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Effect of Fly Ash Content on the Mechanical Properties of the Tire Reclaimed Rubber

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ABSTRACT: This research is performed to enquire about the influence of Fly Ash (FA) imposition in the Tire Reclaimed Rubber (RR) and consequently the variations obtained in the formed reclaimed rubber in terms of its mechanical properties. The disregarded waste tires are produced every year in abundance coherent to the increasing sale of vehicles. As potentially a threat to the environment and to obtain cost value from them, these are recycled. Fly Ash is also produced in abundance in power plants and being a waste product, is disposed off. In this paper, one of the processes of the recycling of these waste tires is the 'Reclamation of Rubber'. This research discusses the use of Fly Ash as filler in the reclamations in the phr ranges of 8, 12 and 20 and its corresponding effects on the mechanical properties (such as tensile strength, % elongation, hardness, specific gravity, Mooney viscosity) of the rubber composites formed there off. The hardness and the specific gravity are found to be the most in case for 20 % reinforced fly ash composite and least for the 8 % reinforced fly ash composite. Other properties such as tensile strength, % elongation and Mooney viscosity are found best in case of 8 % fly ash reinforced sample and worst for the 20 % fly ash reinforced sample.

Keywords: 'Fly Ash; Tire Reclaimed Rubber; Waste Product; Composite'.

I. INTRODUCTION

One of the most cumbersome sources of waste is the vehicle tires. Consistently over 1.6 billion new tires are created and around 1 billion of waste tires are produced every year. One process for their reuse is recycling. However, from that huge amount, the recycling is done for just 100 million tires yearly [1].

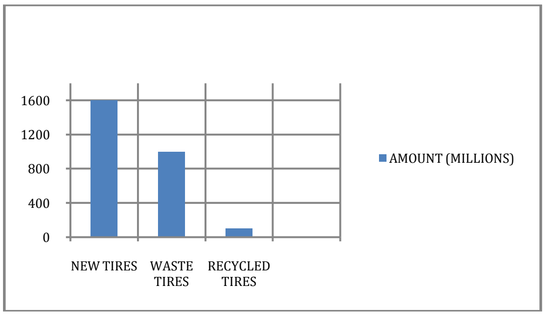

Figure1: Yearly production, wastage and reutilization of tires

As complex procedures are used for its manufacture, it becomes indestructible in nature and much trouble is faced in the reusing of these tires. But with the improvement in technology and for environment protection, driving tire recyclers are spending gigantic sums and advances in hardware and equipments which can help in reusing the tires for different applications. Moreover, it is estimated that about 6, 50000 tires are generated and about 2, 75000 tires are discarded every year in India. For India, the Environment (Protection) Rules of 1986, the Hazardous and Other Wastes (Management and Trans boundary Movement) Rules of 2016, the guidelines of the Central Pollution Control Board (CPCB) for sound environmental management of end of life vehicles of 2016 and the Standard Operating Procedures (SOP) issued by Ministry of Environment, Forest and Climate Change (MoEFCC) [2]. Their strategies are pushing the tire recyclers to fuel the development of the tire recycling market. The crumb from the scrap tires helps elevation of tire industries.

Another kind of waste, the Fly Ash (FA), debris of the power plants is side lined for past many years as likely filler in a wide range of business items including the rubber based products as well. As according to IEA 2019 report, total 26, 700 TWh of energy is produced in 2018 in the whole world, from which 38 % is by coal. It is a fact that huge amount of power is produced by coal ignition and also which is anticipated to arrive at approximately 46% in 2030 according to many reports; a large amount of fly Ash is unavoidably created as waste after ignition. Around 750 million tons of fly debris are delivered every year, except just 39% can be reused in U.S. [3]. For India, 300 million tones of fly Ash are delivered every year and if transmitted by wind to the environment cause dangerous pulmonary infections to the Indian population as well. Moreover, the power plant operators also face astonishing costs for the disposal of the fly Ash. Reuse of the fly Ash is an effective method to forestall such contamination. With this thought, fly Ash is frequently used to improve the concrete's sturdiness in the construction industries. However fly Ash is also utilized in the rubber industries as well. In rubber industries, fly Ash helps in improvement of mechanical properties as well as the curing characteristics of the rubber. However its utilization didn't reach at 100 % level. Various regulations are being accorded by the countries of the world. Indian Ministry of Environment Forest and Climate Change in 1999 published a gazette notification and specified the use of the fly Ash and also published a date for the 100 % utilization to complete for all thermal power plants. A lot of amendments were done in 2003 and in 2009 the deadline was fixed to 2014 but missed by almost 40 %. Then 2015 saw another notification for deadline of 31 December 2017 but still not achieved fully [4].

