AN INVESTIGATION ON EFFECT OF FLYASH ON THE PHYSICAL AND MECHANICAL PROPERTIES OF RECLAIMED BUTYL RUBBER

KHUSHNEET SINGH[1] SOURABH SHARMA[2]

[1]*M. Tech Student in Sri Sai College of Engineering and Technology, Badhani, Pathankot.*
[2]*Assistant Professor in department of Mechanical Engineering, Sri Sai College of Engineering and Technology, Badhani, Pathankot.*

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Abstract *- Butyl rubber (IIR) is co polymer of iso butylene and isoprene. The butyl scrap is de-polymerized and filtered to get reclaimed butyl rubber which can suitably be used for inner tire tubes, tire inner liner and adhesive etc. By analyzing the impact of Fly ash on the mechanical properties of Reclaimed butyl rubber, this paper focuses on exploring the quality and cost-efficient manner of converting waste tire tube into new product. It was observed that an increase in percentage of fly ash improves the hardness and specific gravity. Conversely, tensile strength, Mooney viscosity and elongation at break show a decreasing trend. As fly ash helps in regulating the mechanical properties of reclaimed butyl rubber, thus, depending upon the requirement and application of rubber, the content of fly ash can be varied. For instance, when the focus is on improving the hardness of rubber, fly ash percentage shall be kept high and vice versa where the requirement is better tensile strength.*

Key words: Reclaimed Butyl rubber, Fly ash, Mechanical properties.

1. INTRODUCTION

Recycling is buzzword now-a days. Considering the negative impact of waste on environment, recycling process has gained significant importance. Rubber is one of the major sources of environmental pollution.

Globally about 15.133 million metric tons of synthetic rubber was produced in 2019 [1]. With advancement in technology and rising standard of living, there is an upsurge in demand of motor vehicles and consequently increase in manufacturing of tires. Nonetheless the demand of tires for replacement in old vehicles has also increased. Globally about one billion tires are manufactured every year and same is the number of tires removed from the vehicles which turn out to be waste. These waste tires are then stockpiled, dumped and finally, diverted to landfills. These sites are always at high risk of fire and poisonous smoke. The seriousness of issue can be understood by recalling the havoc caused by worlds largest tyre fire which began in Wales in 1989 and took 15 years to extinguish [2]. Tire stockpiles give rise to numerous health and safety risk. Due to huge size and difficulty to compact, scrap tires are dumped illegally. Illegally dumped tires are harmful to environment as one used tire contains about two gallons of poisonous paralytic oil. Ignition of this oil can lead to devastating consequences. Recycling facilitates in reducing the number of tires in storage. India is estimated to produce about 6500000 tires and 275000 waste tires every day. About 6 percent of global waste tires are produced in India [2]. Although India has been recycling and reusing waste tires since past 40 years and is the second largest producer of reclaimed rubber worldwide. However, about 60% of waste tire is still dumped illegally.

India has huge coal reserves and about 70-75% of power in the country is generated by Coal based thermal power plants [3]. Fly-ash is the finest coal ash particles, produced as by-product during combustion of coal in thermal power plants and is causing a threat to the environment. This hazardous waste generated from combustion of coal, can however, be utilized as raw material in number of industries for instance, cement, bricks, tiles including rubber.

As per the report on fly ash generation and utilization at thermal power station for the year 2017-18 published by central electricity authority (CEA) [4], out of 196.44 million tons fly ash generated in the country, about 131.87 million tons of fly ash has been utilized by construction agencies. Therefore, a major polluting agent is now turning out to be a great resource material. A limited number of published studies are available on exploration of fly ash in rubber compounds.

Rubber has capacity to assimilate various waste materials as fillers. The impact of filler material on mechanical and physical properties of any polymers can be known by practical application. In this study, an endeavor has been made to explore the possibility of utilizing fly ash as filler for production of reclaimed butyl rubber by highlighting the impact of fly ash on mechanical properties of reclaimed butyl rubber.

2. LITERATURE REVIEW

H.Tenchev et al.(1982) an investigation on high-temperature vulcanization method in rubber industry. By reducing the time and increase in the temperature of vulcanization should not deteriorate the properties of the vulcanizates obtained.

Thomas Kurain et al. (1989) studied that for a given rubber compound, the curing temperature has a profound influence on the network structure. Hence the curing temperature for a particular product could be fixed based on the properties required of it. In this study vulcanizate properties are compared at varying temperature.

