Analyzing the Use of Gum Arabic as a Concrete Admixture

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Abstract: This study revolves around the use of Gum Arabic as retarding water-reducing admixture. Retarding agents are used to counter the hydration process of cement as its slowdowns the retarding process especially in the areas where the temperature is a bit elevated. Gum Arabic which consists of soluble sugar tends to use it as a water-reducing admixture. Many factors affect the use of retarders however, the economic factor is one of the reasons to use this retarding agent as other agents are much more expensive and are far from the reach of normal consumers. A pure form of Gum Arabic is used in concrete mixes after being crushed into powder. It is extracted from (Hashab) trees (in western Sudan). Mechanical properties have been studied using Gum Arabic with a substitution level of 0.5%, 1%, and 1.5 % corresponding to cement and a varying w/c ratio from 0.45-0.6 The addition of gum Arabic increases the slump and decreases the water demand of concrete. However, the compressive and flexural strength tends to decrease with an increase in gum Arabic substitution having the same w/c ratio. The sample containing a w/c ratio of 0.45 and gum Arabic addition of 1.5% showed better results among all the mixes.

Keywords: Gum Arabic; Self-Compacted Concrete; Mechanical Properties; Waste Material.

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1. Introduction

The growing need for modified concrete has played a vital role in the development of concrete in recent decades. To meet the need, several experimental studies were carried out from time to time. The purpose of these studies was not only to meet the needs but also to provide a solution that has to be economical having better performance of concrete. The properties of concrete can be modified using various chemical admixtures. Admixtures are chemical additions to concrete which introduced at the time of mixing of grout or concrete to influence its properties. The admixture being used in the construction sector comprises both organic and inorganic depending upon the need for improvement in the properties of

concrete. The advantages obtained depend upon the quantity and type of admixture being used in the concrete. The use of chemical admixtures in concrete is increasing to influence the properties and have the required outcomes. The most preferable admixture is the one which is cost-effective and locally available, therefore admixtures like various gum namely guar gum, well a gum is being used as admixture. However, the use of gum Arabic-like gum is unconventional as an admixture so far.

Admixtures are generally classified on their effects and function obtained as per the classification of ACI. The admixture is classified into seven groups of which one is water reducing and retarding agents. Water-reducing admixtures are the type that helps to modify the concrete by achieving greater workability at low water content, increasing in strength without any addition of cement, maintaining the same w/c ration, and increasing the workability. Khayat [1] classified Gum Arabic (GA) as a viscosity modifying agent (VMA). Cement-based materials are made more stable and cohesive with polysaccharides called VMAs. It increases the capacity for retaining water and improves its ability to segregate and bleed. Hardened concrete performs better due to the improved flow ability of mortar. Self-compacting concrete has also been made workable and deformable with these additives. Adding these admixtures to mortar will prolong both its initial and final setting time. In the construction industry, specifically in climates with hot temperatures, these types of admixtures are commonly used since they allow for a prolonged plastic state of concrete, thus facilitating transportation, laying, and finishing.

Previous studies indicate the use of gum proved to be very effective in water-reducing modification of concrete. American Concrete Institute [2] classifies gum Arabic (GA) as a powerful water-reducer. Gum Arabic is the gum that is easily available yet it has not been exploited extensively in the construction sector. Sudan is the biggest manufacturer of Gum Arabic within side the globe which produces 70-85% of global production, and produces maximum of Gum Arabic in Sudan from the tree Acacia Senegal (in Arabic: Hashab) is the tree located certainly within side the semi-desolate tract in Africa and a few regions of Asia and the Sudan is characterized with the aid of using the presence of the biggest belt of Acacia Senegal within side the west. It originates from south of river Zambezi, Africa and it is the largest exporter of Gum Arabic globally. It is obtained by cutting the bark of a tree, the gum is a sticky fluid material and its color varies from pale to orange-brown when solid and off-white when crushed into powder. The current studies focus on the use of gum Arabic as an admixture in concrete. Gum Arabic can be used as an emulsifier admixture and supplementary cement material to address gaps between conventional and pozzolanic

concretes [3]. The gum Arabic was used in a soluble state after being crushed into powder. Several mixes were made to make the most effective ratios which turned out as 0.5%, 1%, and 1.5%. The prepared samples were tested for compressive strength the enhanced workability was achieved by using the gum. The advancement of these economical and locally available admixtures seems to be increasing in the construction industry.

