International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-08, Issue-01, APR 2022

Durability and Microstructure Studies of Rubber Incorporated Light Weight Concrete: A Review

[1]Arya Murali, [2]Indu Susan Raj, [3]Dr. Elson John

[1]PG Student, [2]Assistant Professor, [3]Professor, [1,2,3]Department of Civil Engineering, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India, [1]aryammurali9@gmail.com, [2]indususanraj@mace.ac.in, [3]elson@mace.ac.in

Abstract - Due to the rapid development in automotive production, there is an increase in tire production. Disposing of dirty tires is a global problem. Natural processes are not available for disposing of dirty tires. These disposable tires must be used in a variety of ways in different industries to achieve environmental sustainability. Another type of application is in the form of crumb rubber. Different types of research have been done using crumb rubber as a replacement material. In this review paper, attempts are made to review the previous studies on crumb rubber concrete. It aims at consolidating the outcomes of several attempted kinds of research of using crumb rubber as a replacement material in aerated concrete.

Keywords- Aerated concrete, Crumb Rubber, Compressive Strength, Durability, Light weight, Microstructure

I. INTRODUCTION

In the construction industry concrete plays an important role as it is the heart of the construction industry. But in the production of concrete and its ingredients such as cement, the concentrations of many natural resources are depleted and more energy is used for its production. The demand for these items is growing day by day. It is necessary to find alternatives. The use of industrial and agricultural waste is widely accepted due to its ability to improve the strength and durability of concrete structures. It is therefore desirable to use industrial and agricultural waste as a transformation of the construction industry after considering its impact costs and assets. Rapid growth in the automotive industry is leading to the production of discarded tires worldwide. This has caused a great deal of trouble getting rid of dirty tires. Many attempts have been made to recycle disposable tires in the form of crumb rubber by grinding in mills in the form of replacing part of aggregates and asphalt. Ground rubber is used as fuel for boilers in the industry, for cement kilns, for surfacing of sports grounds, road subgrade, construction of dumping sites, construction of septic tanks, construction of curbs but does not guarantee a proper disposal method.

II. LIGHTWEIGHT CONCRETE

Lightweight concrete can be classified by density or unit weight, which usually varies from 320 to 1920 kg/ m^3, according to the ACI Committee 213 Guide for Structural Lightweight Aggregate Concrete **(ACI 213, 2001).** There are three different types of lightweight concrete that vary in strength, namely low-density concrete (0.7-2.0 MPa), moderate-strength concrete (7-14 MPa), and structural concrete (17-63 MPa) **(ACI 213, 2001).** The densities of these concrete are between 300-800 kg / m^3, 800-1350 kg / m^3 and 1350-1920 kg / m^3 **(ACI 213, 2001)** respectively. Lightweight concrete has been used ever since the early 1900's in the United States, and lightweight concrete has been used in high-rise buildings, long bridges, coastal platforms, and large buildings **(Mindess, Young, & Darwin, 2003)**. Many advantages in using lightweight concrete for construction are due to its low density, low thermal conductivity, low shrinkage, and high-temperature resistance, in addition to reduced dead load, lower transportation costs, and faster construction **(Wongkeo, Thongsanitgarn, Pimraksa, & Chaipanich, 2012).** A few methods can be used to produce lightweight concrete, especially using lightweight aggregate or lightweight matrix. The lightweight aggregate that can be used varies from a combination of natural pumice to man-made sintered aggregate such as sintered fly ash **(Mindess et al., 2003).** A lightweight cement matrix filled with air is sometimes called aerated concrete or foam concrete. The classification of aerated concrete or foam concrete has been simplified by **(Just & Middendorf, 2009)** to be AAC or air-cured foam concrete. Therefore, there are usually two types of aerated concrete: foam concrete and AAC. Foaming agents that can be used are different types of detergents, resin soaps, glue resins, or proteins such as keratin **(Narayanan & Ramamurthy, 2000).** Foam can be added mechanically or physically as reported by **(Just & Middendorf 2009).** Mechanically produced bubbles use a foaming agent method while the physical method refers to the addition of an already foam solution directly to the mixture. The latter method has been found to produce more normal and stable pores **(Just & Middendorf, 2009).** The autoclaved aerated method is commonly used in production. This is because aerated concrete, sometimes known as cellular concrete, produced from this method has a uniform structure of air

