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Pelletized Cut Rubber: An Alternative Coarse Aggregate for Concrete Mixture

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Abstract

This experimental study aimed to develop an acceptable concrete mixture with pelletized cut rubber tire particles as substitutes to coarse aggregates in concrete mixes adopted from "AA" concrete mixture that can be used for building construction. The study also tries to point out the fact that not all discarded materials classified are waste but can be converted to other uses by manipulating its form to suit the desired use. In this case, pelletizing cut rubber tires that can no longer be used by vehicles nor re-threaded for further use. Adding them as partial or complete substitutes for gravel in concrete mixes, cut rubber tire pellets could lower cost of production and saving valuable funds and resources to be used for construction projects.

Keywords: *Coarse aggregate, construction material, pelletized cut rubber, scrap waste tire*

1. Introduction

The large volume of waste tire rubber becomes a serious problem that impact to the environment. Many alternatives were proposed from many researchers for solving this problem. One methodology is recycling waste tire by cutting or scraping actual waste materials to be smaller sizes down to powder particles and reused this material in many industrial fields, so-called reclaimed rubber. One suitable application of this rubber is to use it as an additive for conventional asphalt in production of asphalt concrete for road pavement.

Tires are not desired at landfills, due to their large volumes and 75% void space, which quickly consume valuable space. Tires can trap methane gases, causing them to become buoyant, or bubble to the surface. This 'bubbling' effect can damage landfill liners that have been installed to help keep landfill contaminants from polluting local surface and ground water [1, 17]. Shredded tires are now being used in landfills, replacing other construction materials, for a lightweight backfill in gas venting systems, leachate collection systems, and operational liners. Shredded tire material may also be used to cap, close, or daily cover landfill sites. Scrap tires as a backfill and cover material are also more cost-effective, since tires can be shredded on-site instead of hauling in other fill materials.

Many countries are experiencing an escalation in waste management problems. This is caused by the indiscriminate disposal of non-biodegradable materials like "discarded" transportation vehicle rubber tires in the environment [2, 17]. By utilizing these "discarded" transportation vehicle rubber tires of cut rubber pellets in

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combination with fine and coarse aggregates rather than directly disposing them, people can minimize the waste material production to ones' country. One sample use of these materials is showcased in the experiment. Making use of pelletized cut rubber tire particles as partial aggregates in a concrete mix can be a step towards recycling "used" cut rubber tires, and reducing the presence of these non-biodegradable often unwanted materials in the environment while at the same time help address the supply requirement of coarse aggregates in low-strength concrete mixes in the construction industry. This process would not only reduce the pollution in our country. It would also reduce quarrying in the rivers and mountains that causes landslide and flashfloods that destroys lives and properties.

The pelletized (6.5 mm size or greater) rubber tire particles can replace coarse aggregate requirements in a low-strength concrete mix enabling the understanding and limitations of coarse concrete aggregate possibilities

The aim of this project is to explore further the theories in the conception of each concrete structure being built today. Initial experimentations showed that unit weights tend to differ and become slightly heavier than that specified in the NSCP C101-01 ranging from 3.9 KN/m^3 – 23.6 KN/m^3 [3].

The use of recycled rubber as aggregate in concrete has not given results that could indicate the possibility of its use as structural material. It is thought that the main cause of the decrease of strength in rubber concrete is due to the weak bond between the recycled rubber particles and the cement. This investigation intents to further explore this issue by comparing an OPC control mix with three mixes with different amount of natural coarse aggregate replacement (10, 15 and 20%) by pelletized cut rubber and with three concrete mixes (10, 15 and 20%) with the surface modified shredded rubber tire particles.

2. Related Literature

Waste tires generated in the New England states are for the most part managed within New England region. Studies show that waste tires generally stay in their area of origin due to the high cost of transportation [4,17]. The most common management method for waste tires is as fuel for either the paper mills in Maine or at a tire-to-energy-facility in Connecticut. There are three paper mills in Maine that supplement their fuel use with Tire-Derived Fuel (TDF). Together the three mills consumed approximately 71,000 tons of TDF in 2000 which equates roughly to 7.1 million passenger tires. The dedicated tire-to-energy facility, Exeter Energy Limited in Sterling, Connecticut burns mainly whole tires, and consumed 10.13 million equivalents in 2000.

State statute defines tires as a "special waste" as opposed to Municipal Solid Waste (MSW) because they require special handling whether in a landfill or an energy recovery plant. However, Connecticut no longer permits the landfilling of waste tires, either whole or in pieces. Most of Connecticut's waste tires are burned to create energy at the tire-to-energy plant in Sterling [5].

