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Research Article

The Use of Gum Arabic as an Admixture in Concrete

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Abstract: This paper is the result of findings on the use of Gum Arabic as an admixture in concrete. The research seeks to find the effect of Gum Arabic on some properties of cement and concrete at both fresh and hardened states. Properties of cement and concrete investigated include: setting times and shrinkage of cement, workability, compressive strength and durability of concrete in acidic medium. Quantities of Gum Arabic added as admixture to the cement and concrete were 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% of the weight of cement. Cement pastes containing the above quantities of Gum Arabic were prepared and tested for shrinkage and setting times of cement. Similarly, concrete mix of 1:2:4 (cement: fine aggregate :coarse aggregate) was designed incorporating 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% of the weight of cement in the concrete mixes, varying the water/(cement + Gum Arabic) ratios. Trial mixes were design first to determine the optimum water/(cement + Gum Arabic) ratios which were used for the actual mixes for workability, compressive strength and durability of concrete in acidic medium. The results of the investigation shows that Gum Arabic could be used as an admixture in concrete and that its use increases the shrinkage of cement, both the initial and final setting times of cement, improves the workability of concrete and reduces its water requirement and compressive strength of concrete but slightly improves its durability in acidic medium. Between 0.2% and 0.6% by weight of the cement is recommended for incorporation in concrete.
Keywords: Admixture, Concrete, Gum Arabic, Use

INTRODUCTION

In concrete technology, an admixture is a material other than the basic ingredients of concrete such as water, aggregate, hydraulic cement, and fiber reinforcement and added to the batch immediately before or during mixing with a view to modifying some properties of the concrete [1]. Admixtures are applied in concrete for one or a combination of the following reason: to prevent the bleeding of water to the surface of concrete; improve the workability of the mix; speed up or retard initial setting of concrete; improve water tightness in concrete; produce non skid concrete; inhibit the setting of cement past; improve early strength gains; produce a coloured surface; make the concrete more resistance to deterioration resulting from repeated freezing and thawing cycles; and to decrease the weight of concrete per cubic metre.

The word additives and admixtures are sometimes used interchangeably though erroneously. The distinction between the two arises from the fact that additives are usually chemical additions to cement during the manufacturing process while admixtures are materials added to concrete during the mixing process. Admixtures used in concrete rang from chemicals (usually added in small quantities in liquid form) to the use of waste materials in the form of powder for which alternative use is sought.

Gum Arabic is among the additives and admixtures being used in concrete to modify the properties of concrete. Gum Arabic is the most abundant plant produced naturally as exudates from the bark of acacia tree [2]. It is a natural product of the Acacia Senegal tree occurring as exudates from the trunks and branches. Gum Arabic is a product of Acacia Senegalis. Other acacia species such as Acacia niotical and Acacia Arabica also produce similar gum of inferior quality [3]. The gum exudates are produced after mechanical damage to the bark of the tree or after a bacterial or fungal attack. The process of gum formation popularly known as gummosis is believed as a protective mechanism by these plants to check further attacks [4]. The tapping of the Gum Arabic is usually done during the cool seasons of the year beginning from November (harmattan period).

In a study by Ref. [5], Gum Arabic liquid was added to concrete mixes at ratios of 0.1%, 0.2%, 0.4%, 0.6%, 0.8%, 1.0 % and 1.2 % of cement content. Eleven

concrete mixes were prepared: One as a control mix, seven with Gum Arabic liquid, and three with Gum Arabic liquid with modified water cement ratios added. This modification was done by reducing water cement ratios in concrete mixes to be 0.4 %, 0.6% and 0.8% of cement content. The study showed that the addition of Gum Arabic to the concrete mixes has a clear effect when equal to 0.4% of cement content. The compressive strength was measured at ages of 7, 21, and 28 days and it was found that it decreases slightly with increase in the proportion of Gum Arabic in concrete mixes. The concrete mixes prepared using modified gum Arabic in its liquid state by reducing (w/c) and adding gum Arabic as a percentage of cement content showed a clear and significant change in the properties of concrete. These ratios resulted in high compressive strength concrete with good workability.

