.3% of steel fibber and 0% of Polypropylene fiber by total weight of mixture). It has less effect to temperature by 67.5%.
- For future work it is recommended to implement more tests such as tensile strength ratio (TSR) to evaluate moisture susceptibility and creep tests to evaluate permanent deformation.

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