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Research Paper

Enhancing Sustainable Concrete Properties by Green Vegetable Substance

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Abstract

From several points of view, disposal of waste materials in an environment is respected to be a significant problem because of its very low biodegradability and existence in huge quantities. Waste of plastic and metal bottles caps, cans of juices and soft drink, and tires rubber being among the most pronounced. This study was conducted to evaluate the efficiency of reusing these waste materials in concrete production and solve the segregation problem. As segregation increases in concrete involving these waste materials due to lighter weight of them relative to nature aggregate, therefore, attention was intensive on using natural product (Gum Arabic) that is an environmentally friendly chemical material for improving concrete properties. The conducted tests include; compressive strength, flexural strength, splitting tensile strength, density, water absorption, and ultrasonic pulse velocity. The results showed that replacing the volume of coarse aggregate by 25% compacted bottles caps and pull-tab of cans, 20% the plastic bottle caps, and 25% tires rubber shreds used decreased the mechanical properties of concrete to some extent less than reference mix and they were enhanced by employing Gum Arabic. In addition, the employment of Gum Arabic as liquid in concrete mixes developed the mechanical properties of concrete, reduced segregation, however raised the water absorption percent and declined the density of concrete.

Keywords: *Sustainable Concrete, waste material, Gum Arabic, and segregation in concrete.*

1. Introduction

Today, one of the materials that used in producing essential parts of the constructions is concrete, it's well known as an infrastructure growth backbone. the engineering community concentrate interest in changing to sustainable production of this material. Investigations prove that it is achievable to occupy recycled items to alternate a numeral of the traditional mix ingredients in concrete and create a new developed green construction material (Raji and Samuel 2015). Wastes reuse benefits to keep and remain raw sources, shrinks the world pollution, as well as its advantages in saving energy processes of construction (Ismail and AL-Hashmi 2008). Wastes and by-products materials should be considered as valued supplies sources just pending proper treatment and function. Plastic wastes are common kinds of wastes, and it cause an unsafe influence environmentally for their long biological disintegration period. Thus, the use of such materials in new creations is a practical technique to reduce its harmful effects (Ismail and AL-Hashmi 2008) strengthen the reused plastics drop is by repeatedly reusing. Henceforth, plastic wastes will end in waste dump. Recurrently considers as an alternative of recycling, if plastic wastes utilized to use as aggregates in concrete, it will combine an improvement to the construction engineering. Comparing the plastic wastes as coarse aggregate to the normal aggregates it will be lighter in weight, and increase crushing resistance. Substitution of ordinary coarse aggregate with plastic wastes by percent of 20% achieved the better value of compressive strength (Subramani and Pugal 2015). Similar results were approved by (Abdulabbas &Abd-Alridha, 2016) in their study. Recycling of rubber, or reuse of tires, is the recycling activity of waste materials from tiers that are not properly maintained for use because of their deterioration or irreparable damage (Azmi et.al. 2008) damaged tires considers one of the major source waste, due to the its mass production, the ecological challenges of this tires are due to its permanence, and materials components in the tires frame (Balaha et.al. 2007) these tires can deplete valuable area in west storage due to its non-biologically degradable materials and highly persistent (Scrap Tires 2010) Tires became the main targets of recycling by using the modern technologies like pyrolysis and thermal decomposition despite the strength of this materials. Final tire applications include fuels (tire-derived), rubbers production, floor coatings, improved asphalt made from rubber and new tires (Scrap Tires 2010) On the other hand, the use of minerals as cans is now very common and safe, especially in liquid materials. Empty metal cans and glass bottles for soft drinks are produce a large amount of mineral waste. This is an environmental problem where it is difficult to analyze mineral wastes.

