Rheological investigation of SBR/ CW/CB tricomposite used to create a sustainable procedure for idler rollers production

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Abstract

The concept of sustainability is now considered as the key of the future, not just for industry but also for all resources on this planet. The real guarantee for the continuation of life is by recycling all types of industrial waste using a method that combines a high level of efficiency and environmental pollution protection. This will create a sustainable resource that keeps earth's natural resources from depletion. In this study, we introduce a technological procedure for the use of cement waste in manufacturing engineering parts with high efficiency. Rheological analysis for styrene butadiene rubber has been investigated as function percentages additives (10-35 pphr) of cement waste (CW) and carbon black (CB). The rheological properties include torque and thermos-plasticity measured at temperature ranges of 165 °C, 175 °C and 185 °C. The tests showed that the cement waste has the ability and efficiency for improving the rheological properties of styrene butadiene rubber.
Keywords: SBR, cement waste, carbon black, rheological properties, sustainability
Kulcsszavak: SBR, cementhulladék, szénfekete, reológiai tulajdonságok, fenntarthatóság

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1. Introduction

Rubber has been used for a long time in many important industrial applications, because of its distinctive characteristics [1-3]. Researchers over the years conducted studies to develop its structure and characteristics not only by creating a new types of rubber, but also develop the existing types by adding fillers or changing processing conditions and study how its properties are affected. Rheological properties are greatly affected by the processing method and additives [4-8]. Because of rubber is a viscoelastic material, its rheological properties will change during processing. In addition, the presence of fillies within rubber composition such as carbon black or silicon dioxide will change the rheological behaviour of rubber making it more complex. The degree of change in processing conditions depends on the amount of the fillers [9-11]. When studying the rheological behaviour of rubber it is important to calculate the rate of flow at different conditions in terms of stress, applied time of stress, temperature and resilience [12-17].

Iraq's environmental regions near cement factories suffers from high concentrations of pollution [18-19]. This is due to the use of old cement factorization techniques and non-compliance with environmental standards and safety requirements. The use of filters to remove suspended dust in the air - which is a result of crushing raw materials - reduces gases emission throughout the process and dust coming out of the oven during the burning stage of raw materials and clinker crushing, are safe methods for disposal from this waste. All these environmental issues caused a significant damage for the surrounding areas of cement factories and travel to far areas by dust particles volatilization [20-21]. Therefore, it is necessary to provide an appropriate technological procedure to safely dispose the wastes for all types of industrial waste not just for cement waste, to be incorporate into useful engineering applications, where it can be used as fillers for rubber and polymers composition [22-36]. The main aim of this research is the use of cement waste as filler for styrene butadiene rubber (SBR) and to study the effect of this additive on the rheological properties in order to prove that these wastes are useful for manufacturing of idler rollers used in chain conveyors and elevators at grain silos of Iraqi State Trade Company.

2. Methodology

2.1 Materials

Styrene butadiene rubber type KER 1502 containing 23.5% Styrene supplied by Synthos S.A., Poland; Carbon black type N375 supplied by Sullivan Qiao Shanghai King Chemicals Co., Ltd., China; Zinc oxide with supplied by Saha Metal San. Tic. Ltd. Şti, Turkey; Stearic acid supplied by Hefei TNJ Chemical Industry Co.,Ltd, China; Antioxidant 6PPD supplied by Flexsys Rubber Chemicals Ltd, Belgium; Accelerator MBS supplied by Richest Group, China. Paraffin Wax supplied by Kerax Limited, England; Sulfur supplied by