This paper discusses the recycling of tire rubber by Reclamation. Reclaimed Rubber is a thermo chemically cured rubber. With the mechanical and the chemical action, the viscous nature is decreased and the cross links of the rubber are broken. There is an availability of reclaims for old as well as the new tires, for tire treading, Fluoro elastomer FKM, butyl, drab, Ethylene Propylene Diene Monomer EPDM, matting, Natural tubes, beltings, footwear, adhesives, sheeting etc. The applications recently have been expanding to the running tracks, boxing and other arena, jumping trampoline for kids and other sporting cabins etc.

This research provides for economical reconsiderations, material management etc. The work reinforces, 'the waste of this day may be the energy of the upcoming day.'

II. LITERATURE REVIEW

Adhikari et al. (2000) [5] studied the waste disposal management. Large rubber tires are used in vehicles, air planes and so on and when becomes unserviceable is discarded. At that time, abrasion there is only about 1 % but most is discarded. Its natural degradation cause 2 major problems; firstly the resource wastage and secondly the disposal pollution to the environment. This paper therefore advocated for recycle, reuse and reclamation of rubber.

N. Sombatsompop et al. (2004) [6] studied the effect of the untreated fly ash particles and the precipitated silica particle fillers from 0 to 80 phr. The PSi loading shows for the range 30 - 75 phr, curing time and also the limit torques increasing progressively and for the fly ash filling, a lower curing time and viscosity is seen in the composites with NR. Up to 30 phr shows the vulcanizing properties similar in both cases of fillers. From above that concentration of filler, PSi filled composites properties improved but not that of FA filled composites.

N. Sombatsompop et al. (2007) [7] studied the effect of 0, 10, 20, 30, 40, 50 phr fly Ash loading on the rubber samples. With the addition of fly Ash content, there observed a decrease in the curing time, cross link density, % elongation and % resilience. However, with the addition of fly Ash, the tensile modulus, the tear strength, % compression and the hardness values increased. For the tensile strength, it is first increased, became highest in between 10 to 20 phr fly Ash filler and then decreased.

Weili Wu et al. (2007) [8] used the reclaim powder RP compound with fly Ash FA and dough modeling compound DMC, which performed excellently at 45/100/25 respectively under 30 minutes curing time at 145^{o} C and pressure of 9 M Pa. This paper depicted the gradual increase in the wear, the tensile strength, the Shore A hardness of composites with increased amount of FA while decreasing the % elongation. The 25 phr FA composite was found best suitable for thermal properties.

H. Ismail et al. (2008) [9] enquired of the Palm Ash loading effects on the characters of the Natural Rubber Composites. With the increase in palm Ash filling; the scorch time, the tensile modulus, the minimum torque and the curing time increases and the tensile strength, the elongation at break and the fatigue life decreases. The fatigue life and the tensile strength could be further increased by the incorporation of the Maleated Natural Rubber MANR in the palm Ash and NR composites.

Thanunya Saowapark et al. (2009) [10] explained about the visco elastic properties of the natural rubber and fly Ash composites, with FA taken in from 0, 50, 100, 150, 200 phr. With the addition of FA, storage modulus and the shear viscosity and the Mooney viscosity increases. It was explained according to the ball bearing effect of fly Ash and isoprene without any non rubber element.