In another research by Ref. [6], Gum Arabic (G.A.) powder and liquid was added to concrete mixes at ratios 0.1%, 0.2%, 0.4%, 0.6%, 0.8%, 1.0 % and 1.2 % of cement content. Fifteen concrete mixes were prepared: One as a control mix, seven with Gum Arabic powder, and seven with Gum Arabic liquid. The study showed that the addition of Gum Arabic to the concrete mixes has a clear effect when equal to 0.4% of cement content. The compressive strength was measured at ages of 7, 21, and 28 days and it was found that it decreases slightly with increase in the proportion of Gum Arabic in concrete mixes. The paper shows that good results of compressive strength and workability of concrete were obtained when using the Gum Arabic liquid.

As a follow up on the above researches on the use of Gum Arabic in concrete, this paper is a similar research into the use of Gum Arabic in concrete with the view to finding its effect on some properties of cement and concrete at both fresh and hardened states. The effect of Gum Arabic on setting times and shrinkage of cement, compressive strength and durability of concrete in acidic medium were among the phenomena investigated in this research work.

MATERIALS AND METHODS

Materials

Cement

The cement used was the ordinary Portland cement (Ashaka brand) produced by Ashaka Cement Company Plc, Bauchi, Nigeria, with a specific gravity of 3.14, consistency of 30%, initial setting times of 88 minutes and final setting times of 132 minutes.

Gum Arabic

The Gum Arabic used for the test was bought from the Kurmi market in Kano city, Nigeria. This product was finely ground and dissolved in appropriate quantity of hot water to ensure proper dissolution and allowed to cool before use.

Fine Aggregate

Naturally occurring sharp river sand was used as fine aggregate. The from the grading curve for the fine aggregate shown in Figure 1, it is seen that the fine aggregate conforms with the specified limit in [7]

Coarse Aggregate

Crushed granite of nominal size 20mm was used as coarse aggregate for all the concrete mixes. From the grading curve for the coarse aggregate shown in Figure 2, it is seen that the coarse aggregate conforms with the specified limit in [7].

Water

Portable tap water fit for drinking was used for all the concrete mixes.

