

# Optimization the physical properties of carbon black filled tread compound by replacement with silica

W.P.M.D.A Perera, A.G.A.W Alakolanga, A.N.Weerawansha  
*Faculty of Animal Science and Export Agriculture, Uva Wellassa University of Sri Lanka*

and

S. Kularathna  
*Loadstar (Pvt) Ltd. Gampaha road, Ekala, Sri Lanka*

## Introduction

In tire industry, carbon black (CB) is a widely used filler all over the world (Studebaker, 1965). Being a product made out of petroleum, there would be scarcity issue with the time, if continue to use in which it is being used today. It is a high time to look at feasibility of replacing CB with an alternative such as silica partially/fully as a solution for foreseen scarcity. Compared to CB, there won't be scarcity as due to the fact it is made out of quartz (SiO<sub>2</sub>) which is readily available in earth crust. In this research, an attempt has been made to study the feasibility to go for possible replacement with silica while meeting the physical property requirement of a tread compound.

## Methodology

The current study was carried out at Loadstar (Pvt) Ltd, Ekala. This study was conducted as two separate experiments. In experiment I, optimum CB/Silica combination which gives overall physical properties was evaluated. Five tread compounds were prepared. Each compound has the same ingredient except filler amount. Total filler amount was kept constant at 50 phr level. Carbon black and powder silica was varied in the ranged from 0 to 50 phr level to prepare the tread compounds with different CB/Silica ratios. Weight of all ingredients in the recipes was in units of per hundred rubbers. Batch weight was 1100 kg. Compound without silica was treated as the reference compound. The compounds were named as Si0, Si15, Si25, Si35 and Si50 to indicate the amount of silica incorporated in the compounds. Silane was added when incorporation of silica as 1 phr of Silane for 8 phr of silica as the coupling agent. Experiment II was carried out to find out the effective silica type in order to optimize the physical properties. Better treatment combination from the experiment I was selected and it has been treated with three silica types (Powder silica, *Hi-sil 243* and *New-sil 155*). Physical properties such as: tensile strength, tearing, abrasion resistance, 300 % modulus, elongation at break, hardness and rebound resilience and cure characteristics were measured in both experiments. Four replicates were used for each test. Data was analyzed with one way ANOVA using Minitab 16 statistical software and mean comparison was done using Tukey test.

## Results and Discussion

According to the previous studies it shows that the increasing silica loading tends to increase in the cure time (t<sub>90</sub>) and scorch time (t<sub>s2</sub>) of the rubber vulcanizates (Okel and Waddell, 1994). These properties have increased with increasing silica. At 15 phr level of silica, it tends to reduce the scorch protection. This can be due to the insufficient coupling of silane with silica during compounding. Higher processing safety obtained as silica loading high due to formation of



salicylic acid at this stage. Maximum torque (MH) tends to decrease as the CB amount decrease.

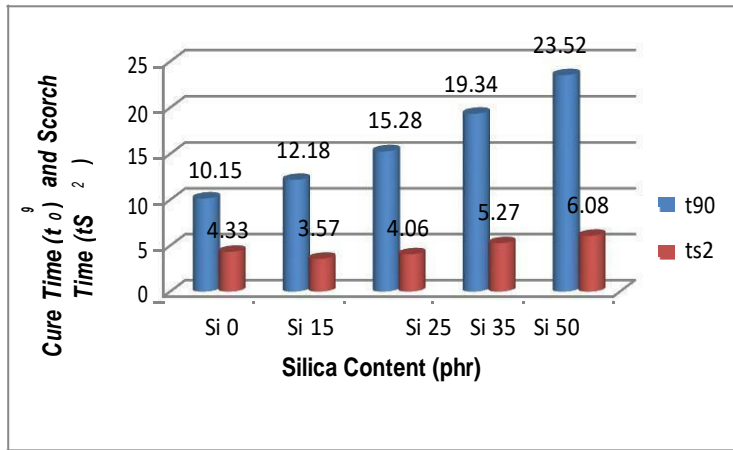


Figure 01: Cure time and Scorch time at various silica ratios

In experiment I, Tensile strength of the vulcanizates decrease as silica content in increasing. This behaviour is due to the decrease in the cross linking density of the tread compounds. With the increasing of silica content, modulus of the tread compounds were tends to decrease. Decreasing cross-linking density has cause to reduce the modulus. As a consequence of this, rise in elongation at break is observed at high silica content. Tear strength of the tread compounds are significantly difference at various filler loading ( $P = 0.000$ ). Results shows that abrasion resistance tends to decrease when silica content is high. Good filler dispersion causes to have better wear properties than poor dispersion (Choi, 2002). Therefore poor silica dispersion or high silica-silica interaction has claimed to decrease the abrasion resistance properties. Hardness of the compound and rebound resilience also have increase at high silica loading. Highest resilience is results in the full replacement of CB with silica. Higher the rebound resilience, gives low heat build up.

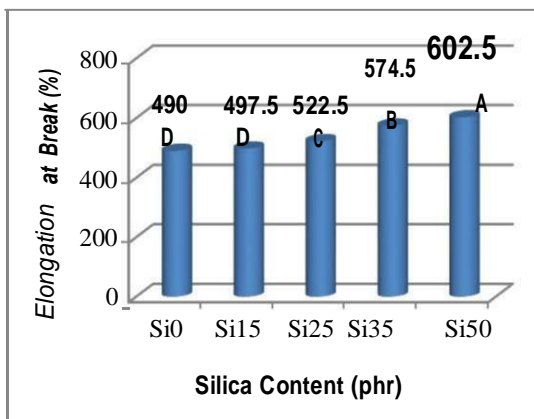


Figure 02: Elongation at break

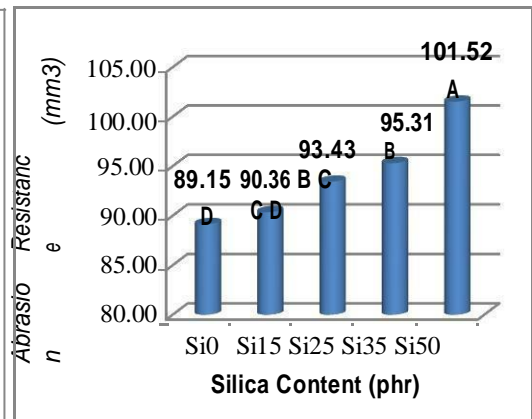


Figure 03: Abrasion Resistance

In experiment II, 25 phr of CB and 25 phr of silica treatment combination was treated with three silica type. Results reveal that tensile strength, tearing, abrasion resistance, 300 % modulus, hardness and rebound resilience show significant difference as P-values are less than  $\infty$  according to one-way ANOVA. Apart from these physical properties, elongation at break do not show significant difference.

Table 01: Physical properties of CB 25/ Si 25 compound at different Silica type

Properties	Powder silica	Hi-sil 243	New-sil 155
Tensile strength	238.19	237.01	231.03
Tearing	64.66	62.81	67.33
Modulus 300%	110.47	109.69	102.86
Elongation	522	513.75	510
Abrasion resistance	93.43	103.39	93.86
Rebound resilience	47	48.50	49.75
Hardness	65.25	64.25	61.75

### Conclusions

As CB and silica has two different chemistry, this replacement result both failure and improved properties. Partial silica replacement is better than the full replacement to this tread formulation. It can be concluded that vulcanizate having 25 phr of CB and 25 phr of silica better overall mechanical properties. *Hi sil* 243 is the effective silica type compare to other studied silica.

### References

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