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Effect of of mixed of Industrial Scraps and Lamp Black Percent on the Mechanical properties of NR70/SBR30 composite

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Abstract : The possibility of using mix of some industrial scraps such as reclaim or cement waste and lamp black as reinforcement in natural rubber/styrene–butadiene rubber (NR70/SBR30), were explored as an alternative filler to prepare batches that it used in fender ship application. Mix of reclaim or cement waste and lamp black used in this paper as additives or fillers to study some of the mechanical properties of NR70/SBR30 blends. Eight different compounds were prepared from SBR30 pphr, NR70pphr and 4 loading level from cement waste (C.W) (0,10,20,30) pphr, reclaim (0,10,20,30) pphr and carbon black (C.B) 50 pphr. The hardness, tensile strength, tear résistance, elongation, elastic modulus, fatigue, and specific gravity have been studied in this research. The results of some of these properties are increasing with the increment of mix of C.B and reclaim loading, such as tear resistance, damping time and resilience, while specific gravity, tensile strength, tear resistance, elastic modulus fatigue, elongation, were decreased with increment mixed of C.B and reclaim loading %. On other hand, in the cement waste loading found that hardness, elastic modulus, wear was increasing with increase loading level, whereas, elongation, tear, tensile, specific gravity, fatigue, resilience, damping time were decreased with increasing loading level.
Keywords: Lamp black, industrial scrap, NR70/SBR30.

Introduction

Lampblack was prepared by the incomplete combustion of vegetable oils in lamps, this was the only commercially available carbon black [1], used for making inks. Lampblack is still used today, although it is now made by combustion of naphthalene. Rich oils which are burned in large shallow plans in a restricted air supply. The resulting carbon smoke passes through a series of settling chambers which effect the automatic grading of particle size [2, 3].

Reclaiming is a procedure in which the scrap tire rubber or vulcanized rubber waste is converted, using mechanical and thermal energy and chemicals, into a state in which it can be mixed, processed, and vulcanized again. The principle of the process is devulcanization. In vulcanization, it is assumed that the cleavage of intermolecular bonds of the chemical network such as carbon–sulfur and/or sulfur–sulfur bonds, takes place, with further shortening of the chains occurring. Many different reclaiming processes have been applied through the years in an attempt to solve the problem of rubber recycling. Generally, ground rubber scrap is, in most cases, the feedstock for the devulcanization step [4].

Reclaiming is the most important process in rubber recycling. Many different reclaiming processes have been used through the year depending on scrap characteristics and economics. Generally, ground rubber scrap is, in most cases, the feedstock for the reclaiming. The pan process digester process (either wet or dry), and mechanical or reclaimator processes are currently the common processes used for reclaiming [5-7].

High elastic polymer composites are very important in the applications of rubber industries, such as tires transportation belts, pipes for fluids and fender. Damping and support parts in the mobiles as well as diaphragm as mentioned above. Rubber composite materials with different type of rubber are used in dampers and support applications [8,9].

Rubbers can be divided broadly into two types: thermosets and thermoplastics. thermosets are three-dimensional molecular networks, with the long molecules held together by chemical bonds. They absorb solvent and swell, but do not dissolve; furthermore, they cannot be reprocessed simply by heating. The molecules of thermoplastic rubbers, on the other hand, are not connected by primary chemical bonds. Instead, they are joined by the physical aggregation of parts of the molecules into hard domains [10]. Hence, thermoplastic rubbers dissolve unsuitable solvents and soften on heating, so that they can be processed repeatedly. In many cases thermoplastic and thermoset rubbers may be used interchangeably. However, in demanding uses, such as in tires, engine mounts, and springs, thermoset elastomers are used exclusively because of their better elasticity, resistance to set, and durability. The addition of various the chemicals to raw rubber to impart desirable properties is termed rubber compounding or formulation [11].

This article study some of the mechanical properties such as tensile set and specific gravity and fatigue, specific gravity tests were carried out by Densitron according to Archimedes principle, it was weighed in air and in water. The specific gravity is calculated by the following equation [12]:

$$\text{Specific gravity} = \frac{\text{Weight in air}}{\text{Weight in air - weight in water}} \times \text{specific gravity of water} \quad (1)$$

The tensile strength can be calculated by the equation;

$$T.S = F/A \quad (2)$$

Where F is the observed force required to break the specimen.

