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MITIGATING THE EFFECT OF RAPID HYDRATION OF FRESH CONCRETE IN HOT WEATHER CLIMATE USING GUM ARABIC POWDER AS A SETTING TIME RETARDER ADMIXTURE

Rabiu Shehu
MSc (student), Civil engineering and construction management
Heriot-Watt University, Edinburgh, Scotland, United Kingdom

Mohammed Habib Jemal
Co-founder and chief operating officer
3riBuild Nigeria Limited, Abuja, Nigeria

Salim Idris Malami
PhD (student), Civil engineering Department
Heriot-Watt University, Edinburgh, Scotland, United Kingdom

Zakari Umar Muhammad
Co-founder and General Manager
3riBuild Nigeria Limited, Abuja, Nigeria

Abstract— **In this research, the setting time of Gum-Arabic infused concrete was investigated, chemical properties of Gum-Arabic were first evaluated and compared to an industrial admixture. A total number of 64 concrete cubes of size 100x100mm^3 with gum Arabic addition at 0.4%, 0.6% and 0.8% of cement were produced for the study and cured for a maximum of 56 days. The workability, setting time, compressive strength and water absorption of the concrete were tested and compared with the control. The result of the experiments shows that Gum-Arabic increases the workability and setting time of concrete with an increase in its concentration, the compressive strength of the concrete decreases with an increase in Gum-Arabic concentration however, it regains strength at increased curing age. Therefore, Gum-Arabic admixture is recommended to mitigate the effect of hot weather climate on concrete, also for work ability improvement, as well as for water absorption reduction, especially for structures to be built in a damp environment.**

Keywords—**Climate, Hydration, Concrete, Gum Arabic, Admixutre.**

I. INTRODUCTION

High temperatures weather conditions adversely affect concrete in both fresh and hardened state, at fresh state it causes faster hydration of the concrete therefore automatically reducing the setting times, this led to high water demand and an increased rate of slump loss for concrete. (Assal, 2017).

At hardened state, it causes visible plastic shrinkage cracks, and this is seen as one of the chief causes of reinforced concrete deterioration as it easily allows absorption of harmful chemicals that can lead to reinforcement corrosion (Khudhairet al., 2018).

In practice, conventional admixtures such as lignosulphonate have been used to prevent the effect of hot weather on concrete, especially at 54°C to 153°C(Montgomery et al., 2021). admixtures are any material other than the basic ingredients of the concrete usually added before or during mixing to modify some of its properties both in plastic and hardened conditions (Neville, 1981), one of such properties is setting time of the concrete.

Gum-Arabic, a natural exudate produced from the branches and trunk of the acacia tree (Ayeni,2000; Williams & Phillips, 2021). Usually, after mechanical damage to the bark of the tree, after a bacterial or fungal attack and usually tapped during the cool seasons of the year beginning from November.

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Because it is a good deflocculates, as well highly soluble in water and has been used as a pumping aid (Ahmed et al., 2018).
This research explores Gum-Arabic as a setting time retarding admixture with the aim to offset the effect of hot weather on concrete.

II. EXPERIMENTAL PROCEDURE

2.1 Material

2.1.1 Gum Arabic

Table 1. Typical properties of Gum-Arabic(Ahmed et al., 2018)

colour	White-yellow beige
Water solubility	soluble
stability	Stable, but not in Alcohol solvent
Density	1.35g/cm^3

The Gum-Arabic used for this study is the Nigerian Acacial Senegal also known as Grade1. obtained from Bauchi state, a northern part of Nigeria. The gum Arabic is then finely ground into powder and sieve (0.73mm sieve) before use for the experiments.

Figure 1. Sample of Gum Arabic Source: (Gabb, 1997)

Table 2. major sugar similarities in Gum-Arabic and Lignosulphonate (Ramachandran and Seshachar, 1995; Al-Assaf, Saphwan, Phillips, Glyn, Williams and Peter, 2005).

