Utilization of Gum Arabic to Improve Waste Materials Uses in Concrete

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Abstract-- **This study aims to reveal the influence of Gum Arabic and waste materials on concrete properties. The waste materials comprised metal cans and bottles caps of juices and soft drinks. The waste materials was used in two manners; the first, it was used as fibers and was added with 15% by weight of cement. The second, it was used with 25% as a replacement of coarse aggregate volume. Gum Arabic was dissolved in water to use it in liquid state. The dosage of Gum Arabic was specified by using slump test. The properties of concrete specimens were evaluated by measuring compressive strength, flexural strength, splitting tensile strength, absorption percent, density, and ultrasonic pulse velocity. The using of bottles caps as waste materials fibers in concrete increased compressive strength, flexural strength, and splitting tensile strength. While the using of walls of cans as waste materials fibers in concrete decreased them. When compacted bottles caps and pull-tab of cans was used as a replacement of coarse aggregate volume in concrete, the mechanical properties of concrete slightly less than reference mix and they were improved by using Gum Arabic. The using of Gum Arabic in liquid state in concrete mixes improved compressive strength, flexural strength, splitting tensile strength, decreased segregation, increased the absorption percent and decreased the density of concrete.**

Index Term-- **Waste Materials, Gum Arabic, Fibers, Portland Cement, Mechanical Properties of Concrete.**

1. INTRODUCTION

Today the construction industry is in need of finding effective materials for increasing the strength of concrete structures with low cost, and with less environmental damages. Use of metals as containers has become popular and safe now, especially to carry the liquids. In spite of the inherent advantages and disadvantages existent in its disposal. Large quantities of metal waste are generated from empty metal cans and bottles caps of juices and soft drinks. This is an environmental issue as metal waste is difficult to biodegrade and involves processes either to recycle or reuse.

Concrete in general weak in tensile strength and strong in compressive strength. To overcome this serious defect partial incorporation of fibers is practiced. Waste material fibers reinforced concrete is an interesting topic discussed by numerous researchers in the last two decades. Murali et.al [1] observed that soft drink bottle caps reinforced blocks exhibited an increase in flexural strength of concrete by 25.88%. Venu M. and Neelakanteswara R. Paturu [2] investigated the impact of cement bags waste (High Density Polyethylene (HDPE)) on concrete, and found that when the percentage of fiber in concrete was 3.5% its compressive and tensile strength increased considerably. Kandasamy R. and Murugesan R. [3] added 0.5% by volume of polythene (domestic waste polythene bags) fiber to concrete and the cube compressive strength, increased by 5.12%, 3.84% and 1.63% respectively.

An attempt has been made in the present investigation to study the influence of addition of waste materials of metal cans and bottles caps of juices and soft drinks as fibers and as coarse aggregate on concrete properties, and solving segregation problem for these waste materials during compaction and enhancing mechanical properties of concrete by using Gum Arabic.

2. GENERAL PROPERTIES OF CANS AND BOTTLES CAPS

Cans of juices and soft drinks consist mostly of aluminum, but they contain small amounts of other metals as well. These are typically 1% magnesium, 1% manganese, 0.4% iron, 0.2% silicon, and 0.15% copper**.** The lid is made of a stronger alloy than that used for the base and sides of the can. It is made of aluminum with more magnesium and less manganese than the rest of the can. This results in stronger metal, and the lid is considerably thicker than the walls. Metal bottles caps are made from thin sheets of steel. They are processed through machinery that cuts the correct shape and crimps the edges.

3. GENERAL PROPERTIES OF GUM ARABIC (ACACIA GUM)

Gum Arabic is a complex, slightly acidic polysaccharide. The precise chemical and molecular structure differs according to the botanical origin of the gum. It is unique among the natural hydrocolloids because of its extremely high solubility in water. Gum Arabic is insoluble in oil and in most organic solvents. It is soluble in aqueous ethanol up to a limit of about 60% ethanol. Limited solubility can also be obtained with glycerol and ethylene glycol. Whereas most gums form highly viscous solutions at low concentrations of about 1-5%. High viscosities are not obtained with Gum Arabic until concentrations of about 40-50% are obtained. This ability to form highly concentrated solution is responsible for the excellent stabilizing and emulsifying properties of Gum Arabic when incorporated with large amounts of insoluble matters [4].