This study aims to study the behavior of Gum Arabic as a locally available natural additive and find out whether it influences concrete properties. A wide range of properties can be obtained by appropriately selecting the constituent materials and adjusting their proportions in concrete, which has been extensively used in construction since the dawn of the 20th century. For this study, the concrete design mix was used with the ratios selected of gum Arabic as 0.5%, 1%, and 1.5% of the total cement content used in the mixes. This study was mainly oriented on the application of natural admixture in the development of concrete its Mechanical properties and the feasibility of modified concrete developed using natural Admixture.

2. Materials And Method

Materials used for gum Arabic concrete are as follows:

2.1. Portland Cement

Concrete composed of Portland cement is the principal concrete of the construction industry across the globe. The cement used in the study was OPC type I. physically, the cement was clean, even in color, and free from any lumps above all the economic factors, availability and adaptive attributes of this constituent make it highly consumable across the globe, as evident from many constructions and Service requirements, and minimal maintenance. The initial and final setting time of cement was observed as 50min and 540min respectively. The specific gravity of cement was 3.13.

2.2. Aggregates

Although cement is the most important component of concrete, well-graded aggregates maintain their strength. Aggregates carry 60-80% of the volume and 70-85% of the mass of concrete. It is also vital for the strength, thermal and elastic properties of concrete, dimensional stability, and volume stability. Shrinkage is more likely to affect cement. Including aggregate in the concrete mix can control the shrinkage level and prevent cracking.

For the study, aggregate from "SAKHI SARWAR' obtained from the crushing of mountains was used for the research. Clean, hard, strong aggregates free of absorbed chemicals or coatings of clay and other fine materials that could deteriorate concrete are required for a good concrete mix. The water absorption and specific gravity were observed as 0.7% and 2.65 correspondingly. The bulk density was found to be 1600kg/m^3. The sand used in this study was “CHENAB SAND” having 2.5 specific gravity and 0.5% water absorption.

2.3. Gum Arabic

Gum Arabic was developed as an admixture in the concrete. Gum Arabic which is a locally available material makes it economically preferable. In this study, the use of gum Arabic in liquid form was used to study its effect on the initial and final setting time of concrete. In hot areas properties that are sensitive to temperature increase the initial and final setting time, workability, hydration, and bleeding and flow ability of mortar. GA as shown in ***Figure 1*** is readily available in these hot areas and was used as an admixture for mortar. Due to costly derivation processes, the majority of the market's available water-reducing and set-retarding admixtures have high prices, raising the final cost of such concrete. Also manufactured admixtures require special storage conditions and have a short shelf-life. Raw gum Arabic does not have an expiry date so can be used as a feasible alternative [4].

Gum Arabic (GA) as a viscosity modifying agent (VMA). Cement-based materials are made more stable and cohesive with polysaccharides called VMAs. It increases the capacity for retaining water and improves its ability to segregate and bleed. Viscosity modifiers are high molecular weight, water-soluble polymers used to raise the viscosity of water [5]. Such compounds increase the cohesiveness of fresh concrete, reducing its tendency to segregate and bleed. They work by joining their long molecules to the water molecules, a process that hinders the free relocation of water. These admixtures help improve the properties of lean concretes with low cement contents, concrete placed underwater, and concretes or grouts that are placed by pumping. In the latter case, they reduce pumping pressures through improved lubricating properties, as well as reducing segregation tendencies. Anti-washout admixtures are substances in this class that are used to improve the cohesiveness of concrete that is placed underwater. When fluid but cohesive concrete is required to resist bleeding and segregation, viscosity-modifying admixtures are added to concretes used in areas with extreme congestion caused by reinforcement configurations or unusual geometry form.

Temperatures make the workability of concrete much harder, for this purpose various kinds of admixtures are used but they're not economical. Gum Arabic is naturally occurring gum

obtained from the bark of trees. The modification of concrete depends upon the various dosages of admixture used. GA has been shown to contain reducing sugars as well as gluconic which makes it a good set retarding and water-reducing admixture. Sucrose and glucose are excellent retarders according to [6] and they improve the workability of concrete. The same reducing sugars are also contained in Lignosulphate which is a good commercial set retarding admixture [7]. Gum Arabic can also be used as a setting time retarder admixture to mitigate the effect of hot weather climate on concrete, improve workability, and reduce water absorption, especially for structures built in a damp environment [8].