DOI : 10.35291/2454-9150.2022.0150

voids at a range of 0.1–1 mm formed in the cement or mortar **(Mindess et al., 2003).**

III. INCORPORATION OF WASTE RUBBER IN CONCRETE

Due to the rapid increase in the number of vehicles worldwide, the accumulation of discarded tires has become a major waste management problem **(Najim and Hall, 2010).** A large number of used rubber tires accumulate in the world each year. For example, there are around 275 million waste tires in the United States **(Papakonstantinou and Tobolski, 2006)** and in the European Union, there are about 180 million tires **(Issa and Salem, 2013).** Traditionally, tires are collected or illegally disposed of, or discarded on the ground. However, none of these are long-term solutions. The basic building materials in concrete construction are mainly aggregate and cement. Adequate use of recycled materials can lead to lower costs and may improve performance. Civil engineering applications of scrap tires are expected to extend significantly as more applications are often proven to be technically and economically viable. A decrease in strength, about 80% **(Eldin and Senouci, 1993),** is expected. On the other hand, rubber particles have a curbing effect on propagation of cracks, leading to a significant increase in strain capacity, ductility and energy absorption capacity **(Topçu, 1997; El-Dieb et al., 2001).**

IV. CLASSIFICATION OF RUBBER AGGREGATES

1. SHREDDED (CHIPPED) RUBBER AGGREGATE

This waste rubber size represents a coarse aggregate (CA) equivalent and has been used as a substitute for crushed stone or crushed limestone **(Ganjian et al., 2009).** Tires shreds or chips include primary, secondary, or both shredding operations. The production of chip tires usually sizes from 76 to 13mm, requires both primary and secondary processing to achieve adequate volume reduction **(Ganjian et al., 1991).**

2. CRUMB-RUBBER AGGREGATE

Typically, the following methods are used to convert discarded tires into crumb rubber. These are (i) cracker mill process, (ii) granular process, and (iii) micro mill process. The cracker mill process tears apart or reduces the dimensions of the rubber by transferring it between the encircling steel drums. This process produces irregular particles with a large surface area. The thickness of these particles varies from 5 to 0.5mm and is commonly known as crumb rubber, which can be used as a substitute for fine aggregate (FA) like natural sand **(Ganjian et al., 2009).**

3. GROUND TIRE RUBBER

The ground rubber for commercial applications may be as thick as 19mm to be as thin as 0.15mm **(Ganjian et al., 2009).** It depends on the type of size reduction equipment and targeted results. Tires processed into ground rubber are subject to two phases of magnetic separation and screening. Fragments of rubber are recovered **(Heitzman, 1992).**

4. SLIT (FIBER) RUBBER AGGREGATE

Fiber rubber waste is produced in tire cutting machines. These machines can split a tire into two parts or separate the side walls and tire line. A number of researchers used rubber left in the form of a short fiber or shredded rubber, usually between 8.5 and 21.5mm long and 12.5mm in diameter **(Baoshan et al., 2004),** and in the form of 68mm long strands **(Emiroglu et al., 2007).**

V. FRESH RUBBERIZED CONCRETE PROPERTIES

1. SLUMP

Significant reductions are made in the slump of concrete as the amount of rubber content increases. This reduction may be due to the high level of inter-particle friction occurring amongst the rubber aggregate and other mix components with a reduction of the unit weight of the plastic mix **(Topçu and Bilir, 2009).** The decline also decreases with increasing rubber content **(Khatib and Bayomy, 1999).** When rubber types were considered, despite a slight reduction in a slump, observations during mixing and casting showed that increasing crumb content still produced a viable mixture compared to the control mix **(Batayneh et al., 2008).** Concrete consisting of crushed rubber achieves the same or better performance as the control concrete without rubber particles **(Raghvan et al., 1998).** Increasing the rubber content up to 38 wt% in the same amount of water-cement ratio will reduce the flowability of the mix but greatly help to control bleeding and separation **(Pierce and Blackwell, 2003).** Decreased performance in workability with increased content of rubber debris in the concrete matrix is observed **(Yang et al. 2015).** It is noteworthy that the incorporation of 20% GBFS as a substitute for OPC by weight reduces the workability performance and the degradation of the slump from 58 mm to 42 mm, respectively. The higher specific area of GBFS (4950 cm2 / g) compared to OPC (3310 cm2 / g) has directly led to an increase in water demand and reduced workability **(Erdemir et al. 2016).**