Table I
Average Composition of Acacia Gum (Sugar Composition after hydrolysis) [4].

GA lactose	35-45%
Arabinose	25-45%
Rhamnose	4-13%
Glucuronic acids	6-15%
Molecular weight average	250,000
PH solution at 25%	4.4
Intrinsic Viscosity	12ml/g
Brookfield viscosity, solution at 25%	60 rpm 70cp
Protein content	1-2%
Total ashes (Potassium, Calcium& sodium salts)	3-4%
Arabino galactan (AG)	89-98%
Arabino galacto protein (AGP)	1-10%
Glycol proteins (GP) Less than	1%

Standards for good quality Gum Arabic have been defined in the United States Pharmacopeia USP 23 and by European Union specification E – 414 [5] as shown in the table below:

Table II
Standards for Gum Arabic

Arsenic (as As)	≤3ppm
Ash (total)	≤4%
Ash (acid insoluble)	≤0.5%
Heavy metals (as Pb)	≤40ppm
Lead	≤10ppm
Insoluble matter	≤1%
Loss on drying	≤15%
No presence of starch, dextrin or tannins by standard test	

4. EXPERIMENTAL PROGRAM

4.1 Materials:

Ordinary Portland cement (O.P.C.) (ASTM C 150 Type I) [6], natural sand, and crushed gravel with a maximum size of 20 mm were used. Gum Arabic was used in concrete mixes after crushing to be in a form of powder which was dissolved in water to get the liquid of this additive. The waste materials - which involved empty cans and bottles caps of juices and soft drinks - was collected, and divided into two groups:

1.The first group was deformed into the rectangular form with an approximate size of 3 mm wide and 30 mm long and used as a form of fibers. This group was also divided into two groups according to metal strength that it made of:

a. fibers of walls of cans (i.e. the body of cans except the top and the bottom base).

b. fibers of bottles caps.

2. The second group which involves bottles caps and pull-tab of cans, was compacted to use as coarse aggregate. These waste materials was chosen to use as coarse aggregate because of its strong metal. The maximum size of waste materials coarse aggregate was 20 mm.

4.2 Gum Arabic– cement compatibility: In order to assess the Gum Arabic – cement compatibility, the percentage of water reduction for the Gum Arabic mixes, using slump method was conducted. The results of this test are shown in fig. 1. and table III. they showed that Gum Arabic when was added to concrete mixes (in liquid state) at ratios of 0.1%, 0.2%, and 0.3% (by weight of cement) was not affected the slump test results. The addition of Gum Arabic at a ratio of 0.4% had a clear effect on the slump without changing the water cement ratio. When it was used with ratios up to 0.4%, the concrete mixes were modified by reducing the water cement ratio. The ratio of 0.6% was chosen as the optimum Gum Arabic ratio with accepted slump.

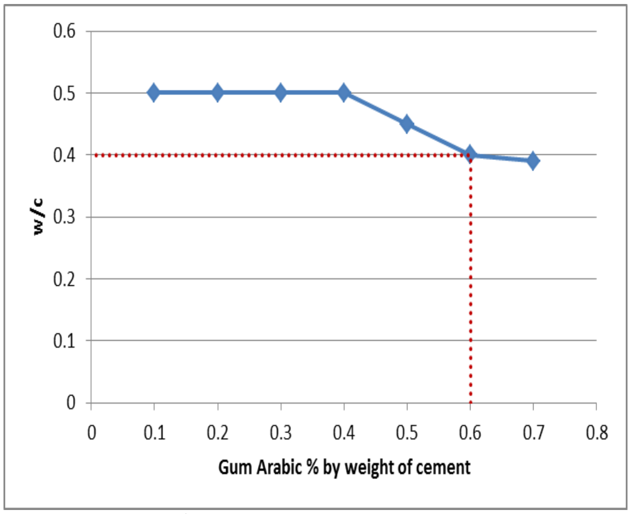

Fig. 1. w/c of concrete mixes which contain Gum Arabic

4.3 Gum Arabic and segregation

The fresh concrete which included Gum Arabic was seemed dense, adhesive and heavy after 2-3 minutes from starting wet mixing. These high density, adhesiveness, and heaviness drained the air and reduced the compaction time and made the concrete ingredients more stable inside the moulds. This behavior accrued as a result of high specific gravity of Gum Arabic. Specific gravity is directly related to viscosity and adhesive property. High specific gravity meant high adhesiveness with solid fine ingredients (like sand and cement particles) and gave strong bonds [7].