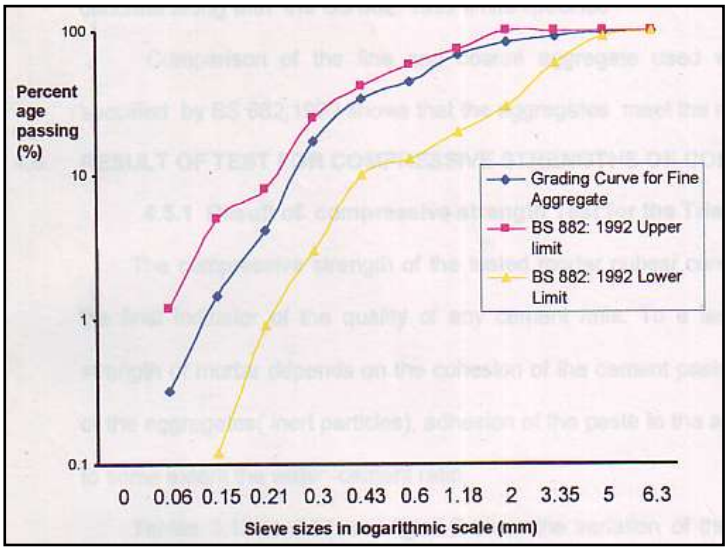

Fig-1:Grading Curve for Fine Aggregate

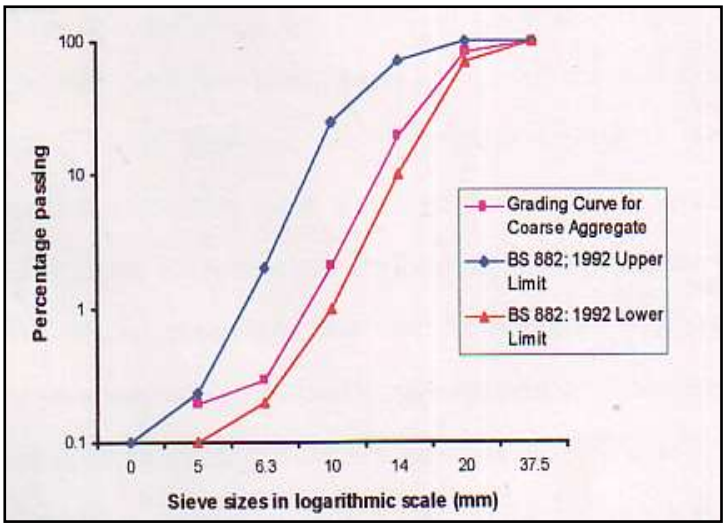

Fig-2:Grading Curve for Coarse Aggregate

METHODS

Chemical Analysis of Gum Arabic

The chemical analysis of the Gum Arabic was carried out from two sources. The extraction of the Gum Arabic was done at the soil laboratory of Geography department of Bayero University, Kano, Nigeria using perchloric, nitric and sulphuric acids. The first sample of the Gum Arabic was taken to the Central Laboratory of Bayero University, Kano, Nigeria where the Alpha 4 Atomic Absorption Flame Spectrophotometer was used for the analysis. The detailed result is in appendix I. Another sample was taken to the Industrial Laboratory of the National Research Institute for Chemical Technology, (NARICT), Zaria, Nigeria for analysis using the Infra Red Transmittance method. Detailed results are presented in appendices J1 and J2.

Specific Gravity Test for Gum Arabic

The gas jar method specified in Ref. [8] was adopted for determining the specific gravity of Gum Arabic. Summary of the specific gravity test is given in Table 1.

Shrinkage Test

The shrinkage test was carried out in accordance with the specification in Ref. [8]. Summary of the test result is given in Table 2.

Test for Setting Time:

The test for setting time was carried out in accordance with the specification of Ref. [9] and Ref. [10]. The results are summarized in Table 3.

Table-1:Specific Gravity of Gum Arabic

Samples	1	2	3
Specific Gravity	1.53	1.52	1.52
Average	1.52		

Table- 2: Effect of Gum Arabic on the Shrinkage of Cement

Gum Arabic Content (%)	Average Shrinkage of Cement – Gum Arabic Paste (%)
0	0.89
0.2	1.43
0.4	2.32
0.6	3.04
0.8	4.65
1.0	5.54

Table-3: Effect of Gum Arabic on the Setting Times of Cement

Gum Arabic Content (%)	Initial Setting Time (min.)	Final Setting Time (min.)
0	88	132
0.2	129	225
0.4	178	333
0.6	195	420
0.8	295	489
1.0	387	562

Concrete Trial Mix Design

The standard mix of 1:2:4 of one part cement to two parts fine aggregate to four parts coarse aggregate and the Absolute Volume method of calculation was adopted for the concrete mix design. The water/cement ratio required to give best performance in terms of compressive strength for varying contents of Gum Arabic were determined. The aims of this trial mix are to determine an optimum water/(Cement + Gum Arabic), W/(C + GA) ratio and an optimum quantity of Gum Arabic to be added to the concrete mix to achieve optimal performance in terms of compressive strength, workability and durability. Gum Arabic was added to the mix in the order of 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% by weight of cement. For each content of Gum Arabic, four trial mixes of varying W/(C + GA) ratio, ranging from 0.5 to 0.65 were used to obtain an optimum ratio. A summary of the trial mixes is given in Table 4.

Concrete Actual Mix Design

The result of the trial mix tests gives the optimum W/(C + GA) ratio for each Gum Arabic content in the mix which are used for the design of the actual or optimal W/(C + GA) ratios given in Table 5. For the actual mixes, six number mixes of each comprising twelve cubes of size 150mm were cast for strength tests at the ages of 7, 14, 21, and 28 days of curing in water. The mixing, compaction and curing for both the trial and the actual mixes were carried out in accordance with the procedure in Ref. [11].

