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APPRAISAL OF CONCRETE USING MODIFIED WASTE TYRE RUBBER CHIPS AS PARTIAL REPLACEMENT OF COARSE AGGREGATE

B. A. Wakili[1], Engr. A. Garba[1], A. B. Yerima[2], Z. A. Wakil[2], K. Yakubu[2]

[1]Dept. of Civil Engineering, Federal Polytechnic, Bauchi, Nigeria.
[2]Nigerian Building and Road Research Institute, North-East Zonal office, Sharu Road, New GRA, Gombe State, Nigeria.

ABSTRACT: *Over dependence on natural aggregate used in concrete production poses a serious challenge on environment, and the need to preserve natural resources emerge as growing concern for protecting the environment. Waste tyre accumulation and disposal serves as a potential threat to the environment, for instance, tyre landfills serves as a breeding ground for mosquitoes, pollution to land, water and air. Several researches carried out using chipped rubber in concrete shown a significant reduction in the mechanical strength of the resulting concrete. This research work aimed at using modified waste rubber tyre aggregate in concrete production. Coarse aggregate was replaced with modified waste tyre rubber at 0%, 10%, 20%, and 30% by volume of coarse aggregate. The physical properties of fresh and hardened concrete such as slump, compacting factor and density, compressive, splitting tensile and flexural strength were examined. The slumps result shows a decreased with an increased in chipped rubber contents (36.73%-44.90%). The density decreased with an increased in chipped rubber contents. The resulting decreased are (2.54%-9.68%). The compressive strength of the MCR_{10} showed a significant increased in strength which resulted in 25.0 N/mm^2 (24.54%) when compared to unmodified series at 10% (CR_{10}) and (4.33%) decreased compared to the control mix. An increased in splitting and flexural strength was recorded at MCR_{10} which were 1.8 N/mm^2 and 5.9 N/mm^2 (24.05%-27%) respectively. It was concluded that incorporating modified waste tyre aggregate in concrete shows a significant increase in mechanical strengths of rubber chips concrete compared with unmodified rubber chips concrete.*

KEYWORDS: Aggregate, Coarse, Concrete, Slumps, Tyre, Rubber.

INTRODUCTION

Cement and aggregate, which are the most important constituents used in concrete production, are the vital materials needed for the construction industry. This inevitably led to a continuous and increasing demand on natural materials used for their production. Parallel to the need for utilization of natural resources emerges a growing concern for protecting the environment and a need to preserve natural resources, such as aggregate, by using alternative materials that are either recycled or discarded as a waste. The discharge of waste tyres are expensive and continuously decreasing numbers of landfills generates significant pressure to the local authorities identifying the potential application for this waste products. One of the largest potential routes is in construction, but usage of waste tyres in civil engineering is currently very low.

The sustainable management of the aforesaid waste tyre rubber is a huge task to the industries and public sectors because of the disposal of waste tyre to landfill is legally banned in all the countries due to the environmental impact. Several studies have been carried out to reuse scrap

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tyres in a variety of rubber products, incineration for production of electricity or as a fuel for cement kilns as well as in asphalt concrete (Mohammed and Mohammed, 2011).

Investigations show that used tyres are composed of materials which do not decompose under environmental conditions and cause serious contaminations. Burning is a choice for their decomposition; however the gases exhausted from the tyre burning results in harmful pollutions. Based on examinations, another way is using the tyres in concrete. This results in the improvement of such mechanical and dynamical properties as energy adsorption, ductility, and resistance to cracking. However, this may cause a decrease in compressive strength of the concrete which will be compensated by adding Nano-silica to rubber containing concretes (Parveen, 2013).

Partial replacement of rubber tyre aggregates in concrete has the additional advantage of saving in natural aggregates used in the production of concrete which are becoming increasingly scarce.

Waste tyre rubber mixture is more workable compare to normal concrete and also it is useful in making light weight concrete (El-Gammal, 2010).

Using rubber waste in concrete, less concrete modulus of elasticity is obtained therefore modulus of elasticity is related to concrete compressive strength and the elastic properties of aggregates have substantial effect on the modulus of elasticity of concrete. The larger amount of rubber additives is added to concrete, the less modulus of elasticity is obtained.

Statement of the Problem

With the increase in urbanization of countries in the word, the number of vehicles and consequently the amount of used tyres is going to increase significantly in the near future. Hence, the environmental nature of these wastes is going to be a potential threat. This includes diseases due to rodents and mosquitoes infestation and pollution to land, water and air.

Several researches carried out using chipped rubber as partial replacement of coarse aggregates shows a significant reduction in the mechanical strength of the resulting concrete. Hence chemical pre-treatment of the rubber aggregate has shown a significant increase in the mechanical strength of the result concrete but the process is costly.

This research therefore, is aimed at appraising the effect of providing an anchorage hole of 10mm in diameter on the surface of the rubber aggregate which will allow the cement paste to form a cylindrical anchorage between the aggregate and the concrete as well as serves as a reinforcement to the rubber aggregate thereby, increase resistance to deformation under load which subsequently increase the mechanical strength.

Purpose of the Study

This study has the following purposes

1. To determine the mechanical properties of concrete using rubber chips as partial replacement of coarse aggregate.
2. To examine the effect of boring a hole on the rubber chips aggregate to the mechanical strength of the resulting concrete.

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REVIEW OF RELEVANT LITERATURE

Nigeria is a developing country, it proposes multipurpose development projects. Every budget proposal involves large construction of roads, bridges, dams, irrigation schemes, public health engineering schemes, educational buildings and residential buildings etc. all these construction schemes demand optimum and efficient use of construction resources. Most of the modern heavy constructions require huge quantity of cement concrete incurs depletion of natural resources such as river sand and rock strata. Cost of river sand and crushed rock particles is rapidly increasing because of inadequate raw materials and rise of transport cost due to the hike in fuel price and other inputs. Further mining of river sand causes severe environmental damage by lowering ground water table and disintegration of rock strata causes landslide and earthquake.