The DEEP Solid Waste Management Regulations, under Section 22a-209-8(g) of the Regulations of CT State Agencies (RCSA) specify the handling requirements for the storage, disposal or processing (sort, shred, grind, *etc.*) of waste tires. Tire-to-energy plants are considered resource recovery facilities. Their design, permitting and operation, including storage of tires, must conform to the requirements of Section 22a-209-10 RCSA [6]. DEEP Solid Waste Management also requires that facilities that process or burn tires are required to report quarterly on the origin of the waste received, amounts received, and amounts recycled and disposed, and the destination of all materials leaving their facility. DEEP Solid Waste

Management does not track the transport of tires. There is no prohibition against the shipment of tires across state lines [7, 9, 17].

Rubber tires have a very high BTU content which makes them a good source of fuel for cogeneration (the joint production of useful heat and electricity) incinerator facilities or other industries that require incinerators, such as paper mills or cement kilns. A BTU is the amount of heat required to change the temperature of one pound of water one degree. The BTU of tires is approximately 15,000 per pound. It is higher than some types of coal and about twice as high as garbage

Previous research has shown that the use of rubber particles in concrete mixes decreases the compressive strength of hardened concrete [8,10]]. It has been reported that the mechanical properties of concrete rubber containing concrete takes place due to the weak adhesion between the rubber particles and the cement paste. In order to address this issue, the modification of the rubber particles surface has been suggested

Several studies has shown that the compressive and tensile strength of rubber containing concrete is affected by the size, shape, and surface textures of the aggregate along with the volume being used indicating that the strength of concretes decreases as the volume of rubber aggregate increases [11, 12, 13]. However, discrepancies have been reported on the effect of recycled rubber size aggregate on the compressive strength of concrete

3. Methodology

Noticing the amount of pollution partially caused by “discarded” rubber tires from transportation vehicles, a study was made on the other significant characteristics of this material. The researcher has found certainly aspects of rubber tires that resemble certain characteristics of coarse aggregates used in concrete mixes. By gathering enough data and resources necessary to conduct a research study of this theory, a comprehensive plan was laid out to test the application of pelletized rubber tires in concrete mixes. The experiment process is as follows: (a) Research about the characteristics of the main materials. (b) Discussion and completing of all the materials to be used in the experiment. (c) Scheduling of testing with a concrete testing facility. (d) Computation of first sample set. (e) Proportioning. (f) Checking of computation before mixing. (g) Mixing and curing concrete, concrete with 15% pelletized cut rubber tire, concrete with 20% pelletized cut rubber tire and concrete with 25% pelletized cut rubber tire. (h) Testing in concrete, concrete with 15% pelletized cut rubber tire, concrete with 20% pelletized cut rubber tire and concrete with 25% pelletized cut rubber tire and (i) Conducting of tests via UCT.

The preparation of the experimentation process flow which includes the preparation of molds and materials to be used and also, the planning of the concrete specimens and their respective specifications which will be classified by the amount of pelletized cut rubber tire percentage used and the curing duration. The percentages to be used will be ranging from 15% - 25% with a 5% incrimination between sample sets. This is to optimize the amount of cut rubber pellets to be used for each mix and to lower cost of production for each specimen.

After determining the number of experiments to be used and the classifications, this will follow curing by submersion and testing using ASTM and NSCP specifications respectively.

Cut rubber tire coarse aggregates experiments will be based on the ASTM’s standard procedures namely C31-91 entitled standard practice for making and curing concrete test specimens in the field [14, 15]. This standard process was chosen based on the actual environment being used in mixing the concrete specimens. After each curing procedure, the samples will be stored in appropriate conditions, also specified within the ASTM code in preparation for UCT testing.

4. Results and Interpretations

After carefully performing mixing, curing and testing for 7 days, 14, days, 21 days, and 28 days aged specimens, certain attributes arose and substantial but not yet verified data can be extracted. The following table displays the weighed, measured and calculated values of certain aspects of the mixes.

As shown in Table 1-6, the unit weights tend to differ and become slightly heavier than that specified in the NSCP C101-01 ranging from 3.9 KN/m^3 – 23.6 KN/m^3.