Table- 4: Summary of Trial Concrete Mixes

Mix No.	Gum Arabic Content (%)	W/(C + GA) Ratio	Concrete Mix Ratio (C+GA):FA:CA
TCM-0/1	0	0.50	(1+0):2:4
TCM-0/2	0	0.55	
TCM-0/3	0	0.60	
TCM-0/4	0	0.65	
TCM-0.2/1	0.2	0.50	(1+0.002):2:4
TCM-0.2/2	0.2	0.55	
TCM-0.2/3	0.2	0.60	
TCM-0.2/4	0.2	0.65	
TCM-0.4/1	0.4	0.50	(1+0.004):2:4
TCM-0.4/2	0.4	0.55	
TCM-0.4/3	0.4	0.60	
TCM-0.4/4	0.4	0.65	
TCM-0.6/1	0.6	0.45	(1+0.006):2:4
TCM-0.6/2	0.6	0.50	
TCM-0.6/3	0.6	0.55	
TCM-0.6/4	0.6	0.60	
TCM-0.8/1	0.8	0.45	(1+0.008):2:4
TCM-0.8/2	0.8	0.50	
TCM-0.8/3	0.8	0.55	
TCM-0.8/4	0.8	0.58	
TCM-1/1	1.0	0.45	(1+0.01):2:4
TCM-1/2	1.0	0.50	
TCM-1/3	1.0	0.55	
TCM-1/4	1.0	0.58	

Note: *mix No. TCM-0/1, …, 0/4; indicate trial concrete mixes with zero Gum Arabic content, series No. 1, 2, .., 4 for different W/(C + GA) ratios etc. FA = fine aggregate and CA = coarse aggregate.*

Table- 5 Summary of Actual (Optimal) Concrete Mixes

Mix No.	W/(C + GA) Ratio	Mix Ratio (C+GA):FA:CA
OCM-0/1	0.55	(1+0):2:4
OCM-0.2/1	0.55	(1+0.002):2:4
OCM-0.4/1	0.52	(1+0.004):2:4
OCM-0.6/1	0.51	(1+0.006):2:4
OCM-0.8/1	0.45	(1+0.008):2:4
OCM-1/1	0.43	(1+0.01):2:4

Note: *mix ratio is (cement+ gum arabic):fine aggregate:coarse aggregate.*
Also mix No. OCM-0/1, 0.2/1 …, 1/1; indicate actual (optimal) concrete mixes with 0%, 0.2%, … 1% Gum Arabic content for respective optimum W/(C + GA) ratios.

Slump Test for Concrete

The slump test which is a measure of the workability of concrete, i.e., the ease with which the fresh concrete can be placed in the form, was carried out in accordance with the procedure in Ref. [11]. The result of the slump test for the trial concrete mixes is presented in Table 7 under analysis and discussion of results.

Compressive Strength Test

The compressive strength of the concrete cubes were determine in accordance with the specifications laid out in Ref. [11].using the Avery Denison universal testing machine in the Civil Engineering Laboratory, Bayero University, Kano, Nigeria. The cubes for the trial and actual mixes were removed from water, surface dried for at least 30 minutes, weighed and crushed to failure at age of 7 days for the former and ages of 7, 14, 21 and 28 days for the later. The results for the trial and actual mixes are given in Tables 6 and 7 respectively.

Table- 6 Result of Compressive Strength Test for the Trial Concrete Mixes

Mix No.	W/(C + GA) Ratio	Compressive Strength (N/mm^2)
TCM-0/1	0.50	31.2
TCM-0/2	0.55	34.1
TCM-0/3	0.60	24.7
TCM-0/4	0.65	17.2
TCM-0.2/1	0.50	22.83
TCM-0.2/2	0.55	26.4
TCM-0.2/3	0.60	24.3
TCM-0.2/4	0.65	15.7
TCM-0.4/1	0.50	19.7
TCM-0.4/2	0.55	28.9
TCM-0.4/3	0.60	25.48
TCM-0.4/4	0.65	20.44
TCM-0.6/1	0.45	22.37
TCM-0.6/2	0.50	26.83
TCM-0.6/3	0.55	24.89
TCM-0.6/4	0.60	20.59
TCM-0.8/1	0.45	15.30
TCM-0.8/2	0.50	18.37
TCM-0.8/3	0.55	14.82
TCM-0.8/4	0.58	13.63
TCM-1/1	0.45	15.12
TCM-1/2	0.50	18.22
TCM-1/3	0.55	14.22
TCM-1/4	0.58	12.65