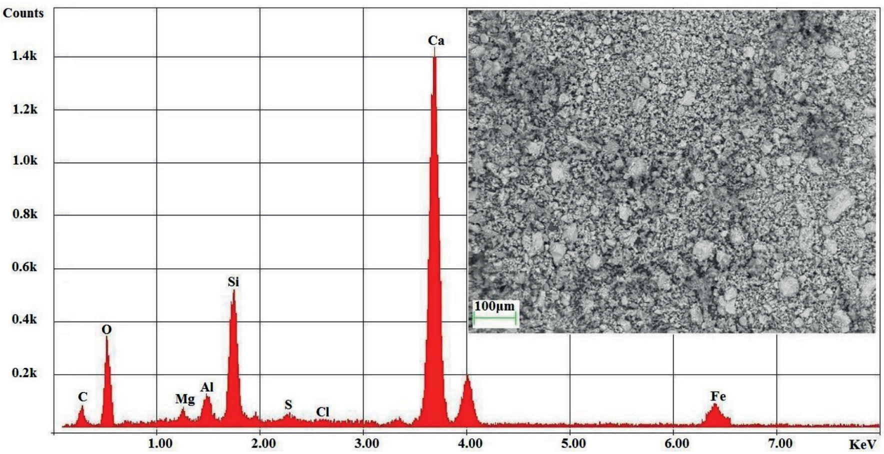

Fig. 1 SEM - energy dispersive X-ray microanalysis for cement waste
1. ábra A cement pásztázó elektronmikroszkóppal végzett energia-diszperzív röntgen mikroanalízise

Leader Technologies Co.,Ltd, China; Processing oil supplied by Shell oil company; and Cement waste (Kiln dust) which results from Portland cement manufacturing at Kufa cement plant, Iraq which using the wet process for producing cement . The chemical composition of cement waste shown in *Table 1*, and scanning electron microscopy (SEM) was used for structural analysis of cement waste as shown in *Fig. 1*.

Material	wt.%
SiO_2	11.11
Al_2O_3	2.38
Fe_2O_2	2.55
CaO	46.29
MgO	1.12
SO_3	0.59
Cl	0.12

Table 1 Chemical composition of cement waste
1. táblázat A cement hulladék kémiai összetétele

Material	Batches composition ratio, pphr			
	C_1	C_2	C_3	C_4
SBR type KER 1502 (23.5% Styrene)	100	100	100	100
Zinc oxid	5	5	5	5
Stearic acid	2	2	2	2
Paraphinic wax	2	2	2	2
Processing oil	5	5	5	5
Antioxidant 6PPD	0.5	0.5	0.5	0.5
Accelerator MBS	1	1	1	1
Sulfur	1.5	1.5	1.5	1.5
Carbon black (CB)	10	20	30	35
Cement waste (CW)	10	20	30	35

Table 2 Samples' ingredients
2. táblázat A minták összetétele

2.2 Sample preparation and testing

The raw material batches illustrated in *Table.2* had been processed by roll mill machine type Comerio Ercole Busto Avsizo with 20 rpm rotating speed, which contains two rolls with 150 mm diameter and 300 mm length rotating with 24 rpm speed. The cure characteristics for the four batches samples were evaluated according to the standard ASTM D2705 by using micro vision enterprises (MV-ODR) devise [37]. The test was done at temperature 165, 175 and 185 °C and 12 min for each sample.

3. Results and discussion

The rheological behaviour of SBR/CW/CB tricomposite at different temperature ranges and percentages of CW/CB additives are shown in *Figs. 2, 3* and *4* respectively. From these figures we can see that the deviations in rheological properties are dependent on the amount of CW/CB additives. At the initial stage of processing, the rubber is primarily heated where the viscosity is decreased and the torque is decreased consequently. In this earlier phase, the rubber compound begins to vulcanize and transform to elastic solid and the torque starts recovering. The minimum shear stress can be recorded also where the molecular chain scission may be occurred. The torque continues to rise up which proves that the crosslinking has been occurred and dominates the rubber structure [38].

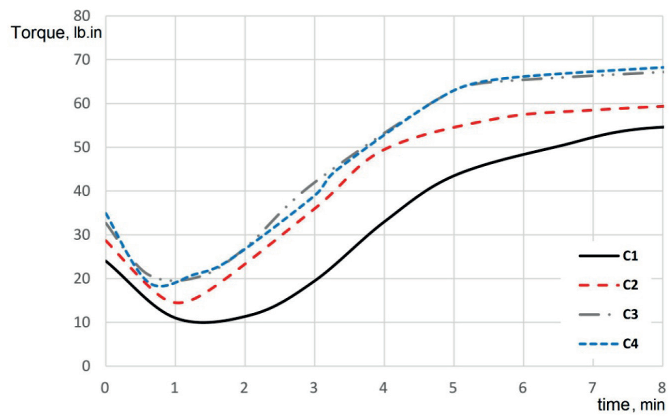

Fig. 2 Rheograph of SBR/CW/CB tricomposite at 165 °C with different percentages additives of CW/CB (C1, C2, C4 and C4 batches)
2. ábra SBR/CW/CB háromkomponensű rendszer Rheograph nyomaték görbéje 165 °C-on különböző CW/CB adagolás esetén (C1, C2, C3 és C4 minták)

