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Investigation of textile waste usage in stone mastic asphalt (SMA) mixtures

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Research Paper

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Investigation of textile waste usage in stone mastic asphalt (SMA) mixtures

Stone mastic asphalt pavements are preferred worldwide as they are more resistant to heavy traffic loads. The stone mastic asphalt pavement design involves the use of 70-80% of coarse aggregate, 8-12% of filler, 5-7% of binder, and approximately 0.3-0.5% of fibre. The gap-graded structure and high binder content of stone mastic asphalt cause bitumen to drain down from aggregates. Marshall test and Schellenberg bitumen drainage test are performed in this research on samples prepared with different quantities of textile waste and cellulose fibre. The results of the research show that textile waste can be used instead of traditional fibres.

Key words:

stone mastic asphalt, drainage, textile waste, cellulose fibre, eco-friendly

Prethodno priopćenje

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Ispitivanje upotrebe tekstilnog otpada u mješavini splitmastiksfalta (SMA)

Na globalnoj razini preferiraju se splitmatiksfaltni kolnici koji su otporniji na teška prometna opterećenja. Sadržaj splitmastiksfaltnog kolnika čini 70-80 % krupnozrnatog agregata, 8-12 % punila, 5-7 % veziva te približno 0,3 do 0,5 % vlakana. Zbog diskontinuirane granulometrije i velikog postotka veziva, splitmatiksfalt omogućava drenažu bitumena iz agregata. Unutar ovog istraživanja provedena su Marshallova i Schellenbergova ispitivanja na uzorcima pripremljenim s različitim količinama tekstilnog otpada i vlakana celuloze. Rezultati ispitivanja pokazali su da se tekstilni otpad može koristiti umjesto tradicionalnih vlakana.

Ključne riječi:

splitmatiksfalt, drenaža, tekstilni otpad, vlakno celuloze, prihvatljivo za okoliš

Vorherige Mitteilung

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Prüfung im Hinblick auf die Verwendung des Textilabfalls in der Mischung des Splitmastiksfalts (SMA)

Auf der globalen Ebene werden die Fahrbahnen aus Splitmastiksfalt bevorzugt, welche gegen die großen Verkehrsbelastungen widerstandsfähig sind. Der Inhalt der Fahrbahn aus Splitmastiksfalt besteht aus dem 70-80%-igen grobkörnigen Granulat, aus 8-12% Füllmitteln, 5-7% des Bindemittels, sowie ungefähr 0,3 bis 0,5% der Fasern. Wegen der diskontinuierlichen Granulometrie und einem hohen Prozentsatz des Bindemittels ermöglicht der Splitmastiksfalt die Dränung des Bitumens aus dem Aggregat. Innerhalb dieser Forschung wurden die Prüfungen von Marshall und Schellenberg auf den Proben durchgeführt, welche mit den verschiedenen Mengen des Textilabfalls und der Zellulosefasern vorbereitet wurden. Die Prüfungsergebnisse haben gezeigt, dass der Textilabfall anstatt der traditionellen Fasern genutzt werden kann.

Schlüsselwörter:

Splitmatiksfalt, Dränung, Textilabfall, Zellulosefaser, umweltfreundlich

1. Introduction

Countries have nowadays become dependent on highways in passenger and freight transport. New highway networks are needed as the traffic volume increases. Therefore, the design of highway networks that requires large capital expenditures is very important [1, 2]. A satisfactory pavement design should be sufficiently serviceable, durable, resistant to permanent deformation, economical, and eco-friendly [3-5]. On a global scale, flexible pavements are the preferred type of highway superstructure [6-8]. In flexible pavement design, four distinct aggregate mixtures are used, i.e. open graded, dense graded, uniformly graded, and gap graded. In the open graded scenario, the mixtures are porous asphalt mixes with low fine aggregate content and high percentage of air voids. Dense graded aggregate mixtures are the most frequently used in the asphalt concrete design that ensures continuity and minimum air void percentage in the aggregate component. Uniformly graded type mixtures refer to a gradation in which most of the particles are in a very narrow size range. In essence, all the particles are of the same size. Gap-graded aggregate mixtures are stone mastic asphalt (SMA) pavements that have a high aggregate ratio in a certain sieve range and a rough surface [9]. The SMA was first developed in Germany in the 1960s in order to obtain a more durable asphalt pavement compared to traditional asphalt designs (dense graded asphalt mixtures) by preventing deformation caused by studded tires [9]. This is an asphalt mixture with a larger type of aggregate involving the stone to stone contact, and with the high content of binder filling the gap-graded structure, which increases an overall durability of asphalt [10]. Although the construction cost is by 20-25 % higher compared to traditional asphalt designs, when initial and final costs are considered together, it becomes clear that the SMA has significant advantages throughout its long term service life [11, 12]. The main advantages of the SMA use are the long service life, high resistance to continuous deformations and abrasion, resistance to moisture, slow ageing, and low noise levels [11-13]. Due to these superior features, it is preferred at intersections, bus stops, parking lots, sloping terrains, bridges, ports, and routes subjected to heavy traffic load [14]. The SMA pavement design involves the use of 70-80 % of coarse aggregate in the total aggregate weight, 8-12 % of filler, 5-7 % of binder, and approximately 0.3-0.5 % of fibre [15, 16]. During the production, transport and spreading of asphalt, bitumen drains from aggregates due to its high binder content and gap-graded structure. This drain down of bitumen from aggregate is an undesirable situation [17]. The cellulose fibre, mineral fibre, or polymers are used to prevent the drainage problem. Generally, cellulose or mineral fibres are preferred as a means to reduce drainage. These traditional fibres, widely used in the SMA, increase the price of pavement because of their high cost. Various studies have been published in the literature on the use of lower cost fibres in order to replace various additives that are now in common use [10, 16]. These research efforts are summarized below.

Oda et al. [2] investigated the use of sisal and coconut waste instead of traditional fibres in order to reduce the cost of stone mastic asphalt pavement. The authors stated that, compared to traditional fibres (cellulose, polyester), sisal and coconut waste have positive effects on mechanical properties of the mixture and reduce bitumen drainage.