Sugar Content	**gum Arabic**	**Lignosulphonate**
Arabinose	51%	5.9%
Mannose	–	48%
Rhamnose	1%	–
Galactose	47%	10%
Gluconic acid	19%	–
Fructose	–	20%
Xylose + acid	–	15%
Protein	19%	–

2.2. Method

2.2.1 setting time of cement

Stiffening of the cement and Gum-Arabic paste when hydration begins according to EN196-3-2016 (European building code) it is basically measured in the laboratory using a Vicat apparatus which records the penetration of a needle into the paste, the time taken for a particular penetration is the required setting time (Yi et al., 2021). The recorded time at 3.4MPa resistance of the needle is known at the initial setting time at this point the plasticity of the paste is lost (Yi et al., 2021), according to BS12 this time is not less than 45minutes for an ordinary Portland cement. The final setting time is achieved when the cement has up to 27.6MPa of penetration resistance, this time is not more than 10 hours in accordance with BS12.

2.2.2 Mix Design (Adopting ACI Method)

The mix proportion 1:2:2 of the concrete used in this study is depicted in Table 3. The coarse aggregate was mixed with cement and sand; Water was then gradually added while the mixing continues for 5-7 min manually in a mixing bay. for the batch to contain Gum -Arabic (0.4%, 0.6% and 0.8%) to achieve effectiveness the gum Arabic was first introduced into the mixing water, due to the small required quantity in the concrete. The paste was placed into the mould in 3 layers with each layer tapped 20 times with a tapping rod to eliminate voids and ensure proper compaction(Rahman & Rahman, 2007). The mould was then demoulded after 24hrs and the resulting concrete cubes specimens were placed in a curing medium (water), kept in the laboratory ambient condition, and tested at 7, 14, and 28-days (BS1881:Part111: 1983). At 28-days, the ultimate cubic compressive strength of 30 MPa was obtained for the control cubes.

Table3. mix design

Material (kg/m^3)	**Quantity of materials**
Cement	417
Fine aggregates	778
Coarse aggregates	960
Water	200

III.EXPERIMENTAL RESULT AND DISCUSSION

3.1 Sieve Analysis of Fine aggregate

particle size distribution experiment carried out on the fine aggregate in accordance with BS882 (1973) is presented in table 4 below, indicates that the sand satisfies the BS range. Hence it is satisfactory.

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Table 4. Result of particle size distribution of fine aggregate sample

Sieves (mm)	Weight Retained (g)	Percentage Retained (%)	Percentage Passing (%)
5mm	0	0	
2.36mm	20.46	1.36	1.36
1.18mm	138.54	9.24	10.60
600micro	275.21	18.35	28.95
300micro	559.77	37.32	66.27
100micro	479.50	31.97	98.24
Pan	17.95	1.20	99.44

3.2 Setting Time of Cement

The setting time result as presented in figure 2 and figure 3 indicates initial setting time of 1 hour 42 minutes and 3 seconds (1:42:3) and final setting time of two hours fifty-nine minutes and eleven seconds (2:59:11) for the control which is inline with BS12 of 1978 Recommendation of Portland cement that initial setting time not less than 45 minutes and final setting time not more than 10 hours. Therefore, the cement was suitable for the experiment.

3.3 Setting time of Gum Arabic powder infused in the concrete mix

Experiment conducted on the mix containing 0.4%, 0.6% and 0.8% of Gum-Arabic presented also in figure2 and figure3 indicates that 0.4% addition has initial setting time of 185 minutes and 40 seconds (3 hours 5 minutes and 40 seconds) and final setting time of 255 minutes and 10 seconds (4 hours 15 minutes and 10 seconds). The 0.6% addition has initial setting time of 208 minutes and 54 seconds (3 hours 28 minutes and 54 seconds) and final setting time of 248 minutes and 5 seconds (4 hours 8 minutes and 5 seconds). Finally, 0.8% addition has an initial setting time of 248 minutes and 30 seconds (4 hours 8 minutes and 30 seconds) and a final setting time of 317 minutes (5 hours and 17 minutes)