Figs. 5, 6 and *7* shows the variation in τ_i,τ_{min}, and τ_{max} due to CW/CB additives and temperatures. From *Fig. 5* we can observe that the increase of initial torque (τ_i) was linear as the percentage of additives increases. It was 0.44 at 165 °C and 175 °C. After that it increased to 0.54 at 185 °C. This is an early indication that the SBR/CW/CB tricomposite is behaving differently at this particular temperature, where is some sort of internal structural changes have been occurred like crosslinking as we mentions above.

Fig. 6 shows that the highest τ_{min} and τ_{max} values were at 30 pphr CW/CB, where the SBR/CW/CB tricomposite has reached the optimum torque improvement. The rate of linear trend in *Fig. 7* for all CW/CB filler percentages is 0.82. Overall torque values obtained from rheographs increase positively with the increasing of the CW/CB additives percentage. This behavior is due to the performance and density of crosslinking inside rubber chains structure and that leads to increase vulcanization efficiency and rubber viscosity [39].

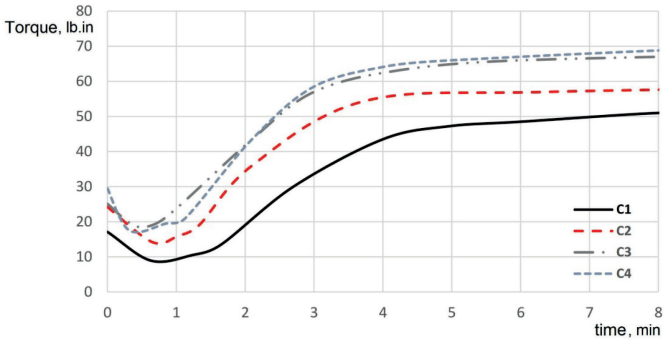

Fig. 3 Rheograph of SBR/CW/CB tricomposite at 175 °C with different percentages additives of CW/CB (C1, C2, C4 and C4 batches)
3. ábra SBR/CW/CB háromkomponensű rendszer Rheograph nyomaték görbéje 175 °C-on különböző CW/CB adagolás esetén (C1, C2, C3 és C4 minták)

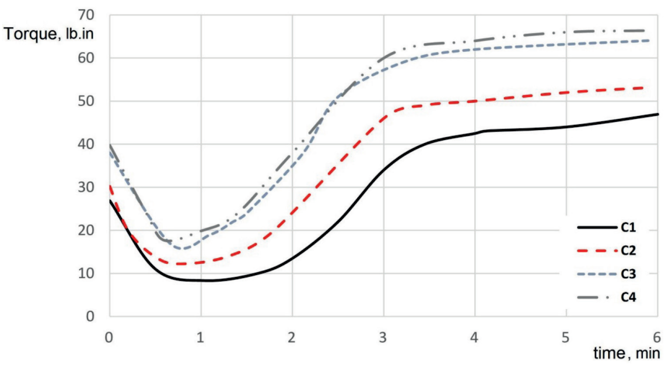

Fig. 4 Rheograph of SBR/CW/CB tricomposite at 185 °C with different percentages additives of CW/CB (C1, C2, C4 and C4 batches)
4. ábra SBR/CW/CB háromkomponensű rendszer Rheograph nyomaték görbéje 185 °C-on különböző CW/CB adagolás esetén (C1, C2, C3 és C4 minták)