In their research, Bindu and Beena [18] examined the effect of additives such as coconut, sisal, banana fibres, waste plastics, and polypropylene on the SMA mixture, the purpose being to eliminate waste. The authors achieved positive results in drainage tests involving mixtures prepared by adding the optimum fibre content of 0.3 %, 7 % of waste plastics, and 5 % of polypropylene, as related to the mixture weight. According to the drainage test results, the authors established that the mixtures prepared with sisal and banana fibre gave values close to each other, and that the best result was obtained for the mixture with coconut fibre.

Arshad et al. [19] added natural fibre (Kenaf) and synthetic fibre (Viatop66) additives to stone mastic asphalt (SMA) mixtures to improve the bitumen drainage feature. The experimental study results show that the optimum bitumen content of the Kenaf additive mixtures is the lowest, with the best performance against the formation of rutting. The authors suggested in the study that natural fibres can be used instead of synthetic fibres.

Rajesh et al. [14] investigated the use of cellulose fibre obtained from bamboo stalks as a stabilizer to reduce the cost of stone mastic asphalt pavements. For this purpose, the authors prepared asphalt samples with various bitumen contents by using 0.3 % of cellulose fibre. The results of the study show that stone mastic asphalt samples prepared with bamboo fibre have higher stability values while also being more resistant to drain down.

Xavier et al. [16] examined literature information on additives that prevent bitumen drain down. The authors proposed to prevent mix drain down by adding cellulose fibres, mineral fibres and polymers, in order to maximize deformation resistance or rutting, and to provide for the durability and longer service life of pavements. The Marshall method of mix design was used for preparing the samples. The findings published in the study indicate that pineapple fibre, which is rich in cellulose, could be used in future studies as the stabilizing additive in SMA mixtures. In their experimental studies, Baby et al. [20] investigated the use of marble dust waste and coconut fibre in stone mastic asphalt pavements. Based on the Marshall test results, the authors determined that for 4 % of air voids, the optimum bitumen content is 5.84 % and that the optimum fibre content is 0.3 %. The study results show that coconut fibre increases the mixture stability by 61.12 % and that it could be used instead of synthetic fibres for preventing drain down of bitumen.

In their scientific research, Shekar et al. [21] investigated the use of sugar cane and coconut waste in the SMA mixtures instead of conventional pelleted fibres. In the light of the data obtained from the research in terms of waste material added to the mixture, the optimum bitumen content according to 4 % air gap was 6.77 % for pelleted cellulose, 6.0 % for sugar cane and 5.3 % for coconut. In addition, the research results showed that the SMA mixtures prepared using coconut waste are the most resistant to drainage.

Kofteci [10] investigated whether the pumice mineral fibre can be used instead of cellulose fibres in stone mastic asphalt mixtures. The results of the study showed that the use of 4 % pumice mineral fibre in SMA mixtures may be an alternative to cellulose fibres.

Mansor et al. [22] compared sugarcane fibre with Viatop66 synthetic fibre using SMA mixtures. According to experimental results obtained by these authors, the drainage value of mixtures containing sugar cane was 0.02 %, while the drainage value of mixtures containing Viatop66 synthetic fibre was 0.19 %. In addition, according to the Hamburg rutting test results, the SMA asphalt samples prepared with sugar cane exhibited higher resistance to the formation of rutting.

Aslan and Aktaş [7] used various proportions of pumice and diatomite minerals as mineral fibre in stone mastic asphalt mixtures. In the scope of experimental studies, the authors determined an optimum bitumen content and conducted the bitumen drainage test according to the Marshall procedure. Based on test results, it was reported that the bitumen drainage was prevented in SMA samples prepared with the addition of pumice (1.5 %) and diatomite (0.5 %) minerals at minimum fibre percentage.

Suraj et al. [3] investigated the effect of sisal cellulose fibre addition on stone mastic asphalt samples. In the scope of experimental studies, the drainage test, tensile test, and creep test were conducted for samples prepared by adding 0.3 % of the sisal cellulose fibre additive. The authors concluded that mechanical properties of the pavement improved by adding sisal fibre to stone mastic asphalt mixtures.

Kumar and Ravitheja [1] conducted research on coconut fibre, sisal and banana fibres in order to investigate engineering properties of natural additives in the stone mastic asphalt. The Marshall test and indirect tensile tests were carried out using 0.3 % of the mixture weight regardless of fibre type. The study revealed that mechanical properties of asphalt mixtures prepared with coconut fibre were better when compared to mixtures prepared with sisal and banana fibres.

Mirza et al. [23] investigated the effect of glass fibre in dense graded and gap graded aggregate mixtures. The 5.5 % optimum bitumen content and the 0.3 % optimum fibre content were used in both mixtures. The study results revealed that the glass fibre additive significantly reduced drainage in both mixtures.

Nazir et al. [24] examined the effect of jute natural fibres in a dense graded and void graded mixture. In the study, 5.5 % optimum bitumen content and 0.3 % optimum fibre content were used for both mixtures. As a result, the authors stated that the jute fibre additive significantly reduced drainage in both mixtures. Based on the literature data, Razahi and Chopra [12] analysed the use of fibres such as the sisal fibre, coconut fibre, and hemp fibre, in highway industry. The researchers emphasized the importance of sisal fibres and coconut fibres. They stated that the optimum fibre content was 0.3 %. The researchers also observed that the sisal and coconut fibre provided better resistance to asphalt mixtures, and that this fibre was effective in preventing mixture flow.

Udayabhanu et al. [15] investigated the use of sunhemp and kenaf fibre in SMA mixtures. The improvement of Marshall properties of the SMA pavement with natural fibres, and reduction of bitumen drainage by 0.21 % for sunhemp and 0.23 % for kenaf according to the drainage test, were among the important results of the study. Kopylov and Burenina [25] used natural zeolite instead of traditional fibres in order to minimize bitumen drainage. By comparing the control sample with Stylobite, the authors concluded that natural zeolite can be used in stone mastic asphalt pavements.

