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Effect of Using Recycled Local Solid Waste Materials On Creep Properties of Asphalt Mixtures

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Abstract

Numerous waste materials result from manufacturing operations in industries. The purpose of this study was to investigate the effect of these waste materials on physical properties of asphalt cement and on surface layer of hot mix asphalt pavement. Asphalt cement with penetration grade (40-50) and 19 mm aggregate maximum size gradation is used in this study with Optimum asphalt content 4.9 %. at the desired temperature of (25°C).Two types of waste materials crushed glass and sawyer wood (both retained on sieve no. 200) with four percentages (0%, 3%, 6%, and 9% by weight of total aggregate) are used. The mixes are tested by using creep test.

From the experimental work, it can be seen that more benefits when additive waste glass or sawyer wood luck improved

mechanical (physical) and rheological properties for asphalt paving mixture.

Keywords: Asphalt, Pavements, Recycling of materials.

1. Introduction

Large amounts of domestic, industrial and mining waste are generated annually in each country (such as in Iraq). According to the Environmental Protection Agency (EPA), municipal solid waste (MSW) alone constituted 180 million tons in 1988. Without source reduction, generation of MSW is projected to reach 200 million tons by 1995. As the generation of waste continues to increase, the capacity to handle is decreasing , and new facilities are often difficult to site (EPA) due to economic and environmental constraints.

There are three techniques for waste disposal:
(a) Recycling;
(b) Incineration, with and without generation of energy; and
(c) Burial.

The construction and maintenance of the roads in Iraq require large amounts of aggregates, which typically account for more than 90% by weight of the asphalt mixtures. The situation seems even more urgent for approved landfill sites, as they are expected to run out of space in the next 5–10 years [1]. Based on such pressures, the UK government introduced the Landfill Tax in 1996 and the Aggregates Levy in 2002.The use of secondary (recycled), instead of primary (virgin), materials helps easing landfill pressures and reducing demand of extraction. This is one way of getting the road construction industry on track towards sustainable construction practices. Current research tends to concentrate on the use of waste materials in the courses. In addition, it can be argued that the cost of transporting and processing waste materials into desired properties can only be justified by using the recycled materials in value added applications such as asphalt surface layers. Thus, the property requirements for these applications need to be understood to ensure that materials intended for recycling are able to meet relevant specifications, by using available technologies and facilities, at a reasonable cost.

2. Review of Literature

Increasing pressure on environment conservation leads to significant reduction of the amount of materials to be exploited from materials quarries. This matter coupled with limited availability of land filled site adds further needs to utilize waste materials for constructions including road asphalt pavement.

The glass- manufacturing sector in the UK has a limited capacity to accept green and mixed color glass. As glass collection increases (to meet the 2006 packaging targets of 60% an “excess” (300,000 to 400,000 tones) of green glass likely for which alternative high value, high volume markets are required [2]. Glasphalt hot mixtures incorporating 30% crushed glass (using 100 pen. bitumen), laid at site in Milton Keynes by aggregates, showed an average indirect tensile stiffness value of 1900 MPa. Meanwhile, on the same trial, the control hot mixture (not containing crushed glass) gave 2200 Mpa. The average porosity for the Glasphalt and the control mixtures on that were 4.9% and 4.7% respectively [3].

The ConnDOT study[4] reports the following on the technical feasibility and economic aspects of using waste glass in bituminous pavements:

- Glasphalt was successfully mixed and placed in at least 45 locations in the U.S. and Canada between 1969 and 1988. However, most glasphalt has been placed on city streets, driveways and parking lots, and not on high-volume, high speed highways.
- Potential problems with glasphalt include: loss of adhesion between asphalt and glass; maintenance of an adequate level of skid resistance; and breakage of glass and subsequent raveling under studded tires.
- Glasphalt should be used only as a base course (if laboratory mixes prove acceptable) to minimize potential skid resistance and surface raveling problems.
- Maximum glass size of 3/8 in. should be used in glasphalt, with hydrated lime added to prevent stripping.

The limited laboratory study conducted by the Virginia DOT[5] used two glass contents, i.e. 5% and l5%, and two asphalt contents (based on 50-blow and 75 blow compactive effort of Virginia S-5 surface mix. The optimum asphalt contents were 6.2% and 5.75% for 50-blow and 75blow compaction, respectively. The study reports the following trends applicable to asphalt mixes containing glass content of 15% or less:

- The use of glass tends to reduce the voids in mineral aggregate (VMA) and voids in total mix, and increase voids filled with asphalt (VFA) of Marshall compacted specimens.
- Resilient modulus and tensile strengths are not adversely affected.

On the economic feasibility, Hughes concludes that “there is little monetary incentive to use recycled glass at the present time” in glasphalt in Virginia[5].

2-1 Effect of Additive Solid Waste Materials on Visco. Elastic properties of Asphalt Concrete Materials

Asphalt concrete materials exhibit a viscoelastic behavior. They behave as linear elastic or linear viscoelastic materials at low mix temperatures and as nonlinear visco-elasto-plastic materials at high temperatures [6]. The main components of viscoelasto-plastic behavior are shown in Figure (1).

The elastic element is a spring obeys Hooke’s Law, for which stress and strain are connected by the relation **$\sigma = E\, \epsilon$**, in which **σ** is the stress**,** **ϵ** is the strain, **E** is the elastic modulus. The simple viscous element is represented by a dashpot which is merely a piston moving in a viscous fluid contained in a cylindrical container, For this element **$\sigma=\lambda(d\epsilon/dt)$,** in which **$\lambda$** is the viscosity and **t** is time, under a constant stress the equation can be easily integrated and becomes **$\epsilon=\sigma t/\lambda$** [7]. Since viscoelastic material combine elastic and viscous effects, it is possible to model them approximately by combing the simple components in various parallel and series arrangements. The three most common types of such models are; the Maxwell, the Kelvin and Burger models as shown in Figure (٢). The Maxwell model is a combination of a spring and dashpot in series, while the Kelvin model is a combination of a spring and dashpot in parallel; however the behavior of asphalt materials can be explained by a Burger model which is a combination of Maxwell and Kelvin models where they connect in series [

Huang explained that a single Kelvin model is usually not sufficient to cover the long period of time which the retarded strain takes place and a number of Kelvin models may be needed[7]. Therefore, the generalized model is used to determine the viscoelastic constants E_o, T_o, E_i and T_i consists of one Maxwell model and two Kelvin models connected in series, as shown in Figure (3). The total strain of a generalized model can be written as:

$$\varepsilon = \frac{\sigma}{E_0}\left(1+\frac{t}{T_0}\right)+\sum_{i=1}^{n}\frac{\sigma}{E_i}\left[1-e^{\left(-\frac{t}{T_0}\right)}\right] \qquad 1$$

Where;

E_o: initial elastic Modulus (N/m^2).
T_o: relaxation time (sec).
E_i: elastic Modulus at any time (N/m^2).
T_i: retardation time (sec).
n : number of the Kelvin models.