Table- 7 Results of Compressive Strength Test for the Actual Concrete Mixes

Age (Days)	Average Compressive Strength for Given Mixes (N/mm^2)					
	OCM-0/1	OCM-0.2/1	OCM-0.4/1	OCM-0.6/1	OCM-0.8/1	OCM-1/1
7	28.30	21.33	19.85	21.43	15.82	14.23
14	34.58	28.63	26.77	24.81	21.47	23.24
21	35.82	29.40	26.82	29.56	23.66	24.65
28	36.20	31.79	27.00	31.00	25.00	24.90

Test for Durability of Concrete in Acidic Medium

In order to find out the effect of acid on concrete with Gum Arabic, 150mm concrete cubes with the actual mixes were prepared and cured in water for 28 days and then immersed in 5% sulphuric acid solution for another 28 days. At the end of the immersion period in acid solution, the cubes were removed, thoroughly rinsed in clean water and air dried under laboratory condition for 48 hours. After the drying period,, each cube was reweighed and the weight loss in each case was determined. Summary of the results are presented in Table 8.

Table- 8 Result of Durability Test on Concrete Mixes

Mix No.	Gum Arabic Content (%)	Weight Loss (%)
OCM-0/1	0	9.05
OCM-0.2/1	0.2	8.91
OCM-0.4/1	0.4	7.68
OCM-0.6/1	0.6	7.43
OCM-0.8/1	0.8	7.93
OCM-1/1	1.0	8.40

ANALYSIS AND DISCUSSION OF RESULTS

Chemical Composition of Gum Arabic

The result of the first analysis of the Gum Arabic using the Alpha 4 Atomic Absorption Spectrophotometer shows that metabolites present in the Gum Arabic sample were only as trace elements. The flame for some of the metabolites was either not available or not functioning at the time of the test. The results of the few metabolites analyses in the sample are presented in Table 6. The result obtained from the second analysis using Infra Red Transmittance method shows that the Gum Arabic sample used for this research comprised a mixture of polysaccharide along with the metabolites. The analysis revealed that the Gum Arabic contained functional groups of carboxylic acids, (COOH) of the many glucuronic acid monomers in the molecule. The sample contains un-oxidized K-D glucan which is actual starch. It contains magnesium, manganese, calcium, potassium, iron and cobalt cations as show in Table 9.

Table- 9 Chemical Composition of Gum Arabic

Constituent Material	Composition (%)	Composition (mg/l)
Manganese (Mn)	2.95	0.6
Cobalt (Co)	6.0	1.22
Calcium (Ca)	ND	ND
Potassium (K)	14.10	2.87
Sodium (Na)	ND	ND
Magnesium (Mg)	65.8	13.4
Iron (Fe)	11.15	2.27

RESULTS OF SHRINKAGE TEST:

The effect of Gum Arabic on the shrinkage of cement is illustrated in Figure 3. It could be seen in the figure that the shrinkage of cement increases with increase of Gum Arabic content. This phenomenon can be explained from the fact that of Gum Arabic requires high water content for normal consistency.