In general, tensile strength is defined as a measurement of the force required to pull something such as rope, wire, or a structural beam to the point where it breaks [13, 14]. The tensile strength of a material is the maximum amount of tensile stress that it can take before failure, for example breaking [15,16].

Young's modulus was reported as the slope of the initial linear region of the stress–strain. Actual experimental values were reported as stress–strain curves. The stress (σ) and strain (ε) are described by the following expressions [12];

$$\sigma = F/ \text{Cross sectional area (A)}$$
$$\varepsilon = (L - L_o)/ L_o \quad (3)$$

where F is the maximum force or load, L_o is the initial thickness, L is the final thickness, and A is the cross-sectional area.

Thus, Young's modulus in a tensile test is given by;

$$E=\Delta\sigma/\Delta\varepsilon \quad (4)$$

Therefore, the ultimate elongation is mathematically calculated by the relation;

$$E= [(L-L_o)/L_o]*100\% \quad (5)$$

with respect to the tear strength or the tear resistance in rubber, it may be described as the resistance for growing a neck or cut when the tension is applied on the specimen and it depends upon the width and thickness of the test piece and the test results as the load necessary to tear specimen of standard width and thickness.

$$\text{Tear. S} = F*t_1/t_2 \quad (6)$$

where t_1 is the thickness of standard piece, and t_2 is the measured thickness of the specimen tested.

Fatigue may be defined as the change in properties that occur in a material after prolonged period action of stress or strain [17]. The fatigue failure process involves a period during which cracks nucleate in regions that were initially free of observed cracks. Mechanical failure of structures and components is a serious concern in all types of industries. It has been estimated that between 50 to 90 % of these failures are due to fatigue [18]. Many factors influence fatigue nucleation [19].

1. Type of rubber, the type and degree of cross- linking, additives such as protective agents, reinforcement phase such as filler (type, volume fraction) and fibers (type, aspect ratio, orientation) which control the basic crack growth characteristics and the size of the flaws that are present initially.
2. Mechanical considerations such as the shape and size of the article, the nature and magnitude of the deformations and the frequency and the form of the cycling.

The two widely used fatigue life parameters which are reported in point (2) for crack nucleation prediction in rubber are maximum principle strain (or stretch); minimum strain; and strain energy density, our study is focused on maximum strain. Strain is a natural choice because it can be directly determined from displacements x which can be readily measured in rubber. Another factor is the R – ratio which is defined in the following equation:

$$R = \frac{\sigma_{min}}{\sigma_{max}} \quad \text{or} \quad R = \frac{\varepsilon_{min}}{\varepsilon_{max}} \qquad (7)$$

Where σ_{min} is minimum stress; σ_{max} is the maximum load stress, ε_{min} is minimum strain; and ε_{max} is the maximum strain. The R – ratio of strain cycle has a significant effect on fatigue life [20].

There are many equations to described abrasive wear the simplest equation to calculate the specific wear rate is by measuring wear volume from the measurement of loss in weight by the following equation:

$$K_o = \frac{\Delta V}{Nd} \qquad (8)$$

Where K_o is the specific wear rate, ΔV is volume loss in cubic millimeters or cubic centimeter, N is the load in Newton's; and d is the sliding distance in meters. Resilience is the ratio of the energy returned upon recovery from deformation to the energy required to produce the deformation, it shows the ability of a rubber vulcanized to return the energy used to deform [21].

Rebound resilience (R%) uncorrected = (1-cosi) /(1-cosj) ×100 (9)
Where i= rebound angle, j=angle of drop (45^o)
Then from equation
R% = 341.421 (1-cosi) (10)
(R %) corrected = (1-cos {i+i.x/2}) /(1-cos {j+j.x/2}) × 100 (11)
Where x = 1/2n × $\log_e$ j/i , and n= number of swings

Experimental Part

Materials

The NR, SBR were reinforced by different volume fractions of carbon black (lamp black) particle size (100-150) nm and industrial scraps such as reclaim (specific gravity 1.16 gm/cm3) (supplied by the Babylon tire company) and cement waste (C.W) (supplied by the Karbala cement company). NR used in this study was of SMR20, supplied by the Perlis, Malaysia. The SBR used is SBR–1502 with 23.5% styrene content (made by the emulsion process), Supplied by the Petkim, Turkey.