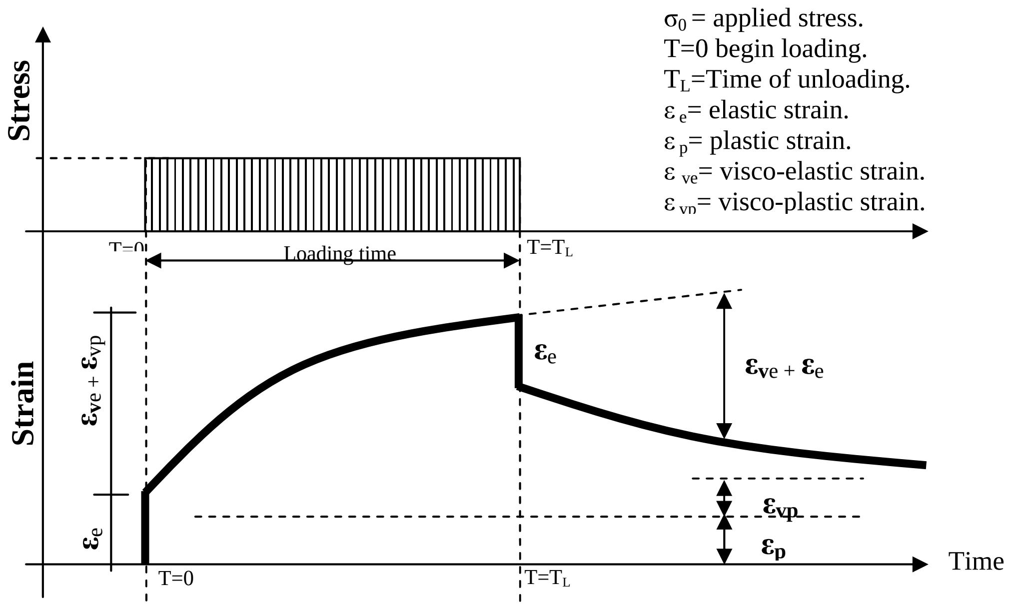


Figure (1) Schematic Representation of the Various Strain Components in an Elasto-Visco-Plastic Material [6]

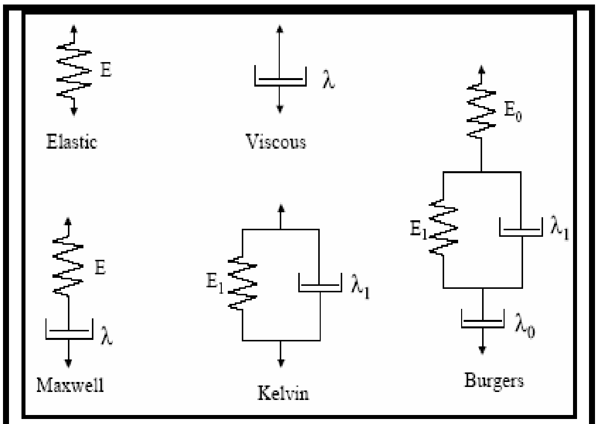
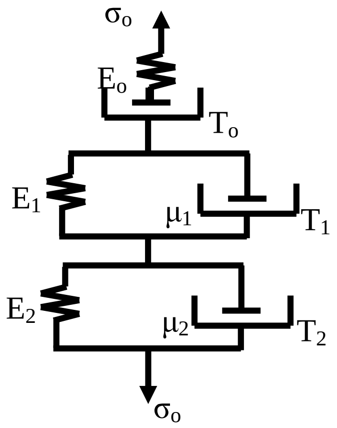


Figure (٢) Mechanical Models for Viscoelastic Materials [7]



Figure(٣) Generalized Model (Burgher Model) Consists of Two Kelvin Models and a Single Maxwell Model

Under a constant stress, the creep compliance is the inverse of Young’s modulus. For the generalized model, the creep compliance can be expressed as:

$$D(t)=\frac{1}{\mathrm{E_o}}(1+\frac{t}{T_o})+\sum_{i=1}^{n}\frac{1}{E_i}[1-e^{(-\frac{t}{T_i})}] \qquad 2$$

The constants of a generalized model (Burgher model) can be determined by two methods:-
a) The method of successive residuals.
b) The approximate method of collection.
Hunag explains that the method of successive residuals is better than the approximate method; therefore, it is used in this study[7].

Successive Residuals Method

The successive residual method is used to determine directly the constants, Ei and T_I, of viscoelastic materials from the creep compliance curve first, the creep compliance D(t) due to retarded strains is determined by deducting the instantaneous and viscous strains from the total strains as shown in Figure (4).

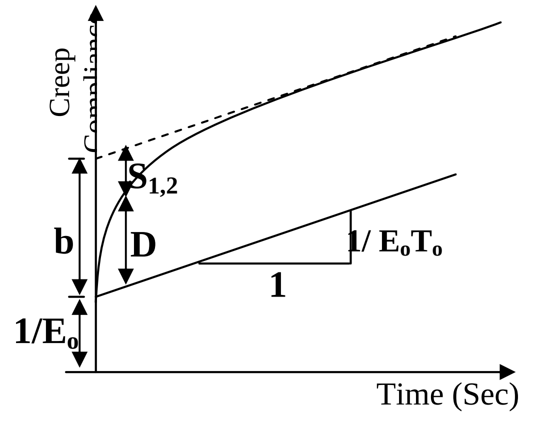


Figure (4) Separation of Creep Compliance [7]

In this study it is assumed that a generalized model consists of two Kelvin models are needed to describe retarded strains and a single Maxwell model.

$$D=\frac{1}{E_1}[1-e^{(-\frac{t}{T_1})}]+\frac{1}{E_2}[1-e^{(-\frac{t}{T_2})}] \qquad 4$$

$$\mathrm{b}=\frac{1}{\mathrm{E}_1}+\frac{1}{E_2}$$

$$\mathrm{S}_1=b-D=\frac{1}{E_1}e^{(-\frac{t}{T_1})}+\frac{1}{E_2}e^{(-\frac{t}{T_2})} \qquad 5$$

If T_1 is much greater than T_2, then after a sufficient period of time the last terms on the right side of eq.8 can be neglect.

$$S_1=\frac{1}{E_1}e^{(-\frac{t}{T_1})} \qquad 6$$

Plot log S_1 versus time (t), results in a straight line, as indicated by equation (6) and Figure (5).

$$\log S_1=\log(\frac{1}{E_1})-\frac{0.434t}{T_1} \qquad 7$$

The slope of the straight line can be used to determine T_1, and the intercept at t=0 can be used to determine E_1. After E_1 and T_1 are found, equation (5) can be written as:-

$$S_2=b-D-\frac{1}{E_1}e^{(-\frac{t}{T_1})}-\frac{1}{E_2}e^{(-\frac{t}{T_2})} \qquad 8$$

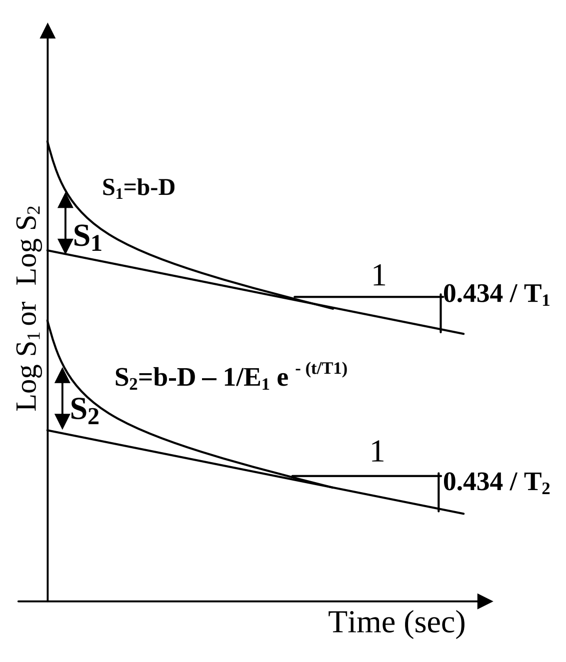


Figure (5) Method of Successive Residuals

3.**Materials**

The materials used in this study are locally available and selected from the currently materials used in roads construction in Iraq.