This emerging problem obliges contemporary material usage to balance the ecology. In this essence the abundant availability of waste tyre rubber can be utilized as an effective replacement for natural aggregate which will be beneficial for both circumstances. Hence this research investigates the use of waste tyres in various aspects of construction. There has been a few number of rubber based concrete projects developed in all the corners of Civil Engineering. A critical review of the existing literature on the utilization of waste rubber is presented in the following areas:

Civil engineering Applications of Waste Tyres

Scrap tyre chips and their granular parts such as ground rubber and crumb rubber; have been used in a number of Civil Engineering applications. Tyre chips which is roughly shredded into 2.5 to 30 cm lengths have been researched extensively as lightweight fill for embankments and retaining walls, but it has also been used as drainage layers for roads and in septic tank leach fields (Humphrey, 1999).

According to Humphrey (1999), some of the advantageous properties of tyre chips include low material density, high bulk permeability, high thermal insulation, high durability, and high bulk compressibility. In many cases, scrap tyre chips may also represent the least expensive alternative to other fill materials. Crumb rubber has been successfully used as an alternative aggregate source in both asphalt concrete and Portland cement concrete (PCC). This waste material has been used in several engineering structures like highway base-courses, embankments, etc.

Sub Grade Insulation for Roads

Excess water is released when sub grade soils thaw in the spring. Placing a 15 to 30 cm thick tyre shred layer under the road cab prevents the sub grade soils from freezing in the first place. In addition, the high permeability of tyre shreds allows water to drain from beneath the roads, preventing damage to road surfaces (ASTM D6270-98).

ASTM D6270 In 1998, ASTM International published the Standard Practice for Use of Scrap Tires in Civil Engineering Applications, which is numbered ASTM D6270. This standard was revised in 2008 and reapproved in 2012. It presents several definitions which are useful for discussing the use of TDP in civil engineering applications. The definitions provided in Section 3.1 of ASTM D6270 which are used in subsequent sections of this report are reproduced below.

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Nominal Size: the average size that comprises 50% or more throughputs in a scrap tire processing operation. Tire Derived Aggregate (TDA): pieces of scrap tires of basic geometric shape generally between 0.5 and 12 inches in size which are intended for use in civil engineering applications.

Tire Chips: pieces of scrap tires of basic geometric shape generally between 0.5 and 2 inches in size with most of wire removed. Tire Shreds: pieces of scrap tires of basic geometric shape generally between 2 and 12 inches in size. Rough Shred: piece of shredded tire larger than 2 by 2 by 2 inches but smaller than 2 by 4 by 30 inches. Whole Tire: a scrap tire that has been removed from a rim but has not been processed.

ASTM D6270 provides guidance for physical property testing, design considerations, construction practices, and leachate generation potential of processed and whole scrap tires used instead of conventional materials. It is intended for the use of TDA, TDA/Soil mixtures, tire sidewalls, and whole tires in civil engineering applications.

The ASTM standard is based on the recommendations of the Ad- Hoc committee discussed previously in this report (Section 2.2.1) and is intended to limit exothermic reactions in TDA fills. Therefore, the construction practices within the ASTM standard apply to TDA fills which are less than 10 feet thick.

Section 7.1 of the ASTM standard provides material specifications for two TDA types. The intent is to define TDA products that can be reasonably produced and used to construct embankments with conventional equipment, while limiting the internal heating of the TDA fill. Type A TDA is smaller and suitable for use in insulation, drainage, and vibration damping applications. Type B TDA is larger and suitable for use as lightweight embankment fill, retaining wall backfill, and landfill drainage/gas collection systems. For both types, ASTM states that the TDA should:

- Be free of all contaminants, including petroleum products and organic materials;
- Be free of any tire remains that have been subject to a fire.

Contain less than 1% free metal fragments (by weight); and

For partially encased metal fragments, the metal should protrude no more than o 1" on 75% of the pieces (by weight) and 2" on 90% of the pieces (by weight).

The size requirements of Type A and Type B TDA discussed in ASTM D6270 Section 7.1 are summarized in the following table.

TDA TYPE	A	B
Maximum size any direction	8’’ (200mm)	
Size	% passing by weight	% passing by weight
12’’ (300mm)	-	90-100%
8’’ (200mm)	-	75-100%
4’’ (100mm)	100%	-
3’’ (75mm)	95-100%	0-50%
1.5’’ (40mm)	0-5%	0-25%
No. sieve (4.75mm)	0-5%	0-1%
Note	At least one sidewall removed	

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Topcu, I. B. & Avcular, N. (1997). Analysis of rubberized concrete as a composite material. Cement and Concrete Research, Vol. 27, No. 8, pp. 1135-1139.

ASTM D6270 Section 6.11 also defines two classes of fills, which are summarized below.

Class I: less than 3 feet thick, use Type A TDA, and no special design guidelines are required.

Class II: 3 to 10 feet thick, use Type B TDA, and special design guidelines are as follows: Separate TDA from all organic matter and soil with geotextile, Cover TDA with at least 1.5 feet of soil with at least 30% passing the No.200 sieve, Minimize infiltration of water into TDA by sloping to drain away from TDA fill and extending pavement beyond edge of TDA, and o Minimize infiltration of air into TDA by avoiding open-graded drainage layers, using well-graded soil for drainage layers, and minimizing drainage layer thickness at daylight points.

In addition, ASTM D6270 recommends the following:

Minimum Cover Thickness: 1 to 1.5 feet for unpaved roads, 2 to 3 feet for paved roads with light traffic, and 3 to 6.5 feet for paved roads with heavy traffic (Section 6.8)

Geotextile Encapsulation: complete with woven or non-woven geotextile for TDA below pavement, in highway drainage applications, or behind retaining walls (Section 6.9)

The ASTM standard also references seven field studies of TDA placed above the groundwater and three field studies of TDA placed below the ground water. To summarize the conclusions provided therein, TDA placed above or below the groundwater table should not affect off-site groundwater quality.

Sub Grade Fill and Embankments

Tyre shreds can be used to construct embankments on weak, compressible foundation soils. Tyre shreds are viable in this application due to their light weight. For most projects, using tyre shreds as a lightweight fill material is significantly a cheaper alternative (Tyres Manufacture's Association, 2003).

Backfill for Walls and Bridge Abutments

Tyre shreds can be useful as backfill for walls and bridge abutments. The weight of the tyre shreds reduces horizontal pressures and allows for construction of thinner, less expensive walls. Tyre shreds can also reduce problems with water and frost build-up behind walls because tyre shreds are free draining and provide good thermal insulation. Recent research has demonstrated the benefits of using tyre shreds in backfill for walls and bridge abutments. (Tyres Manufacture's Association, 2003).