Table 1. Weight measurements and calculations for concrete cylinder specimens in 7 days

Specimen Specification (Cylinder)	Calculated weight (kg)	Calculated w/o water (kg)	Measured weight (kg)	Calculated unit weight w/ water (KN/m^3)	Measured unit weight w/ water (KN/m^3)
Plain Concrete (PC)	15.715	14.325	13.5	27.73	23.819
PC +15% pelletized cut rubber	14.845	13.455	12.5	26.19	21.173
PC +20% pelletized cut rubber	14.556	13.166	12	25.68	19.408
PC +25% pelletized cut rubber	14.266	12.876	12	25.17	19.408

Volume of Cylinder = 0.005559999m^3

Table 2. Weight measurements and calculations for concrete beam specimens in 7 days

Specimen Specification (Beam)	Calculated weight (kg)	Calculated w/o water (kg)	Measured weight (kg)	Calculated unit weight w/ water (KN/m^3)	Measured unit weight w/ water (KN/m^3)
Plain Concrete (PC)	35.060	31.89	30	27.76	23.756
PC +15% pelletized cut rubber	33.123	29.953	Uncast specimen	26.23	Uncast specimen
PC +20% pelletized cut rubber	29.308	26.138	Uncast specimen	23.21	Uncast specimen
PC +25% pelletized cut rubber	28.620	25.45	Uncast specimen	22.66	Uncast specimen

Volume of beam = 0.01238862m^3

Table 3. Weight measurements and calculations for concrete cylinder specimens in 14 days

Specimen Specification (Cylinder)	Calculated weight (kg)	Calculated w/o water (kg)	Measured weight (kg)	Calculated unit weight w/ water (KN/m^3)	Measured unit weight w/ water (KN/m^3)	Wastage (kg)
Plain Concrete (PC)	15.715	14.325	Uncast specimen	27.73	Uncast specimen	Uncast specimen
PC +15% pelletized cut rubber	14.845	13.455	Uncast specimen	26.19	Uncast specimen	Uncast specimen
PC +20% pelletized cut rubber	14.556	13.166	12.45	25.68	21,97	1.932
PC +25% pelletized cut rubber	14.266	12.876	12.73	25.17	22.46	1.301

Volume of Cylinder = 0.005559999m^3

Table 4.Weight measurements and calculations for concrete beam specimens in 21 days

Specimen Specification (Beam)	Calculated weight (kg)	Calculated w/o water (kg)	Measured weight (kg)	Calculated unit weight w/ water (KN/m^3)	Measured unit weight w/ water (KN/m^3)	Wastage (kg)
Plain Concrete (PC)	35.060	31.89	Uncast specimen	27.76	Uncast specimen	Uncast specimen
PC +15% pelletized cut rubber	33.123	29.953	Uncast specimen	26.23	Uncast specimen	Uncast specimen
PC +20% pelletized cut rubber	29.308	26.138	29.91	23.21	23.68	No wastage
PC +25% pelletized cut rubber	28.620	25.45	28.10	22.66	22.25	No wastage

Volume of beam = 0.01238862m^3

As shown in Figure 1, the higher the percentage of pelletized rubber that is added, the lesser the unit weight would be. This is due to the change in unit weight of the materials being used in the mix. Apparently, rubber has a much lesser unit weight than gravel thus, explains where the concrete specimen inherits this attribute.

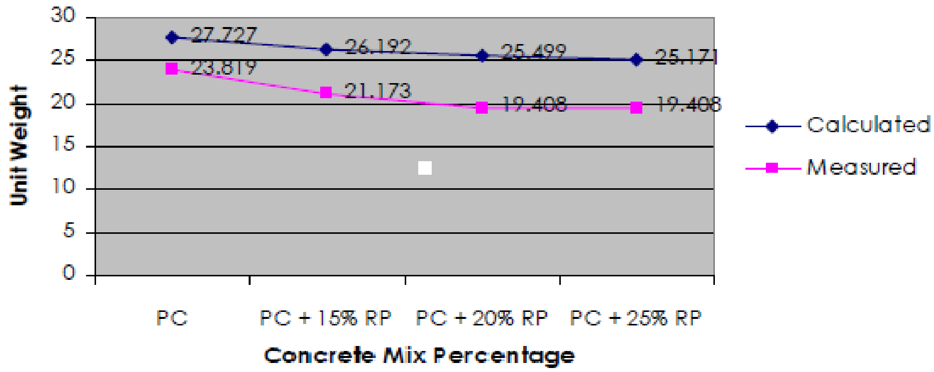

Figure 1. Unit weight of cylindrical specimens

Table 5. Weight measurements and calculations for concrete cylinder specimens in 28 days

Specimen Specification (Cylinder)	Calculated weight (kg)	Calculated w/o water (kg)	Measured weight (kg)	Calculated unit weight w/ water (KN/m^3)	Measured unit weight w/ water (KN/m^3)	Wastage (kg)
Plain Concrete (PC)	15.715	14.325	Uncast specimen	27.73	Uncast specimen	Uncast specimen
PC +15% pelletized cut rubber	14.845	13.455	Uncast specimen	26.19	Uncast specimen	Uncast specimen
PC +20% pelletized cut rubber	14.556	13.166	Uncast specimen	25.68	Uncast specimen	Uncast specimen
PC +25% pelletized cut rubber	14.266	12.876	Uncast specimen	25.17	Uncast specimen	Uncast specimen