3.1 Asphalt Cement

One type of asphalt cement is used, (40-50) Penetration grade from Daurah Refinery. The physical properties for the asphalt cement are presented in Table (1).

3.2 Aggregate

The aggregate used in this work was crushed quartz obtained from Amanat Baghdad asphalt concrete mix plant, its source is Al-Nibaie quarry. This aggregate is widely used in Baghdad city for asphaltic mixes. Routine tests were performed on the aggregate to evaluate their physical properties. The results together with the specification limits as set by the SCRB are summarized in Table 2. The coarse and fine aggregates used in this work were sieved and recombined in the proper proportions to meet the surface course gradation as required by SCRB specification [9]. 19 mm aggregate maximum size gradation is used in this study. Aggregate gradation shown is in Table (3) and Figure (6).

Table (1) Physical Properties of Asphalt Cement

Property	ASTM Designation[8]	Penetration Grade 40-50	
		Test Results	SCRB Specification[9]
1-Penetration at 25˚C,100 gm,5 sec, (0.1mm)	D-5	43	40-50
2- Softening Point, (˚C)	D-36	54	……
3-Ductility at 25 ˚C, 5cm/min,(cm)	D-113	>100	>100
4-Flash Point, (˚C)	D-92	325	Min.232
5-Specific Gravity	D-70	1.045	……
6- Residue from thin film oven test	D-1754		
- Retained penetration,% of original	D-5	60	55^+
- Ductility at 25˚C , 5cm/min,(cm)	D-113	82	25^+

Table (2) Physical Properties of Aggregate

Property	ASTM designation	Test results	SCRB specification
<u>Coarse aggregate</u>			
1. Bulk specific gravity	C-127	2.611	……
2. Apparent specific gravity		2.689	……
3. Water absorption,%		0.443	……
4. Percent wear by Los Angeles abrasion ,%	C-131	18.7	30 Max
5. Soundness loss by sodium sulfate solution,%	C-88	3.1	10 Max
6. Fractured pieces, %		96	95 Min
<u>Fine aggregate</u>			
1. Bulk specific gravity	C-127	2.663	……
2. Apparent specific gravity		2.697	……
3. Water absorption,%		0.727	……
4. Sand equivalent,%	D-2419	55	45 Min.

Table (3) Specification Limits of SCRB and the Selected Gradation

Sieve Size	Sieve Opening (mm)	Percentage Passing by Weight of Total Aggregate Surface or Wearing Course	
		Specification Limit (SCRB)	Selected Gradation
3/4"	19	100	100
1/2"	12.5	90-100	95
3/8"	9.5	76-90	83
No.4	4.75	44-74	59
No.8	2.36	28-58	43
No.50	0.3	5-21	13
No.200	0.075	4-10	٧

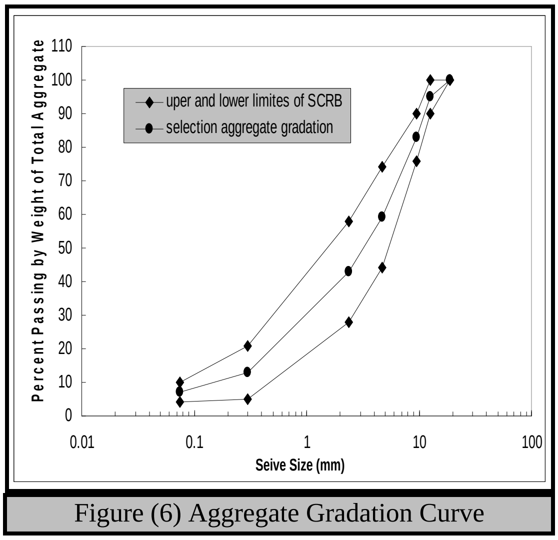


Figure (6) Aggregate Gradation Curve

3.3 Mineral Filler

One type of mineral filler is used: ordinary Portland cement (from Kubaisa factory). It is thoroughly dry and free from lumps or aggregations of fine particles. The physical properties are shown in Table (4).

Table (4) Physical Properties of Mineral Filler

Property	Test results
% Passing Sieve No. 200	98
Specific Gravity	3.13
Specific Surface area (m^2/kg)	356

3.4 Additives

Two types of additives have been used in this work as solid waste materials, which are crushed glass and sawyer wood. Both passing from sieve no. 200. The percentage 3%, 6%, and 9% by weight of total aggregate are used. Figure (7) shows sample of crushed glass and sawyer wood.

Sample of Sawyer Wood

Sample of Crushed Glass

Figure (7) Samples of Solid Waste Materials that Used in this Study

4. Test Methods And Results

4. 1 Marshall Test

This method includes preparation of cylindrical specimens which are 4 inch (101.6 mm) in diameter and 2.5 ±0.05 inch (63.5 ±1.27 mm) in height according to ASTM (D 1559) [6].

The Marshall mold, spatula, and compaction hammer were heated on a hot plate to a temperature between (120-150 ˚C). In this study 4.9% optimum asphalt content was used.

The asphalt mixture is placed in the preheated mold and it is then spaded vigorously with the heated spatula 15 times around the perimeter and 10 times in the interior.

The temperature of the mixture immediately prior to compaction is between (142-146˚C) [10]. Then, 75 blows on the top and bottom of the specimen are applied with a compaction hammer of 4.535 kg sliding weight, and a free fall in 18 inch (457.2 mm).The specimen in mold is left to cool at room temperature for 24 hours and then it is removed from the mold.

Marshall Stability and flow tests were performed on three samples without containing waste material. The cylindrical specimen is placed in water bath at 60 ˚C for 30 to 40 minutes, and then compressed on the lateral surface at constant rate of 2in/min. (50.8mm/min) until the maximum load (failure) was reached. The maximum load resistance and the corresponding flow value were recorded.

Table (5) presents the mixtures properties at optimum asphalt contents (4.9%). The data in Table (5) indicate that mixture meet the Iraqi specification requirements [8].

The bulk specific gravity and density ASTM (D 2726), theoretical (maximum) specific gravity of voidless mixture are determined in accordance with ASTM (D 2041). The percent of air voids, voids in mineral aggregate (VMA), and void filled filled with asphalt (VFA) were then calculated. The result are shown in Table (6). Each result represents an average of three reading.