Mridul Dasgupta et al. (2013) [11] witnessed about fly Ash / ESBR compounds and compared it with clay and whiting. With the increase in fly Ash loading, the tensile strength remains comparable but the elongation at break increases gradually. Lowest heat builds up and at 70^o C, the tan delta (stable up to 60 % and thereafter increasing) is seen in fly Ash as compared with others. The minimum abrasion resistance is installed by Ash filled compounds but retaining capacity is the highest. Thus up to 60 phr, fly Ash forms the top spot at applications having less importance of abrasion resistance.

Arti Maan et al. (2014) [12] studied of the natural rubber and fly Ash reinforced composite. The properties like density, skid resistance, water absorbing capacity, hardness and compression of the composite increase while the properties like the abrasion resistance and the tensile strength decrease. The loss of some of these properties is found useful in the sidewalks rubber, the mats and the tiles etc, in which these properties and that much quality are wastage. The less cost of the fly Ash reduces the overall cost and makes up for the purposeful work and removes the non purposeful expenses.

Panu Panitchakarn et al. (2018) [13] studied the natural rubber and the coal fly Ash composites by the process of latex aqueous micro dispersion. This paper discusses the addition of the mechanical properties due to the addition of Coal Fly Ash CFA and Coal Fly Ash treated with acid CFAT and at about 20 phr the Young's Modulus, the Elongation at Break and the Tensile Strength improves the highest compared to the untreated Natural Rubber. The formed composites showed minute swelling in water as demonstrating better stability in structure and the improved resistance to the toluene. Also composites formed are biodegradable and can be used for the fabrication bags like the medical waste disposals in the landfills.

C. Sathiskumar et al. (2019) [14] reviewed the recycling of the Waste Tires. This paper discusses the variety of the recycling methods like reclaiming, retreading, grinding, pyrolysis and combustion and describes pyrolysis as the ultimate technique. With the increase in its temperature, the TPO yield decreases. The catalyst use increases the catalyst and the tire ratio but asphaltness in oil decreases. The waste oil makes carbon nanotubes and these nanotubes may be used in the batteries, the solar cells, the super capacitors, the oil spilling and the EMI shielding etc. Another product of pyrolysis forms hydrogen gas, a fuel efficiently used recently. And also one more is the solid char used for the active carbon preparation. The pyrolysis therefore forms high value from a waste like tires.

Eva Marlina Ginting et al. (2020) [15] enquired the Natural Rubber (NR) and the Palm Oil Boilers Ash (OPBA) composites with Ash in the ratio of 0, 2, 4, 6 and 8 weight %. This paper describes that with the increase in the Ash content, the thermal properties increase as the cross links and also the melting point increase. The XRD pattern shows the amorphous structure the mixture has without the filler and the crystalline with the addition of Ash. The FTIR graph shows no major deviance in composites with and without fillers. With OPBA addition, the mechanical properties, therefore, are elevated.

Xu Junqing et al. (2020) [16] showed the waste tires' high value utilization in China with free market system with sets standards with the supervision of market operations and the waste tires' self digestion and helps in the adjustments in pricings. It talks about pressure, temperature, heating rate and time affect of the rubber, improvement of pyrolysis efficiency, quality and the product yield by appropriate catalyst. This study suggests for CBp instead of TPO for clean and high value process. And also the oil and the gas of the pyrolysis are used in the production of heat and helps saving expenses.

III. OBJECTIVE OF THE RESEARCH

- To have a better utilization of a waste product of thermal power plants as fly Ash FA and the rubber waste of vehicles generated every year.
- As these waste for environment polluting agents, reducing these wastes is like doing good to the environment.
- To provide variety of alternatives in the market for purposeful utilization, specific applications and with overall cost reduction of the product being developed.
- To open further scope in this field of study.