4.4 Mix Design:

The concrete mixes were designed according to British mix design method B.S. 5328. Part 2:1991 [8]. The target compressive strength was 35 MPa. at age of 28 days. A total of seven concrete mixes were prepared. The details of these mixes were shown in table III.

Table III
Properties of mixes used.

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
M1	0.5	220	440	578	948	----	----	100
M2	0.5	220	440	578	948	----	(fibers of walls of cans) 15% by weight of cement	100
M3	0.5	220	440	578	948	----	(fibers of bottles caps)15% by weight of cement	100
M4	0.5	220	440	578	711	----	(compacted bottles caps and pull-tab of cans) 25% as a replacement of coarse aggregate volume	100
M5	0.4	176	440	578	948	2.64	----	150
M6	0.4	176	440	578	948	2.64	(fibers of bottles caps)15% by weight of cement	150
M7	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

5. RESULTS

After the detailed investigation on different strength parameters has been done, the following results have been achieved:

Table IV
Results of tests through this study

No.	Compressive Strength (MPa.) 7- days	Compressive Strength (MPa.) 28- days	Flexural Strength (MPa.) 28- days	Splitting Tensile Strength (MPa.) 28- days	Absorption % 28- days	Density (Kg/m^3)	Ultrasonic pulse velocity Km/sec.
M1	26.53	35.88	3.341	2.670	1.060	2341.82	4.281
M2	20.32	26.33	2.110	1.845	4.278	2340.00	5.698
M3	30.31	39.23	3.730	2.883	0.903	2340.91	4.420
M4	26.50	33.00	2.634	1.830	1.009	2315.18	4.298
M5	31.32	40.52	4.326	2.950	2.806	2260.27	4.418
M6	41.14	48.00	6.039	3.187	2.691	2249.45	4.429
M7	29.50	38.10	3.395	2.586	2.633	2238.91	4.481

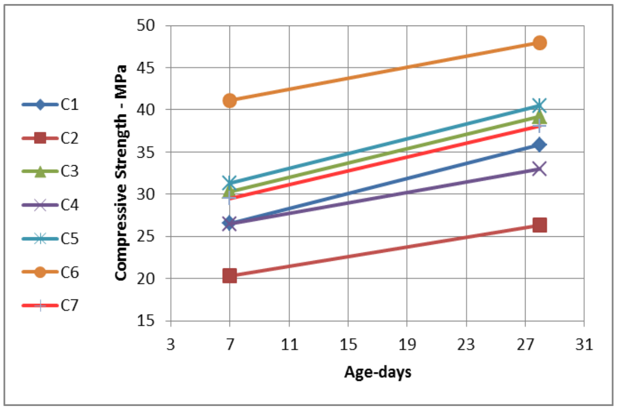

Fig. 2. Development of compressive strength of concrete mixes.

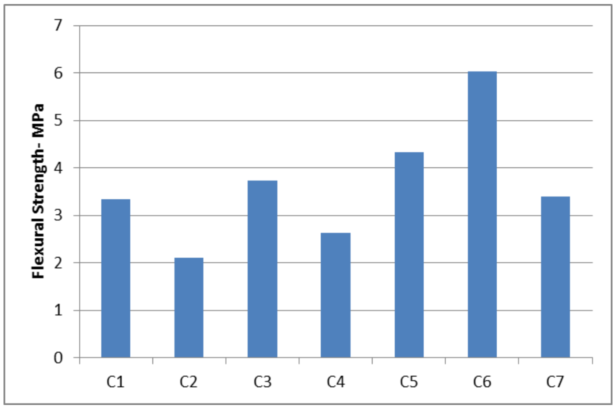

Fig. 3. Flexural strength of concrete mixes at age of 28 days .

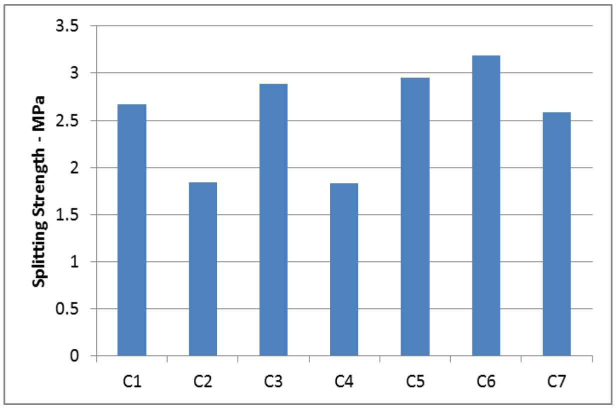

Fig. 4. Splitting strength of concrete mixes at age of 28 days .