Table (5) Mix Properties with Optimum Asphalt Content (Surface Layer)

Marshall Property	AC40-50	Specification Requirements (SCRB)
Stability, kN	9.430	8 min.
Flow, mm	3.048	2-4
Percent air voids	3.86	3-5
Percent VMA	14.927	14 min.
Percent VFA	74.141	70-85
Bulk Density of Compacted Mixtures (gm/cm^3)	2.331	2.1-2.45

Figure (7) shows the relationship between solid waste content and air voids. It is observed that the air voids increase with the increase in crushed glass content. It also, can be seen that the air voids increase by 3.4% at 3% sawyer wood content then it decreases with the increase in sawyer wood content up to 6% then it increases. Table (6) and Figure (7) indicate that (%air voids) for all modified mixtures are out off the range of (3-5) percent required by SCRB specification.

Figure (8) shows the relationship between percentage of voids in mineral aggregate (%VMA) and solid waste content. The Figure; shows that (%VMA) increases with the increase in crushed glass content. It also, can be seen that (%VMA) increases by 2.7% at 3% sawyer wood content then it decreases with the increase in sawyer wood content up to 6% then it increases. However, for all crushed glass and sawyer wood voids content in mineral aggregate (VMA) remains within the limits recommended by SCRB specification.

Table (6) Effect of Solid Wastes Material on Marshall Volumetric Properties

% Solid Waste (by weight of total mix)		Bulk Density (gm/cm^3)	Maximum Theoretical Density (gm/cm^3)	% Air Void	%VMA	%VFA
0%		2.33	2.424	3.877	14.939	74.042
Crushed Glass	3%	2.22	2.408	7.807	18.955	58.811
	6%	2.154	2.434	11.50	21.364	46.155
	9%	2.12	2.47	14.170	22.605	37.166
Sawyer Wood	3%	2.255	2.434	7.354	17.677	58.397
	6%	2.304	2.46	6.341	15.888	60.087
	9%	2.284	2.494	8.420	16.618	49.332

Figure (9) shows the effect of solid waste content on the percentage of voids filled with asphalt (%VFA). The Figure shows that increasing the percent of crushed glass content in the mixture will cause a decrease in the (%VFA) values. %VFA decreases by 15% at 3% sawyer wood content then it increases with the increase in sawyer wood content up to 6% then it decreases. Table (6) and Figure (9) indicate that (% VFA) for all modified mixtures are out off the range of (70-85) percent required by SCRB specification.

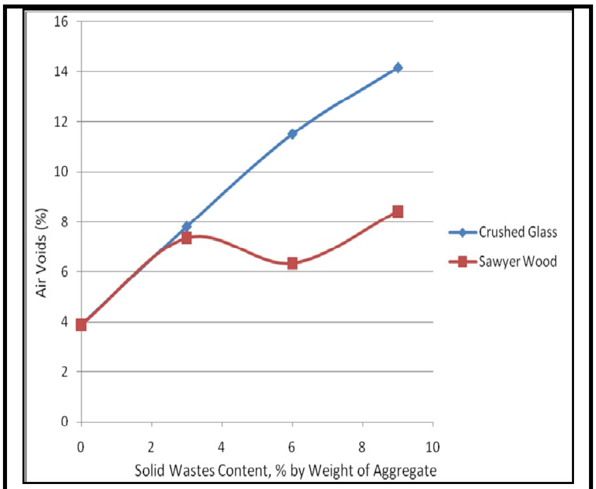


Figure (7)Relationship between Solid Waste Content and Air Voids

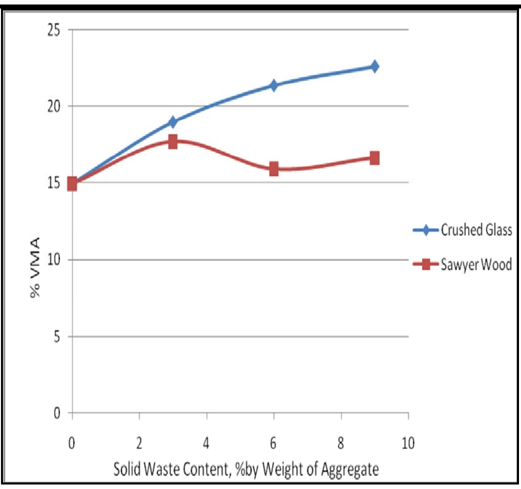


Figure (8) Relationship between Solid Waste Content and VMA

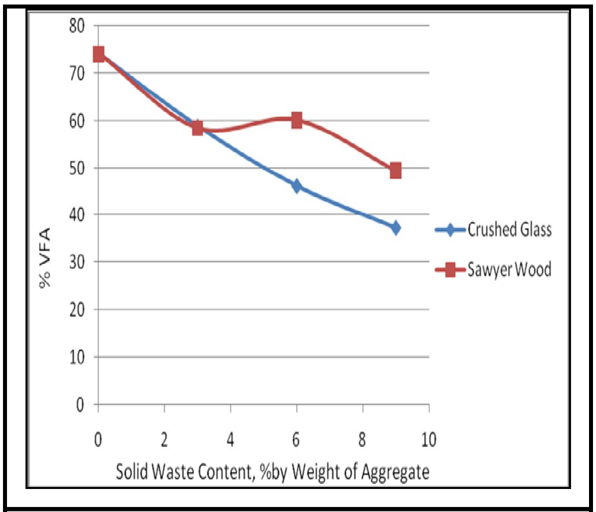


Figure (9) Relationship between Solid Waste Content and VFA

4.2 Creep Test

The diametric-indirect tensile creep test has been used to determine the stiffness of asphalt mixture by measuring strain-time values.

The Marshall specimens are used in these tests after they after cooling at room temperature for 24 hours, and then the specimens were immersed in a water bath for 30 min. at the desired temperature of 25˚C. The specimen was loaded to a static stress of 0.141 Mpa for one hour, and the deformation is recorded at certain time increments (6, 15, 30, 60, 120, 240, 480, 900, and 1800) seconds. The load was then released, and the recovered strain for 1 hour is recorded, at the same periods.

The vertical strain was calculated by using the following formula:

$$\varepsilon_{mix} = \Delta H / D_0 \qquad \text{(mm/ mm)} \quad 9$$

where: -

ΔH = The total measured vertical deformation at a certain loading time (mm), and

D_0 = The original diameter of specimen (101mm).

The stiffness modulus of the mixture is calculate by:

$$S_{mix} = \sigma / \varepsilon_{mix} \qquad (\text{N/mm}^2) \quad 10$$

where: -

S_{mix} = Stiffness modulus (N/mm^2).

σ = Applied stress (N/mm^2),and

ε_{mix} = Vertical strain in the mix (mm/mm).

$$D(t) = \varepsilon(t) / \sigma \qquad \text{(1/ Kpa)} \quad 11$$

Where:

D(t): the creep compliance in (1/ Kpa).

$\varepsilon(t)$: vertical strain (mm/mm).

σ : applied stress in (Kpa).

Three specimens are prepared for each mix combination.