Volume of Cylinder = 0.005559999m^3

As shown in Table 7 and Figure 2, the compressive strength for all mixes was higher when the pelletized cut rubber particles where treated with the sodium hydroxide solution. This increase in strength with respect to the concrete containing untreated rubber particles is thought to be attributed to the surface modification of the recycled particles. The saturated sodium hydroxide solution had an effect on the hydrophilic of the rubber allowing it to adhere better to the cement paste that surrounded it [16]. It is generally found that as the paste aggregate bond increases so does the strength of the concrete whether in tension, flexure or compression.

Table 6. Weight measurements and calculations for concrete beam specimens in 28 days

Specimen Specification (Beam)	Calculated weight (kg)	Calculated w/o water (kg)	Measured weight (kg)	Calculated unit weight w/ water (KN/m^3)	Measured unit weight w/ water (KN/m^3)	Wastage (kg)
Plain Concrete (PC)	35.060	31.89	Uncast specimen	27.76	Uncast specimen	Uncast specimen
PC +15% pelletized cut rubber	33.123	29.953	30	26.23	23.76	0
PC +20% pelletized cut rubber	29.308	26.138	31	23.21	24.55	0
PC +25% pelletized cut rubber	28.620	25.45	28.10	22.66	Uncast specimen	Uncast specimen

Volume of beam = $0.01238862m^3$

Table 7. Compressive strength of specimens (concrete with pelletized rubber)

Specimen Specification (Beam)	Diameter (mm)	Area (mm2)	Maximum load (KN)	Compressive strength (MPa)
Plain Concrete (PC)	152.40	18241.47	214.04	11.73
PC +15% pelletized cut rubber	152.40	18241.47	142.69	7.82
PC +20% pelletized cut rubber	152.40	18241.47	136	7.46
PC +25% pelletized cut rubber	152.40	18241.47	133.77	7.33
Beam modulus of rupture = 457.20 mm				
Sample specs	Maximum load (N)	Average depth (mm)	Average width (mm)	Modulus of rupture, R (MPa)
Plain concrete	16587.818	152.00	152.00	3.24

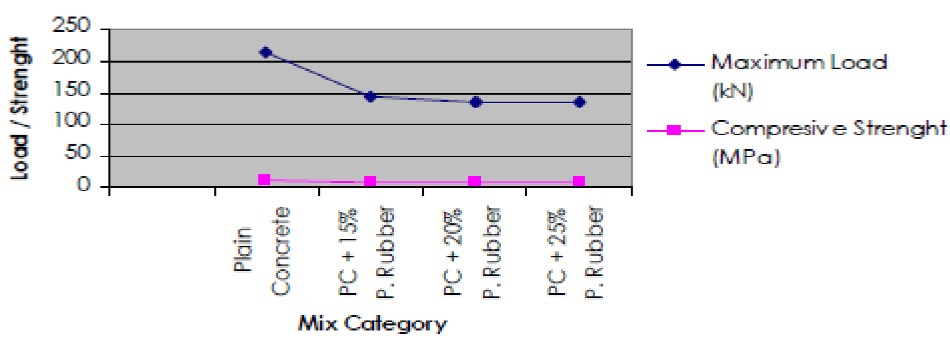

Figure 2 . Compressive strength of specimens (concrete with pelletized rubber)

5. Conclusion

Adding cut rubber tire pellets in concrete mixes will significantly reduce the amount of standard coarse aggregates used in concrete resulting in more economical and cost-efficient projects in the future. Furthermore, this study will aid in the disposal of excess and/or “discarded” transportation vehicle rubber tires in the environment and help ensure that the construction era of the future will be an environmentally friendly one.

With regards to scientific observations, the lesser unit weight of the pelletized rubber being added to the concrete mix replacing some volume of gravel reduce the weight of the concrete mix. Reduction is at least within the range of 10% - 20% by weight more or less.

However, the increase in toughness and ductility of the material indicates that further testing is necessary in order to increase the strength while maintaining ductility. Currently, another test is being executed exploring the use of waste materials and further surface treatment to determine if this objective may be achieved, keeping in mind that as this point, pelletized rubber could be successful in its use as substitute to coarse aggregate in non-structural applications, and it represents a viable alternative to recycle tires helping the conservation of the environment in the process.

6. Appendix

Figure 3. Preparation of concrete cylindrical specimens with 25% with cut rubber pellet composition

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