Garde et al. (1999) investigated that the mechanical properties of polyisoprene rubber loaded with fly-ash were inferior, as compare to polyisoprene filled with silica.

N.Rattanasom et al. (2005) an investigation on the mechanical properties such as tensile properties, tear strength, and abrasion resistance of the vulcanizates were determined. The results shows an increase in their hardness and modulus with increasing reclaim rubber content while other mechanical properties are significantly affected. However, for some applications, the properties of the blends are still suitable.

N. Sombatsompop et al. (2007) reported that when the content of filler is relatively small in the rubber compounds the reinforcing effect of fly ash was similar to the reinforcing effect of silica.

H. Ismail et al. (2010) shows the effect of WTD/CB hybrid filler loading on tensile strength of natural rubber compounds. With increased in carbon black percentage, tensile strength increases. SEM study indicated that better WTD/CB hybrid filler dispersion and wettability by natural rubber matrix increased the tensile strength and fatigue life.

Zhilei Zhang et al. (2012) demonstrated that Waste tire powder (WTP) was reclaimed mechanically in presence of a new composite additive which consists of reinforcing materials (RM) and toughening materials (TM), and the effects of technical parameters and additives were investigated. With reinforcing material, Tensile strength and Elongation at break apparently show increasing trend and then decreased.

Bahruddin et al., (2012) reported that Palm based fly ash (PFA) is a solid waste of palm oil processing industry which contains silica components can be used to improve the mechanical properties of thermoplastic vulcanizate.

Lin Li et al. (2012) explained that recycled butyl rubber and virgin butyl rubber compounds have much better properties. To obtain optimal physical and mechanical properties, the optimal curing time Tc90 is required. It is also observed that the optimum curing time varies with increase in Recycled Butyl Rubber. Further, waste rubber powder contains void space which increases effective volume fraction of waste rubber and hence, results in higher viscosity.

Formela et al. (2014) as per this study, addition of crosslinked butyl rubber to the investigated blends increased the compatibility between the low density polyethylene and the ground tire rubber (GTR) particles.

J.Wu et al. (2015) an experimental results showed that the rubber elongation at break decreased with the increasing of cross-link density, therefore, the curing degree should not be too high for rubber product of high elongation. For the rubber products of high elongation, curing degree should not be too high. Initially, tensile strength increased and then decreased with increase in curing time.

3. OBJECTIVE OF RESEARCH:

To determine the impact of fly ash on the mechanical and physical properties of reclaimed butyl rubber.

To produce reclaimed butyl rubber in a cost effective manner.

To attain dual purpose of utilizing waste tire tube rubber and fly ash; and reducing the environmental pollution caused by them.

4. EXPERIMENTATION PROCEDURE

Manufacturing of reclaimed butyl rubber: For manufacturing reclaimed butyl rubber, scrap tire tube rubber undergoes through different processes. Firstly, scrap tire tube is washed at washing station to remove the dust, oil, peddles etc from it.

With the aid of conveyors belt, rubber is then fed into the cracker, which converts rubber into small pieces (i.e to reduce the size upto 25mm). Thereafter, small pieces of scrap rubber is transmitted to breaker through conveyor belts, which produces the fine required mesh powder to be used for further processing. Proper blending and mixing of the powders are essential for uniformity of finished product. Mixture of fine, texture free scrap rubber is blended with accelerators like MBT and DPG, stearic acid, carbon black, acetone and fly ash in the Digester. To facilitate occurrence of reaction, the material is heated up to a temperature of 200^{o}C in the Digester. Afterwards, the mixture is put into the two-roll mixing mill to break the polymer chain. It also helps in refining and blending the reclaimed butyl rubber. In refiner required thickness sheet is manufactured. Then curing is done at 150^{o}C for 25 minutes.

Fig 1: Manufacturing process of Reclaimed Butyl rubber.

5. TESTING OF RECLAIMED BUTYL RUBBER

5.1. Procedure for testing mooney viscosity: To calculate Mooney viscosity, put the sample in the rotor and insert the rotor in the shaft. Switch on the mooney viscometer. Ensure that there is nothing in between glass shield. Now, rotor is preheated for one minute. To perform the test, we need to maintain the temperature at 100^{o}C with pressure @ 5kg/cm^2. Afterwards, rotor embedded in the material turns at a speed of 2rpm. Once the test is completed, safety shield and Die will automatically open. Lastly, remove rotor and tested material from the die and note down the results obtained.