IV. EXPERIMENTAL WORK

A. Manufacturing Process

The RR composite sample is prepared by firstly isolating the non usable tires and other items and these are fed in the Tire Cutter. The Tires are cut in 2 to 3 pieces in Tire Cutters after the separation of side walls. The Bead Wire is removed for sale from the Bead Ring with the use of the Bead Wire Remover machine. Shredding then happens in tire Shredder which cuts in ≤ 50 mm pieces. Further Cracker is used to reduce the size to ≤ 25 mm. Crumb of desired 30 meshes is then made in the Breaker and the Iron Wires are removed through magnet and collected in a bag for sale. The left over iron pins are removed by the use of Double drum Magnetic Separator containing the 5000 and the 10000 Gauss Magnetic Drums. The crumb rubber is weighted and is collected in bins and stored for use thereafter. The required quantity with the addition of oil and chemicals and the fly ash FA are placed in the 12 M3 Rotary Autoclaves and the corresponding de vulcanization is done at a 200^o C temperature in digester by Electric Heaters and pressure from the Boiler is released for a definite period after the pre defined time (1 hour cooking time) for the process of de vulcanization. Then the Effluent Treatment Plant ETP is used for the recycle of the used water. The de vulcanized material is then dispersed on the floor for instant cooling (as is required for the best output). Thereafter the material is masticated in the Mixing Mills. After mixing mills, the material is passed through 2 stages Pre Refiner for making a thin roll. Then Straining or Extrusion by a particular counterfeit is done for filtering the foreign particles. Lastly, in the Refiner, sheet according to the required thickness is made by winding on the drum of the refiner. Thereafter the process of curing is done at 140^o C for 20 minutes.

The procedure is repeated for different samples by taking 8 % Fly Ash for sample 1, then 12 % for sample 2 and then 20 % for sample 3.

Figure 3: One RR Specimen for each 8 %, 12 % & 20 % FA reinforcement from left to right

B. Mechanical Testing

The tire reclaim rubber specimens thus obtained are tested for various **mechanical properties**;

Tensile Strength (T.S.) (kg/cm^2) and Elongation (El.) (%) are measured by the Tensile Testing Machine and the test is performed according to ASTM D412, ISO 37. The test shows the tensile strength and the % elongation at breakage. A specified dumbbell is made for each specimen. This dumbbell is fitted in the grips of the machine. Machine is then put on. The dumbbell specimen is pulled until fracture by increasing the applied load and corresponding results are obtained from the load versus displacement graph. The process is repeated for all the specimens.

Mooney Viscosity (M.V.) (Mooney Units) is tested according to ASTM D 1646. Sample is put on the rotor of the machine and it is allowed to rotate at 2 rpm under standard temperature 100^o C and pressure 5 kg/cm^2 for specified time. When it stops rotating, the results are noted at the end of the test. It should be made sure that nothing is present in between the glass shield. The test procedure is repeated for all the specimens.

Specific Gravity (S.G) is tested by Digital Specific Gravity Balance made by ASIAN and measurement is done according to ASTM D 1646. The test button is pressed, sample is hanged and as stable, the test button is pressed again and it is shown to 'dip in water' and when dipped and stable, by pressing test button again specific gravity of the sample is displayed. The procedure is repeated for all the specimens for the corresponding results.

Hardness (Hd.) (Shore) is measured by Shore A Durometer according to ASTM D2240 or ISO 7619-1. The Durometer indenter is fussed in the specimen put on a flat surface. Load is then applied on the specimen to get specific indentation. When the depth of the indentation is proper, the Durometer shows the resulting hardness value of the specimen on the dial. To test harness, Put rubber on a flat surface. The process is repeated for all the rubber samples and the corresponding mechanical properties are noted down.