Rahman et al. [6] conducted extensive research on the use of various environmentally damaging waste substances in asphalt industry. In the research, high density polyethylene, marble quarry waste, building demolition waste, crushed rubber, cooking oil, palm oil, fuel ash, coconut, sisal, cellulose and polyester fibres, starch, plastic bottles, waste glass, waste brick, waste ceramics, waste fly ash, and various other waste materials, such as cigarette butts, were investigated within the asphalt mixtures. The authors emphasized that these waste materials, which are of high concern to the world, would play an important role in reducing the costs of asphalt pavement and in curbing environmental pollution by eliminating waste in asphalt industry to ensure a sustainable future.

The aim of this research is to investigate the use of textile waste instead of traditional fibres in order to prevent the bitumen drainage problem in stone mastic asphalt pavements. Asphalt samples prepared with textile waste and traditional fibres selected as control samples were subjected to the Marshall stability test. In the scope of the research, the optimum bitumen ratio and mechanical performance of samples were determined by calculating design parameters according to the Marshall stability test. In addition, the Schellenberger bitumen drainage test was performed and the drain down features of stone mastic asphalt samples were compared.

2. Experimental studies

2.1. Materials

In this research, materials were selected according to the regulations of the Turkish General Directorate of Highways (KGM) [26]. The aggregate consists of crushed stone reduced to solid, durable and clean grains. Basalt remaining on the No.4 (4.75 mm) sieve was used in the coarse aggregate component. Due to the fact that basalt is difficult to break and the fine aggregate production is low, limestone was used in the fine aggregate component (passing through the No.4 sieve). The limestone component was also used as additional mineral filler in grading calculation. The limestone type aggregate used in the research was obtained from the Uşak Oktaş quarry and the basalt type aggregate was obtained from the Uşak Gedikler quarry. Traditional aggregate test results for both limestone and basalt are presented in Table 1 and Table 2, respectively. In this research, the mixture gradation of the aggregates was

Table 1. Physical properties of fine limestone aggregate

Test	Specification	Result	Specification limits
Specific gravity (fine aggregate)	ASTM C 128		
Dry surface saturated		2.531	–
Apparent		2.563	–
Water absorption [%]		0.820	
Specific gravity (filler)		2.610	–

Table 2. Physical properties of coarse basalt aggregate

Test	Specification	Result	Specification limits
Specific gravity (coarse aggregate)	ASTM C 127		
Dry surface saturated		2.582	–
Apparent		2.591	–
Water absorption [%]		0.23	
Abrasion (Los Angeles) [%]	ASTM C 131	21	Max. 20
Flatness index [%]	ASTM D 4791	8.5	Max. 10
Durability [%]	ASTM C 88	8.35	Max. 10 – 20

prepared according to the wear course (Type-1A) [26]. The SMA mixture gradation curve within design limits is shown in Figure 1, and the component of the aggregates forming the gradation is shown in Figure 2.

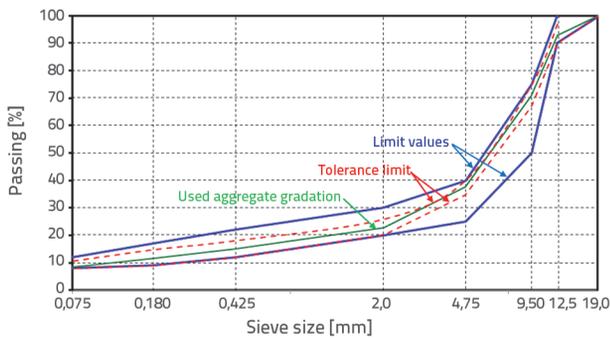


Figure 1. Mixture gradation curve



Figure 2. Component of aggregates

In this research, neat bitumen with 50/70 penetration in accordance with TS EN 12591, obtained from İzmir Aliğa

Table 3. Conventional test results for neat bitumen

Test	Specification	Result	Specification limits
Tests on non-aged samples			
Penetration (25 °C; 0.1 mm)	TS EN 1426	59.8	50-70
Softening point [°C]	TS EN 1427	47.6	46-54
Specific weight [g/cm³]	TS EN 15326	1.03	-
Flash point [°C]	TS EN ISO 2592	350	230<
Tests on aged samples after short term ageing with RTFOT (163 ° C)			
Mass loss [%]	TS EN 12607-1	0.04	<0.5
Permanent penetration [%]	TS EN 1426	96.4	%50<
Increase in softening point [°C]	TS EN 1427	6.48	<9

Refinery, was used as bituminous binder [27]. Unmodified bitumen was used as it enables better observation of the effect of fibres by eliminating the favourable effect of polymers in bitumen drainage tests. Conventional test results for neat bitumen are given in Table 3.

Cellulose or mineral fibres are used to prevent the bitumen drainage problem. In this research, textile waste was used instead of traditional cellulose fibres. This textile waste is cotton that is collected from the cotton yarn spinning mill at Polat Textile Company. Mechanical properties of textile waste set according to Turkey General Highways Directorate regulations are shown in Table 4 [26]. The image of the traditional cellulose fibre and textile waste used in SMA mixture is given in Figure 3 and Figure 4, respectively. The textile waste in loose form was passed through a sieve (1.70 mm) in order to distribute it homogeneously before adding it to the aggregate mixture.



Figure 3. Cellulose fibre



Figure 4. Textile waste

In literature studies, the optimum cellulose fibre content is generally set to 0.3 % of the mixture weight [1, 12, 19]. For the wear course in SMA, fibres are added to the mixture at a rate of 0.3 % - 0.1 % of the mixture weight or at the rates recommended by the manufacturer. In this paper, the drainage condition of the bitumen was evaluated by using the textile waste at a rate of 0.3 % and cellulose fibre at a rate of 0.3 %. The drainage behaviour of the bitumen was compared by using 0.1 % of textile waste and 0.2 % of cellulose fibre.

Table 4. Properties of textile waste

Property	Specification Limits	Result
Ash content	18% ± 5%	14
PH	7.5 ± 1%	6.9
Oil absorption	Fibre weight 5 ± 1 multiple	6.0
Moisture absorption	5% by weight	5

2.2. Marshall test

Marshall samples were produced according to the SMA design criteria [26, 28, 29]. The 1100 gr aggregate mixture was prepared by heating each SMA sample at approximately 170 °C. The textile waste (0.3 % - 0.1 %) and cellulose fibre (0.3 % - 0.2 %) were added separately to the aggregate mixture. SMA samples were produced by adding bitumen in different proportions (5.5-6.0-6.5-7.0 %) to the aggregate mixture. SMA mixture samples were prepared at the temperature between 130-140 °C and both surfaces of the samples were compacted with 50 Marshall blows.