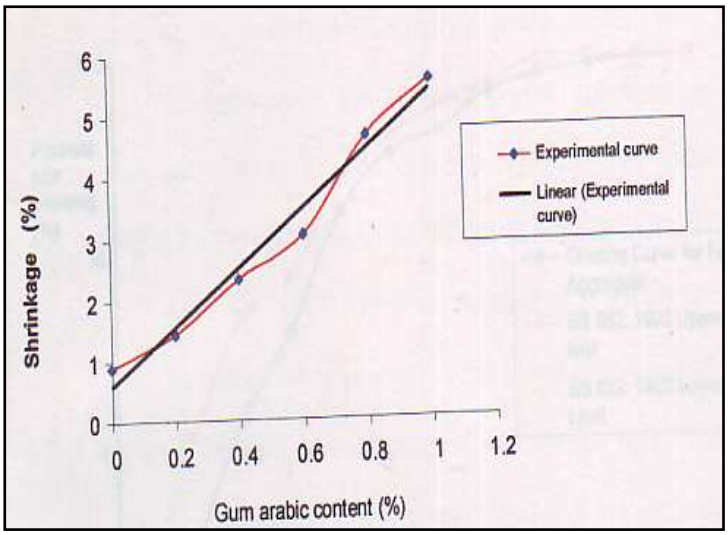

Fig-3: Variation of Shrinkage with Gum Arabic content

RESULTS OF SETTING TIMES TEST

The effect of Gum Arabic on the setting times given in Table 5 is illustrated in Figure 4. From the figure, it is seen that both the initial and final setting times of cement increases with increase in Gum Arabic content. . The initial setting time increases from 88 minutes at 0% Gum Arabic content to 387 minutes at 1% Gum Arabic content while the final setting time increases from 132 minutes at 0% Gum Arabic content to 562 minutes at 1% Gum Arabic content. The initial and final setting times of the OPC (Ashaka brand) used in this research is 88 minutes and 132 respectively which meet the standard requirement of Ref. [12] and Ref. [9] of a minimum initial setting time of OPC of 45 minutes and a maximum final setting time of OPC of 600 minutes.

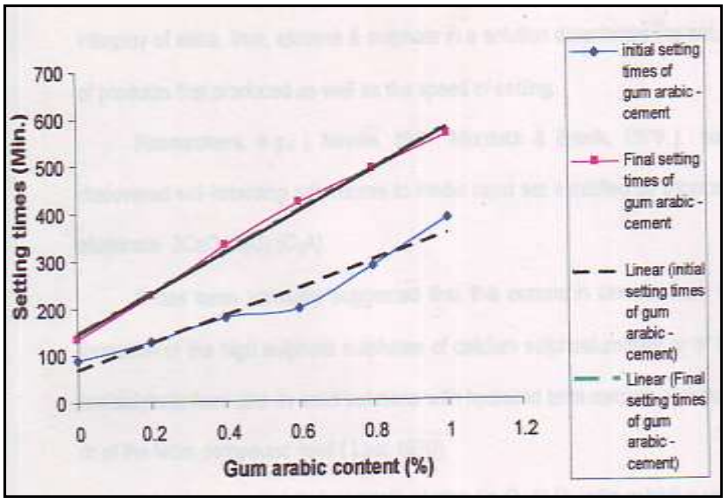

Fig-4: Variations of Setting Times of Cement with Gum Arabic Content

RESULTS OF SLUMP TEST FOR WORKABILITY:

The result of slump test for workability is given in Table 7. It can be seen from the table that as the Gum Arabic content increases, the slump in millimeter reduces and the degree of workability changes from high to medium for the maximum W/(C + GA) Ratio. This is an indication that the use of Gum Arabic in concrete improves workability of concrete.

Table- 7 Result of Slump Test on Concrete Mixes

Mix No.	W/(C + GA) Ratio	Gum Arabic Content (%)	Slump (mm)	Degree of Workability
TCM-0/1	0.50	0	0	Very low
TCM-0/2	0.55		7	Low
TCM-0/3	0.60		83	Medium
TCM-0/4	0.65		150	High
TCM-0.2/1	0.50	0.2	0	Very low
TCM-0.2/2	0.55		10	Very low
TCM-0.2/3	0.60		14	Low
TCM-0.2/4	0.65		100	Medium
TCM-0.4/1	0.50	0.4	0	Very low
TCM-0.4/2	0.55		42	Medium
TCM-0.4/3	0.60		69	Medium
TCM-0.4/4	0.65		47	Medium
TCM-0.6/1	0.45	0.6	2	Low
TCM-0.6/2	0.50		5	Low
TCM-0.6/3	0.55		58	Medium
TCM-0.6/4	0.60		73	Medium
TCM-0.8/1	0.45	0.8	0	Very low
TCM-0.8/2	0.50		5	Very low
TCM-0.8/3	0.55		49	Medium
TCM-0.8/4	0.58		102	Medium
TCM-1/1	0.45	1.0	0	Very low
TCM-1/2	0.50		10	Low
TCM-1/3	0.55		69	Medium
TCM-1/4	0.58		85	Medium