V. RESULT AND DISCUSSION

Taking the machine and the worker limitations into account; accordingly results of mechanical properties for each different kind of rubber samples are taken three times each at the Fly Ash contents of 8 %, 12 % and 20 % and at constant other input parameters. The mechanical properties obtained are understated in the Table I and to get close to the desired results, it is necessary to take their mean values as in Table II;

TABLE I. RESULT VALUES OF DIFFERENT MECHANICAL PROPERTIES FOR DIFFERENT FLY ASH CONTENTS

S. NO.	%FLY ASH	T.S.	El.	M.V.	S.G.	Hd.
1	8	48.45	213	41.50	1.072	64
2	8	48.10	210	39.72	1.075	63
3	8	47.62	196	41.25	1.078	65
4	12	47.52	220	27.85	1.079	71
5	12	42.66	192	32.55	1.078	70
6	12	38.95	189	35.53	1.076	72
7	20	37.62	188	18.37	1.082	80

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S. NO.	%FLY ASH	T.S.	El.	M.V.	S.G.	Hd.
8	20	33.33	166	16.32	1.080	79
9	20	33.05	182	18.46	1.084	81

TABLE II MEAN VALUES OF MECHANICAL PROPERTIES FOR DIFFERENT FLY ASH CONTENTS

S. NO.	% Fly Ash	T.S.	El.	M.V.	S.G.	Hd.
1	8	48.05	206	40.82	1.075	64
2	12	43.04	200	31.97	1.077	71
3	20	34.66	179	17.71	1.082	80

From the mean value Table II, the relationship among the various mechanical properties with respect to Fly Ash percentage can be represented graphically as;

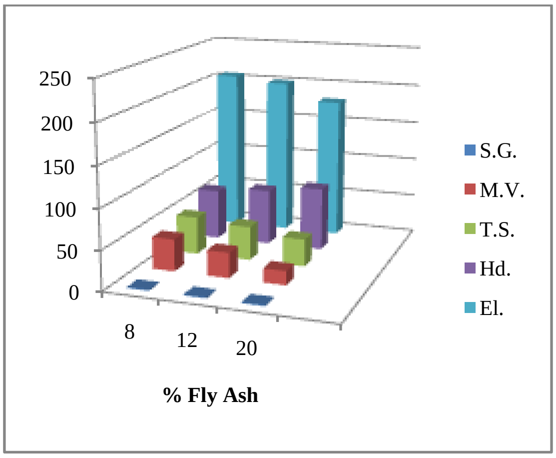

Figure 4: Representation of mechanical properties w.r.t. % Fly Ash Content

As a lot of congestion is found in the graphical representation in Figure 4 and it is really difficult to understand the trends. For better understanding of the results, therefore, these mechanical properties can be understood one by one w.r.t. % Fly Ash graphically as given below;

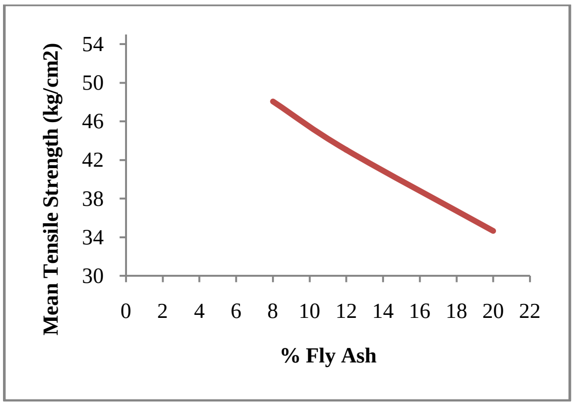

Figure 5: Representation of Tensile Strength w.r.t. % Fly Ash Content

The Figure 5 shows the change in the tensile strength of the fly ash reinforced rubber sample with the percentage of fly ash reinforcement. At 8 % Fly Ash Content, the tensile strength obtained is 48.05 kg/cm^{2}. This tensile strength decreases to 43.04 kg/cm^2 when seen for 12 % Fly Ash content sample and for another sample with 20 % Fly Ash content, the tensile strength furthur decreases to 34.66 kg/cm^2. The relationships suggest that with the filling up of more and more Fly Ash in the tire rubber reclaim, there happens to be the decrease in the values of the tensile strength. This decrease in the tensile strength values is accordingly with the more strength of the cohesive bonds of the rubber molecules in comparison to its adhesion bonds with the fly ash and this leads to the ineffective stress transfer and more and more voids in the structure begins to form, which prompt lesser tensile strength of the specimens.