5.2. Procedure for Testing Specific gravity: To compute Specific gravity, press “test” button on Digital specific apparatus. Display screen will give message: “Hang sample”. Now, hang the sample and wait for it to get stable. Again Press “Test” button. Display will give message: “Dip in water”. Dip your sample in water now and let it get stable. Now, again Press “Test” button. Display screen will show the specific gravity value of the sample.

5.3. Procedure for testing tensile strength and elongation: Place the standard dumbbell shaped specimen in the micro vision tensile testing machine. Hold specimen with the help of the grip and apply load. Keep stretching the specimen by increasing the weight constantly, until it reaches the breaking point. Resultantly, a load (amount of weight) versus displacement (amount of stretch) graph is drawn which shows the Tensile strength and elongation at break.

5.4. Procedure for testing Hardness: To test harness, Put rubber on a flat surface. Now, put durometer over the sample in such a manner that indentor touches it. Thereafter, apply load over the sample till presser foot comes in firm contact of the sample rubber. The hardness depends on the depth of indentation and is displayed on durometer scale.

6. Results: To obtain results, nine different samples have been tested. Since with same percentage of fly ash, some variations were observed in the results obtained. Therefore, to achieve more explicit outcomes, 3 set of samples containing different percentage of fly ash (i.e. 4%, 5%, 6%) were taken at curing temperature and time of 150 ^{o}C and 25 minutes respectively. In each sample set, the percentage of fly ash was kept same and in total 9 samples were tested. Table 1 reflects the general results obtained and variations in Mooney viscosity, Specific Gravity, hardness, Tensile strength, Elongation at break with same percentage of fly ash as well as with change in percentage of fly ash. Table 2 shows the average results obtained with each percentage of fly ash.

Table 1: Analysis of Mooney viscosity, Specific Gravity, Hardness, Tensile strength, Elongation at break with different percentage of fly ash.

Fly ash (%)	Mooney viscosity (Mooney Unit)	Specific gravity	Hardness (shore)	Tensile strength (kg/cm^2)	Elongation (%)
4	44.37	1.072	50	92.3	586
4	48.36	1.078	49	92.8	564

4	48.96	1.072	50	93.1	571
5	42.6	1.082	51	83.32	541
5	41.78	1.084	51	83.72	553
5	43.12	1.081	52	85.86	566
6	36.21	1.089	54	76.63	532
6	37.24	1.094	53	77.59	509
6	38.82	1.096	54	73.87	539

Table 2: Average results at different percentage of fly ash.

Fly ash (%)	Average Mooney viscosity (Mooney Unit)	Average Specific gravity	Average hardness (shore)	Average Tensile strength (kg/cm^2)	Average elongation (%)
4	47.23	1.074	49.67	92.73	573.67
5	42.5	1.082	51.3	84.3	553.33
6	37.42	1.093	53.66	76.03	526.67

The graphs below reflect the impact of fly ash on different mechanical properties of reclaimed butyl rubber. To be more specific, the average results obtained in table 2 are reflected through graphs.