Zinc oxide (97%) and stearic acid (99.4%) were supplied by Durham, U.K. The 6PPD [N- (1,3 – Dimethyl butyl) – N – Phenyl – Para – Phenylenediamine] (98%) was supplied by Flexsys Belgium MBS [N-oxydiethylenebenzothiazole 2- sulfonamide] (98.2%) is supplied by ITT, India. Paraphenic oil was supplied by the South Patrol Company. Sulfur was supplied by the Durham, U.K.

Preparations of batches.

The batches are prepared by mill laboratory as shown in the Table 1;

Table 1: Ingredients of batches.

Compounding ingredients%	Recipe 1	Recipe 2
SBR 1502	30	70
NR SMR 20	30	70
ZINC OXID	5	5
STEARIC ACID	2	2
PARAPHINIC OIL	2	2
RECLAIM	Variable(10,20,30,40)	
CEMENT WASTE		Variable(10,20,30,40)
LAMP BLACK	50	50
6PPD	0.5	0.5
MBS	1	1
SULFUR	1.5	1.5

Equipment and Instruments

Laboratory mill

Baby mill was used in this research contain two roll having provisions for passing cold water. These rolls are cylindrical in shape and of 150mm diameter and 300mm length. The roll speed is 20 r.p.m.

Equipment for Specific gravity measurement

Monsanto–Densitron equipment was used to measure the specific gravity. The operating of equipment according to Archimedes principle, the sample prepared was weighed in air then in water the resulting data were given to the compile which was linked to the equipment.

Equipment for the measurement of Tensile Strength, Tear resistance, Elongation and Modulus of elasticity.

Tests are carried out on samples which were prepared mill laboratory according to ASTM D412. Monsanto T10 tensometer was used. The test sample which is movable at speed of 500 mm/min for all except tear resistance at 50 mm/min.

Equipment for Fatigue measurment

Tests are carried out on prepared samples and according to ASTM D430 by using the Wallace tester.

Equipment for Hardness (IRHD) measurement

The International Hardness test is used in measurement of the penetration of rigid ball (according to Brinall method) into the rubber specimen Test was carried out according to ASTM D1415 specifications.

Equipment for Abrasion wear

The Croydon Akron Abrasion Tester was used to these tests. Tests were carried out on at temperature of 25°C according to British standard (BS) 903 method C.

Equipment for Rebound Resilience Measurement

The Dunlop tripsometer takes the form of an out of balance metal disc revolving on virtually frictionless bearing and which acts as a slow moving pendulum. The test piece is placed against a rigid support so that it receives a blow at its center. A circular scale is provided for measuring the angle of displacement. The measured quantity is the angle to which the disk rebounds after the hammer strikes the specimen. Tests are carried out according to ASTM D1054.

Moulds preparation

The necessary moulds were manufactured for test samples to study their mechanical properties according to British standard (BS).

Mould for Testing hardness, resileince and specific gravity

For preparing samples for hardness, impact, and density tests, the mould in the laboratories of tyre company was used. The mould consists of three parts, the middle part in a dimension of 200*180*6.5mm which contains (9) circular equi-volume open with 65mm diameter and 5 mm thickness while one of other two parts is bottom base and the other is a cover for the purpose of samples thickness regulation. They have a dimension of 150*150*10mm.

Mould for preparing samples for tensile, elongation, and modulus tests

For preparing samples for the above tests, slice from each recipe with a dimension of 150*150*2.5mm was prepared by using mould which consists of three parts, the middle one in a dimension of 395*158*2.5mm contains six sections with 150*150*2.5mm dimension fixed on base of 395*160*10mm and covered with a cover of the same dimension as that of the base for regulation of thickness.

Mould for Fatigue Test Samples

For preparing fatigue test samples with dimensions contain half circular middle notch with a radius of 2.5mm. The mould consists of three parts, the middle part with a dimension of 282*222*6mm contains on 6 empty spaces with (153*62mm) dimension a circular middle notch with a radius of 2.5mm divided the part and the 6 vacant.

Results and Discussion

Figures 1 and 2 show that the hardness and elastic modulus increasing at increase the loading level of waste for these composites, this attributed to the filling the vacancies between the rubber chains by cement waste, inversely, it should be noted that hardness of volcanizes are decreasing with increase loading level of reclaim. From Figure 3 and 4, it is clear that the damping time and resilience were increased with decreasing loading level of reclaim (0,10,20,40) pphr, this is due to the increasing the hardness which is inversely proportional with resilience, contrary the inverse behavior happen with cement waste this is due to the increasing the hysteresis in this composites.