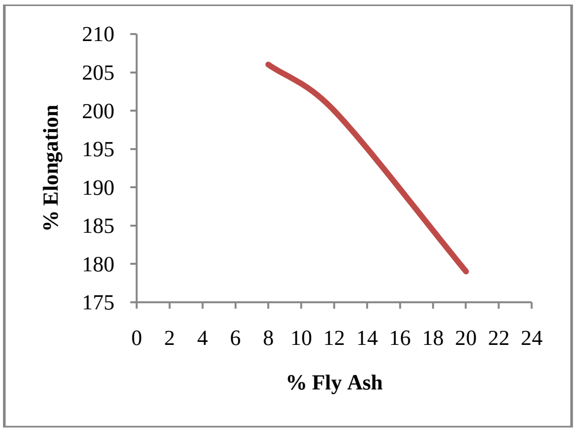

Figure 6: Representation of % elongation w.r.t. % Fly Ash Content

The Figure 6 shows the change in the % Elongation of the fly ash filled tire reclaimed rubber sample with the changes in the percentage of the fly ash reinforcement. For the 8 % Fly Ash Content

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specimen, the % Elongation obtained is 206 %. This % Elongation decreases to 200 % for the 12 % Fly Ash content reinforced and for another specimen with 20 % ash reinforcement, the % elongation furthurmore decreases to a much lesser value of 179 %. The relationships for the % Elongation with % Fly Ash content represent the same trend as the Figure 5 (for tensile strength). With elevated filling of Fly Ash content in tire reclaimed rubber, its % elongation decreases gradually. The reason for this kind of response is the increased stiffness of the composite which resists the stretching with the more addition of the fly ash.

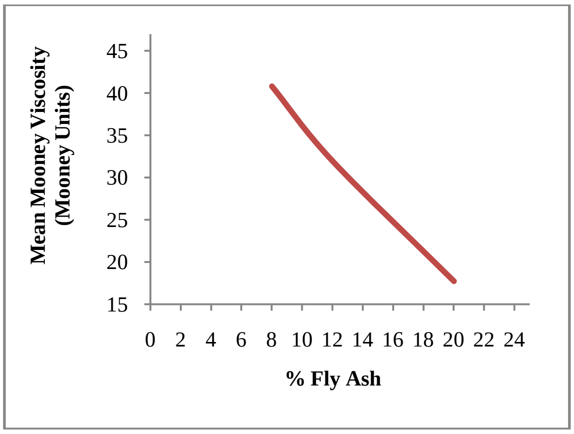

Figure 7: Representation of Mooney Viscosity w.r.t. % Fly Ash Content

The Figure 7 shows the relationship between Mooney Viscosity with the changing Fly Ash content. When seen for the specimen with 8 % reinforced Fly Ash content, the Mooney Viscosity (the rotational viscosity) is found to be 40.82 Mooney Units which decreases to 31.97 Mooney Units for the specimen with 12 % Fly Ash content. This value furthermore decreases to 17.71 Mooney Units for extra reinforcement of 20 % fly ash. The representation of Mooney Viscosity with % Fly Ash Content, therefore, shows the gradual depreciation of Mooney viscosity when the tire reclaim rubber is filled more and more with the Fly Ash filler. The decrease in the molecular weight and more uneven distribution in the rubber matrix due to the increase in the reinforcement of fly ash cause this effect. This relationship follows the same trend as followed by the tensile strength and also the % elongation.