2. UNIT WEIGHT

The density of rubberized concrete was found to be significantly lower than that of conventional concrete. As the percentage of rubber increases in concrete, its density decreases **(Danko et al., 2006).** The density of concrete depends largely on the amount of air entrained or entrapped, the water-cement ratio, which depends on the size of the aggregates. Increased rubber content in concrete increases air content which reduces the density (unit weight) of concrete. About 25% of the rubber content in concrete, density decreases to 90% of standard concrete. However, this decrease is very small if the rubber content is less than

10-15% of the total volume **(Hasanan et al. 2006).** Factors affecting concrete density include aggregate density, air content, and water and cement content. Increased rubber content in the concrete mix causes a reduction in the unit weight of the mixture. Due to the low specific gravity of the rubber particles which is about 0.53, the unit weight of the rubber-containing compounds decreases with the percentage of rubber content. The reduction in the unit weight of the rubber concrete is very small with rubber content less than 10-20% of the total volume **(Khatib and Bayomy, 1999).** Rubberized concrete shows a decrease in density with the increased maximum particle size. With 50% of fine rubber and coarse rubber replacement, for example, up to 75% reduction in dry density is achieved compared to a 10-30% reduction of dry density reduction for FA modification only **(Fattuhi and Clark, 1996).** Increased air-entraining of concrete mixtures with the addition of rubber-waste can be explained by the higher porosity of rubber-waste particles than sand particles and the extremely porous nature of rubber particle surface **(Skripkıūnas et al., 2007; Batayneh et al., 2008).** Vibration time affects the density of rubberized concretes. The fresh rubber concrete vibrated for 30s showed distinct separation. Therefore, vibration over 15s is proposed. Low vibration time can also cause lower fresh-state density **(Bravo and Brito, 2012).**

VI. MECHANICAL PROPERTIES OF RUBBERIZED CONCRETE

1. COMPRESSIVE STRENGTH

The size, proportion, and surface texture of the rubber particles significantly affect the compressive strength of the rubberized concrete. Concrete mixt with tire chips and crumb-rubber aggregates show lower compressive strength than conventional concrete. There is approximately a 60% reduction in compression strength when the CA is replaced by an average of 45% by coarser rubber chips. However, an approximately 40% reduction in compression strength is obtained when the FA is replaced by 45% with fine crumb rubber. Both of these compounds exhibit ductile failure and the ability to absorb large amounts of energy under compressive and tensile loads **(Kaloush et al., 2005). Khatib and Bayomy (1999) and Topçu (1995)** also showed that the addition of coarser rubber chips to concrete leads to a decline in the compressive strength than the addition of fine crumb rubber. However, the results reported by **Fattuhi and Clark (1996)** show the opposite nature. Studies have shown that if rubber particles have rougher surfaces or are given some pre-treatment, bonding may improve with the surrounding matrix and may result in higher compressive strength. Replacement of the aggregates with granulated rubber waste has damaged the mechanical properties of concrete **(Eldin and Senouci, 1993; Topçu and Avcular, 1997a; Lee et al., 1993)**. The decrease in the compressive strength of concrete after substitution with rubber aggregates is due to the more elastic and softer rubber particles compared to sand particles **(Khaloo et al., 2008).** A second reason for the reduction of the strength of concrete is the lower compressive strength of rubber particles compared to the aggregate **(Topçu, 1995; Taha et al., 2008).** The low adhesion between the rubber particles and the cement matrix deteriorates the mechanical properties of the mix **(Issa and Salem, 2013).** Regardless of age, strength is influenced by the content of the rubber and the strength decreases as the TRCW content is increased. At an early age, samples tested after three days of treatment showed a decrease of almost 10% and the loss of strength increased significantly to 60.5% with an increase in TRCWs from 5% to 30% respectively **(AM Mhaya. et al., 2020).** Better bonding develops with the surrounding matrix by roughening the rubber particles used in concrete and higher compressive strength can be achieved. Pretreatments include washing the rubber particles with water, acid etching, plasma pretreatment, and various coupling agents. This increases the strength of the rubberized concrete by increasing the surface roughness of the rubber and improving the adhesion to the cement paste. Generally, concrete with washed rubber particles shows a 16% higher compressive strength than concrete containing untreated rubber aggregates **(Rostami et al., 1993).** Rubber aggregates can be considered weak areas, and when the microcrack penetrates into the interface with the cement paste, the concentration of stress around its tip is reduced **(Karakurt, 2014). (Kumaran SG et al, 2008)** performed various experiments on rubberized concrete with rubber crumbs of size 36, 24, and 18 mm and found an 85% decrease in compression strength and a 50% reduction in split tensile strength but shows a large energy absorption. **(Kaloush K.E. et al, 2004)** investigated the increase in rubber content in concrete reducing compressive strength. This decrease is due to the entrapped air.