2. Materials and Methods

Materials

Cement: Ordinary Portland cement (O.P.C.)(ASTM C 150Type I).
Sand: The sand used in this research was natural sand.
Course Aggregate: Crushed gravel with a maximum size of 20 mm within the limits of Iraqi specification IQS 45/1984 were used as course aggregate.
Water : Normal tap water was used throughout the research.
Plastic Bottle Caps: Polyethylene Terephthalate (PET, PETE or polyester) is usually employed in, water and juices bottles and several food products. PET provides very good alcohol and oil properties, general safe chemical resistance (taking into account that acetone and ketones will attack PET) and a high level of tensile strength and impact resistance. The steering process is concerned with developing the characteristics of the gas barrier, humidity and impact strength. This item does not provide resistance to extreme temperature functions, maximum temperature 93 ° C (ebottles).

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Plastic bottle caps were deformed into 10 x 10 mm parts, as shown in Picture 1



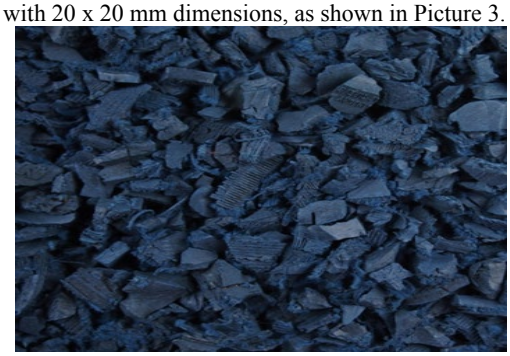
Picture 1: Plastic bottle caps

Metal bottles caps and pull-tab of cans: The caps of metal bottles are treated across machinery that cuts the appropriate form and folds the ends and its created from thin steel layers. Cans of liquids made commonly of aluminum, however they include additional quantities of metals. These are usually 1% of Mg, 1% of Mn, 0.4% of Fe, 0.2% of Si, and 0.15% of Cu (William and John 1991).The lid is formulated of aluminum with additional magnesium and a lesser amount of manganese than the frame of the can, so normally the lid made of tougher alloy than that used for rest of the can and significantly thicker than the walls. (William and John 1991). Rough aggregate was used from the metal bottles caps and pull-tab of cans, 20 mm was the largest size of aggregated waste materials, as shown in Picture 2.



Picture 2: Metal Bottle Caps and Pull-Tab of Cans

Tire is built up generally by rubber: there is a small difference between the normal car tires and heavy truck tires. Rubber consists of a mix of elastomers, polyisoprene, polybutadiene and stirene-butadiene (Bekhiti et al. 2014). Stearic acid (1.2%), zinc oxide (1.9%), extender oil (1.9%) and carbon black (31.0%) are also of the fundamental materials in tires. The steel amount is usually about 15%, and it has more implication for the heavy trucks tires (Bekhiti et al. 2014). In this work, steel was detached. Tires rubber pieces with 20 x 20 mm dimensions, as shown in Picture 3.



Picture 3: Tires Rubber Shreds

Gum Arabic: Gum Arabic is a compound, molecularly forms are vary according to the plant formation of the gum to some amount of acidic polysaccharide. it has a great degree of incredible solvency in water and this make it sole among the regular hydrocolloids. While it is insoluble in the biggest part natural solvents and oil. It is dissolvable in fluid ethanol more 60% than ethanol (Saleh and Bala 2010). With glycerol and ethylene glycol may grabbed the constraint of dissolvability. High viscosities are not found with Gum Arabic until centralizations of right around 40-50% are accomplished. Even though all gums structure unbelievably viscus solutions at little groupings of around 1-5%. This ability to grow incredibly focused arrangement is directed to the praiseworthy balancing out and the Gum Arabic emulsify properties as joined with extraordinary of unsolvable amounts materials (Saleh and Bala 2010).Standards designed for high-quality Gum Arabic are delineated in the USA Pharmacopeia USP 23 and by (European Union specification (E – 414)) .

Gum Arabic crushed to be as fine grind, and melted in water to get its liquid as a chemical addition before usage as shown in Picture 4 and 5.