Landfills

Landfill construction and operation is a growing market application for tyre shreds. Scrap tyre shreds can replace other construction materials that would have to be purchased. Scrap tyres may be used as a lightweight backfill in gas venting systems, in leach ate collection systems, and in operational liners. They may also be used in landfill capping and closures, and as a material for daily cover. (Tyres Manufacture's Association, 2003).

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Waste Tyre in Concrete Hollow Blocks

Another research was done using Chopped Worn-Out Tyres in production of light weight concrete masonry units (Al-Hadithi et al. 1999).This research, generally aimed at defining the possibility of using chopped worn-out tyres to produce lightweight concrete building units. Many experimental mixtures were made with different percentages of chopped worn-out tyres after identifying the importance of produced characteristics of the mixtures. For producing lightweight Chopped worn-out tyres concrete mixes, many trials were adopted in selecting the required miens.

These walls were tested to study the structural behavior of such walls. All the mixes used Ordinary Portland Cement. The sand was a washed and dried natural river sand with a size range of (0.15-4.75mm), with bulk specific gravity 2.6. The gravel was washed and dried natural gravel with a size range of 1.18 to 9.5 mm, with specific gravity of 2.7. The Chopped worn-out tyres used in this work had a maximum size of 6.35mm and a specific gravity of 0.95.

The dry constituents were initially mixed for 1.0 minute with Chopped worn-out tyres mixes, the Chopped worn-out tyres were then incorporated into the dry mix through a dispenser, and the mixing continued for another 1.0 minute to allow uniform distribution of the Chopped worn-out tyres in the mixture. After adding the water, the constituents were then mixed for a further 2.0 minutes to produce a homogeneous mixture. Different specimens were prepared and a number of tests were made, the tests included compressive strength, axially load capacity of walls and prisms, measurement of longitudinal and traverse strains were made on both faces of walls using mechanical extensometers with high sensitivity. The conclusions arrived from this investigation were, incorporating Chopped worn-out tyres into the mortar and concrete mixes as a partial replacement of aggregate reduced its unit weight, compressive strength and flexural strength and increased its thermal insulation significantly.

Other Uses

Fattuhi and Clark (1996) have suggested that tyre rubber aggregate concrete (TRAC) could possibly be used in the following areas: Where vibration damping is needed, such as in foundation pad for rotating machinery and in railway stations, For trench filling and pipe bedding, pile heads, and paving slabs, and The resistance against impact and blast is required such as in railway buffers, jersey barriers (a protective concrete barrier used as a highway divider and a means of preventing access to a prohibited area) and bunkers. TRAC, because of its light unit weight (density ranges from 900 to 1600 kg/m3) may also be suitable for architectural applications such as: (1) Nailing concrete, (2) False facades, (3) Stone backing and (4) Interior construction.

Topcu and Avcular (1997) suggested that TRAC may be used in Highway construction as: (1) Shock absorber in sound barriers, (2) Sound Boaster (which controls the sound effectively), and (3) in buildings as an Earthquake shock-wave absorber. However, research is needed before definite recommendations can be made.

Pierce and Blackwell (2003) highlighted the use of crumb rubber in flow-able fill. In their investigation, they replaced sand with crumb rubber to produce flow-able fill. Experimental results indicated that waste tyre rubber can be successfully used to produce a lightweight (1.2–1.6 g/cm3) flowable fill which can able to excavate at 28-day compressive strengths ranging from 0.02 to 0.09 MPa. Their research concluded that a crumb rubber-based flow-able fill can

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be used in a substantial number of construction applications, such as bridge abutment fills, trench fills and foundation fills.

The following are also some examples of using scrap tyres:

- Playground surface material.
- Gravel substitute.
- Drainage around building foundations and building foundation insulation.
- Erosion control/rainwater runoff barriers (whole tyres).
- Wetlands/marsh establishment (whole tyres).
- Crash barriers around race tracks (whole tyres).
- Boat bumpers at marinas (whole tyres).
- Artificial reefs (whole tyres).

Waste Tyre Rubber in Concrete

Fresh concrete properties

Previous investigations have shown that the Tyre Rubber Aggregate Concrete (TRAC) possesses good aesthetics, acceptable workability and a smaller unit weight than that of ordinary concrete.

Aesthetics

Eldin and Senouci (1993) reported that TRAC showed good aesthetic qualities. The appearance of the finished surfaces was similar to that of ordinary concrete and surface finishing was not problematic. However, the authors reported that mixes containing a high percentage of larger sized rubber aggregate required more work to smooth the finished surface. They also found that the colour of rubberized concrete did not differ noticeably from that of ordinary concrete.

Workability

Khatib and Bayomy (1999) investigated the workability of waste tyre rubber aggregate. They observed a decrease in slump with increased rubber aggregate content by total aggregate volume. Their results show that for rubber aggregate contents of 40% by total aggregate volume, the slump was close to zero and the concrete was not workable by hand. Such mixtures had to be compacted using a mechanical vibrator. Mixtures containing fine crumb rubber were, however, more workable than mixtures containing either coarse rubber aggregate or a combination of crumb rubber and tyre chips.

Air Content

Ali et al. (1993) reported that when rubber aggregate was added to the concrete, the air content increased considerably (up to 14%). Fedroff et al (1996) and Khatib and Bayomy (1999) observed that the air content increased in waste tyre rubber mixtures with increasing amounts of rubber aggregate. Although no air-entraining agent (AEA) was used in the waste tyre rubber mixtures, higher air contents were measured as compared to control mixtures made with an AEA (Fedroff et al 1996).

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The higher air content of waste tyre rubber mixtures may be due to the non-polar nature of rubber aggregates and their ability to entrap air in their jagged surface texture. When non-polar rubber aggregate is added to the concrete mixture, it may attract air as it repels water. This increase in air voids content would certainly produce a reduction in concrete strength, as does the presence of air voids in plain concrete (Benazzouk et al 2007).