RESULTS OF COMPRESSIVE STRENGTH OF CONCRETE FOR THE TRIAL TEST

The variation of compressive strength of concrete at the age of 7 days with W/(C + GA) ratio for particular Gum Arabic content is given in Figure 5.

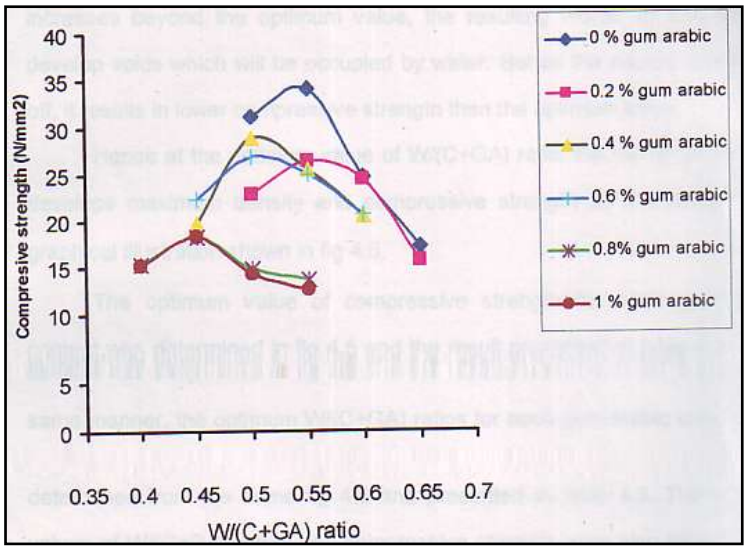

Fig- 5: Variation of Compressive Strength of concrete with W/(C + GA) ratio for Particular Gum Arabic Content

A glance at the figure reveals two trends. The first trend is that as the W/(C + GA) ratio increases, the compressive strength of the concrete increases until a maximum value is reached at an optimum W/(C + GA) ratio and then decreases with increase beyond the optimum value. The second trend is that the compressive strength of the concrete decreased with increase in Gum Arabic content. This second trend is usual with concrete containing admixtures or pozzolanas.

The first trend occurs because at very low W/(C + GA) ratio, there is insufficient quantity of water for the complete hydration of the cement; at such W/(C + GA) ratio, the concrete is generally unworkable, lean and difficult to compact. However, as the W/(C + GA) ratio increases, more moisture is made available for proper hydration of the cement which results in increased compressive strength of the hardened concrete. As the W/(C + GA) ratio increases beyond the optimum value, the resulting concrete will develop voids which will be occupies by water. But as the excess water dries off, it results in lower compressive strength than the optimum value.

The optimum W/(C + GA) ratios used for the actual tests on concrete given in Table 5 were determined from Fig-5.

RESULTS OF COMPRESSIVE STRENGTH OF CONCRETE FOR THE ACTUAL TEST:

The variation of compressive strength for the actual concrete mixes with age for particular Gum Arabic content is illustrated in Figure 6. It can be seen from the figure that the compressive strength increases with age for particular Gum Arabic content but decreases with increase in Gum Arabic content for reasons already discussed above.