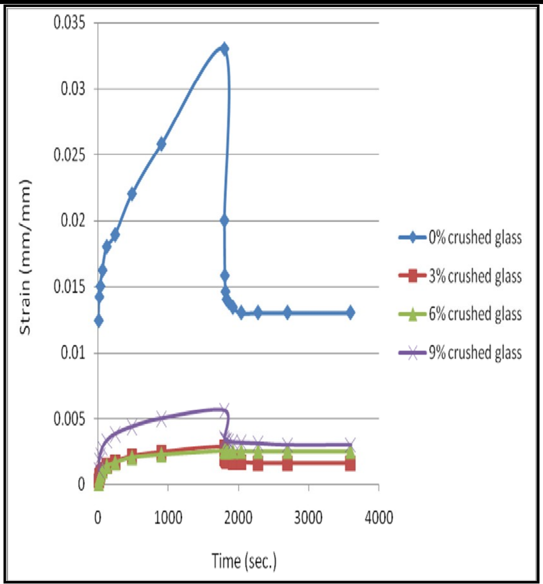
The typical results of the creep tests are presented in Tables (7) and (8) and Figures (10), (11), (12), (1

(7) Effect of Crushed Glass Content on Creep Test (Stress=0.141 Mpa, Temp. =25?C), (strain values as average of three Marshall Specimens)

Time (Sec.)	Crushed Glass Content (%)											
	0%			3%			6%			9%		
	Strain (mm/mm)	Stiffness (Kpa)	compliance (1/Kpa)	Strain (mm/mm)	Stiffness (Kpa)	compliance (1/Kpa)	Strain (mm/mm)	Stiffness (Kpa)	compliance (1/Kpa)	Strain (mm/mm)	Stiffness (Kpa)	compliance (1/Kpa)
Loading												
6	0.0124	11370	8.79433E-05	0.0003	470000	2.12766E-06	0.0001	1410000	7.0922E-07	0.0011	128181	7.8014E-06
15	0.0142	9929	0.000100709	0.00064	220312	4.53901E-06	0.0005	282000	3.5461E-06	0.0018	78333	1.2766E-05
30	0.015	9400	0.000106383	0.00086	163953	6.09929E-06	0.00076	185526	5.39007E-06	0.0022	64090	1.5603E-05
60	0.0162	8703	0.000114894	0.0011	128181	7.80142E-06	0.00106	133018	7.51773E-06	0.00276	51086	1.9574E-05
120	0.018	7833	0.00012766	0.0014	100714	9.92908E-06	0.00142	99295	1.00709E-05	0.0033	42727	2.3404E-05
240	0.0189	7460	0.000134043	0.0017	82941	1.20567E-05	0.00168	83928	1.19149E-05	0.00382	36910	2.7092E-05
480	0.022	6409	0.000156028	0.00212	66509	1.50355E-05	0.00206	68446	1.46099E-05	0.00436	32339	3.0922E-05
900	0.0258	5465	0.000182979	0.00242	58264	1.71631E-05	0.00228	61842	1.61702E-05	0.00498	28313	3.5319E-05
1800	0.033	4272	0.000234043	0.00284	49647	2.01418E-05	0.00258	54651	1.82979E-05	0.0056	25178	3.9716E-05
Unloading												
0	0.02			0.002			0.00254			0.0035		
6	0.0158			0.0019			0.00253			0.0034		
15	0.0146			0.00186			0.00252			0.0033		
30	0.014			0.0018			0.00252			0.0034		
60	0.0138			0.00176			0.00252			0.00328		
120	0.0134			0.00174			0.00252			0.00322		
240	0.013			0.00168			0.00252			0.00318		
480	0.013			0.0016			0.00252			0.00312		
900	0.013			0.0016			0.00252			0.003		
1800	0.0١٣			0.0016			0.00252			0.003		

Table (8) Effect of Sawyer Wood Content on Creep Test (Stress=0.141 Mpa, Temp. =25?C), (strain values as average of three Marshall Specimens)

Time (Sec.)	Sawyer Wood Content (%)											
	0%			3%			6%			9%		
	Strain (mm/mm)	Stiffness (Kpa)	compliance (1/Kpa)	Strain (mm/mm)	Stiffness (Kpa)	compliance (1/Kpa)	Strain (mm/mm)	Stiffness (Kpa)	compliance (1/Kpa)	Strain (mm/mm)	Stiffness (Kpa)	compliance (1/Kpa)
Loading												
6	0.0124	11370	8.79433E-05	0.0013	108461	9.21986E-06	0.00028	503571	1.99E-06	0.0004	352500	2.83688E-06
15	0.0142	9929	0.000100709	0.0016	88125	1.13475E-05	0.00071	198591	5.04E-06	0.00088	160227	6.24113E-06
30	0.015	9400	0.000106383	0.002	70500	1.41844E-05	0.0022	64090	1.56E-05	0.0023	61304	1.63121E-05
60	0.0162	8703	0.000114894	0.00244	57786	1.7305E-05	0.0034	41470	2.41E-05	0.004	35250	2.83688E-05
120	0.018	7833	0.00012766	0.0037	38108	2.62411E-05	0.0063	22380	4.47E-05	0.0065	21692	4.60993E-05
240	0.0189	7460	0.000134043	0.004	35250	2.83688E-05	0.008	17625	5.67E-05	0.009	15666	6.38298E-05
480	0.022	6409	0.000156028									
900	0.0258	5465	0.000182979									
1800	0.033	4272	0.000234043									
Unloading												
0	0.02											
6	0.0158											
15	0.0146											
30	0.014											
60	0.0138											
120	0.0134											
240	0.013											
480	0.013											
900	0.013											
1800	0.0١٣											



Figure(10) Effect of Crushed Glass Content on Creep Strain Results

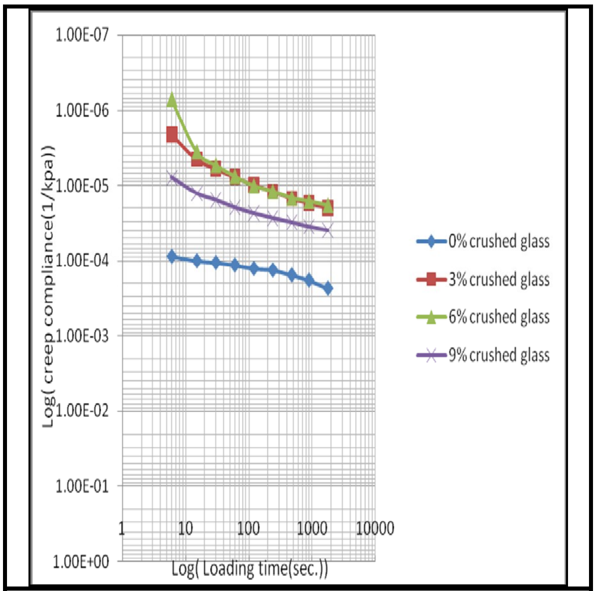
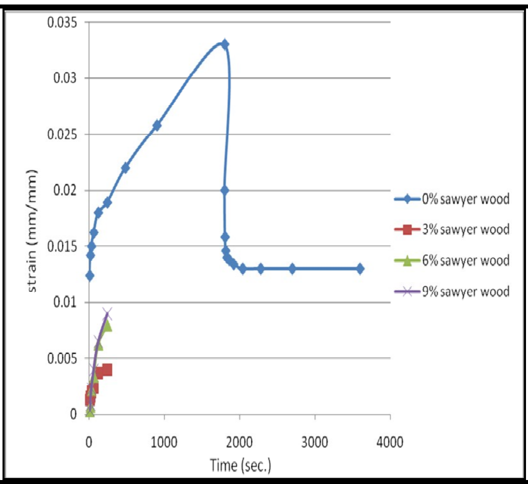
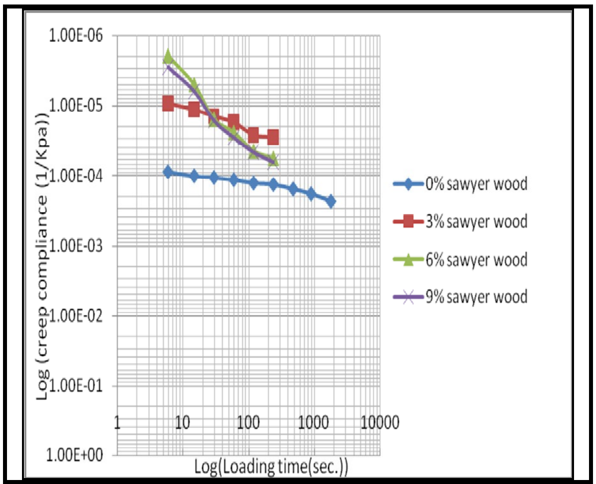