Since rubber has a specific gravity of 1.14, it can be expected to sink rather than float in the fresh concrete mix. However, if air gets trapped in the jagged surface of the rubber aggregates, it could cause them to float (Nagdi 1993). This segregation of rubber aggregate particles has been observed in practice.

Hardened Properties

Several studies had been carried out to describe the use of tyre rubber aggregate in concrete. Results had indicated about the size, proportions and surface texture of rubber particles that noticeably affect the compressive strength of rubber concrete mixtures. Goulias et al (1998) conducted an experimental study incorporating crumb rubber, as fine aggregate with Portland cement. Test results showed modifications in the brittle failure of concrete, which indicates that rubber concrete specimens exhibited higher ductility performance than normal concrete. Results showed large deformation without full disintegration of concrete.

Eldin and Senouci (1993) conducted experiments to examine the strength and toughness of rubberized concrete mixtures. Three sets of experiments were performed, the first set using coarse rubber aggregate (chipped tyres) of 19-38 mm size and the second and third sets using smaller diameter chips of 6 mm and 2 mm respectively. The results found that the specimen containing rubber when loaded in compression exhibits more gradual failure, either of a splitting (for coarse rubber aggregate) or a shear mode (for fine crumb rubber).

Topcu (1995) investigated the effect of particle size and content of tyre rubbers on the mechanical properties of concrete. The researcher found that, although the strength was reduced, the plastic capacity was enhanced significantly.

Khatib et al (1999) concluded that reinforced Portland cement concrete (RPCC) mixtures can be made using ground tyre in partial replacement by volume of CA and FA. Based on the workability, an upper level of 50% of the total aggregate volume may be used. Strength data developed in their investigation (compressive and flexural) indicates the systematic reduction in the strength with the increase of rubber content. From a practical viewpoint, rubber content should not exceed 20% of the aggregate volume due to severe reduction in strength. Once the aggregate matrix contains nontraditional components such as polymer additives, fibers, iron slag, and other waste materials, special provisions would be required to design and produce these modified mixes. At present, there are no such guidelines on how to include scrap tyre particles in PCC mixtures.

Gregory Garrick (2004), showed the analysis of waste tyre modified concrete used 15% by volume of coarse aggregate when replaced by waste tyre as a two phase material as tyre fiber and chips dispersed in concrete mix.

Kamil et al (2004), analyzed the properties of Crumb Rubber Concrete, The unit weight of the CRC mix decreased approximately 6 pcf for every 50 lbs of crumb rubber added. The compressive strength decreased as the rubber content increased. Part of the strength reduction was contributed to the entrapped air, which increased with the rubber content. Investigative

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efforts showed that, the strength reduction could be substantially reduced by adding a de-airing agent into the mixing truck just prior to the placement of the concrete.

Guoqiang Li (2004) conducted investigation on chips and fibers. The tyres surfaces are treated by saturated NaOH solution and physical anchorage by drilling hole at the centre of the chips were also investigated and they concluded that fibers perform better than chips. NaOH surface treatment does not work for larger sized tyre chips using physical anchorage has some effect.

A systematic experimental study was performed recently for improving strength and toughness of Rubber Modified Concrete (RMC) (Li et al 2004). Two types of rubber particles of different sizes (large and small) were used to study the size effect on mechanical properties of RMC.

Result of tension test, fatigue test, and ultrasound velocity test showed that the

RMC has higher energy dissipation capacities than regular concrete. The failure modes of the RMC indicate that the RMC samples can withhold very large deformation and still keep their integrity.

Toughness and Impact Resistance

Tantala et al (1996) investigated the toughness (toughness is also known as energy absorption capacity and is generally defined as the area under load deflection curve of a flexural specimen) of a control concrete mixture and waste tyre rubber mixtures with 5% and 10% buff rubber by volume of coarse aggregate. They reported that toughness of both waste tyre rubber mixtures was higher than the control concrete mixture. However, the toughness of waste tyre rubber mixture with 10% buff rubber (2 to 6 mm) was lower than that of waste tyre rubber with 5% buff rubber because of the decrease in compressive strength. Based on their investigations on use of rubber shreds (having two sizes which were, nominally, 5.5 mm to 1.2 mm and 10.8 mm to 1.8 mm) and granular (about 2mm in diameter) rubber in mortar.

Raghavan et al (1998) reported that mortar specimens with rubber shreds were able to withstand additional load after peak load. The specimens were not separated into two pieces under the failure flexural load because of bridging of cracks by rubber shreds, but specimens made with granular rubber particles broke into two pieces at the failure load.This indicates that post-crack strength seemed to be enhanced when rubber shreds are used instead of granular rubber.

Khatib and Bayomy (1999) reported that as the rubber content is increased, waste tyre rubber specimens tend to fail gradually and failure mode shape of the test specimen is either a conical or columnar (conical failure is gradual, whereas columnar is more of shreds having two sizes which were, nominally, 5.5 mm to 1.2 mm and 10.8 mm to 1.8 mm (length diameter) sudden failure).

At a rubber content of 60%, by total aggregate volume, the specimens exhibited elastic deformations, which the specimens retained after unloading.

Eldin and Senouci (1993) demonstrated that the failure mode of specimens containing rubber particles was gradual as opposed to brittle. Biel and Lee (1998) reported that failure of concrete specimens with 30, 45, and 60% replacement of fine aggregate with rubber particles occurred as a gradual shear that resulted in a diagonal failure, whereas failure of plain (control) concrete specimens was explosive, leaving specimens in several pieces.

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Goulias and Ali (1997) found that the dynamic modulus of elasticity and rigidity decreased with an increase in the rubber content, indicating a less stiff and less brittle material. They further reported that dampening capacity of concrete (a measure of the ability of the material to decrease the amplitude of free vibrations in its body) seemed to decrease with an increase in rubber content. However, Topcu and Avcular (1997) recommended the use of rubberized concrete in circumstances where vibration damping is required.

Similar observations were also made by Fattuhi and Clark (1996), and Topcu and Avcular (1997) reported that the impact resistance of concrete increased when rubber aggregates were incorporated into the concrete mixtures. The increase in resistance was derived from the enhanced ability of the material to absorb energy.