Figure 1 Gum Arabic

2.4. Mix Design

It is the ratio of the components of concrete, such as cement, sand, aggregates, and water that determines the strength of the concrete. To determine the mix ratio, construction type, and mix design are taken into consideration. The design procedure was by the ACI code. For preparing the mix the determination of properties related to aggregate and sand is carried out in the following way, determine the desired air content, coarse aggregate volume, and sand content then design the paste composition and determine the optimum water-to-powder ratio and super plasticizer dosage in mortar. Finally, the concrete properties are assessed by standard tests.

The optimization of these factors significantly increases the compressive strength of the concrete. The strength of conventional concrete paste is determined by the water-to-cement ratio. This is also true for high-strength concrete but it is also the effect of the porosity within the paste. Further, it is the particle size distribution of the crystalline phases and the presence of in homogeneities within the hydrated paste that must be considered in detail. A reduction in the water/cement ratio will produce a paste in which the cementations particles are initially closer together in the freshly mixed concrete. This results, in less capillary porosity in the hardened paste and hence a greater strength [9].

2.5.Batching Procedure

Concrete can be mixed by hand or using any mixer. Mixing plays a crucial role in developing the required product. The addition of admixture should be done very precisely. To achieve a high strength concrete, the factor that governs the strength of concrete are, the proportion of constituent material, the properties related to aggregate, and the properties related to cement. The process of batching was conducted in a series of steps and the quantities were determined in terms of volume. The steps are following: Predetermined quantities of fine and coarse aggregate were added to the mixer and mixed for 30 seconds, predetermined quantity of cement was added to the mixer and mixed with the aggregates as shown in ***Figure 2***.

Figure 2 Mixing of concrete

The numbers of samples were cast for different tests as shown in

***Figure* 3**. All concrete specimens have been cast and cured according to [10] Compressive, splitting tensile strengths and Flexural strength of concretes were performed according to [11] respectively.

Figure 3 Preparation of moulds

2.6.Fresh properties of concrete

'Fresh concrete' refers to concrete that is fresh from the mixer and just about to go into the forms. Fresh concrete has properties that determine how it behaves over the long run. To

achieve the desired long-term results, fresh concrete needs to undergo some testing as mentioned below.

2.6.1 Workability of Concrete:

The slump test is used to determine how workable new concrete is. This test is performed on fresh concrete in the field before it is placed in forms. Fresh concrete is poured in three equal-volume levels in a cone, and each layer is consolidated by tamping it 25 times with a tamping rod. The cone is then straightened and the concrete sag is measured to the closest 1/4 inch from the top of the slump cone. [12] Was followed to determine the workability of concrete.

2.7. Hardened Properties of concrete

As the name implies, hardened concrete has acquired its shape and has completed the initial set period, and it is no longer plastic. It will not be workable, i.e. the shape or structure will not be able to be changed. It's a stage of "plasticity" where it's fully lost its flexibility. Hardened concrete increases strength with time, therefore it's necessary to keep an eye on its strength and quality. The various properties of hardened concrete can be quantified using a variety of approaches. It is very important to conduct these tests to ensure that the desired properties are achieved.

2.7.1 Compressive strength test

It is the strength of concrete required to resist the compressive load. Measure the ability of concrete blocks to resist failure from cracks. In this test basically, we apply a compressive load and then record the maximum load a specimen can withstand before failure which is equal to the compressive strength of concrete. The chamber examples are projected in steel, cast iron, or any shape made of non-permeable material. Much under serious conditions, the molds utilized should hold their unique shape and aspects. The shape should hold the substantial with next to no spillage. Before putting the substantial blend inside the form, the inside of the shape should be appropriately lubed to work with simple expulsion of the solidified chamber. The blended cement is put into the molds in layers at least 5cm deep. The strokes per layer during the compaction should not be under 30 in number. Compaction should arrive at the basic layers permitting most of the air voids to get away. The examples are put away undisturbed in a spot with a minimum 90% relative dampness at a temperature

of 27° ± 2°C for 24 hours. After this period, the examples are taken and lowered in perfect and new water until the testing age is reached.

The concrete cylinder is cast for standard size and allowed to cure for 14 and 28 days. For testing, three specimens of the same dimensions are cast. Take out the specimen from the curing tank. Remove any excess water from the specimen's surface with a damp cloth. Place the specimen on the compression testing machine's platform in a vertical position. Having pad caps at the ends of the cylinders makes it easier to apply and distribute uniform loads. Before starting to apply the load, make sure that the loading platforms touch the top of the cylinder. At a rate of 315 kN/min, apply the load continuously and uniformly without causing any shock. And carry on loading until the specimen fails. Keep track of the maximum load used. The test is repeated for the remaining specimens.