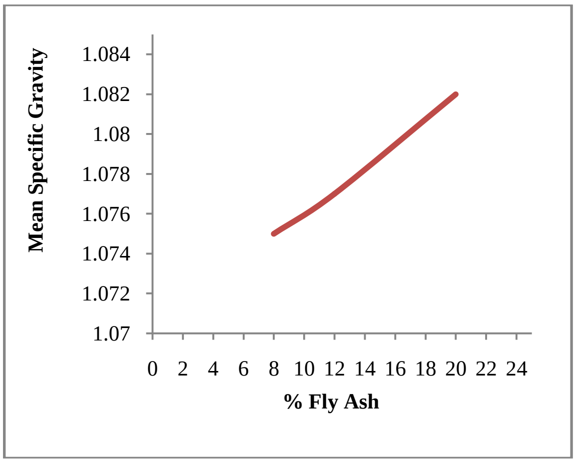

Figure 8: Representation of Specific Gravity w.r.t. % Fly Ash Content

The Figure 8 shows the change in specific gravity of the specimen with the change in the Fly Ash reinforcement. The specific gravity for the 8 % reinforced Fly Ash sample is found as 1.075. This value increases to 1.077 with the 12 % Fly Ash reinforced sample which further increases to 1.082 with the enhancement in reinforcement. The graphical representation shows an elevating trend for the specific gravity with the increasing addition of the fly Ash filler in the compound. The specific gravity follows the opposite trend as compared to the previously demonstrated mechanical properties. As the density cannot be measured, Specific Gravity, therefore, plays a vital role in determining the batch volume during the process of mixing and the formation of rubber compound.

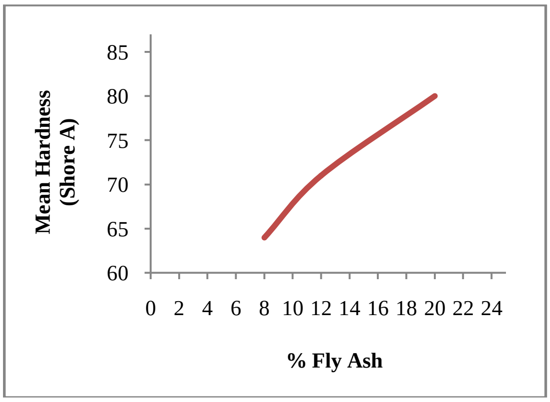

Figure 9: Representation of Hardness w.r.t. % Fly Ash Content

The Figure 9 shows the variations of hardness with the changes in the Fly Ash reinforcements. With 8 % reinforcement of fly ash in tire reclaimed rubber, the shore A hardness is found as 64. This hardness number changed to 71 due to the increase in reinforcement to 12 % which furthermore increased to 80 for the elevated reinforcement of 20 % Fly Ash content. The hardness also follows the same trend as the specific gravity. From the graphical representation, it is seen that the hardness values increase with the addition of fly ash in the tire reclaimed rubber specimens. With the increase in the fly ash addition, the cross links in the structure increase which leads to the increase in the hardness of the composite.

VI. CONCLUSION

From the results, it is seen that the two waste products can be effectively utilized to make useful products. The Fly Ash addition in the waste tire reclaimed rubber greatly impacts mechanical properties of the reclaimed rubber. The hardness properties are elevated with the addition of Fly Ash filler in the Tire Reclaimed Rubber along with the Specific Gravity. However, the other mechanical properties such as tensile strength, % elongation, Mooney Viscosity follow the opposite trend i.e. these are decreased with the fly ash filler addition. The FA/RR composites developed in the study may be utilized in applications such as mating, jumping trampolines for kids, running tracks, sidewalk pavement tiles, boxing and other sporting arena and so on i.e. the applications which don't require excellent quality like tires and beltings etc. (which have the requirements of expensive reinforcements). This study significantly provides for market alternatives at reduced costs. Furthermore, this study opens the door for further studies in the subject matter of the tire reclaim rubber, may be the variation in the mechanical properties w.r.t. time period or the effect of taking the crumb size and curing temperature along with the Fly Ash alterations.

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