2. MODULUS OF ELASTICITY

The use of rubber as an additive to concrete reduces the static modulus of elasticity because rubber particles are effective in increasing concrete deformability. Applying rubber waste to concrete reduces the modulus of elasticity **(Zheng et al., 2008)**. The modulus of elasticity is related to the compressive strength of concrete, as well as the elastic properties of aggregates. The larger the number of rubber additives added to concrete, the modulus of elasticity also decreases. Usage of rubber waste in concrete, the static as well as dynamic modulus of elasticity decreases compared to conventional concrete. The reduced and static and dynamic modulus of elasticity in concrete with waste rubber particles may be defined by the lower modulus elasticity of rubber particles than the natural aggregate **(Topçu and Avcular, 1997).**

3. TOUGHNESS

DOI : 10.35291/2454-9150.2022.0150

Toughness is defined as the absorption capacity of the energy and is generally defined as the area under the load-deflection curve of a flexural or stress-strain graph of a compressive test of the specimen. The toughness of rubberized concrete is higher than the concrete control mixes. However, the toughness of 10% rubber-based concrete is less than 5% of rubber-based concrete due to reduced compressive strength. Changes in the toughness values while incorporating rubber are determined by measuring the areas under the stress-strain diagrams. Although decreases in toughness with the incorporation of rubber are evident some changes are witnessed in their energy capacities during the fracture phase. Rubber concrete absorbs more energy and shows more strain at the point of fracture **(Topçu, 1997).** Toughness values taken at the time of fracture were investigated in two different ways as plastic and elastic properties. Plastic energy is the energy consumed during the failure process and is not recovered. Elastic energy is the recovered deformation energy that is obtained at the moment before fracture **(Topçu, 1995).** The initial high elastic energy capacities of conventional concrete decrease with the inclusion of rubber, and the initial low plastic energy capacities increases. Higher plastic energy shows higher deformation at the point of fracture and absorbs more energy. Rubber inclusions into the concrete result in increased plastic energy capacities **(Topçu, 1997). (Danko et al., 2006)** investigated all failures of rubberized concrete observed that the specimens did not disintegrate during loading.

4. SPLIT TENSILE STRENGTH

The strain at failure increases as the rubber content increases, but the tensile strength decreases. High tensile strain at failure is an indication of more ductile mix and more energy absorbent mix. In splitting tensile strength, specimens show a high capacity for absorbing plastic energy. Failed specimens take up immense post-failure loads and underwent displacement, which is partially recoverable. Thus, the concrete mass was able to withstand loads even when severely cracked **(Liu et al., 2013).** This is due to the ability of rubber aggregate to undergo large elastic deformation. Specimens with rubber did not exhibit brittle failure under compression due to rubber's plastic behavior. Splitting gradually occurs based on the type and amount of rubber used **(Topçu, 1995).** An approximately 65% decrease in the splitting strength of concrete is observed with a 45% increase in rubber particles compared with an approximately 75% reduction for the same coarse rubber content **(Topçu, 1995).** The coarse tire aggregate had lower splitting strengths than the fine tire chips. This is due to the weak interfacial bonds between the surface between the cement paste and tire aggregate. **(Danko et al., 2006)** noted that the tensile strength of rubber concrete is influenced by the size, shape, and textures of the aggregate, and the strength of concretes decreases as rubber aggregate increases. The tensile strength of rubberized concrete decreases but the strain at failure increases as well. Higher tensile strain at failure implies more energy absorbent mixes **(Kaloush et al., 2004).** Tests performed to analyze the behavior of rubberized concrete containing tire chips and crumb rubber as a substitute for aggregates having sizes 38, 24, and 19 mm showed a reduction in tensile strength by almost 50%. They possess maximum energy absorption during tensile loading **(Kumaran et al., 2008).**