Concrete Density

The replacement of natural aggregates with rubber aggregates tends to reduce the density of the concrete. This reduction is attributable to the lower unit weight of rubber aggregate compared to ordinary aggregate. Previous studies have found that the unit weight of waste tyre rubber aggregate mixtures decreases as the percentage of rubber aggregate increases. Topcu (1995) included low volumes of rubber aggregate during the preparation of the concrete, while Rostami et al (1993) appeared to use larger volumes of rubber aggregate. Their results indicated that concrete densities were reduced to 87% and 77% of their original values, respectively, when the maximum amounts of rubber aggregate were used in the investigations. Eldin and Senouci (1993) reported a reduction in density of, up to 25% when ordinary aggregate was replaced by coarse rubber aggregate. Li et al (1998) found that the density of waste tyre aggregates was reduced by around 10% when sand was replaced by crumb rubber to the amount of 33% by volume.

Tensile Strength

Tensile strength is an important property of concrete, because concrete structures are highly vulnerable to tensile cracking due to various kinds of effects and applied loading itself. However tensile strength of concrete is very low in compared to its compressive strength.

Due to difficulty in applying uniaxial tension to a concrete specimen, the tensile strength of the concrete is determined by indirect test methods (1) split cylinder test (2) flexural test it- should be noted that both of these methods give the higher value of tensile strength than the uniaxial tensile strength.

Flexural Strength

The test could be performed in accordance with as per BS;1881;Part 118 1993, a simple plain concrete beam is loaded at one-third span point normal standard size of specimen is 100 x100 x500mm. If the largest normal size of the specimen dose exceed 25mm size of 100 x 100 x 500mm may also be used, span of the beam is 3 times it depth .

Flexural strength test was used to determine the flexural strength of concrete. The test was performed on prism by immersing under water.

Applications and Advantages of Waste Tyre Rubber

The waste tyre rubbers are affordable, cost effective and withstand for more pressure, impact and temperature when compared to the conventional concrete. It is observed that the Rubber

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Modified Concrete (RMC) is very weak in compressive and tensile strength. But it has good water resistance with low absorption, improved acid resistance, low shrinkage, high impact resistance, and excellent sound and thermal insulation. Studies shows the Crumb Rubber Concrete (CRC) specimens remained intact after failure (did not shatter) compared to a conventional concrete mix. Such behavior may be beneficial for a structure that requires good impact resistance properties. The impact resistance of TRAC was higher, and it was particularly evident in concrete samples aggregated with thick rubber (Kamil et al 2005).

Moreover the unique qualities of TRAC will find new areas of usage in highway constructions as a shock absorber, in sound barriers as a sound absorber and also in buildings as an earthquake shock-wave absorber. It reduces plastic shrinkage cracking and reducing the vulnerability of concrete to catastrophic failure.

Currently, the waste tyre modified concrete is used in precast sidewalk panel, non-load bearing walls in buildings and precast roof for green buildings (Fuminori et al 2005). It can be widely used for development related projects such as roadways or road intersections, recreational courts and pathways, and skid resistant ramps (Kamil et al 2005). With this new property, it is projected that these concretes can be used in architectural applications such as nailing concrete, where high strength is not necessary, in wall panels that require low unit weight, in construction elements and Jersey barriers that are subject to impact, in rail road’s to fix rails to the ground (Topcu 1995).

TRAC can also be used in non load bearing members such as lightweight concrete walls, building facades, or other light architectural units, thus the waste tyre modified concrete mixes could give a viable alternative to the normal weight concrete (Khatib and Bayomy 1999). Rubberized mixes could be used in places where cement-stabilized aggregate bases are needed, particularly under flexible pavements. The other viable applications well suited for use in areas where repeated freezing and thawing occur, and can also be poured in larger sheets than conventional concrete.

Critical Reviews

The previous studies have shown that the inclusion of rubber aggregate in concrete as a full or partial replacement for natural aggregates reduces the compressive strength of the concrete. These studies also indicate that the mechanical strength of waste tyre rubber aggregate is greatly affected by the size, proportion and surface texture of the rubber aggregate and the type of cement used. This strength reduction can be expected primarily because rubber aggregate is much softer (elastically deformable) than the surrounding cement paste. Secondly, the bonding between the rubber aggregate and the cement paste is likely to be weak, so that soft rubber aggregate may be viewed as voids in the concrete mix. It has also been recognized that, the strength of concrete greatly depends upon the density, size and hardness of the aggregates. In addition, the previous studies have shown that the workability of concrete containing rubber aggregate is reduced. This could affect the method of preparation of concrete samples and products and requires further study during the present investigation.

A critical review of literature presented above indicated that the proportion of rubber aggregate in the concrete should be restricted to prevent great loss in mechanical properties. Further there is no specific literature found to analyze the flexural performance, deflection and ductility behavior of Reinforced Cement Concrete beams made of waste tyre rubber aggregate. In addition an attempt is also made to make use of rubber strips as rebar in tensile zone. As such,

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the research focus on waste tyre rubber as material itself is in infant stage. Hardly there is any literature available in the area of structural application. In these circumstances it is important to investigate the relevant properties of tyre rubber aggregate concrete beams to enhance its primary structural Applications in concrete construction. The possibilities include reduced weight, enhanced toughness, increased ductility and impact resistance.

MATERIALS AND METHOD

Cement (Portland cement)

Portland cement consists of five major compounds and a few minor compounds.

The Portland cement of grade 43.5 N/mm^2 used for this research work and was obtained from Dangote cements Deport in Bauchi. Below is the table for oxide composition of ordinary Portland cement (OPC).

Table 1: Oxide composition of OPC.

Composition	Weight percentage	Chemical Formula
Tricalcium silicate	50%	Ca3SiO5 or 3CaO.SiO2
Dicalcium silicate	25%	CaSiO4 or 2CaO.SiO2
Tricalcium Aluminate	10%	Ca3Al2O6 or 3CaO.Al2O3
Tetracalcium aluminoferrite	10%	Ca4Al2Fe2O10 or 4CaO.Al2O3.Fe2O3
Gypsum	5%	CaSO4.2H2O

SOURCE: Dangote cement Deport Bauchi.

Coarse Aggregates

The coarse aggregate was sourced from crushed granite stone from the TRIACTA quarry plant closed to Federal Polytechnic Bauchi.