Figure (11) Effect of Crushed Glass Content on Creep Compliance Results



Figure(12) Effect of Sawyer Wood Content on Creep Strain Result



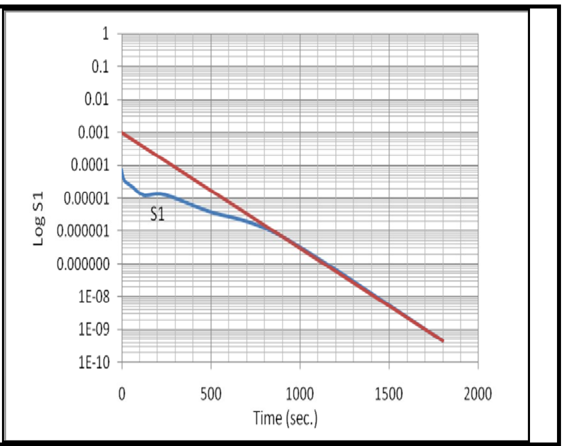
Figure(13) Effect of Sawyer Wood Content on Creep compliance Results

Table (9) shows the procedure for computing successive residuals. A plot of log S_1 and S2 versus time and results of straight line are shown in Figure(14) to Figure (20). The slope of the straight line is (0.434 / T_1). The equation for predicting the creep compliance is shown in Table (9). While, The strain of a generalized model found in Table (10).

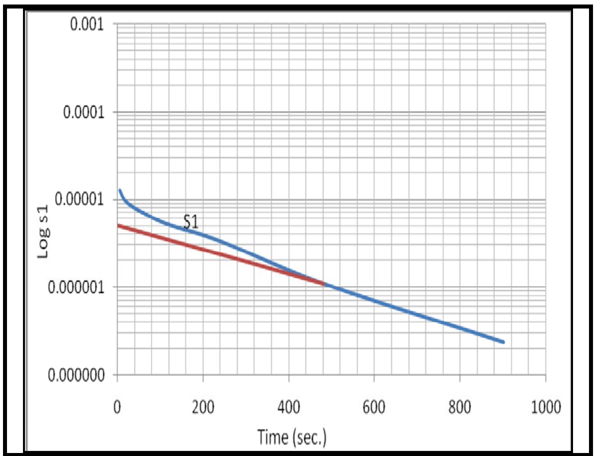
Table (9) Computation of Successive Residual

1	2	3	E0 (kpa), T0 (sec.), Change in creep compliance per unite time	4	E1 (kpa), T1(sec.)	5	6
Time (sec.)	Creep Compliance (1/kpa)			S1 (4)=3-2		e(-t/T1)/E1	S2 (6)= 4-5
	Total(3)	Dashed line					
	0% Solid Wastes Material Content						
6	8.79433E-05	0.000133579	E0=16785.71 T0=1050 Change in creep compliance per unite time= 5.67376E-08	4.56357E-05	E1= 10000 T1=119.76	0.0001	-2.63315E-05
15	0.000100709	0.000134083		3.33738E-05		9.51134E-05	-4.94777E-05
30	0.000106383	0.000134923		2.854E-05		8.82276E-05	-5.48538E-05
60	0.000114894	0.000136603		2.17094E-05		7.78411E-05	-4.9301E-05
120	0.00012766	0.000139963		1.23034E-05		6.05923E-05	-3.88829E-05
240	0.000134043	0.000146683		1.26404E-05		3.67143E-05	-2.44109E-05
480	0.000156028	0.000160123		4.09463E-06		1.34794E-05	-8.38947E-07
900	0.000182979	0.000183643		6.64277E-07		1.81694E-06	2.27769E-06
1800	0.000234043	0.000234043		4.46809E-10		5.44834E-08	6.09793E-07
3% Crushed Glass Content							
6	2.12766E-06	0.000014718	E0=٤٧٠٠٠٠ T0=٦٤٢.٨٥ Change in creep compliance per unite time= 3.3097E-09	1.25903E-05	E1=100000 T1=574.34	9.89608E-06	2.69426E-06
15	4.53901E-06	0.000014745		1.0206E-05		9.74221E-06	4.63781E-07
30	6.09929E-06	0.00001479		8.69071E-06		9.49107E-06	-8.0036E-07
60	7.80142E-06	0.00001488		7.07858E-06		9.00804E-06	-1.92946E-06
120	9.92908E-06	0.00001506		5.13092E-06		8.11448E-06	-2.98355E-06
240	1.20567E-05	0.00001542		3.36326E-06		6.58447E-06	-3.22121E-06
480	1.50355E-05	0.00001614		1.10454E-06		4.33553E-06	-3.23099E-06
900	1.71631E-05	0.0000174		2.36879E-07		2.08667E-06	-1.84979E-06
1800	2.01418E-05	0.0000201		0			
6% Crushed Glass Content							
6	7.0922E-07	0.000014612	E0=١٤١٠٠٠٠ T0=٣٠٠ Change in creep compliance per unite time= 2.3641E-09	1.39028E-05	E1= 100000 T1= 666.79	9.91042E-06	3.99236E-06
15	3.5461E-06	0.00001463		1.10839E-05		9.77755E-06	1.30635E-06
30	5.39007E-06	0.00001466		9.26993E-06		9.56005E-06	-2.90125E-07
60	7.51773E-06	0.00001472		7.20227E-06		9.13946E-06	-1.93719E-06
120	1.00709E-05	0.00001484		4.76908E-06		8.35298E-06	-3.5839E-06
240	1.19149E-05	0.00001508		3.16511E-06		6.97723E-06	-3.81212E-06
480	1.46099E-05	0.00001556		9.50071E-07		4.86817E-06	-3.9181E-06
900	1.61702E-05	0.0000164		2.29787E-07		2.59305E-06	-2.36326E-06
1800	1.82979E-05	0.0000182		0			