5. FLEXURAL STRENGTH

The flexural strength of concrete decreases with the incorporation of rubber aggregate. Although rubber particles result in a reduction of flexural strength; the specimens of rubberized concrete (RC) do not undergo sudden failure under bending load in the flexural test. This is due to the higher deformations that the rubber particles take up **(Liu et al., 2013).** The brittleness index shows a decrease in the inclusion of rubber beyond 15%. We can also observe a transition from brittle to ductile behavior **(Topçu, 1997). (Kaloush et al., 2004)** examined the flexural strength of concrete and postulated that a decrease is observed with the increasing content of rubber. **(Jingfu et al., 2008)** further studied that flexural strength increased by including rubber in the development of roller-compacted concrete. As the content of rubber increases, the flexural strength increases with constant compressive strength in the case of roller-compacted concrete.

VII. DURABILITY PROPERTIES OF RUBBERIZED CONCRETE

Although the strength of rubberized concrete is considerably reduced as compared to conventional concrete, there is a positive impact on several durability properties as indicated by numerous studies by other researchers.

1. FREEZE–THAW RESISTANCE

When water freezes it will expand. The water present in the moist concrete freezes and it produces pore pressure in the concrete. The cavity might dilate and rupture in certain cases where the pressure developed exceeds the tensile strength of the concrete. When subjected to successive freeze-thaw (F–T) cycles, expansion and cracking, scaling, and crumbling of the concrete may initiate due to the interference of paste and aggregate **(Fedroff et al., 1996).** Especially in cold regions, the durability of concrete structures is critical. Freeze-thaw damages may be dangerous in such situations. Although there is a reduction in the strength of rubberized concrete, the freeze-thaw damage is not severe when compared to the conventional concrete mix **(Topçu and Demir, 2007).** Sustainable rubber crumb possesses a low modulus of elasticity **(Khaloo et al., 2008).** The inclusion of rubber introduces several pressure-relief chambers. The inclusion of rubber in the cement matrix along with smaller particle-sized rubber improved the porosity of the matrix and resulted in higher air entrainment. To resolve the durability issues several air-entraining agents were used. Rubberized concrete can produce frost-resistant concrete without including air-entraining agents. The proper control of the parameters of cement and rubber increases the porosity **(Rangaraju and Gadkar, 2012).** We can observe the improvement in workability and air entrainment and highly stabilized air bubbles in the matrix by the artificially entrapped air voids using new air-entraining agents. Rubber-waste additives play the role of an absorber and effectively balances all the internal stresses in concrete paste due to the hydrostatic water pressure **(Benazzouk et al., 2006).** Fine crumb-rubber aggregates as substitutes to the sand have depicted the evolution of a system of well-distributed air bubbles into the concrete mix. This aids in freeze-thaw resistance. At higher replacement proportions of 16% and 24% by volume of sand the finer size fractions depict improved performance in the F–T resistance. The finer crumb-rubber aggregates produce more air bubbles in the matrix. This helps in improving F–T resistance **(Richardson et al., 2011).**

2. FIRE PERFORMANCE OF RUBBERIZED CONCRETE

The compressive strength of the conventional concrete strength under the effect of high temperatures is reduced by the rise of the addition of rubber. There is an increase in compressive strength at 300 ° C **(Topçu and Demir, 2007).** It is thought that the reason for this is that the hydration of the mortar is completed at this temperature **(Topçu and Demir, 2007).** However, a high-strength concrete specimen without rubber particles shows spalling on the exposed side, whereas specimens with rubber do not show spalling as the rubber content is increased. When the rubber particles are burned, they allow water vapor to evaporate from the sample, reducing stress due to vapor pressure. Small holes can be seen in the fire-exposed surface of the specimen with rubber fiber. There are no holes in the sample without rubber **(Topçu and Demir, 2007).** High-strength concrete shows a tendency to explosive spalling when under rapid fire. This behavior is mainly due to the low permeability leading to the formation of pore pressure inside the hydrated cement paste. Other solutions, such as the incorporation of polypropylene fibers to allow vapor to escape from the concrete matrix, have been proposed to reduce the risk of spalling. Applying rubber aggregates to concrete may be an alternative to high-strength concrete under rapid-fire or high temperatures **(Hernandez-Olivares and Barluenga, 2004).**