Table 2: classes of Aggregates

Class	Examples of Aggregates Used	Use
Ultra-lightweight	Vermiculite Ceramic sphere Prelate	lightweight concrete which can be sawed or nailed, also for its Insulating properties.
Lightweight	Expanded clay Shale or slate Crushed brick	used primarily for making lightweight concrete for structure, also used for its Insulating properties.
Normal Weight	Crushed Limestone Sand river Crushed recycled concrete	Used for normal concrete projects.

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Adopted from Fedroff et al (1996) Mechanical properties of concrete with ground waste tyre rubber.

Table 3: physical properties of coarse aggregate

Physical properties	coarse aggregate
Specific Gravity (g/cm^3)	2.81
Bulk Density (kg/m^3)	1312

Fine Aggregates

The fine aggregate was obtained from washed river sand in Bauchi borrow pit.

Table 4: Physical properties of fine aggregate

Physical properties	Fine Aggregate
Specific Gravity (g/cm^3)	2.51
Bulk Density (kg/m^3)	1456

Tyre Chipped Rubber

The rubber chips were obtained from shredding truck tyres which contained thread fibres inside. The tyres are cut into small cubes of 20× 20 ×10mm for the unmodified and a 10mm diameter hole was bored on the modified.

Table 5: Physical properties of Rubber Chips

Specific Gravity (g/cm^3)	1.11
Bulk Density (kg/m^3)	480

Water

Good and clean drinkable water was used to mix the concrete. All forms of impurities that will affect the concrete were avoided. The water was obtained from the tap supplies from the water board Bauchi.

Experimental Design

Basically, the test is divided into 3 major series; the first series was the conventional concrete with 0% addition of rubber chips (control) mixture to be designated as S1 mix. The second series was by adding or replacement of the coarse aggregate with 10%, 20%, and 30% unmodified rubber chips by volume of chipped rubber and designated CR mix. The third series was by replacement of the coarse aggregate by 10%, 20% and 30% of modified rubber chips by volume of coarse aggregate and designated MCR.

A mix ratio of 1:2:4 and water to cement ratio of 0.56 w/c was adopted and used.

Sample Production

The cement, fine and coarse aggregates were weighted according to mix proportion of 1:2:4. All are mixed together in a bay until mixed properly and water was added at a ratio of 0.56. The water was added gradually and mixed until homogeneity is achieved. Any lumping or balling found at any stage was taken out, loosened and again added to the mix. For the second and third series of the mixture, the modified and unmodified rubber chips were added at 10%, 20% and 30% by volume coarse of aggregate. Immediately after mixing, slum and compacting factor test were carried out for all the concrete series mixture. A standard 100×100×100mm cube specimens, 150mm×300mm cylindrical specimen and 100×100×500mm beam specimen were casted. The specimens were covered with gunny immediately after placing in the mould for complete moisture retention. The samples were then stripped after 24hours of casting and are then be ponded in a water curing. As casted, a total of (63) 100×100×100mm cubes, (48) 150mm×300mm cylinders and (27) 100×100×500mm beams specimens were produced.

Curing

The method of curing adopted was the ponding method of curing and produced samples were cured for 3days, 7days, and 28 days.

Slump Test

Slump Test (on fresh concrete)

The slump test was carried in accordance with B.S:1882 PART2:1970

Compacting Factor

The compacting factor test was conducted in accordance with B.S 1881: PART 2:1970. The compacting factor was computed using:-

$$\text{Compacting factor} = \frac{WEIGHT\ OF\ FREELY\ FALL\ OF\ SAMPLE}{WEIGHT\ OF\ COMPACTED\ SAMPLE} \ldots\ldots\ldots\ldots \quad 1$$

Density Test

The density test was conducted in accordance with BS 1881: Part 114:1983. The density was computed using:-

$$\text{Density} = \frac{MASS\ OF\ SAMPLE\ (Kg)}{VOLUME\ OF\ SAMPLE\ (M3)} \ldots\ldots\ldots\ldots\ldots\ldots \quad 2$$

Compressive strength Test

The compressive test was conducted in accordance with BS 1881: Part 116:19. The compressive strength was computed using:-

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$$\text{Compressive strength} = \frac{CRUSHED\ LOAD\ (N)}{AREA\ OF\ SAMPLE\ (mm2)} \ldots\ldots\ldots\ldots\ldots \quad 3$$

Splitting Tensile Strength Test

The test was conducted in accordance with the BS1881 part118:1983

The splitting tensile strength was computed using:-

$$\text{Tensile strength} = \frac{2P}{\pi dt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 4$$

Flexural Strength Test

The test was performed in accordance with as per BS; 1881; Part 118 -1993. The flexural strength was computed using:-

$$\text{Flexural strength} = \frac{PL}{bd2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 5$$

RESULTS AND DISCUSSION

Slump Test Result

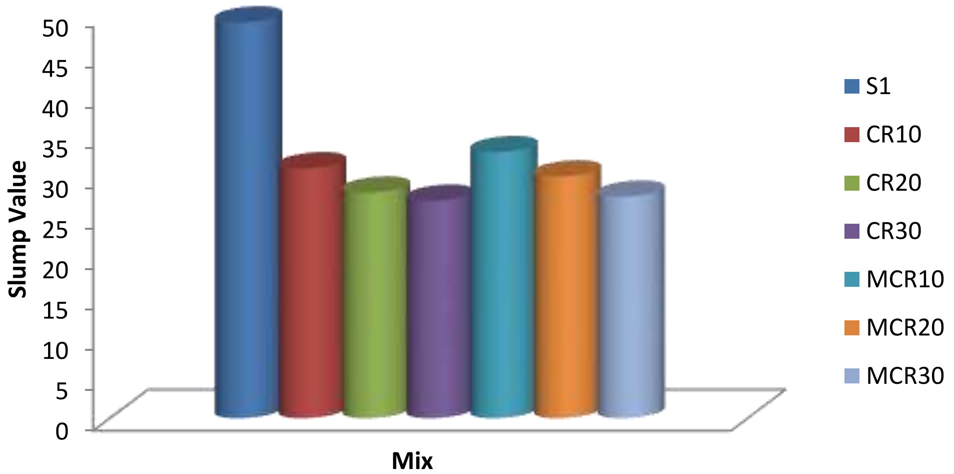

Figure 4.1.1: Slump test results

The above figure 4.1.1 shows the slump results. It was observed that, the slumps decreased as the rubber content were increased in the mix. This confirms Khatib and Bayomy (1999) investigation.