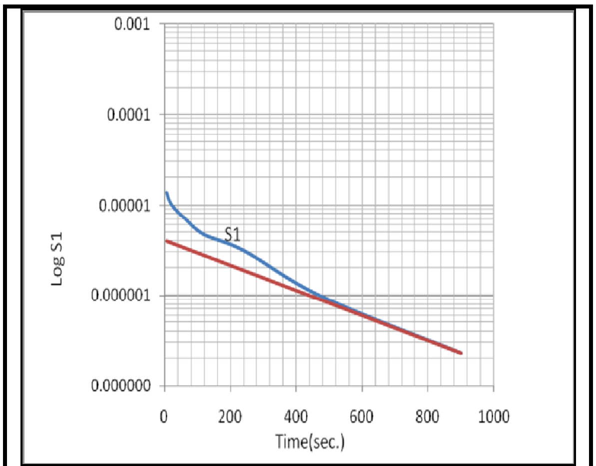
9% Crushed Glass Content							
6	7.8014E-06	0.000032524	E0=١٢٨١٨١.٨ T0=١٥٩٦.٧٧ Change in creep compliance per unite time= 4.88574E-09	2.47226E-05	E1=71428.5 T1=299	1.3722E-05	1.10007E-05
15	1.2766E-05	0.00003256		1.9794E-05		1.3315E-05	6.47904E-06
30	1.5603E-05	0.00003262		1.70172E-05		1.2664E-05	4.35366E-06
60	1.9574E-05	0.00003274		1.31655E-05		1.1455E-05	1.71095E-06
120	2.3404E-05	0.00003298		9.57574E-06		9.3719E-06	2.03801E-07
240	2.7092E-05	0.00003346		6.3678E-06		6.2738E-06	9.39982E-08
480	3.0922E-05	0.00003442		3.49801E-06		2.8115E-06	6.86545E-07
900	3.5319E-05	0.0000361		7.80851E-07		6.9006E-07	9.079E-08
1800	3.9716E-05	0.0000397		0			
3% Sawyer Wood Content							
6	9.21986E-06	0.000024322	E0=١٠٨٤٦١.٥٣٨٥ T0=٥٢٠ Change in creep compliance per unite time= 1.77305E-08	1.51021E-05	E1=١٠٠٠٠٠٠ T1=10.2	5.5531E-06	9.54908E-06
15	1.13475E-05	0.000024475		1.31275E-05		2.2979E-06	1.08296E-05
30	1.41844E-05	0.00002473		1.05456E-05		5.2804E-07	1.00176E-05
60	1.7305E-05	0.00002524		7.93504E-06		2.7882E-08	7.90715E-06
120	2.62411E-05	0.00002626		1.88652E-08		7.7742E-11	1.87875E-08
240	2.83688E-05	0.0000283		0			
6% Sawyer Wood Content							
6	1.99E-06	0.0000333	E0=٢٨٢٠٠٠ T0=٣٥.٢٩ Change in creep compliance per unite time= 1.00473E-07	3.13142E-05	E1=٨٣٣٣٣ T1= 8.68	6.01145E-06	2.72885E-05
15	5.04E-06	0.0000342		2.91645E-05		2.13144E-06	3.20686E-05
30	1.56E-05	0.0000357		2.00972E-05		3.78587E-07	3.53214E-05
60	2.41E-05	0.0000387		1.45865E-05		1.19439E-08	3.86881E-05
120	4.47E-05	0.0000447		1.91489E-08		1.18881E-11	4.47E-05
240	5.67E-05	0.0000567		0			
9% Sawyer Wood Content							
6	2.83688E-06	0.000048122	E0=٣٥٢٥٠٠ T0=٤٢ Change in creep compliance per unite time= 1.47754E-07	4.52851E-05	E1= 71428.5 T1=276.4	-3.0391E-07	4.5589E-05
15	6.24113E-06	0.000048725		4.24839E-05		-7.5977E-07	4.3244E-05
30	1.63121E-05	0.00004973		3.34179E-05		-1.5195E-06	3.4937E-05
60	2.83688E-05	0.00005174		2.33712E-05		-3.0391E-06	2.641E-05
120	4.60993E-05	0.00005576		9.66071E-06		-6.0781E-06	1.5739E-05
240	6.38298E-05	0.0000638		0			



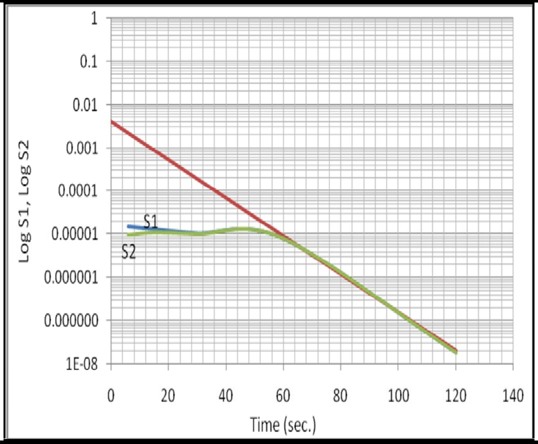
Figure(14) Log S1, verses Times for 0% Solid Wastes Material Content



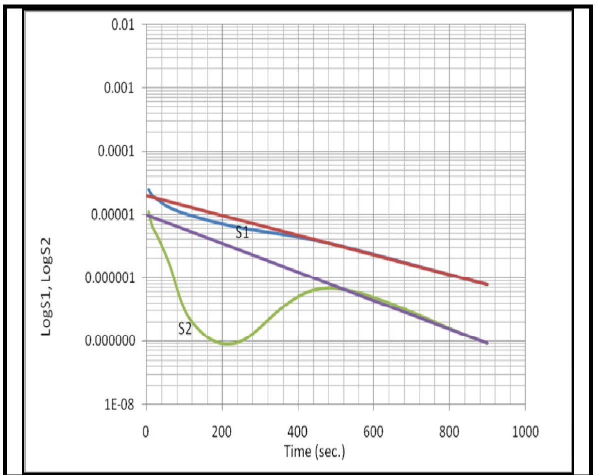
Figure(15) Log S1, verses Times for 3% Crushed Glass Content



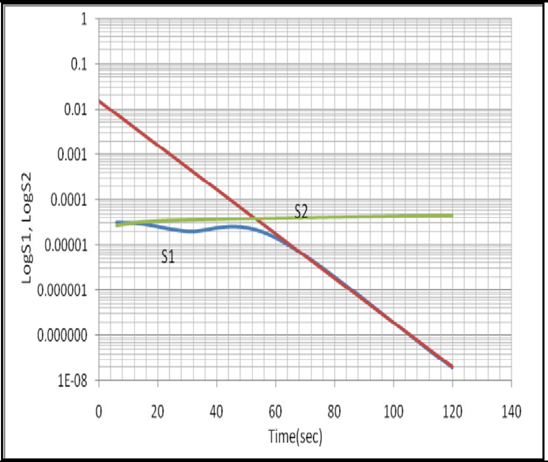
Figure(16) Log S1, verses Times for 6% Crushed Glass Content