Volume specific gravity (D_p) was determined by measuring the weight in air, weight in water and saturated surface weight for each of the SMA samples extracted from the Marshall briquette at room temperature, as presented in Figure 5. After calculating the maximum theoretical specific gravity (D_t), the air void ratio (V_h), the void ratio between aggregates (VMA) and voids filled with bitumen (VFA) as well as the optimum bitumen ratio of SMA mixtures were obtained from the graphs. The flow and stability results were obtained by performing the Marshall stability test. The results read from the graphs are summarized in Table 5.



Figure 5. Marshall sample

2.3. Schellenberg test

The Schellenberg test is used to measure the bitumen drainage rate in stone mastic asphalt mixes. The Schellenberg bitumen drainage test, which is widely used for cellulose fibres, was prepared in accordance with TS EN 12697-18 [30]. 1000 g of SMA mixtures prepared at 130-140 °C were placed loosely in

Table 5. Summarized Marshall test results

Properties	Mixtures		Specification limits		Specification	
	Cellulose fibre	Textile waste	Cellulose fibre	Textile waste		
Stabilizer rate [%]		0.3	0.2	0.1	0.3 - 0.1	-
Optimum bitumen [%]	6.70	6.50	6.60	6.40	>5.80	TS EN 12697-1
Dp [g/cm ³]	2.271	2.277	2.274	2.281	-	-
Dt [g/cm ³]	2.352	2.358	2.355	2.361	-	-
Vh [%]	3.50	3.50	3.50	3.50	2 - 4	TS EN 12697-8
VMA [%]	16.84	16.48	16.66	16.24	>16.00	TS EN 12697-8
VFA [%]	79.0	78.2	78.5	77.9	-	-
[mm]	4.42	4.48	4.28	4.31	-	-
Stability [kg]	814	838	798	812	-	-

a glass beaker previously heated in oven for 15 minutes at 110 °C. The glass beaker mixture was weighed to a precision of 0,1 g and the top of the glass beaker was covered.

SMA mixture samples were kept in oven at 175 °C for 1 hour as shown in Figure 6. At the end of that period, the asphalt mixture was removed from the oven, emptied without shaking, and measured using the 0.1 g precision scale. The drainage percentage was obtained by proportioning the filtered bitumen remaining in the beaker to the mixture weight. According to the specification, the Schellenberg bitumen drainage percentage should not exceed 0.3 % [26].



Figure 6. SMA mixture samples prepared for Schellenberg test

In this research, drainage quantities were first obtained for textile waste and cellulose fibre mixtures at an optimum bitumen ratio. Then SMA mixture drainage quantities were compared with various bitumen ratios (5.5-6.0-6.5-7.0 %) and various fibre ratios (0.1 % textile waste, 0.2 % cellulose fibre).

3. Analysis results

3.1. Marshall test results

Marshall test results related to SMA mixtures containing 0.3 % cellulose fibre, 0.3 % textile waste, 0.2 % cellulose fibre and 0.1 % textile waste are shown in Figure 7, Figure 8, Figure 9, and

Figure 10, respectively. On the other hand, the volume specific gravity (Dp, g/cm³), maximum theoretical specific gravity (Dt, g/cm³), air void (Vh, %), void ratio between mineral aggregates (VMA, %), voids filled with bitumen (VFA, %), flow (mm), and stability (Kg) results are shown in Figures 7-10.

The air void ratio is generally used to determine an optimum bitumen content in SMA mixtures. When the air void ratio (Vh) of each SMA mixture is reached as 3.5 % from the figures, optimum bitumen ratios are obtained separately and the void between aggregate (VMA) corresponding to 3.5 % air void has been achieved according to the specification limits. According to regulations set by Turkish General Directorate of Highways, the air void rate for the SMA wearing course is 2-4 % (3-4 % in hot climates), the gap rate between aggregates contained in Type-1A aggregate mixtures is minimum 16 %, and the bitumen binder ratio is minimum 5.8 % [26]. The optimum bitumen ratio results determined from graphics are summarized in Table 5.

Graph based optimum bitumen ratios for SMA blends containing 0.3 % cellulose fibre, 0.3 % textile waste, 0.2 % cellulose fibre and 0.1 % textile waste amount to 6.70 %, 6.50 %, 6.60 %, 6.40 %, respectively. When Marshall results are evaluated at an optimum bitumen ratio, for the same type of SMA mixtures, an increase in the use of stabilizers resulted in an increase in the optimum bitumen ratio, while the volume specific gravity (Dp) tended to decrease. It was determined from the figures that the optimum bitumen ratio of the mixtures prepared with textile waste was lower compared to cellulose fibre mixtures. While the theoretical specific gravity (Dt) of SMA mixtures changed inversely with the amount of bitumen, the void between aggregates (VMA) and the change in the voids filled with asphalt (VFA) was directly proportional to the amount of bitumen.