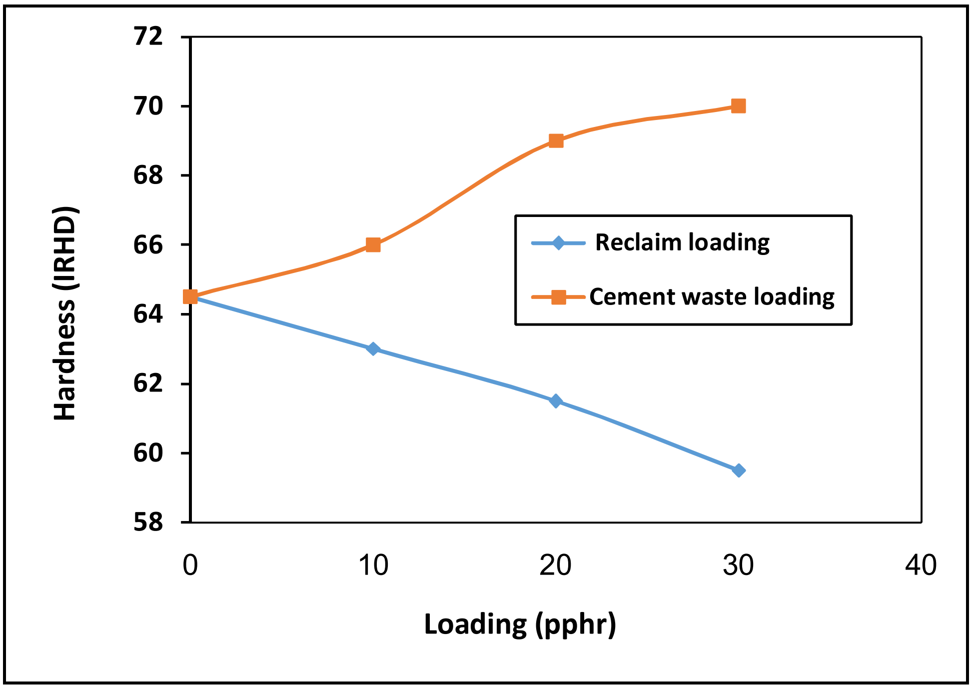

Figure 1: Graphical relation between hardness and loading levels of reclaim or cement waste.

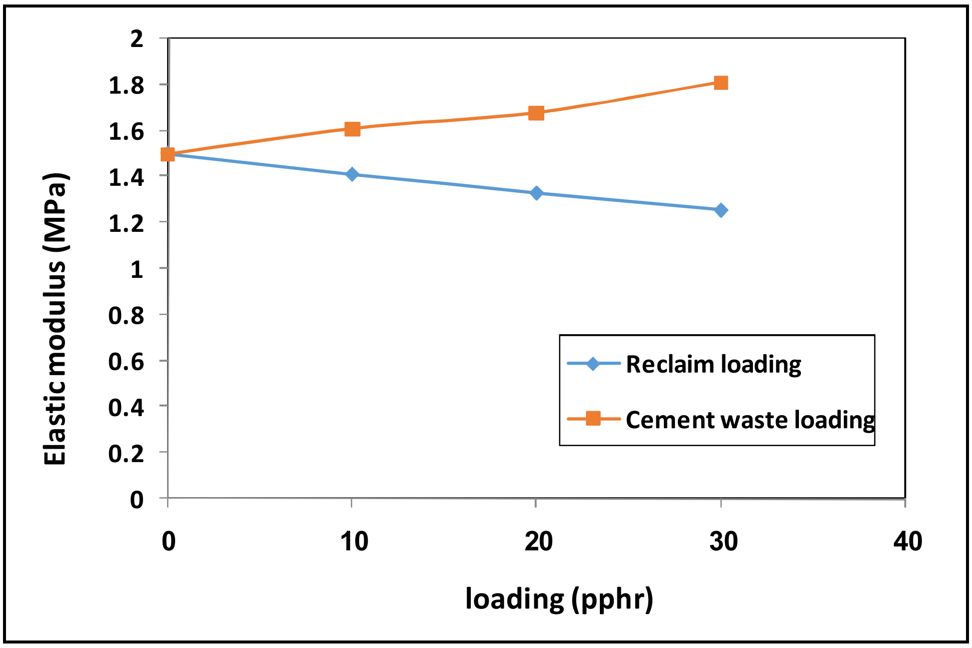

Figure 2: Graphical relation between elastic modulus against loading levels of reclaim or cement waste.