Picture 4: Gum Arabic



Picture 5: Crushed Gum Arabic

Mix Proportions: British mix design method were used to made a mixtures of concrete with compressive strength of 35 MPa. at an age of 28 days (B.S. 5328, Part 2:1991). The mixtures proportions listed in table 1. Eight concrete mixtures were arranged in total. The performance of the mixtures were evaluated by performing the below tests:

-compressive strength
- flexural strength.
- Ultrasonic pulse velocity (UPV)
- splitting tensile strength
- water absorption, and density.

3. Results

Compatibility of cement and Gum Arabic: To evaluate the compatibility of cement - Gum Arabic mixture, slump test was achieved considering the proportion of water lessening for concrete mixes with Gum Arabic. The obtained results represented in Figure 1. It showed that when Gum Arabic was combined (in liquid state) it will not altered the slump test results if the ratios of Gum Arabic is between 0.1% - 0.3% of cement weight to the concrete mixture. However, with a ratio of 0.4% they had obvious influence on the slump test result with same water-cement ratio. While, the mixture was improved by decreasing the water-cement ratio when it was used with ratios up to 0.4%. The accepted slump test result with ideal Gum Arabic ratio was found about 0.6%.

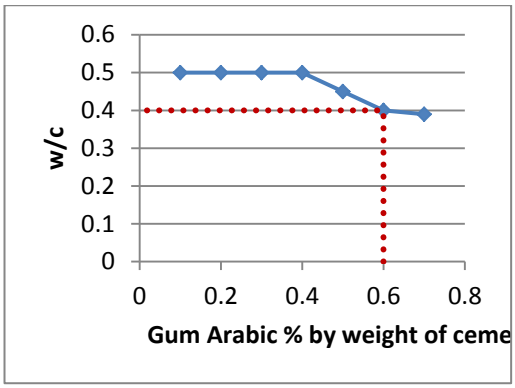


Fig.1: water-cement ratio of concrete mixes verses Gum Arabic

Gum Arabic and segregation: Behind 2-3 minutes from beginning of wet mixing, the fresh concrete with Gum Arabic was looked weighty, adhesive and thick. The air drained and time shrunken due to these compaction properties and the concrete ingredients inside the moulds became more stable. The compaction time was about 55±10 second.
the high specific gravity of Gum Arabic gives this performance. viscosity and adhesive property is completely associated to specific gravity. specific gravity directly proportional to adhesiveness with solid fine ingredients and provided a strong bonds (Nuhu A. A. and Abdullahi A.T., 2009).

Compressive strength: For sustainable construction, achievement of high compressive strength is normally favorable. However, this is not the single target. Further aims should be considered into account, for instance employing different construction material or distinctive additions that are evenhanded for environment besides protecting the natural sources. From Figure 2 many reflections could be notified; in overall when waste materials were used, the compressive strength reduced obviously, while the compressive strength improved in the ages of testing when using Gum Arabic.
The use of Gum Arabic in concrete mix without waste materials (C2) increase the compressive strength about 3.79 MPa and 4.64 MPa at ages of 7 and 28 days, respectively in comparison to reference mix (C1). A drop in the compressive strength(C3) by about 6.03 MPa and 5.88 MPa at ages of 7 and 28 days respectively relative to C1 this occurred due to the use of metal bottles caps and pull-tab of cans as coarse aggregate. The adding of Gum Arabic to the mix with these waste materials (C4) enhanced the compressive strength by about 3 MPa and 4.1 MPa at ages of 7 and 28 days respectively compared with C3. Besides a reduction in the compressive strength by 3.03 MPa and 1.78 MPa at ages of 7 and 28 days, respectively in comparison to C1.

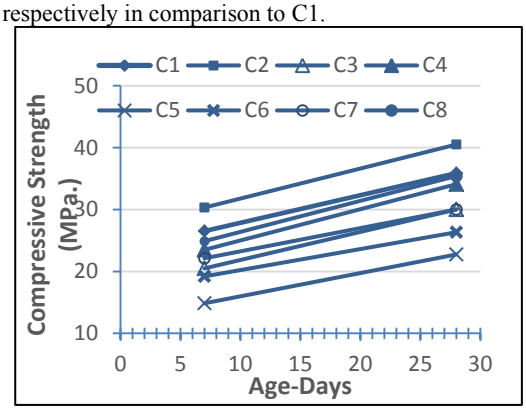


Fig. 2: Compressive strength test results.