The amount of flow obtained from the Marshall stability test showed a change parallel to the stability results. While the SMA mixture with 0.3 % textile waste content had the highest stability value, the lowest stability was obtained for the 0.2 % cellulose fibre mixture. SMA mixtures prepared with textile waste contributed to Marshall stability. In addition, because of the problem of bitumen drainage from aggregates in the

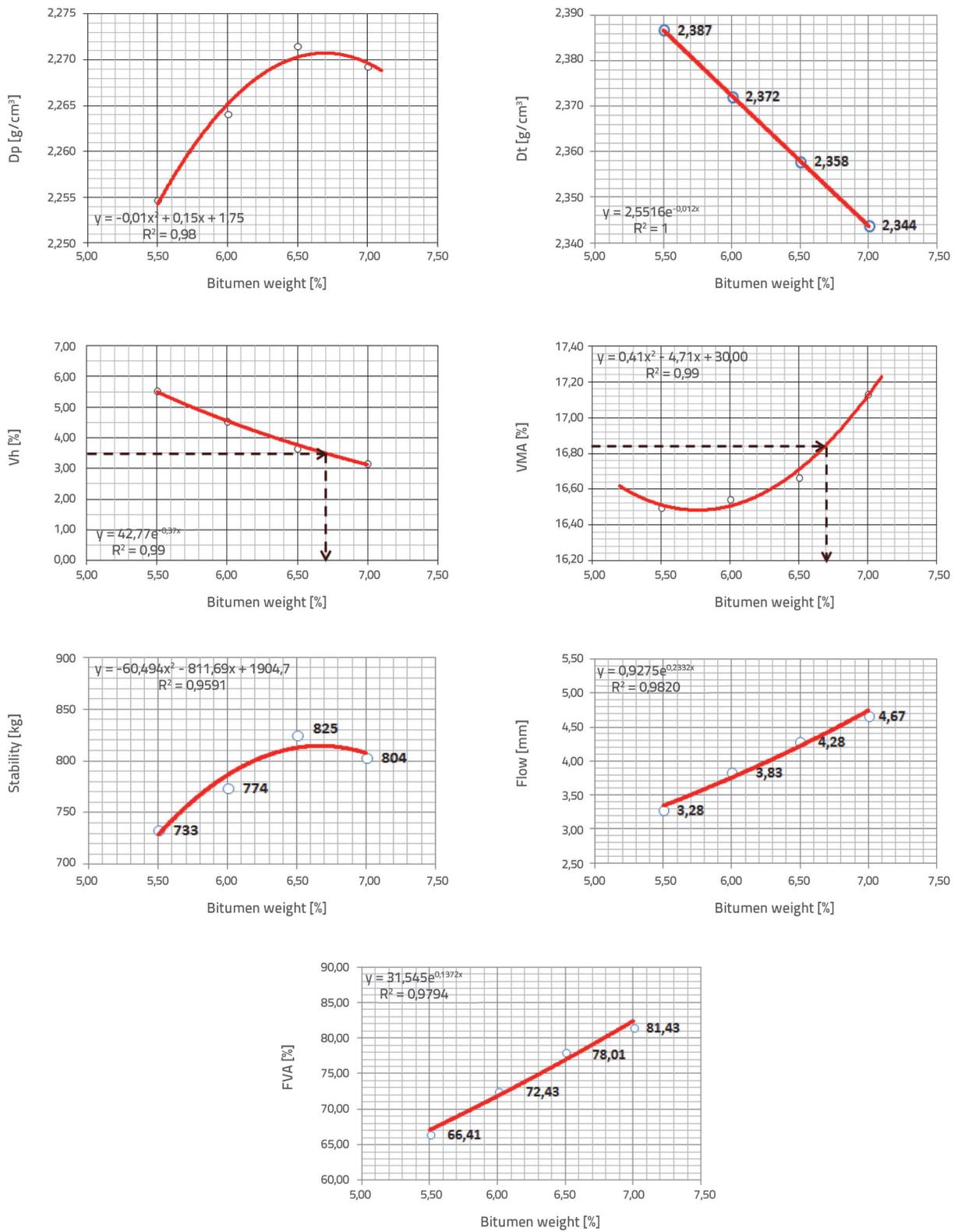


Figure 7. Marshall test results for SMA mixture with 0.3% cellulose fibre

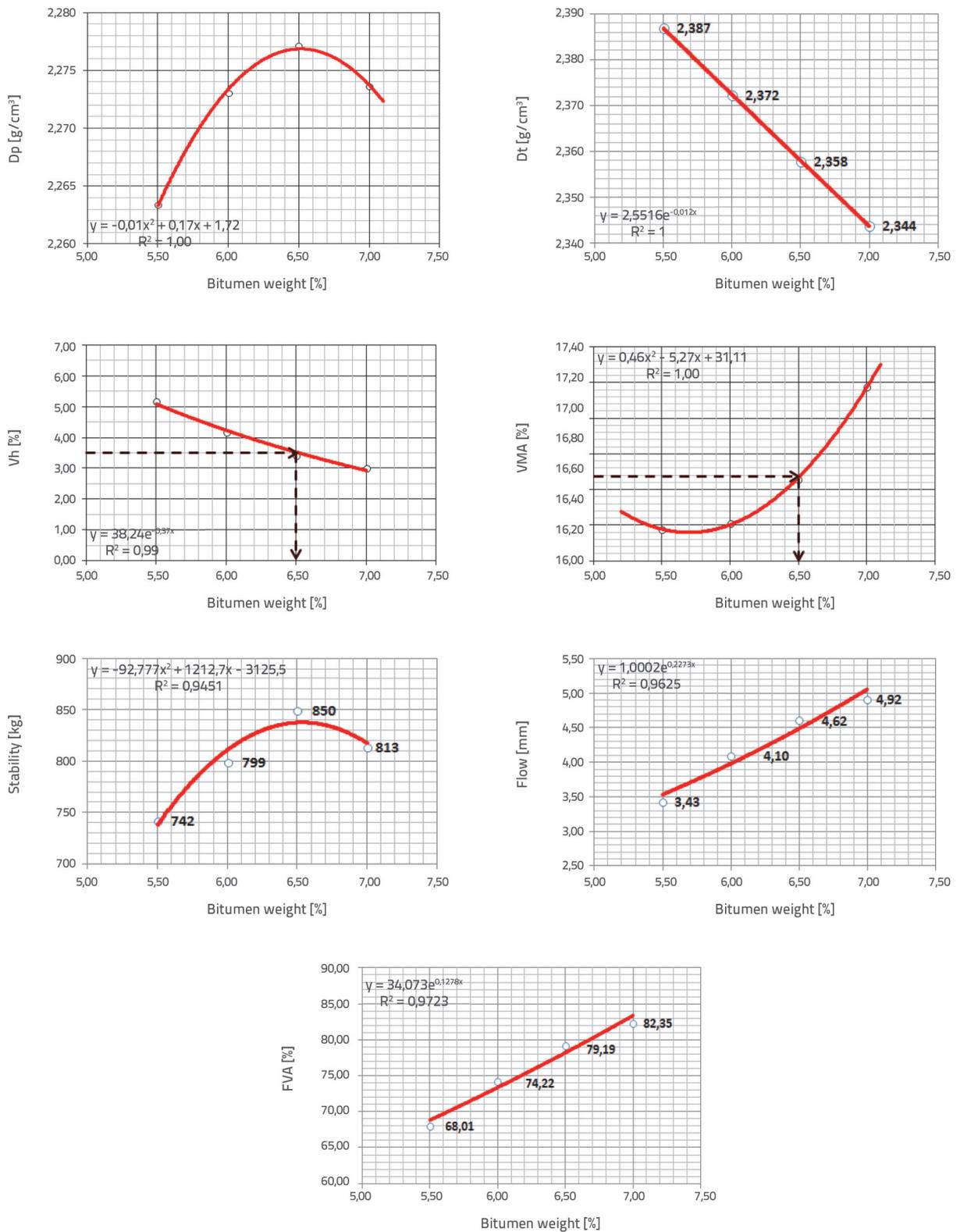


Figure 8. Marshall test results for SMA mixture with 0.3 % textile waste

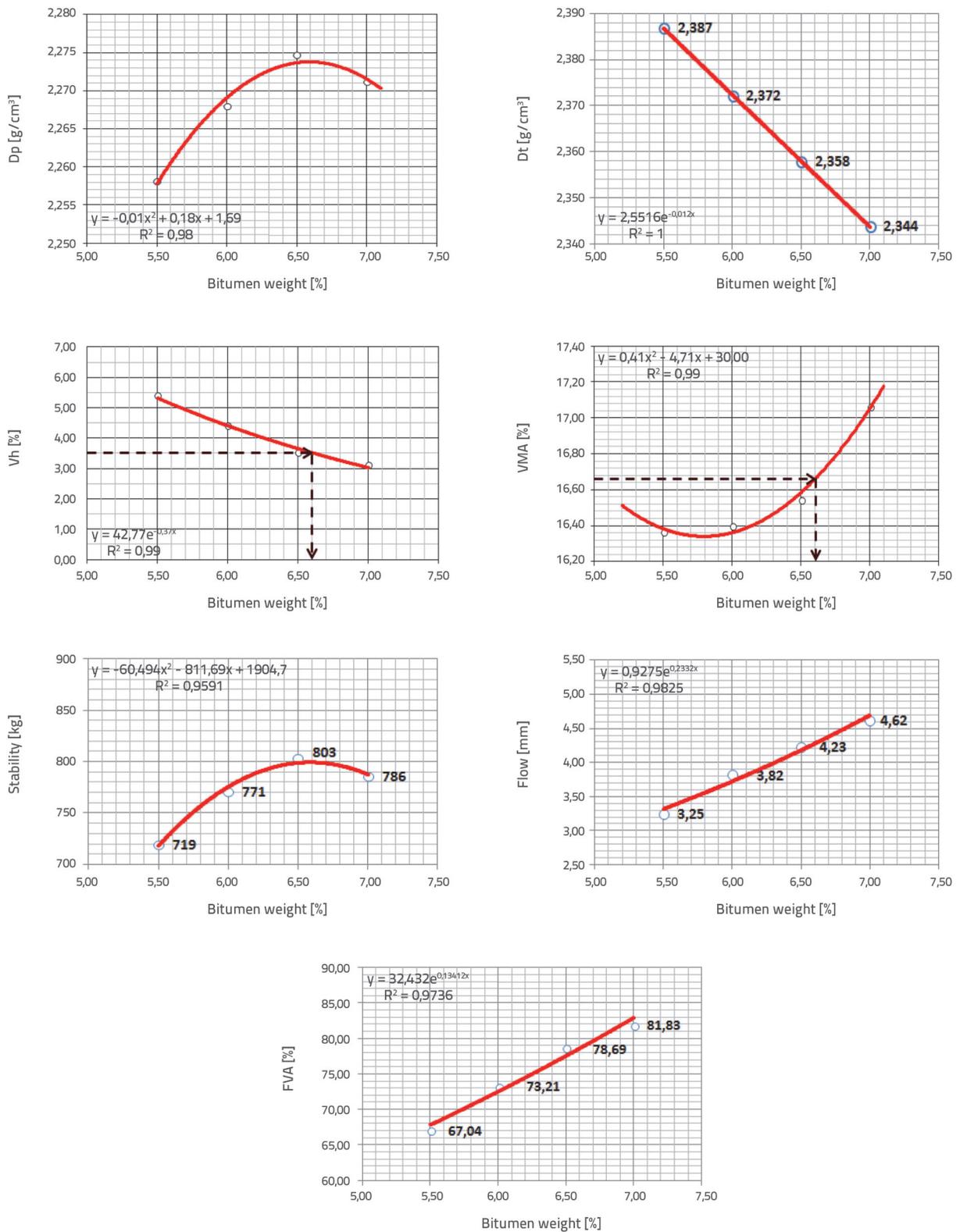


Figure 9. Marshall test results for SMA mixture with 0.2% cellulose fibre

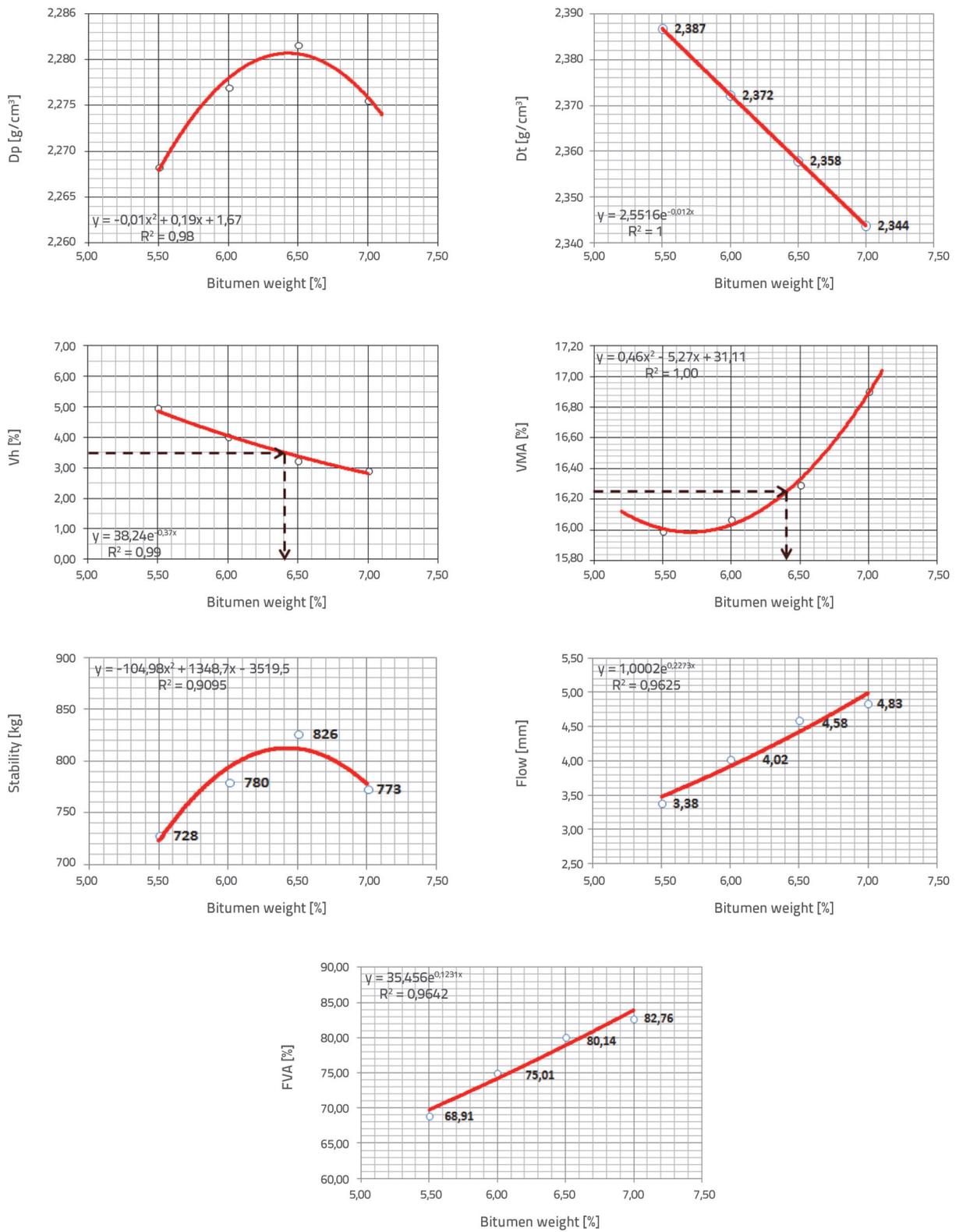


Figure 10. Marshall test results for SMA mixture with 0.1 % textile waste

SMA mixture used in this research, the Marshall test could not be performed at the SMA sample without fibre additive (0.0 % fibre) as expected.