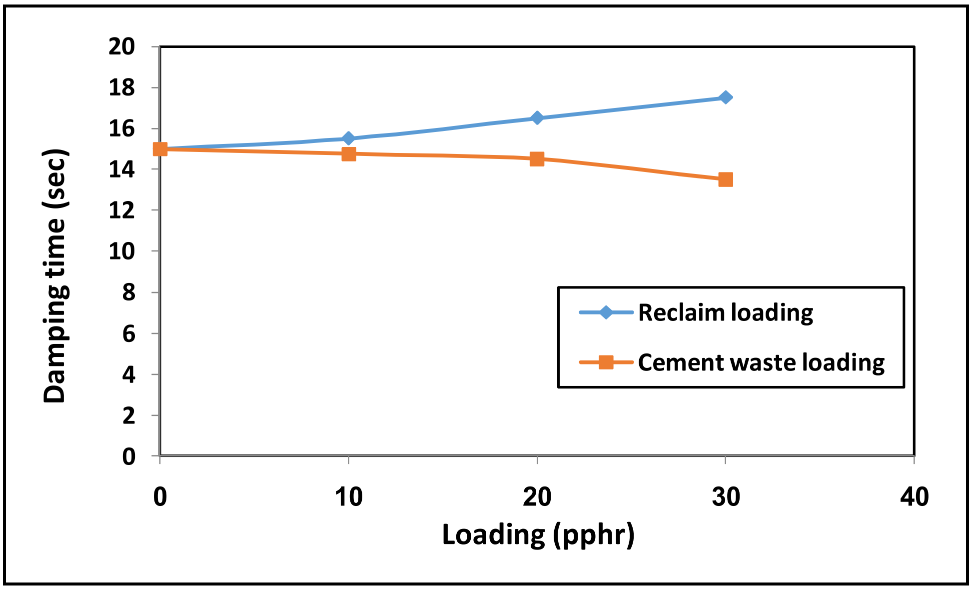

Figure 3: Graphical relation between damping time and loading levels of reclaim or cement waste.

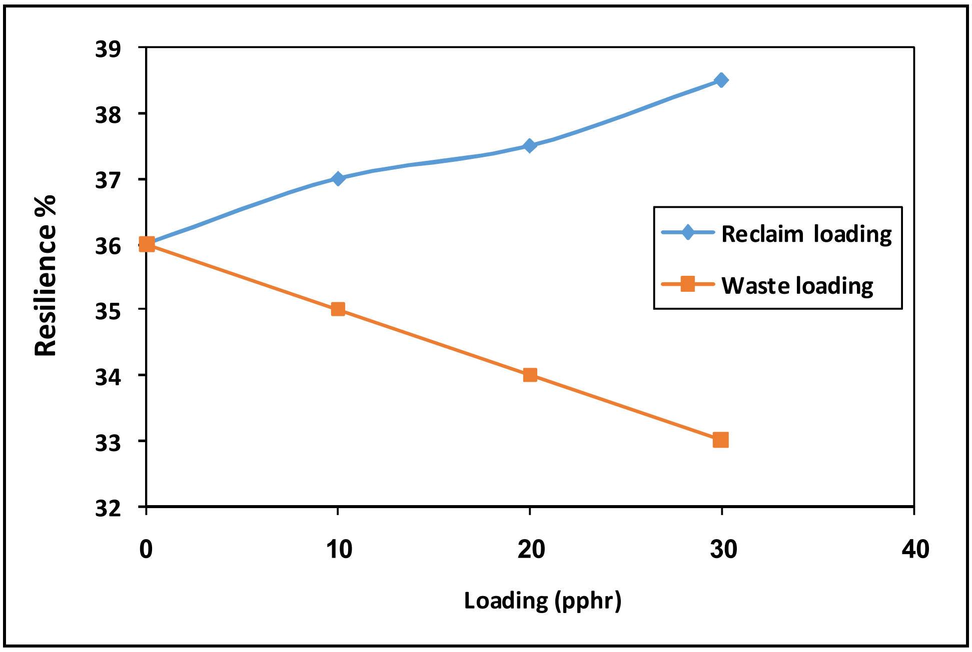

Figure 4: Graphical relation between resileince and loading levels of reclaim or cement waste.