2.7.2 Flexural strength test

It is also an indirect method to determine the tensile strength of concrete. In this method, we note the maximum stress on the tension face of an un-reinforce concrete beam or slab at the point of failure in bending as shown in

***Figure* 4.**

Figure 4Tested samples

The sample is prepared through mortar i.e. A beam in the specified mold with the tampering usually in three layers with 35 tamping/layer covering the surface to assess an equal distribution. The sample prepared is then set in water for curing. The surface of the bearings is cleaned thoroughly. The standardized rollers are adopted by the proper placing based on the type of test. A set of four rollers is to be applied out of them three are to be liable for rotating about them on the axis. The spacing is set as per the standards adopted. After the sample preparation and curing it is placed in the machine in a correct position. Load is

applied of 4000kg per minute for a specimen of 15cm and 180kg per minute for a 10cm specimen. The rupture is observed and obtained for strength determination.

3. Results And Discussions

This study depicts the use of gum Arabic as an admixture in the development of high-strength concrete. A few mixes of concrete with the addition of different ratios of gum Arabic were developed and tested for the compressive and flexural forces of concrete. The details of these tests are described as under:

3.1. Properties of fresh concrete

Concrete is characterized by several characteristics, including workability, air content, temperature, and setting time.

3.2.Workability

The ease with which concrete can be carried, put, consolidated, and completed without significant bleeding or segregation of elements in the mix is referred to as workability. Concrete's workability can be improved by adding water, but a larger water-to-cement ratio diminishes its strength. As a result, admixtures (plasticizers, super plasticizers, or water reducers) are recommended for improving concrete workability. The slump test is used to determine the workability of concrete as shown in ***Figure 5***. In this study, Slump was 65 mm without gum Arabic, 42mm when 0.5% gum Arabic was added, 69mm when 1% gum Arabic was added, and 85mm when 1.5% gum Arabic was added.

Figure 5 Slump Test on Concrete

The detailed result of the workability of concrete having different content of gum Arabic and W/b ratio is mentioned in

Table 1. It can be seen that with an increase in gum Arabic and a decrease in the w/b ratio, the slump value decreases and then increases in the workability of concrete. The increase in gum Arabic with a constant w/b ratio also increases the slump value of concrete.

Table 1 Slump Value of Different Concrete Mixes

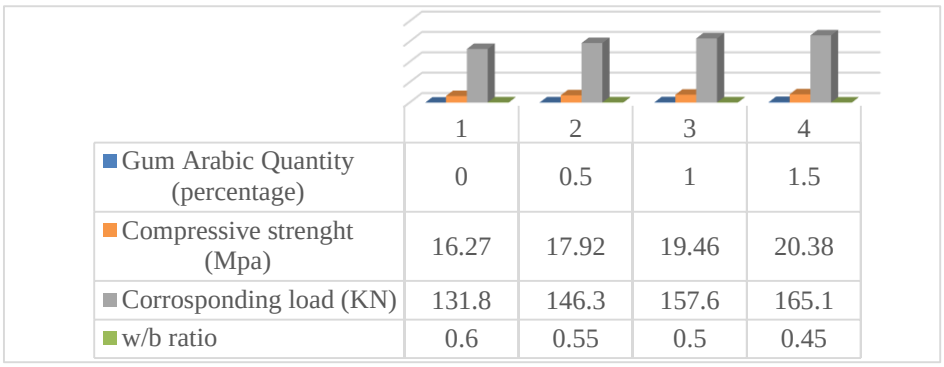
Gum Arabic content (%)	W/b ratio	Slump (mm)	Degree of Workability
0	0.6	65	Medium
0.5	0.55	42	Medium
1	0.50	69	Medium
1.5	0.45	85	Medium

The increase in workability by using different types of gums is reported by different researchers [13, 14]. The increase in workability may be due to the increment in fluidity and zeta potential because of the content of sugar [15]. It may also be due to the dispersion created in cement particles by gum Arabic [16].