Similarly performances were observed in mixes comprise the plastic bottle caps and mixes with tires rubber shreds. The applying of plastic bottle caps as coarse aggregate (C5) decreased the compressive strength by 11.67 MPa and 13.14 MPa at ages of 7 and 28 days respectively compared with C1. The utilization of Gum Arabic with these waste materials (C6) developed the compressive strength about 4.35 MPa and 3.61 MPa at ages of 7 and 28 days respectively compared to C5. However, relative to C1, there was a reduction in the compressive strength by 7.32 MPa and 9.53 MPa at ages of 7 and 28 days, respectively. The employment of tires rubber shreds in concrete mix as coarse aggregate C7 decreased the compressive strength by 4.41 MPa and 5.86 MPa at ages of 7 and 28 days, respectively compared with C1. The improvement in compressive strength when using Gum Arabic (C8) was 2.76 MPa and 5.4 MPa at ages of 7 and 28 days, respectively compared with C7. In addition, the reduction in compressive strength relative to reference mix was only 1.65 MPa and 0.46 MPa at ages of 7 and 28 days, respectively.

Flexural and Splitting Tensile Strengths: From Figures 3&4, flexural strength and splitting tensile strength had the same tendency to that of the compressive strength. The application of the waste materials individually (without Gum Arabic) reduce the strength of concrete, and the presence of Gum Arabic in mixes enhance the strength.

For mix with metal bottles caps and pull-tab of cans (C3), the reduction in flexural strength and splitting tensile strength were 0.707 MPa and 0.84 MPa, respectively compared with C1. However, the use of Gum Arabic C4 upgraded the two types of strength by 0.761 MPa and 0.756 MPa for flexural strength and splitting tensile strength, respectively relative to C3. In comparison to C1, C4 showed higher flexural strength by 0.054 MPa and lower splitting tensile strength by only 0.084 MPa.

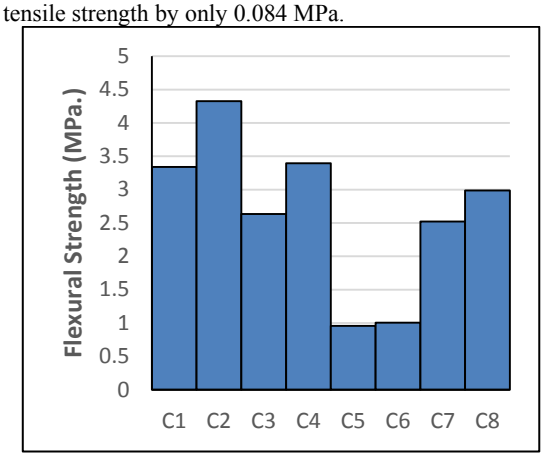


Fig. 3: Flexural strength test results

For mix with the plastic bottle caps (C5) the drop in flexural strength and splitting tensile strength were 2.383 MPa and 1.149 MPa, respectively compared with C1. The employment of Gum Arabic (C6) modernized flexural strength and splitting tensile strength by 0.046 MPa and 0.37 MPa, respectively relative to C5. Although the addition of Gum Arabic to C5 slightly improved these strengths, however, there were a reduction on the flexural strength and splitting tensile strength by 2.337 MPa and 0.779 MPa in comparison to C1.