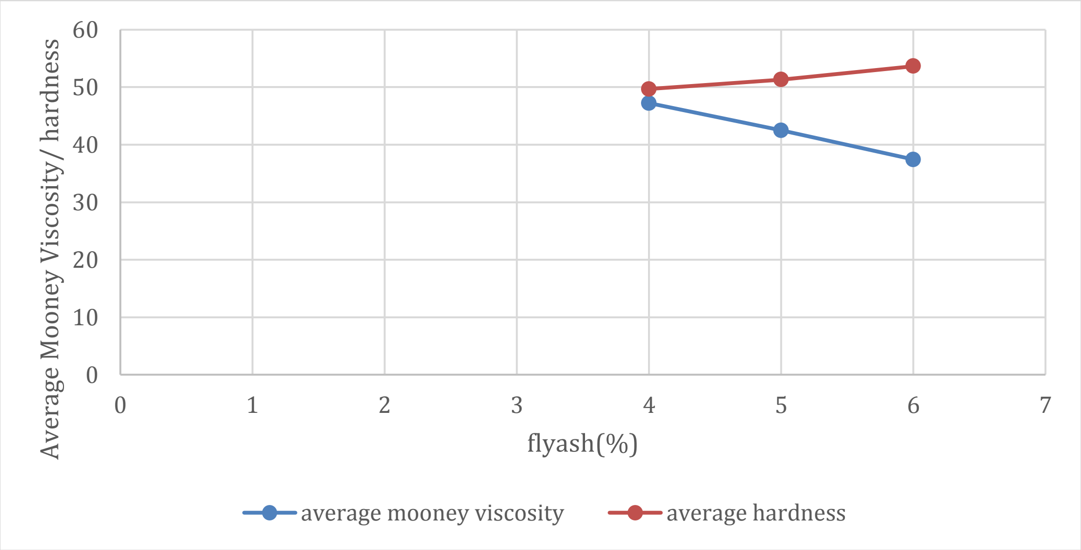

Fig 2: Effect of Fly ash on Mooney Viscosity and hardness of reclaimed butyl rubber.

In fig 2, graph shows upward trend for hardness and downward trend for mooney viscosity as the percentage of fly ash increases. Therefore, hardness increases and mooney viscosity decreases with increase in fly ash content.

Hardness of a material is generally defined as its resistance to scratching or to wear. Hardness of reclaimed butyl rubber increases with increasing cross-linking of the molecular chain due to increase in fly ash content. When fly ash is 4%, hardness is 49.67. As fly ash content is increased to 5%, hardness goes upto 51.3 and further to 53.66, with 6 % fly ash content.

Mooney viscosity, also known as rotational viscosity is measured by Mooney viscometer. Reclaimed rubber has low molecular weight as compare to virgin rubber. Therefore, due to low molecular weight and narrow distribution range, mooney viscosity decreases with increase in fly ash content. As observed, specimen with 4% reinforced fly ash content, the mooney viscosity is 47.23 Mooney unit and it decreases to 42.5 and 37.42 Mooney unit with 5% and 6% fly ash content, respectively.

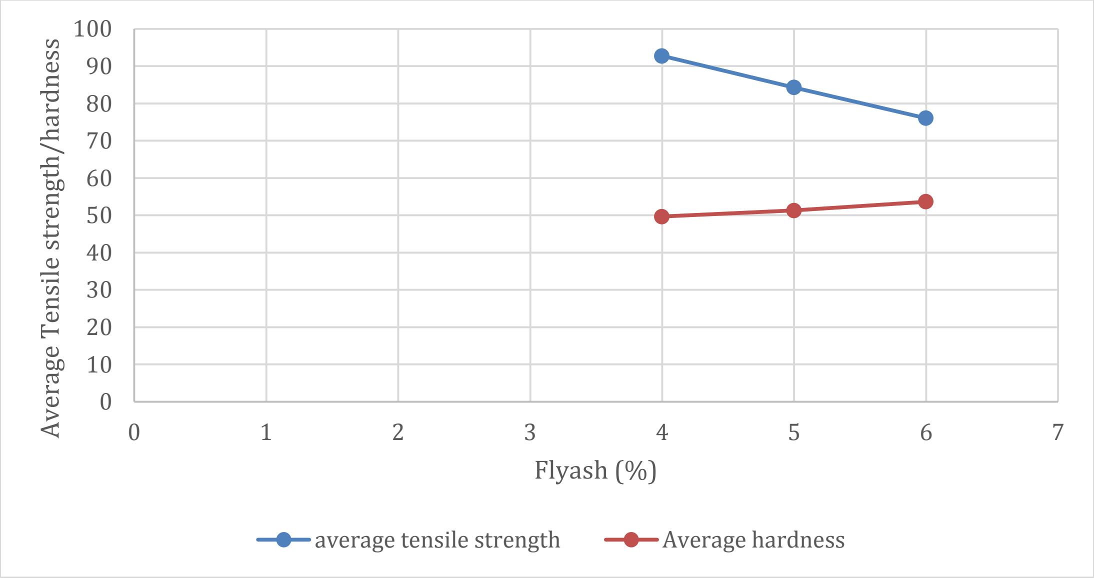

Fig 3: Effect of fly ash on tensile strength and hardness in reclaimed Butyl Rubber.