Figure 5 shows decreasing in the flexibility or fatigue as reclaim or cement waste loading increases when C.B=50 pphr, this is due to increasing of the contact area of reclaim or waste with the rubber chain and increasing the defects' or cracks between the chains. This results agrees with the other result [3,23].

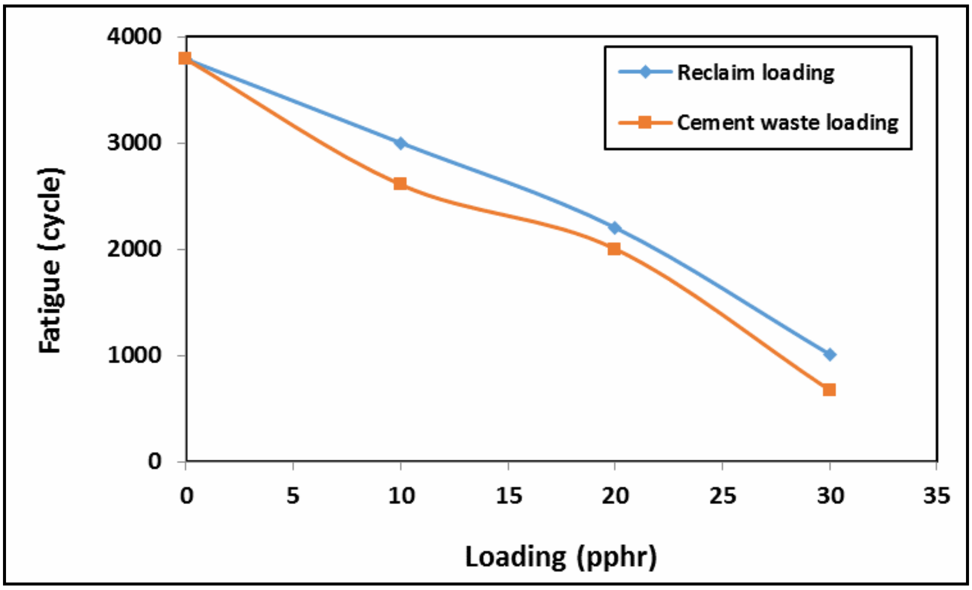

Figure 5: Graphical relation between fatigue and loading levels of reclaim or cement waste.

The relationship between specific gravity and the loading level of reclaim for various batches at C. B=50 pphr are shown in Figures 6, From the figure, it can be seen that the specific gravity is linearly decreased with increasing the loading level of reclaim. With respect to the waste, it is found that simple increment in specific gravity, this makes rubber composite denser per unit volume.

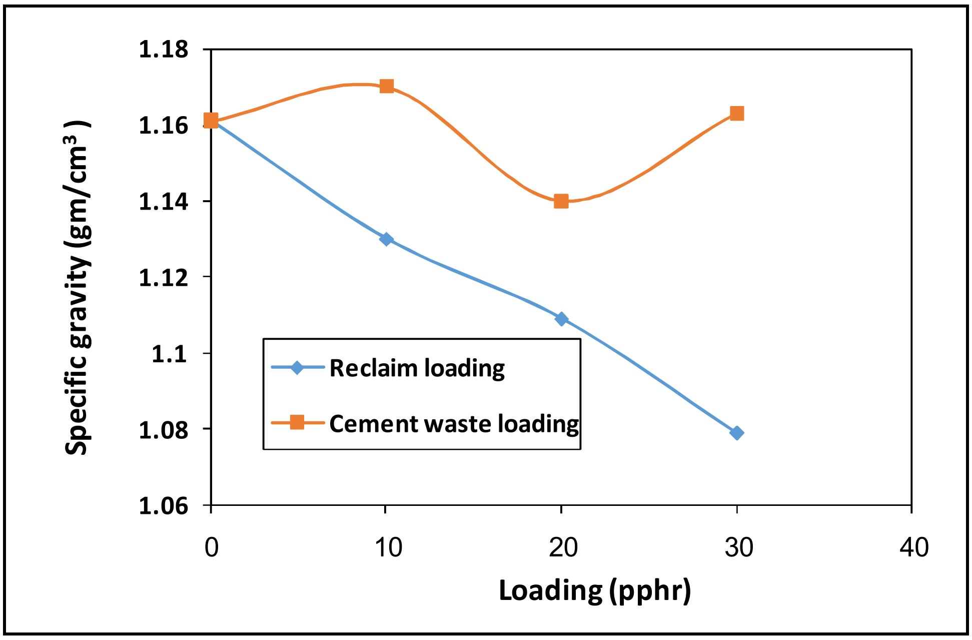

Figure 6: The dependence specific gravity on loading levels of reclaim or cement waste.