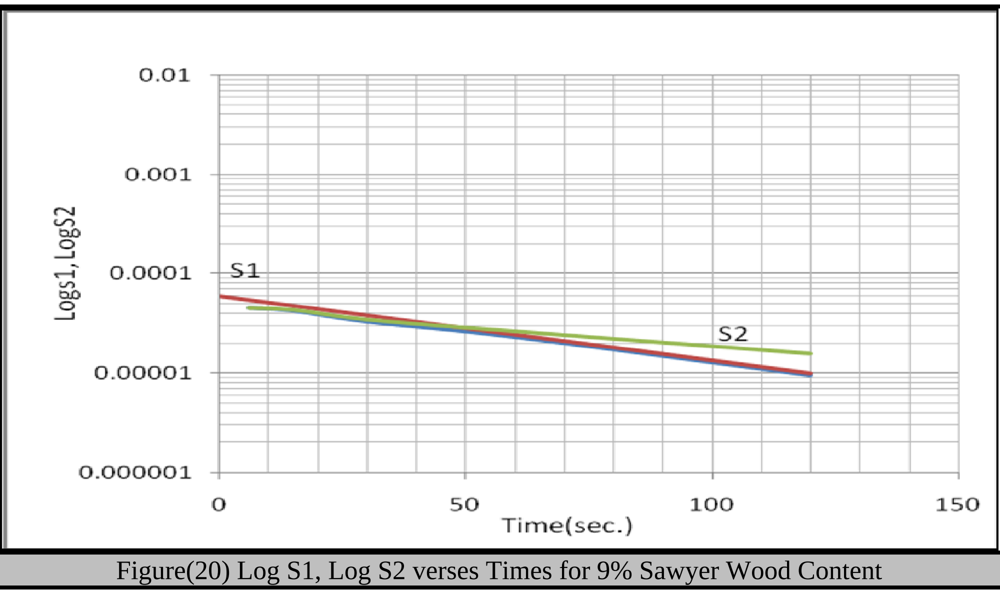
Figure(18) Log S1, Log S2 verses Times for 3% Sawyer Wood Content



Figure(17) Log S1, Log S2 verses Times for 9% Crushed Glass Content



Figure(19) Log S1, Log S2 verses Times for 6% Sawyer Wood Content



Figure(20) Log S1, Log S2 verses Times for 9% Sawyer Wood Content

Table (9) Creep Compliance Equations

Solid Wastes Material Content	Creep Compliance Equations
0% Solid Wastes Content	$D(t)=\frac{1}{16785.71}(1+\frac{t}{1050})+\frac{1}{10000}[1-e^{-\frac{t}{119.76}}]$
3% Crushed Glass Content	$D(t)=\frac{1}{470000}(1+\frac{t}{642.85})+\frac{1}{100000}[1-e^{-\frac{t}{574.34}}]$
6% Crushed Glass Content	$D(t)=\frac{1}{1410000}(1+\frac{t}{300})+\frac{1}{100000}[1-e^{-\frac{t}{666.79}}]$
9% Crushed Glass Content	$D(t)=\frac{1}{128181.8}(1+\frac{t}{1596.77})+\frac{1}{71428.5}[1-e^{-\frac{t}{299}}]+\frac{1}{100000}[1-e^{-\frac{t}{196.622}}]$
3% Sawyer Wood Content	$D(t)=\frac{1}{108461.53}(1+\frac{t}{520})+\frac{1}{100000}[1-e^{-\frac{t}{10.2}}]+\frac{1}{100000}[1-e^{-\frac{t}{10.2}}]$
6% Sawyer Wood Content	$D(t)=\frac{1}{282000}(1+\frac{t}{35.29})+\frac{1}{83333}[1-e^{-\frac{t}{8.68}}]+\frac{1}{33333.3}[1-e^{-\frac{t}{295.755}}]$
9% Sawyer Wood Content	$D(t)=\frac{1}{352500}(1+\frac{t}{42})+\frac{1}{71428.5}[1-e^{-\frac{t}{276.4}}]+\frac{1}{20000}[1-e^{-\frac{t}{111.15}}]$

Table (10) Strain of Generalize Model

Solid Wastes Material Content	Strain of Generalize Model
0% Solid Wastes Content	$\varepsilon=\frac{\sigma}{16785.71}(1+\frac{t}{1050})+\frac{\sigma}{10000}[1-e^{-\frac{t}{119.76}}]$
3% Crushed Glass Content	$\varepsilon=\frac{\sigma}{470000}(1+\frac{t}{642.85})+\frac{\sigma}{100000}[1-e^{-\frac{t}{574.34}}]$
6% Crushed Glass Content	$\varepsilon=\frac{\sigma}{1410000}(1+\frac{t}{300})+\frac{\sigma}{100000}[1-e^{-\frac{t}{666.79}}]$
9% Crushed Glass Content	$\varepsilon=\frac{\sigma}{128181.8}(1+\frac{t}{1596.77})+\frac{\sigma}{71428.5}[1-e^{-\frac{t}{299}}]+\frac{\sigma}{100000}[1-e^{-\frac{t}{196.622}}]$
3% Sawyer Wood Content	$\varepsilon=\frac{\sigma}{108461.53}(1+\frac{t}{520})+\frac{\sigma}{100000}[1-e^{-\frac{t}{10.2}}]+\frac{\sigma}{100000}[1-e^{-\frac{t}{10.2}}]$
6% Sawyer Wood Content	$\varepsilon=\frac{\sigma}{282000}(1+\frac{t}{35.29})+\frac{\sigma}{83333}[1-e^{-\frac{t}{8.68}}]+\frac{\sigma}{33333.3}[1-e^{-\frac{t}{295.755}}]$
9% Sawyer Wood Content	$\varepsilon=\frac{\sigma}{352500}(1+\frac{t}{42})+\frac{\sigma}{71428.5}[1-e^{-\frac{t}{276.4}}]+\frac{\sigma}{20000}[1-e^{-\frac{t}{111.15}}]$

5. Conclusions

1- The air voids increase with the increasing the percentage of crushed glass content.
2- The VMA% increase with increase percent of crushed glass content.
3- Increasing the percent of crushed glass content in mixture will cause a decrease in VFA%.
4- The creep strain decrease with increase percent of crushed glass and sawyer wood.
5- The creep stiffness increase with increase percent of crushed glass content or sawyer wood.

6. References

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تأثير استخدام المواد المخلفة المحلية على خصائص الزحف للخلطات الإسفلتية

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الخلاصة

توجد العديد من المخلفات التي تنتج من عمليات التصنيع في المصانع. في هذا البحث تم دراسة تاثير اضافة نوعان من هذه المخلفات وهو الزجاج المطحون ونشارة الخشب على الخصائص الفيزيائية للمادة الاسفلتية ومدى تاثيرها على الطبقة السطحية للتبليط الاسفلتي. في الخلطة الاسفلتية تم استخدام اسفلت ذو درجة اختراق (٤٠-٥٠) ومقاس اقصى للركام ١٩ ملم وبنسبة اسفلت مثلى ٤.٩% وبحرارة 25˚C وباربع نسب مضافات من هذه المخلفات ٠%، ٣%، ٦% و٩% من الوزن الكلي للخلطة. تم فحص هذه النماذج باستخدام فحص الزحف. من خلال هذا البحث تم التوصل الى ان استخدام هذه المخلفات يحسن الخواص الفيزيائية والريولوجية للخلطات الاسفلتية.