3.3. Hardened properties of concrete

3.3.1. Compressive strength of concrete

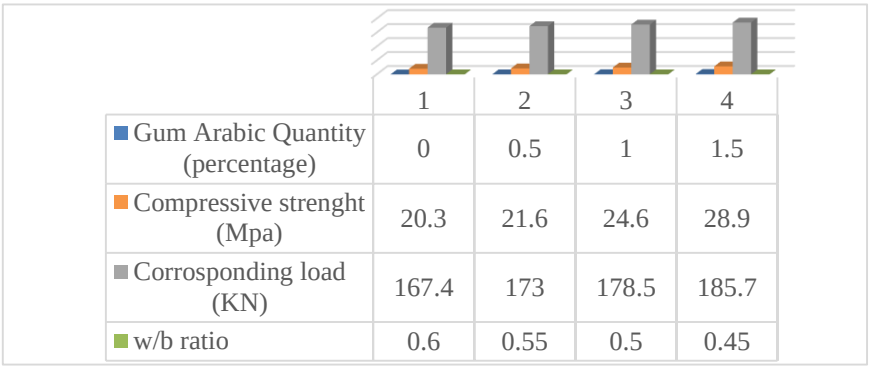
Materials and structures are measured for their compressive strength, or the ability to carry loads on their surfaces without cracking or deflecting. The effect of gum dosage at different dosage levels and w/b ratio at the age of 14 days is shown in **Error! Reference source not found.**. It can be seen that at low-level dosages of 0.5%, there was little change in both workability and compressive strength. This was probably because the concrete's properties were unaffected by low dosages of GA. An increase in compressive strength was observed for all samples as the curing period increased. The increase in the dosage level of gum Arabic had very little effect on the compressive strength of concrete as the increase in strength is because of the lower w/b ratio in the concrete mix. The increase in strength is offered by the lesser w/b ratio. However, the decrease in the w/b ratio does not affect the workability due to the presence of gum Arabic.



	1	2	3	4
Gum Arabic Quantity (percentage)	0	0.5	1	1.5
Compressive strenght (Mpa)	16.27	17.92	19.46	20.38
Corrosponding load (KN)	131.8	146.3	157.6	165.1
w/b ratio	0.6	0.55	0.5	0.45

Figure 6 Compressive strength after 14 days with admixture and different w/b ratios

Similarly, the trend was observed on the 28-day cylinder strength of concrete followed by the 14-day strength as shown in **Error! Reference source not found.**. The increase in gum Arabic dosage level and decrease in w/b ratio increase the compressive strength of concrete at the age of 28 days. The least compressive strength is achieved in gumless concrete having a 0.65 w/b ratio. The highest compressive strength was achieved at a 1.5% dosage of GA with a w/b ratio of 0.45 relative to the control. Concrete with this kind of high strength is typically made by adding more cement. In this study, high-strength concrete was made by using the same amount of cement but reducing the w/b ratio by reducing the water content.



	1	2	3	4
Gum Arabic Quantity (percentage)	0	0.5	1	1.5
Compressive strenght (Mpa)	20.3	21.6	24.6	28.9
Corrosponding load (KN)	167.4	173	178.5	185.7
w/b ratio	0.6	0.55	0.5	0.45

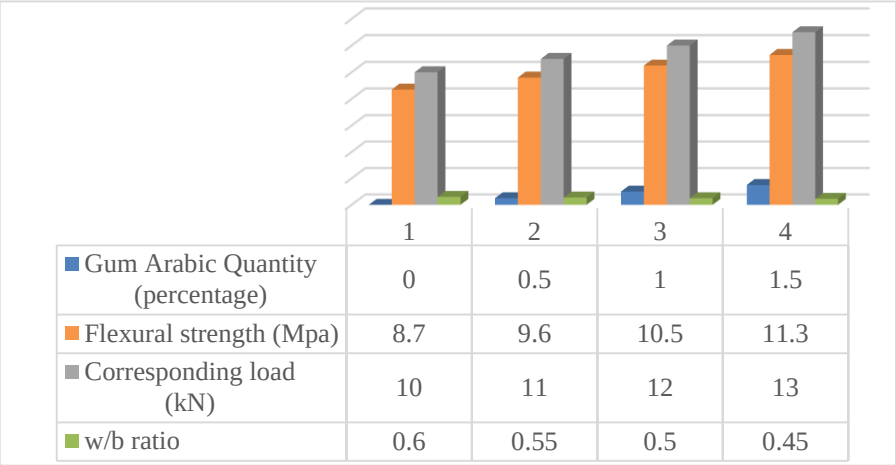
Figure 7 ***Compressive strength after 28 days with admixture and different w/b ratios***

The advantage of using gum Arabic is to achieve compressive strength without decreasing the fresh property of concrete which is also helpful in the placement of concrete. The slight increase in compressive strength may be because of the filling of microscopic pores by the fine particles of gum Arabic. It may also be because of a decrease in air content with the presence of Arabic gum [17].