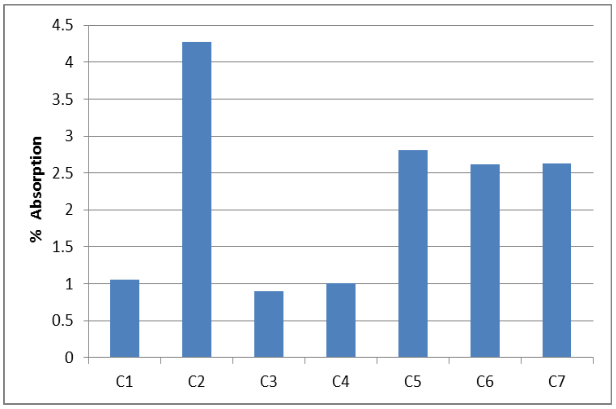

Fig. 5. Absorption test results of concrete mixes at age of 28 days.

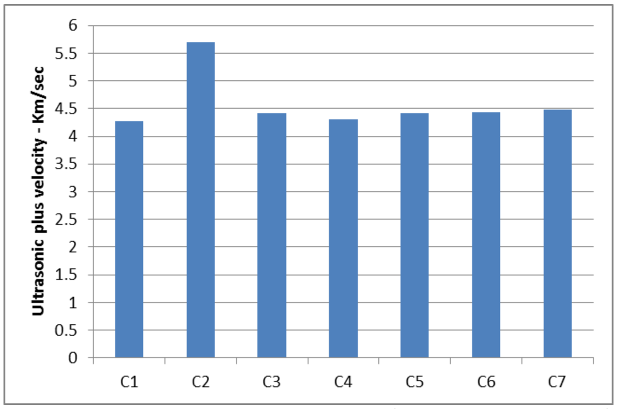

Fig. 6. Ultrasonic puls velocity test results of concrete mixes at age of 28 days.

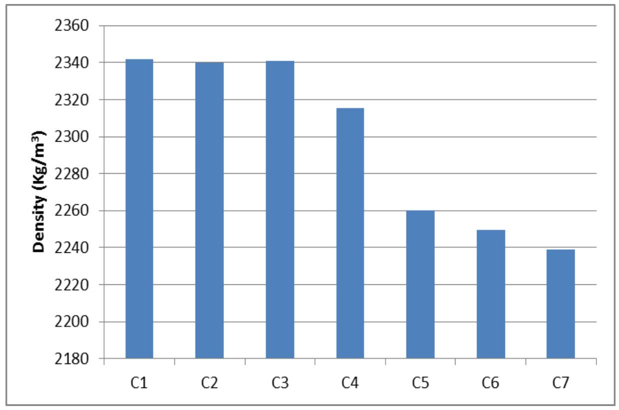

Fig. 7. Density test results of concrete mixes at age of 28 days.

1. When fibers of bottles caps was used, compressive strength, flexural strength, and splitting tensile strength increased (i.e. in concrete mixes M3, and M6) over the reference mix M1. The increase in compressive strength at age of 7 days was about 3.78, and 14.61 MPa. for M3, and M6, respectively. The increase in compressive strength at age of 28 days was about 3.35, and 12.12 MPa. for M3, and M6, respectively. While the increase in flexural strength was about 0.389, and 2.698 MPa. for M3, and M6, respectively. The increase in splitting tensile strength was about 0.231, and 0.487 MPa. for M3, and M6, respectively. It is clear that the maximum increase in strengths was occurred in concrete mix M6 where Gum Arabic was used in addition to fibers of bottles caps.

2. When fibers of walls of cans was used, compressive strength, flexural strength, and splitting tensile strength decreased (i.e. in concrete mix M2) compare with the reference mix M1. The decrease was about 6.21, 9.55, 1.231, and 0.825 in compressive strength at age of 7 days, compressive strength at age of 28 days, flexural strength, and splitting tensile strength, respectively. The cracks was noticed at the surface of concrete near the reinforcement zone after 14 days age.