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Compacting factor test result.

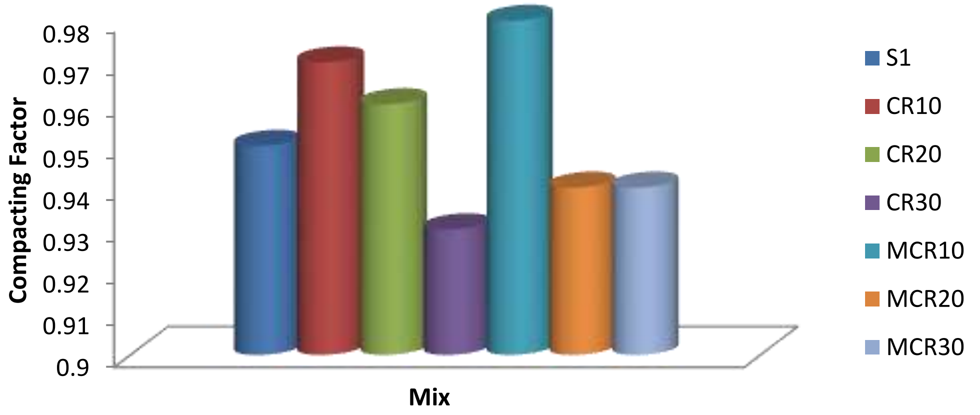

Figure 4.1.2: compacting factor test

The figure above shows the results of the compacting factor. The results show that, the compacting factor decreased as the rubber content was increased. It was observed a slight increase at MCR_{10} and a decreased at the control mix.

Density Test result.

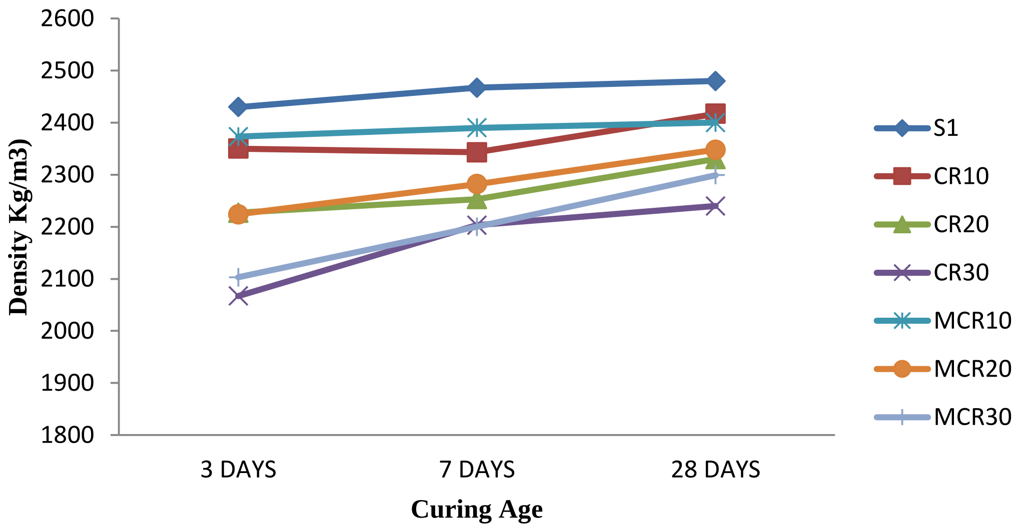

Figure 4.1.3: density test result

Figure4.1.3 above shows the density results. The result shows a decreased as the content of the rubber chips were increased in the mix. The decreased recorded was up to 2.54% - 9.67% compared to the control.

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Compressive Strength Test Result

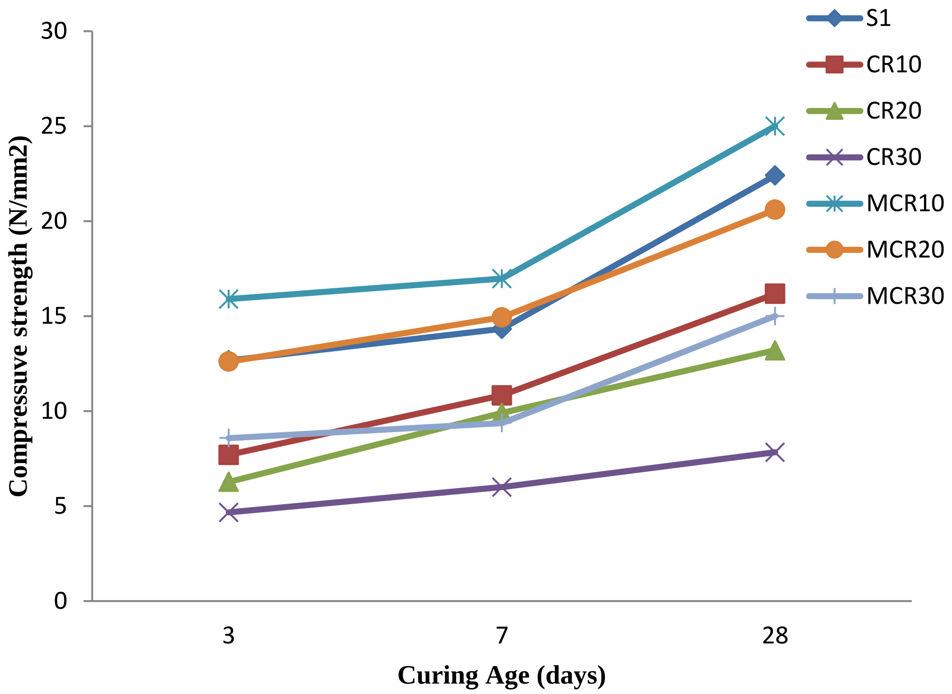

Figure 4.1.4: compressive test result.

The figure above shows the compressive strength test results. It was observed that the strength decreased as the rubber chips content was increased. At 28 days, the decreased at CR_{10} was found to be 16.17 N/mm^2 which was up to 27.81% - 65.04% and MCR_{10} was found to be 25.0 N/mm^2 which was up to 11.68% - 33.04% compared to the control which was 22.4 N/mm^2. At MCR_{10}, an increased in strength was recorded at MCR_{10} Compared with the unmodified chipped rubber series.