Figures 7 and 8 show the decreasing in the tensile strength, elongation as reclaim or cement waste loading level increases because of this decreasing the interaction between these filler and rubber blends chain so happen waste or reclaim aggregation in the waste or reclaim composites and creating micro cracks in the reclaim composites. Figure 9 illustrated the relationship between tear resistance values and loading level of reclaim and cement waste, from this figure indicated decrease in tear strength of the vulcanizates with increasing cement waste. In the same time, there a significant increase in tear strength of the vulcanizates with increasing reclaim due to the increasing of the crosslinking between reclaim and blends [24].

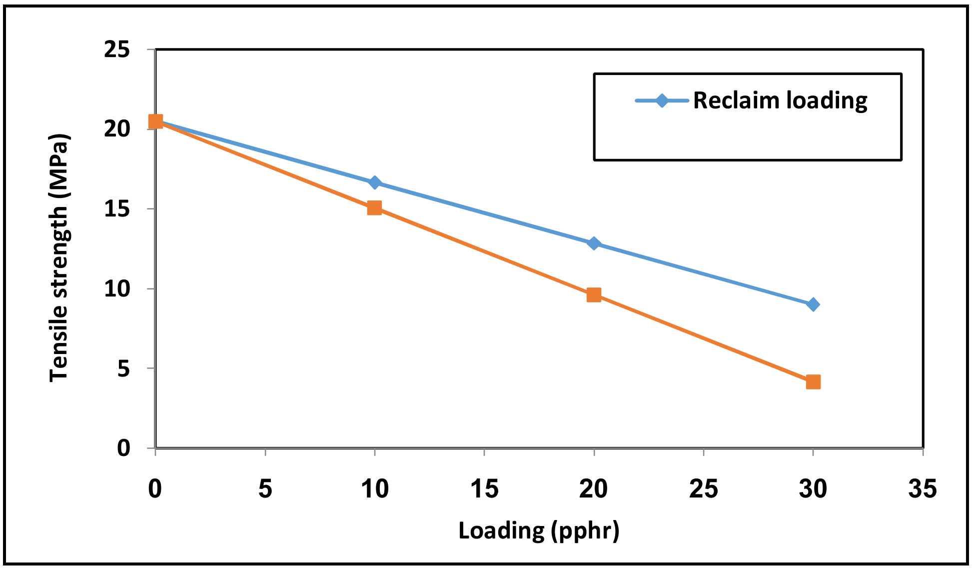

Figure 7: The dependence of tensile strength on loading levels of reclaim or waste.

Abrasion wear examination was carried out by Croydon Akron Abrasion Tester at 1000 cycle for these recipes when the lump black loading (50 pphr) as shown in Figure 10, it can be noticed from the figure that the abrasion wear increased with increasing cement waste or reclaim loading level (i.e. increasing the volume lose), this attributed to the abrasion wear property is due to decreasing correlate and cohesive and abrasion resistance between these filler and rubber chains

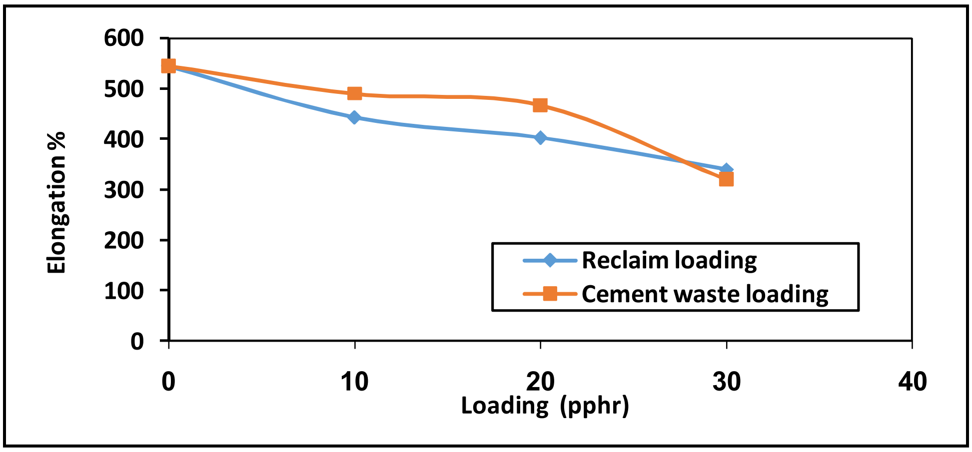

Figure 8: Graphical relation between elongation against loading levels of reclaim or cement waste.