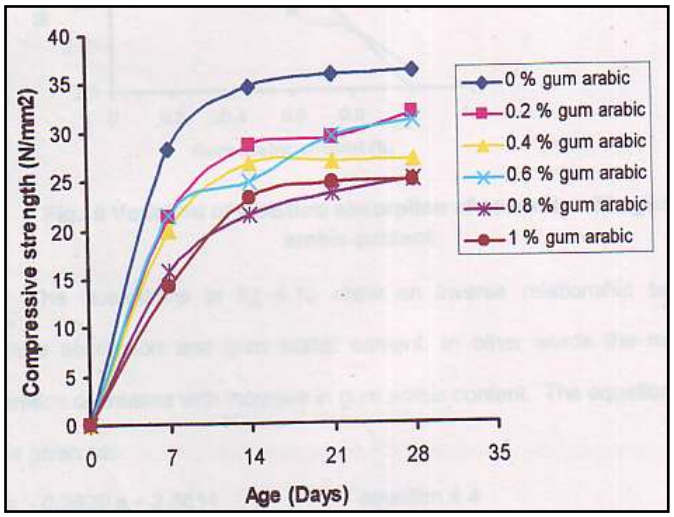

Fig-6: Variation of Compressive Strength of concrete with Age for Particular Gum Arabic Content

RESULTS OF DURABILITY TEST FOR CONCRETE:

The effect of Gum Arabic on the durability of concrete in acidic medium is illustrated in Figure 7.

Durability as referred to in this research is the measure of the weight loss of concrete cubes after immersion in 5% sulphuric acid solution for a period of 28 days. A quick look at the figure reveals that the weight of the concrete decreases with increase in Gum Arabic content. This can be interpreted as an improvement in durability of concrete in acidic medium when Gum Arabic is used in the concrete.

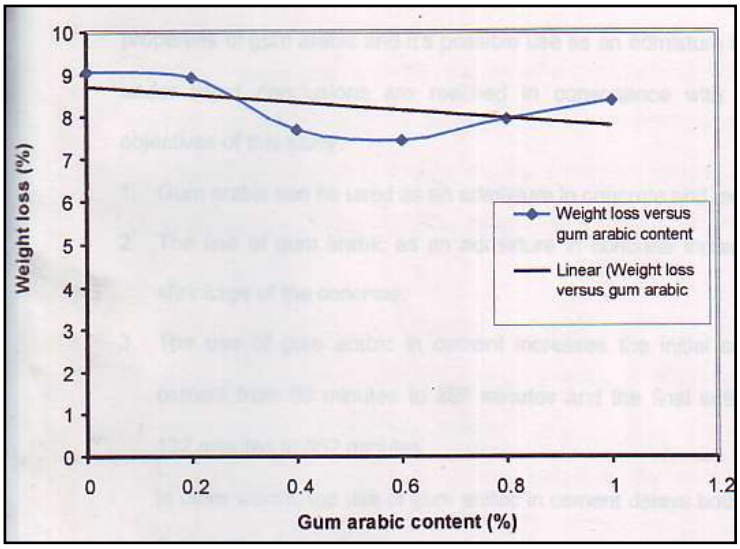

Fig-7: Variation of Weight Loss of Concrete with Gum Arabic Content

CONCLUSIONS AND RECOMMENDATION

From the various findings of the investigation carried out on the use of Gum Arabic as an admixture in concrete, the following conclusions are reached in consonance eith the aims and objectives of the research.

- Gum Arabic could be used as an admixture in concrete.
- The use of Gum Arabic as an admixture in concrete increases the shrinkage of concrete.
- The addition of Gum Arabic to cement increased both the initial setting times of cement from 88 minutes to 387 minutes and the final setting times of cement from 132 minutes to 562 minutes. That is to say that the use of Gum Arabic in cement delays both the initial and final setting times of cement.
- The incorporation of Gum Arabic in cement increased the shrinkage of cement from 0.89 for 0% Gum Arabic to 5.54% for 1% Gum Arabic content.
- The use of Gum Arabic as an admixture in concrete improves the workability of concrete and reduces its water requirement.
- The incorporation of Gum Arabic in concrete reduces the compressive strength of concrete but slightly improves its durability in acidic medium.

It is recommended that where Gum Arabic is to be used as an admixture in concrete it should be limited to 0.2% to 0.6% by weight of the cement. Increasing the Gum Arabic content above 0.6% by weight of cement may be over dosage. It is also recommended that where concrete is to be hauled over a long distance, especially for hot weather concreting, addition of small quantity of Gum Arabic will prevent stiffening of the concrete.

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