Table 1: Mixes Proportions

No.	w/c	water Kg/m^3	Cement Kg/m^3	Fine aggregate Kg/m^3	Coarse aggregate Kg/m^3	Gum Arabic Kg/m^3	Waste Materials	Slump mm
C1	0.5	220	440	578	948	—	—	100
C2	0.4	176	440	578	948	2.64	—	150
C3	0.5	220	440	578	711	—	(compacted bottles caps and pull-tab of cans) 25% as a replacement of coarse aggregate volume	100
C4	0.4	176	440	578	711	2.64	(compacted bottles caps and pull-tab of cans) 25% as a replacement of coarse aggregate volume	150
C5	0.5	176	440	578	758.4	——	plastic bottle caps 20% as a replacement of coarse aggregate volume	100
C6	0.4	176	440	578	758.4	2.64	plastic bottle caps 20% as a replacement of coarse aggregate volume	150
C7	0.5	176	440	578	711	——	tires rubber shreds 25% as a replacement of coarse aggregate volume	100
C8	0.4	176	440	578	711	2.64	tires rubber shreds 25% as a replacement of coarse aggregate volume	150

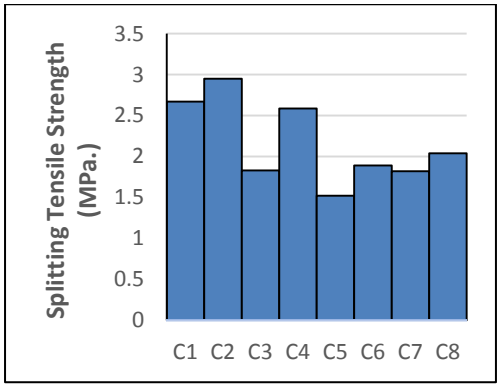


Fig. 4: Splitting tensile strength test results

In mix with tires rubber shreds (C7), there were a decrease in flexural strength and splitting tensile strength by 1.521 MPa and 0.85 MPa, respectively compared with C1. The use of Gum Arabic (C8) improved flexural strength and splitting tensile strength by 0.467 MPa and 0.22 MPa, respectively C7. In addition, the decrease in flexural strength and splitting tensile strength for C8 relative to C1 were 0.353 MPa and 0.63 MPa, respectively.

Water Absorption: It can be seen Figure 5 that the water absorption percent in the mixes comprise waste materials slightly decreased in comparison with the reference mix. The decrease were about 0.051%, 0.044%, and 0.15% for mix with metal bottles caps and pull-tab of cans (C3), mix with plastic bottle caps (C5), and with tires rubber shreds (C7), respectively. While, in the mixes that contain Gum Arabic the absorption percent clearly increased. The increase in absorption percent's compared with reference mix were about 1.746%, 1.573%, 1.462% and 1.452% for mix with Gum Arabic (C2), mix with metal bottles caps and pull-tab of cans (C4), mix with plastic bottle caps (C6), and with tires rubber shreds(C8), respectively.

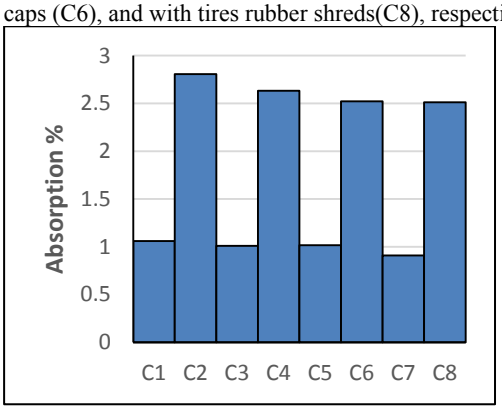


Fig. 5: Absorption test results.

Density: It is obvious from Figure 6 that the density was decreased in all mixes compared with the reference mix. The maximum reduction occurred in mixes included Gum Arabic (i.e. C2, C4,C6, and C8). The decrease in density was 81.55 kg/m^3, 102.91 kg/m^3, 240.79 kg/m^3, and 99.5 kg/m^3 for mix with Gum Arabic (C2), mix with metal bottles caps and pull-tab of cans (C4), mix with plastic bottle caps (C6), and with tires rubber shreds (C8), respectively.