In fig 3, graph shows downward trend for tensile strength as the fly ash percentage increases and vice versa for hardness. This figure also reflects a comparative analysis of variation in tensile strength and hardness with change in fly ash content. Crystallization is disrupted on incorporation of fly ash because of poor interfacial bond, leading to ineffective stress transfer and poor adhesion between fly ash and reclaimed rubber and this ultimately results in decrease in tensile strength. As stress distribution is dependent on concentration and orientation of fly ash, therefore tensile strength decreases with increase in fly ash content. When fly ash is 4%, tensile strength is 92.73 kg/cm^2. When fly ash is increased to 5%, tensile strength decreased to 84.3%.

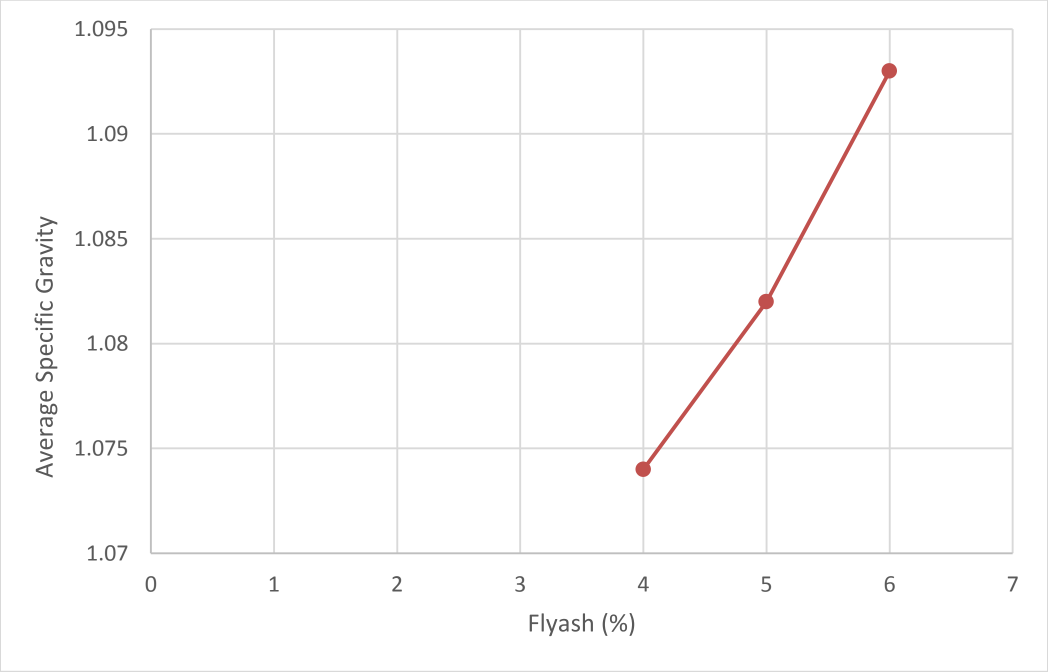

Fig 4: Effect of Fly ash on Specific Gravity

From fig 4, it shows that as the fly ash content increases, its specific gravity increases. At 4% fly ash, specific gravity is 1.074 but as the fly ash content increases (i.e at 6%), specific gravity is 1.093. Specific gravity is used in determining batch volume during mixing and compound formation of rubber.