3. The decrease in compressive strength - compare with the reference mix - at age of 7 days was not that significant and it was about 0.03 MPa. Also, compressive strength at age of 28 days, flexural strength, and splitting tensile strength decreased and they were about 2.88, 0.707 and 0.84 MPa., respectively, when compacted bottles caps and pull-tab of cans was used as coarse aggregate (i.e. in concrete mix M4). However, the strengths were improved when Gum Arabic was used in addition to the waste materials aggregate (i.e. in concrete mix M7). The increase was about 2.97, 2.22, 0.054, and 0.016 in compressive strength at age of 7 days, compressive strength at age of 28 days, flexural strength, and splitting tensile strength, respectively.

4. Compressive strength, flexural strength, and splitting tensile strength increased over the reference mix M1, when Gum Arabic was used alone without any reinforcement (i.e. in concrete mix M5). The increase was about 4.79, 4.64, 0.985, and 0.28 in compressive strength at age of 7 days, compressive strength at age of 28 days, flexural strength, and splitting tensile strength, respectively

5. The using of waste materials singly without Gum Arabic had not obvious effects on the results of density test (i.e. in concrete mixes M2 and M3). The decrease slightly appear in M4 and it was about 26.63 Kg/m^3. While the using of Gum Arabic in concrete mixes decreased the results of density test clearly. The decrease was about 81.55, 92.36 and 102.99 in concrete mixes M5, M6 and M7, respectively.

6. The using of Gum Arabic had noticeable effects on absorption percent (i.e. in concrete mixes M5, M6, and M7). The increase was about 1.476, 1.631, and 1.573% in concrete mixes M5, M6 and M7, respectively. While the changes in absorption percent were not that noteworthy in concrete mixes without Gum Arabic (i.e. in concrete mixes M3 and M4). The decrease was about 0.157 and 0.051 in concrete mixes M3 and M4, respectively. The clear increase in absorption percent in concrete mix M2 was due to the cracks on the surface of concrete.

7. The ultrasonic puls velocity for all concrete mixes converged except M2. The increase of ultrasonic puls velocity in M2 was about 1.417 Km/sec. while the increase in other mixes was about 0.139, 0.017, 0.137, 0.148, and 0.20 Km/sec. in concrete mixes M3, M4, M5, M6, and M7, respectively.

6. DISCUSSIONS

The best reinforcement of concrete was obtained when fibers of bottles caps was used. This is because bottles caps are made of steel, and they are thicker than the walls of cans. In addition to their meandering surface when were deformed to be fibers because of their crimped edges. The meandering surface increased the bond between fibers and concrete.

The using of fibers of walls of cans as reinforcement materials, decreased mechanical strengths of concrete because walls of cans are made of alloy involves mostly aluminum, which is weaker than steel. The smooth surface of walls of cans decreased the bond between fibers and concrete. Because of the weak bond between fibers and concrete, the cracks appeared at the surface of concrete near the reinforcement zone after 14 days age.

The using of Gum Arabic improved the mechanical strengths of concrete. The increase in strengths could be due to the reduction in (w/c) when using Gum Arabic. In addition to its polysaccharide organic components render it very reactive as the multiple diradical groups (-COOH) present in it react with the base concrete to give strong bonds.

In concrete mixes with Gum Arabic, the absorption percent was increased and the density was decreased. This behavior is still not fully understood, and could be as a result of gas evolution from Gum Arabic when it absorbed water. (However this is not a detrimental factor as its low melting point will ensure all gasses are evolved before casting solidification [7]).

The converged of ultrasonic puls velocity test results for all concrete mixes except M2 was accepted. This is because the metal bars which have diameter equal to or less than 6 mm have no effects on ultrasonic puls velocity [9].

7. CONCLUSIONS

1. The using of bottle caps as waste materials fibers in concrete enhanced the mechanical properties of concrete. While the using of walls of cans as waste materials fibers decreased the mechanical properties of concrete.
2. When compacted bottles caps and pull-tab of cans was used of 25% as a replacement of coarse aggregate volume in concrete, the mechanical properties of concrete slightly less than reference mix and they were improved by using Gum Arabic.
3. The using of Gum Arabic in liquid state in concrete mixes improved the mechanical properties of concrete, decreased segregation, but increased the absorption percent and decreased the density of concrete.

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