Splitting tensile test results

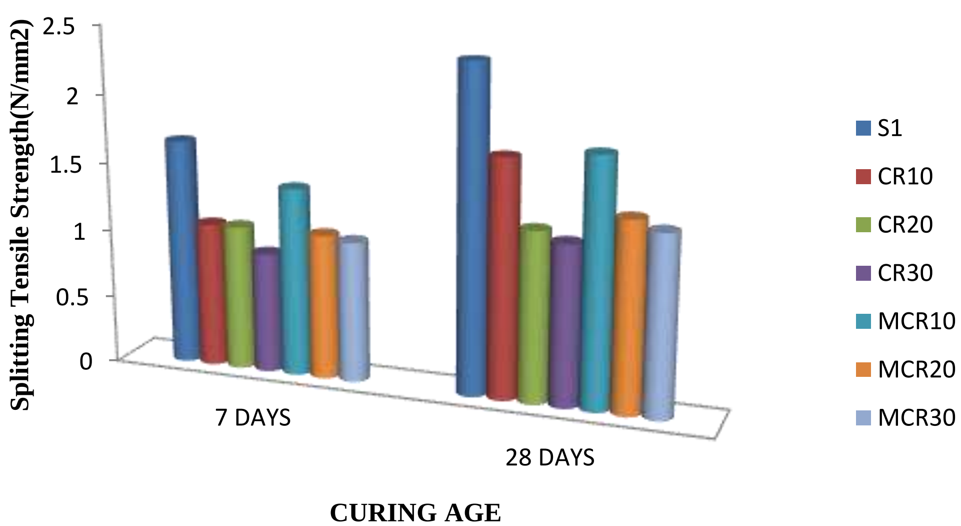

Figure 4.1.5: Splitting tensile test result

The above figure shows the results for the splitting tensile strength. The strengths of the concrete samples decreased as the rubber chips contents were increased. At 28 days, the strength at CR_{10} was 1.73 N/mm^2 and decreased by 27% and at MCR_{10} was 1.80 N/mm^2 and decreased by 24.05% which showed a slight increased in strength at MCR_{10} compared to the unmodified chipped rubber mix series.

Flexural strength test results

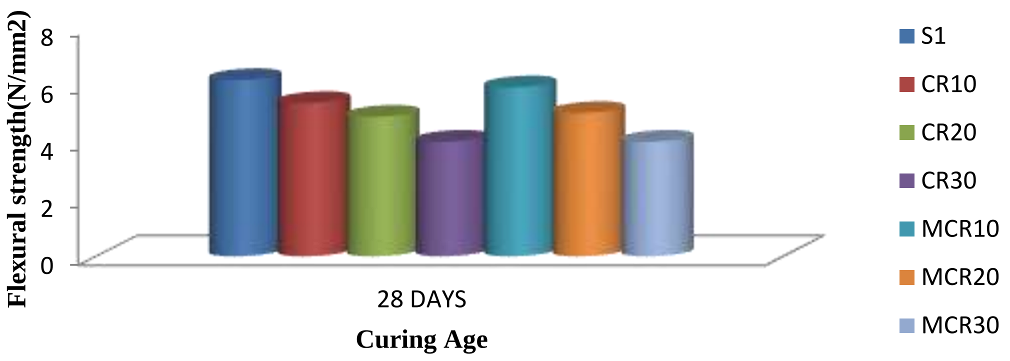

Figure 4.1.6: flexural strength test result

The above figure shows the results of the flexural strength. It was observed that the strength of the concrete reduces as the contents of the rubber chips were increased. A slight increased in strength was observed at MCR_{10} when compared to CR_{10} at 28 days which was found to be 5.9 N/mm^2 represented 9.32% increased compared to the unmodified series.

Findings of the Study

The modified chipped rubber aggregates shows some encouraging results when used as replacement in concrete production. From this study, the compressive strength was found that the optimum percentages of the chipped rubber aggregates that yielded the maximum strength was 10% and has the result of 25.0 N/mm^2 when compared to the control mix which yielded strength of 22.4 N/mm^2. This showed an increased in strength of 10.4%.

The strength comparison between the modified and unmodified chipped rubber aggregate at 28 days, increased by 24.54%. And the splitting and flexural strength results at MCR_{10} were found to be 1.8 N/mm^2 and 5.9 N/mm^2 which are the highest strength recorded.

CONCLUSION

Base on the findings of this study, the following conclusions were made.

1. Chipped rubber decreases the density of the concrete by 9.67% reduction in the weight of the conventional concrete.
2. The modified chipped rubber increased the compressive strength of the concrete from the unmodified chipped rubber by 24.54% increase in strength.

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3. Increased in contents of the chipped rubber in concrete mix decreased the strength of the concrete.

4. The decreased in strength of the modified chipped rubber concrete when compared with the control mix was 10.4% for the MCR_{10} at 28 days.

5. The boring of hole on the chipped rubber has a significant effect on the strength increase of the chipped rubber concrete.

Therefore, the study made the following recommendations:

1. Since the partial replacement of MCR_{10} chipped rubber tyre has resulted in 10.4% increased in the compressive strength, it is recommended to use modified chipped rubber concrete in building such as floor slabs, partitions, kerbs, underground slabs etc.

2. It is recommended to increase the diameter of the hole on the rubber chip to allow cement paste be filled properly.

3. It is recommended that modified rubber chips and granite waste should be used in percentage replacement in concrete.

4. It is recommended to use iron fibres in concrete to determine its strength in plain concrete.

5. It is recommended to explore the effect of other raw materials in these mixes and study the changes in the physical characteristics.

Implication to Research and Practice

This research will drastically reduce the effect of environmental pollution as a result of dumping used rubber tyres on land, as rubber is non-degradable in soil and which can only get rid of by burning. This activity increases the emission of harmful gases into the atmosphere and cause Global warming. The cost of shredding the waste tyre aggregate is high since it was done manually for the cause of this research. Mechanical means of shredding should be adopted for larger volume so that the cost of production will reduce.

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