3.2. Schellenberg test results

According to regulations set by Turkish General Directorate of Highways, the Schellenberg bitumen drainage test was carried out in accordance with TS EN 12697-18 [26, 30]. The drainage of SMA mixtures prepared according to the standard should not exceed 0.3 % [26]. Schellenberg test results related to SMA mixtures containing different proportions of cellulose fibre and textile waste are presented in Figure 11 and Figure 13.

The optimum bitumen ratio of the textile waste and cellulose fibre mixtures, added to the mixture at the rate of 0.3 % by weight of mixture, is shown in Figure 11. The drainage amounts remaining in the beaker are respectively shown in Figure 12. While the textile waste drainage ratio was 0.03 %, the reference sample mixture ratio was found to be 0.25 % for cellulose fibre. The SMA mixture prepared with textile waste has shown high performance, not only by having a low optimum bitumen ratio, but also by preventing drainage significantly.

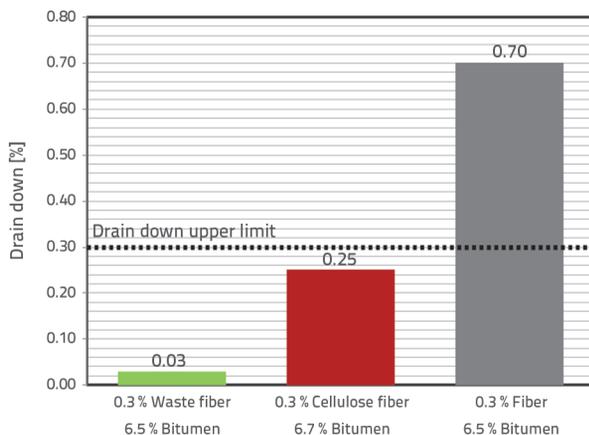


Figure 11. Schellenberg test results

Table 6. Summary of Schellenberg drainage test results

Stabilizer rate [%]	Optimum bitumen rate [%]	Drainage rate [%]	Specification limits [%]	Specification
0.3 (cellulose fibre)	6.70	0.25	< 0.30	TS EN 12697-18
0.3 (textile waste)	6.50	0.03	< 0.30	
0.2 (cellulose fibre)	6.60	0.27	< 0.30	
0.1 (textile waste)	6.40	0.07	< 0.30	

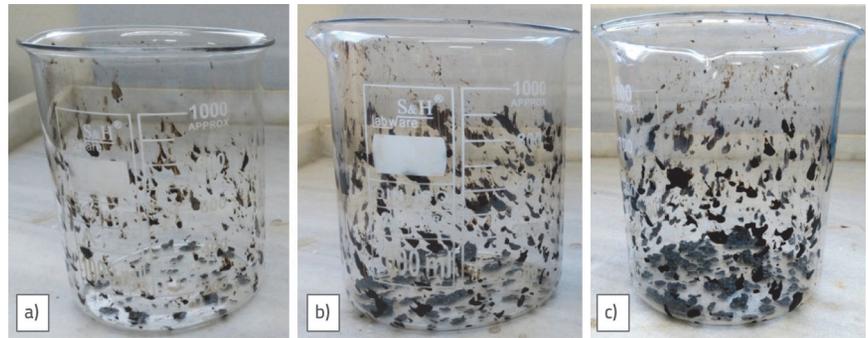


Figure 12. a) Textile waste, b) cellulose fibre, c) without fibre

Also, in Figure 11, the drainage condition of the mixture without fibre additive (0.0 % fibre) at 6.5 % of bitumen was evaluated. The bitumen drainage value amounted to 0.70 %, which exceeds the drainage upper limit of 0.3 % for the mixture without fibre additive. This drainage amount shows that there is a drainage problem with bitumen in Type-1A aggregate gradation that we used in the scope of the research.