3. SEAWATER EFFECT AND ACID ATTACK

Structures in the marine environments may have one face exposed to wetting and others to drying conditions and several detrimental effects can be observed. The effects of chemical reaction of seawater constituents with cement hydration products result in crystallization products within concrete and corrosion of embedded steel in reinforced or prestressed members **(Huynh and Raghavan, 1997; Olutoge and Amusan, 2014).** Rubberized concrete kept in NaCl solution are compared with samples kept in normal curing conditions for 28 days. The compressive strength decreased in the sample under the seawater condition than under normal curing conditions. The mortar specimens immersed in salty water for 28 days, showed a decline in the compressive strength from 33.75 to 5.18MPa **(Topçu and Demir, 2007).** The specimens with 10%, 20%, 30%, and 40% of rubber additions resulted in lower compressive-strength compare to the control mix and are affected by the salty water **(Topçu and Demir, 2007).** Rubberized concretes are susceptible to acidic mediums much more than to seawater. Rubberized concrete specimens with the same strength as conventional concrete shows a negligible reduction in mass when immersed in seawater. The replacement of FAs by rubber results in a less reactive mix against chloride environments **(Ganesan et al., 2012).**

VIII. PHYSICAL PROPERTIES

1. MICROSTRUCTURE

The method of pore-formation (viz., gas release, or foaming) plays a vital role in the microstructure development and properties of the aerated concrete. Aerated concrete is characterized by the solid microporous matrix and macropores. Expansion of the mass due to aeration creates the macropores and the micropores form in the walls between the macropores **(Alexanderson et al., 1979).** Macro pores are pores with a diameter of more than 60 µm **(Petrov et al., 1994).** The presence of voids significantly alters the orientation of the products of hydration of cement. Pore size distribution, inter-cluster pores, and inter-particle pores and their distribution in the matrix are critical. The classification based on the porous system of aerated concrete is also possible **(Prim et al., 1983).** Another method in terms of pores with a radius of 50±500µm, (pores of 5 µm size are considered as large pores in ordinary mortar) introduced by aerating or surface-active agents, microcapillaries of 50 nm or less formed in the walls between the air pores referred to as micropores **(Alexanderson et al., 1979)** and very few pores of 50 nm to 50 µm, called macro capillaries **(Tada et al., 1983).** Although the air void system is nearly the same, the structure of Autoclaved Aerated Concrete (AAC) and Non-Autoclaved Aerated Concrete (NAAC) differs due to differences in the hydration products, which explains the differences in their properties. A portion of the siliceous material combines chemically with calcareous material, such as lime and lime released by cement hydration, during autoclaving, generating a microcrystalline structure with a considerably lower specific surface. Due to the presence of excess pore water, NAAC has a greater volume of fine pores, according to **(Tada et al., 1983).** The macropore size distribution has been found to have no impact on compressive strength **(Alexanderson et al., 1979).**

DOI : 10.35291/2454-9150.2022.0150

2. POROSITY, PORE SIZE DISTRIBUTION AND PERMEABILITY

Concrete's porosity and pore size distribution are integrally related to its strength, permeability, diffusivity, shrinkage, and creep. As a result, pore structure characterization is critical, especially in the case of aerated concrete, where porosity can reach up to 80%. The porosity and pore size distribution of aerated concrete varies greatly depending on the composition and curing procedure. Aerated concrete has been shown to have higher porosity as a result of increased macropore volume **(Alexanderson et al., 1979).** As a result, pore walls become thinner, lowering the micropore volume share. The porosity must also be qualified with the pre-treatment procedure used, as oven drying of the sample to assess the porosity has been found to cause the cell structure to collapse **(Day et al., 1988).** Although the porosity of AAC produced by foaming and gas forming processes differs significantly, the permeability does not. The permeability was shown to be unaffected by the artificial air pores **(Jacobs et al., 1992).**

IX. CONCLUSIONS

The following are the findings of study into the use of rubber as a concrete aggregate. When rubber is substituted for aggregates in concrete, it has a lower compressive strength than regular concrete. However, prior to failure, it exhibits some ductile behavior. When compared to control concrete specimens, rubberized concrete exhibits a lower density. When compared to concrete built with chipped rubber as coarse aggregate, concrete made with crumb rubber as fine aggregate has a lot of strength. There was no discernible increase in the compressive strength of concrete density when varying percentages of rubber were used as fine particles. To boost the compressive strength of rubberized concrete, silica fume is recommended. Rubberized concrete is recommended for small constructions such as like road curbs and non-bearing walls etc.