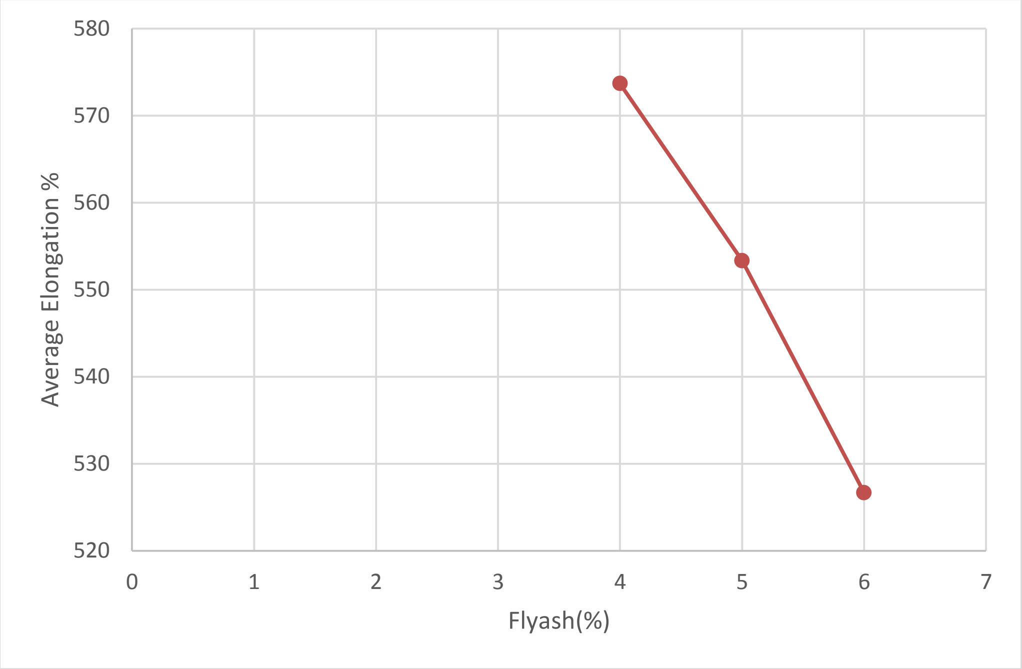

Fig 5: Effect of fly ash on Elongation at break.

From fig 5, graph shows downward trends as the fly ash content increases. Therefore, elongation at break decreases with increase in fly ash content. This can be explained in terms of adherence of the fly ash to the reclaimed rubber matrix leading to the stiffness of the rubber composite and hence, resistance to stretch when strain is applied.

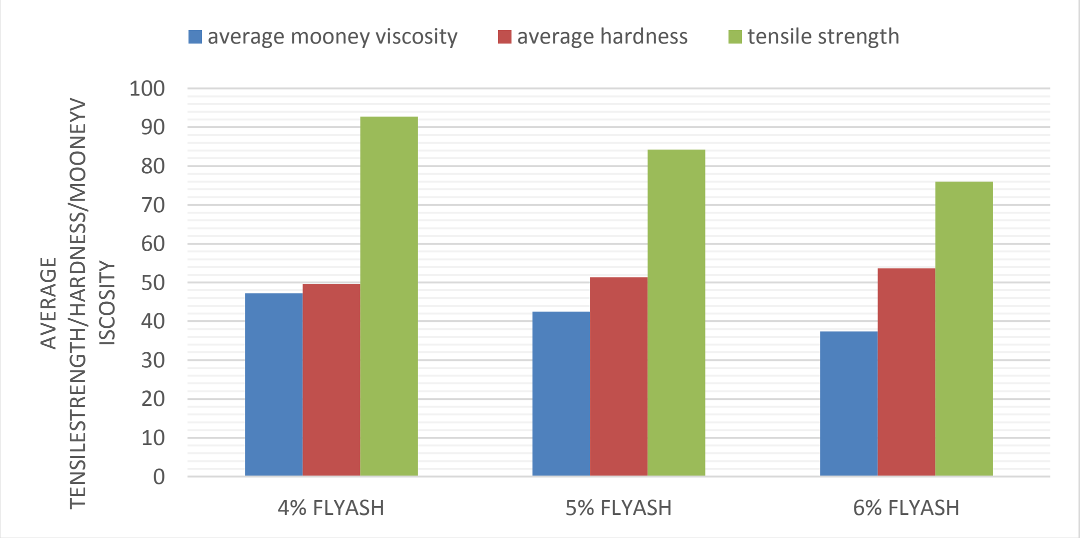

Fig 6: Analysis of Tensile strength, Mooney viscosity and Hardness with different percentage of fly ash in reclaimed Butyl Rubber.

From fig 6, we can relate the different properties i.e. at 4% fly ash, tensile strength and mooney's viscosity are maximum whereas, with increase in fly ash percentage, tensile strength and mooney's viscosity decrease. In contrast, hardness is maximum at 6% fly ash and minimum at 4% fly ash content.

7. Conclusion:

In this study, impact of fly ash on mooney viscosity, hardness, tensile strength specific gravity, elongation at break of reclaimed butyl rubber at constant curing time and curing temperature has been observed. As per the analysis, with increasing percentage of fly ash hardness and specific gravity increase. On the contrary, Mooney viscosity, tensile strength and elongation at break show a decreasing trend. In this study the curing time and temperature of all the samples tested has been kept constant. There are fewer research papers available in this field. The results obtained in this study has widen the scope for further research. The effect of fly ash on different mechanical properties of reclaimed butyl rubber at varied Curing time and curing temperature is another significant topic for research.

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