The amount of drainage at the optimum bitumen rate is summarized in Table 6. According to Table 6; the drainage rate corresponding to the optimum bitumen content (6.60 %) of the 0.2 % cellulose fibre mixture was found to be 0.27 %, while the drainage rate corresponding to the optimum bitumen content (6.40 %) of the 0.1 % textile waste mixture was found to be 0.07 %. Although the textile waste content in the mixture was used 50 % less than the cellulose fibre content, the textile waste mixture at the same bitumen ratio or the optimum bitumen ratio showed high performance as lower drainage.

On the other hand, the drainage amounts of bitumen obtained by adding different bitumen rates (6.0-6.5-7.0 %) and different fibre rates (0.1 % textile waste, 0.2 % cellulose fibre) to the SMA mixtures are shown in Figure 13. Schellenberg test results for SMA mixture showed that, when prepared at the rate of 6.0-6.5-7.0 % of bitumen, the drainage of textile waste was found to be 0.04-0.09-0.34 % respectively, while the drainage of cellulose fibre was 0.08-0.21-0.59 %. It was concluded that the textile waste or cellulose fibre mixtures significantly reduced drainage of bitumen from aggregate.

Another interpretation to be made from Figure 13 is that the mixture with cellulose fibre (at the rate of 0.2 %) exceeded the drainage upper limit (0.30 %) after the 6.65 % of bitumen

content, while the mixture with textile waste (at the rate of 0.1 %) exceeded the drainage upper limit (0.30 %) after the 6.92 % bitumen content.

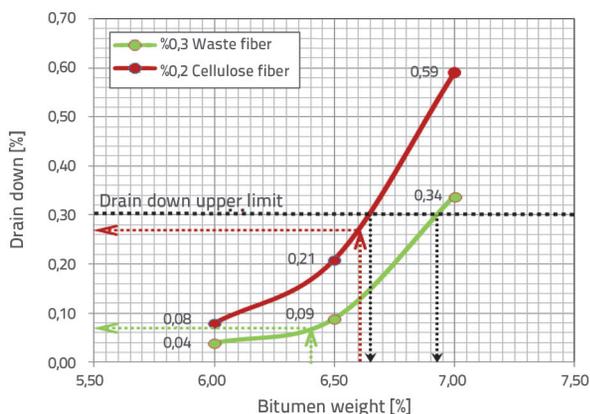


Figure 13. Schellenberg results

Hence, increasing the fibre usage rate in SMA designs increases the optimum bitumen ratio, thus causing an increase in pavement costs. Since the optimum cellulose fibre amount was used as 0.3 % in the research on SMA mixtures, the Marshall test was performed by using 0.3 % of textile waste at the beginning, and the optimum bitumen rate was obtained at 6.50 %. The use of 0.1 % of textile waste showed high performance against drainage, and exceeded the upper drainage limit (0.3 %) after the rate of about 6.92 % of bitumen.

As a result, when textile waste is used instead of cellulose fibres to prevent drainage of bitumen in SMA pavements, it contributes to both the decrease in asphalt pavement costs and the decrease in environmental pollution.

4. Conclusion

The use of textile waste instead of traditional cellulose fibres was evaluated in this study in order to prevent drainage problem in SMA pavements. When an asphalt mixture without fibre was tested with the 6.50 % of bitumen, it was determined that it exceeded the upper limit of the specification by being drained at 0.70 %. The aggregate gradation selected in the scope of this research showed that the bitumen has a drainage problem.

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According to Schellenberg test, when prepared at an optimum bitumen ratio, the cellulose fibre mixture was drained at the rate of 0.25 %, while the textile waste was drained at the rate of 0.03 %. The use of textile waste or cellulose fibres in the SMA mixture reduced bitumen draining. At the same stabilizer ratio (0.3 %), the main point of interest is that textile waste significantly reduced drainage compared to cellulose fibre.

When 0.2 % cellulose fibre content and 0.1 % textile waste content were separately used in SMA mixtures, corresponding to 3.50 % of air voids, the optimum bitumen ratio of cellulose fibre was found to be 6.60 %, while the textile waste rate in SMA designs increased the optimum bitumen ratio, the drainage behaviour at different bitumen ratios and different stabilizer content was evaluated. Although the textile waste content in the mixture was by 50 % lower than the cellulose fibre content, the textile waste mixture showed high performance by draining less.

According to the Marshall stability testing of SMA samples, 0.3 % textile waste mixture with the highest load capacity was obtained, while 0.2 % cellulose fibre mixture with the lowest load capacity was obtained. It was observed that SMA mixtures prepared with textile waste contribute to Marshall stability.

When the results of Marshall and drainage tests were considered together, the SMA mixture prepared with textile waste showed high performance compared to the cellulose fibre mixture selected as the reference sample. As a result, it was observed that the use of textile waste instead of expensive cellulose fibres in SMA pavements to reduce drainage contributes to reduction of cost of asphalt pavements, and to the reduction of environmental pollution due to disposal of waste.

In the scope of this research, the utilization of textile waste and traditional cellulose fibres was compared based on the Marshall test and Schellenberger bitumen drainage test results, the aim being to reduce drainage of bitumen. SMA mixtures containing textile waste significantly reduced the drainage of bitumen, demonstrating the potential for use instead of fibres in SMA pavements. As to future research in the sphere of SMA design, it is recommended to conduct the water sensitivity test, the Indirect tensile strength test, and the rutting test, so as to confirm properties of SMA with textile waste.

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