3.4. Flexural Strength

Flexural strength is one measure of the tensile strength of concrete. The resistance of a concrete beam against loading is measured to evaluate flexural strength. Three samples for each ratio (Three ratios) and material were developed and tested. These beams were subjected to a three-point loading mechanism. The effect of the dosage level of gum Arabic on flexural strength at the different dosage levels and w/b ratio is shown in

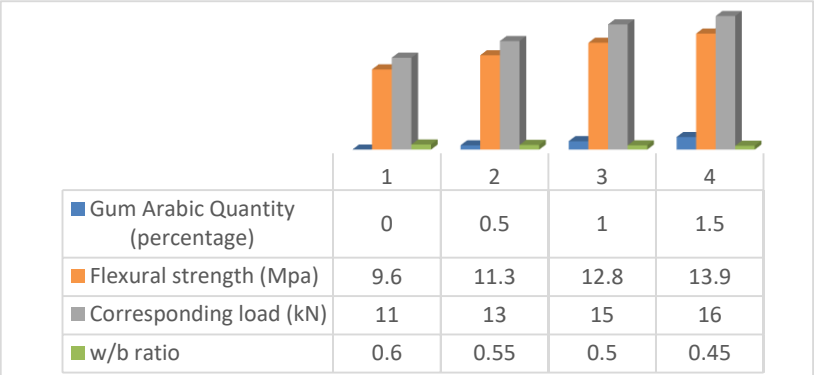
Figure 8. The minimum flexural strength is 8.3MPa at the dosage of 0% gum Arabic and a w/b ratio of 0.6. As the dosage level increases the flexural strength also increases at the age of 14 days.



	1	2	3	4
Gum Arabic Quantity (percentage)	0	0.5	1	1.5
Flexural strength (Mpa)	8.7	9.6	10.5	11.3
Corresponding load (kN)	10	11	12	13
w/b ratio	0.6	0.55	0.5	0.45

***Figure 8* Flexural strength after 14 days with admixture and different w/b ratios**

Similarly, the effect of the addition of gum Arabic on the flexural strength of concrete at the age of 28 days can be seen in **Figure 9**. The same trend can be seen at the age of 28 days as the strength increases with the increase in the dosage level of gum Arabic. The minimum flexural strength of concrete observed was 9.6MPa while the higher value of Flexural strength was 13.9MPa. This can be seen that the increase in gum Arabic and decrease in w/b ratio increase the flexural strength of concrete specimens.



	1	2	3	4
Gum Arabic Quantity (percentage)	0	0.5	1	1.5
Flexural strength (Mpa)	9.6	11.3	12.8	13.9
Corresponding load (kN)	11	13	15	16
w/b ratio	0.6	0.55	0.5	0.45

Figure 9 ***Flexural strength after 28 days with admixture and different w/b ratios***

The increase in flexural strength may be because it forms denser CSH that leads to a denser microstructure which improves the properties of concrete. The denser microstructure reduces the permeability and porosity of concrete and increases the durability of concrete [18, 19].

4. Conclusions

Concrete having different dosage levels of gum Arabic and w/b ratio has been studied thoroughly in this study. Fresh and Hardened properties of concrete (workability, compressive strength, and flexural strength) were studied, and found that gum Arabic can be utilized in concrete as retarding agent. The summarized results of the testing are:

1. Concrete tends to be more workable in hot weather climates if it is added with water. Adding GA to concrete can reduce this tendency. GA was used at a dosage above 0.5% and contributed to a remarkable improvement in concrete workability.
2. The increase in gum Arabic also enables the liberty to decrease the w/b ratio which may help to achieve higher strength characteristics without compromising the workability of concrete which is also helpful in handling and placement of concrete.
3. The addition of a higher dosage of gum Arabic in concrete increases the compressive strength by 1.5%. The higher strength of GA enables it to be used as a water-reducer admixture, thereby lowering the cement demand, which in turn reduces carbon emissions and energy usage, giving the construction industry a cleaner, greener, and more environmentally friendly admixture. Furthermore, the gain of strength at an early age allows for the removal of formwork earlier, reducing construction time.
4. The flexural strength also increased with the higher dosages of the gum Arabic. As the dosage level increases the flexural strength of concrete also increases with the increase of gum Arabic dosage due to the change in microstructure of concrete.

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