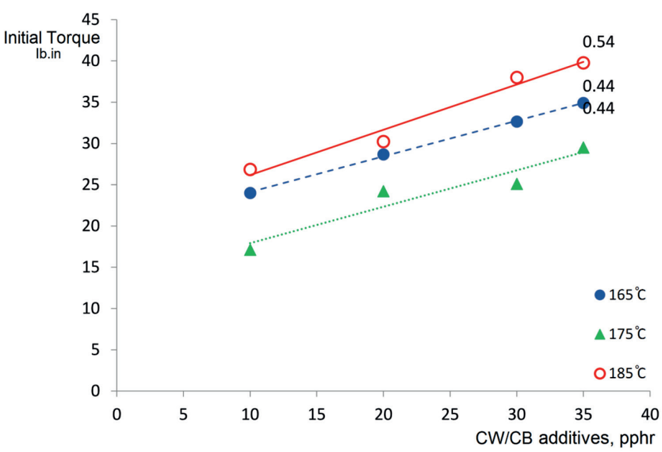

Fig. 5 Initial torque of SBR/CW/CB tricomposite as a function of CW/CB additions at 165 °C, 175 °C and 185 °C temperature ranges
5. ábra SBR/CW/CB háromkomponensű rendszer kezdeti nyomatéka 165 °C, 175 °C és 185 °C-on a CW/CB adagolás függvényében

4. Conclusions

1. The success of cement waste as an effective filler for improving the rheological properties of SBR has been proven by rheological tests.
2. The optimum of the rheological properties were obtained with CW/CB 30 pphr addition.
3. As a result of crosslinking enhancing for the interior structure of SBR tricomposite by CW/CB additives, the torque values (τ_i, τ_{min} and τ_{max}) has been refined.

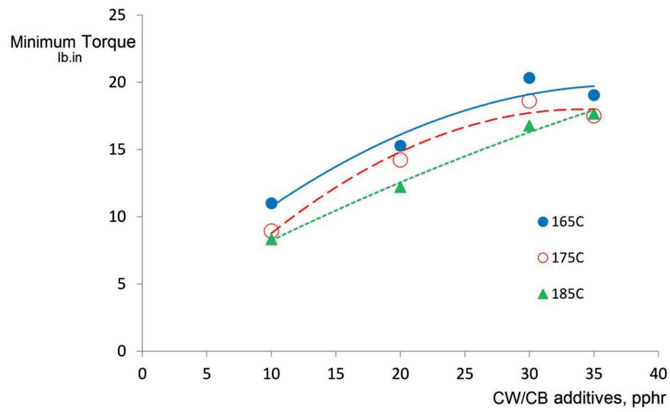

Fig. 6 Minimum torque SBR/CW/CB tricomposite as a function of CW/CB additions at 165 °C, 175 °C and 185 °C temperature ranges
6. ábra SBR/CW/CB háromkomponensű rendszer minimális nyomatéka 165 °C, 175 °C és 185 °C-on a CW/CB adagolás függvényében

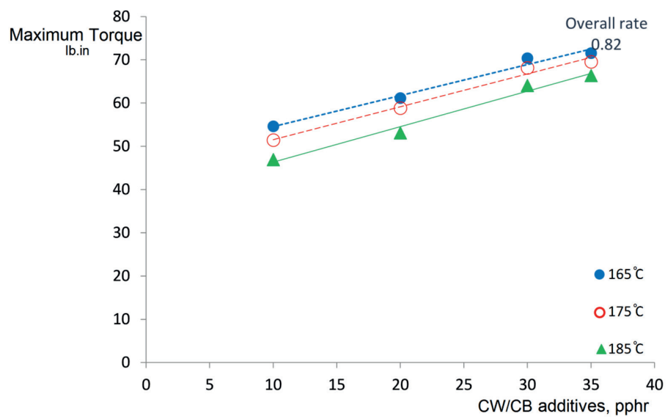

Fig. 7 Maximum torque SBR/CW/CB tricomposite as a function of CW/CB additions at 165 °C, 175 °C and 185 °C temperature ranges
7. ábra SBR/CW/CB háromkomponensű rendszer maximális nyomatéka 165 °C, 175 °C és 185 °C-on a CW/CB adagolás függvényében

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