X. REFERENCES

[1] Toutanji, H. A. (1996), “The use of rubber tire particles in concrete to replace mineral aggregates.” Journal of Cement & Concrete Composites, ELSEVIER, 18, 135-139.

[2] Mohammad Reza sohrabi, Mohammad Karbalaie, “an experimental study on compressive strength of concrete containing crumb rubber” Journal of Cement and Concrete Research, ELSEVIER, 44, 2309-2358.

[3] A. Abdollahzadeh, R. Masoudnia, S. Aghababaei, “Predict strength of rubberized concrete using artificial neural network” Journal of Cement and Concrete Research, ELSEVIER, 34, 2309-2372.

[4] A. Mohammad Mustafa al bakri, S.A. Syed Nuzul Fadli, M.D. Abu bakar and K.W leong, Comparison of rubber as aggregate and rubber as filler in concrete. Journal of Cement and Concrete Research, ELSEVIER, 84, 2309-2323

[5] Guneyisi, E., Gesoglu, M., and Ozturan, T. (2004), “Properties of rubberized concretes containing silica fume.” Journal of Cement and Concrete Research, ELSEVIER, 34, 2309-2317.

[6] Siddique, R. and Naik, T. R. (2004), “Properties of concrete containing scrap-tire rubber – an overview” Journal of Waste Management, ELSEVIER, 24, 563-569.

[7] Eldin, N. N., and Senouci, A. B. (1993), “Rubber-tire particles as concrete aggregate.” Journal of Material in Civil Engineering, ASCE, 5(4), 478-496

[8] Khatib, Z. K., and Bayomy, F. M. (1999), “Rubberized Portland cement concrete” Journal of Materials in civil engineering, ASCE, 11(3), 206-213.

[9] Batayneh, M. K., Marie, I., and Asi, I. (2008), “Promoting the use of crumb rubber concrete in developing countries.” Journal of Waste Management, ELSEVIER, 28, 2171-2176.

[10] Malek K. Batayneh ,Iqbal Marie , Ibrahim Asi, “Promoting the use of crumb rubber concrete in developing countries”.

[11] Aiello, M. A., and Leuzzi, F. (2010), “Waste tyre rubberized concrete: Properties at fresh and hardened state.” Journal of Waste Management, ELSEVIER, 30, 1696-1704. [

[12] Najim, K. B., and Hall, M. R. (2010), “A review of the fresh/hardened properties and applications for plain- (PRC) and self-compacting rubberized concrete (SCRC).” Journal of Construction and Building Materials, ELSEVIER, 24, 2043-2051.

[13] Ganjian, E., Khorami, M., and Maghsoudi, A. A. (2009), “Scrap-tyre-replacement for aggregate and filler in concrete.” Construction and Building Materials Journal, ELSEVIER, 23, 1828-1836.

[14] Michelle Danko, Edgar Cano and Jose Pena, Use of Recycled Tires as Partial replacement of Coarse Aggregate in the Production of Concrete, Purdue University Calumet, 2006.

[15] Ling T.C. and Hasanan M.N., Properties of Crumb Rubber Concrete Paving Blocks with and without Facing Layer, Kuala lumpur, 2006.

[16] Kumaran S.G., Nurdin M. and Lakshmipathy M., A Review on Construction Technologies that Enable Environmental Protection: Rubberized Concrete, USA, Science Publications, 2008.

[17] Kaloush K.E, George B. W. and Han Z., Properties of Crumb Rubber Concrete, Arizona: Arizona State University, 2004.

[18] Felipe J.A., Jeannette Santos, The Use of Recycled Polymers and Rubbers in Concrete, Florida, 2004.

[19] Carol Carder, Rubberized concrete, Colorado: Rocky Mountain Construction, 2004.

[20] Neville A.M., Properties of Concrete, 4th edition, Addison Wesley Longman ltd, 1996.

[21] Gintautas S., Audrius G. and Benjaminas C., Deformation Properties of Concrete With Rubber Waste Additives, Lithuania: Kaunas University of Technology, 2007.

[22] Yunping Xi, Yue Li, Zhaohui Xie, and Lee J.S., Utilization of Solid Wastes (Waste Glass and Rubber Particles) as Aggregates in Concrete, Colorado, 2003.