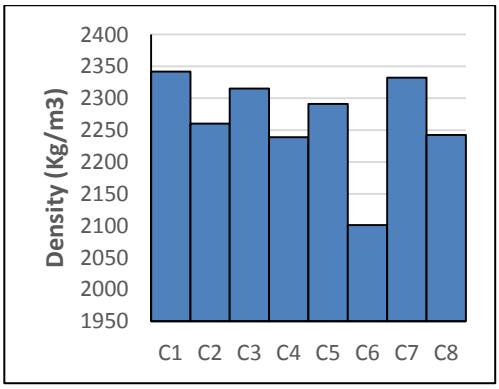


Fig. 6: Density test results.

3.5 Ultrasonic Pulse Velocity (UPV)

It can be seen from Figure 7 that the ultrasonic pulse velocity that the presence of Gum Arabic without any replacement for the aggregate (C2) improved the UPV results by 0.137 Km/s relative to C1. Figure 7 also shows that by replacing 25% of coarse aggregate by compacted bottles caps and pull-tab of cans (C3), the UPV results increased slightly. However, the addition of Gum Arabic to that mix (C4) increased the UPV by 0.20 Km/s. One the other hand, replacing 20% of coarse aggregate by plastic bottle caps (C5) reduced the UPV by 0.082 Km/s. the addition of Gum Arabic to that mix (C6) improved the UPV by 0.076 Km/s and showed close results to C1. In contrast, replacing 25% of coarse aggregate by tires rubber shreds (C7) improved the UPV by 0.017 Km/s. However, the addition of Gum Arabic to that mix (C8) reduced the UPV by 0.103 Km/s.

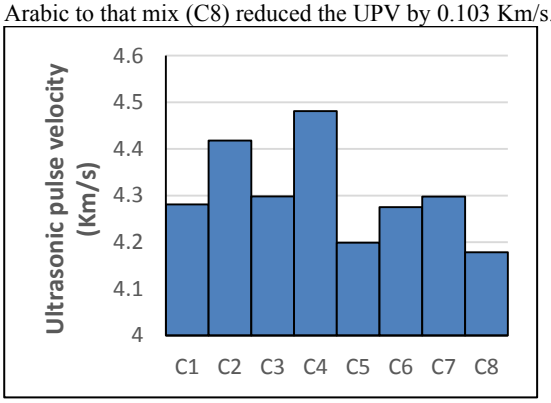


Fig.7: UPV test results.

1. Discussions

The using of waste materials as partial replacement to coarse aggregate decreased the mechanical strengths of concrete. This performance of mixes associated to wastes properties which including the characteristics of rigidity and flexibility of these waste type.

The mechanical strengths of concrete was developed by using Gum Arabic. This development in strengths might be attributed to the saving in (w/c) when adding Gum Arabic. Additionally to its polysaccharide organic constituents render it very responsive as the multiple diradical groups (-COOH) existent in it act in response with the base concrete to provide strong bonds (Nuhu A. A. and Abdullahi A.T., 2009). The water absorption percent was increased and the density was decreased in concrete mixes with Gum Arabic. This behavior is not completely understood, and it might be related to gas growth from Gum Arabic when it attracted water. On the other hand, this is not an unfavorable influence as its low melting point will confirm all gasses are grown before casting solidification (Nuhu A. A. and Abdullahi A.T., 2009).

The UPV test may not give respectable index when waste materials were added to the mixes by reason of the waves transmit with various rapidity within these materials (Abdulabbas &Abd-Alridha, 2016).

4. Conclusions

When proportions of 25% compacted bottles caps and pull-tab of cans, 20% the plastic bottle caps, and 25% tires elastic shreds utilized as a fractional substitution of coarse aggregate volume in concrete diminished the mechanical properties of cement to some degree not as much as reference blend and they were improved by utilizing Gum Arabic

The profiting of Gum Arabic as fluid in concrete blends is built up the mechanical properties of concrete, diminished isolation, anyway raised the absorption percent and declined the thickness of cement.

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