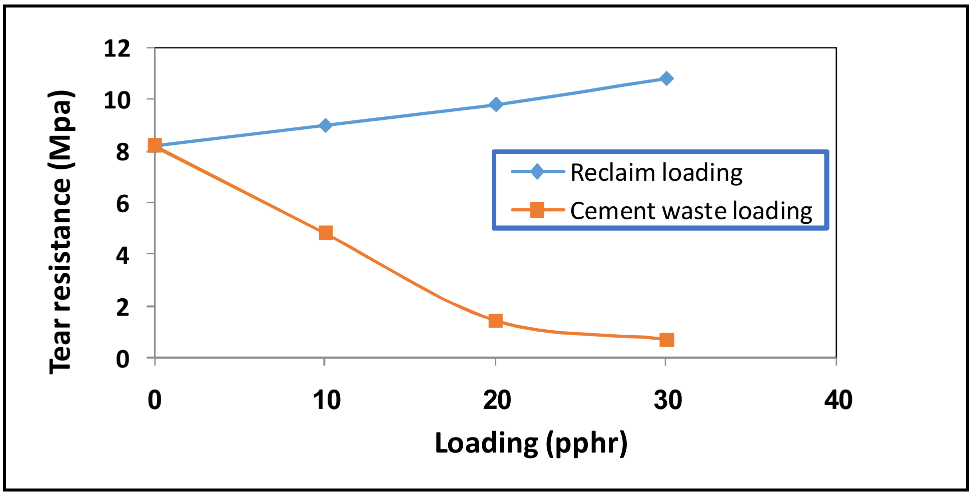

Figure 9: Graphical relation between tear resistance and loading levels of reclaim or cement waste.

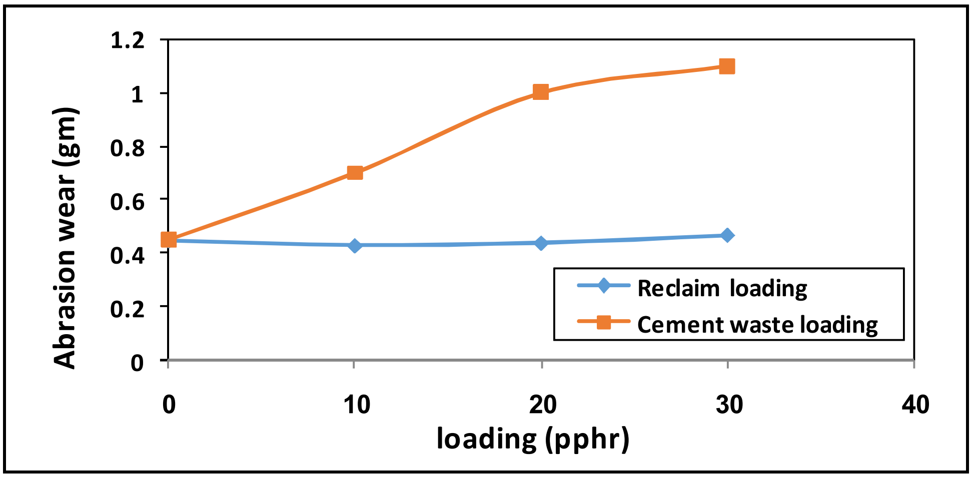

Figure 10: The dependence of wear abrasion on loading levels of reclaim or cement waste.

Conclusions

1. The best mechanical properties were found at the loading level of reclaim or cement waste at 10 pphr.
2. Improvement some of mechanical properties has advantages and disadvantages according to the engineering uses such as fenders in the port.
3. Hardness and elastic modulus increase with increasing loading level of cement waste, while it was decrease with increasing loading level of reclaim.
4. The abrasion wear increasing with increase loading level of cement waste, while it remains approximately constant with increasing loading level of reclaim.
5. Tensile strength, fatigue and elongation were decreasing with increase all of cement waste or reclaim.
6. Tear resistance and rebound resilience increasing with increase loading level of reclaim, while it was decreasing with increase loading level of cement waste.

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