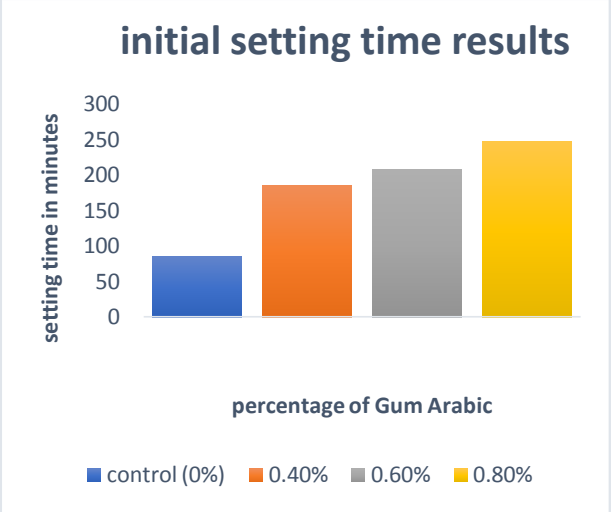

Figure 2. initial setting time concrete

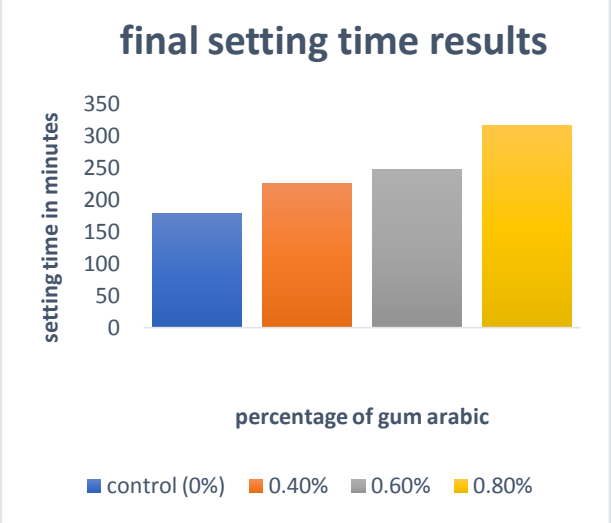

Figure 3. final setting time concrete

3.4 Workability (slump) Test

The conducted test result on workability is presented below in figure 4. The lowest slump was recorded on the control (0%) concrete with a reading of 20mm, this is classified as having low concrete workability (Shetty, 2005) and confirmed by BS 1881, part 103 (1983) specifications. The maximum value was recorded from the concrete mixture prepared with Gum-Arabic at 0.8% addition.

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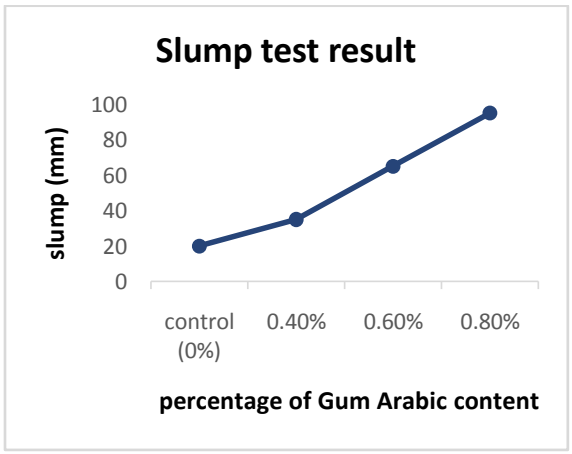

Figure 4. slump test result

3.5 Compressive Strength

Figure 5 presents the result of the compressive strength test of the cubes used in this study. To evaluate the effect of Gum-Arabic on the compressive strength of concrete, a comparison was made between the result of the control cubes and cubes containing 0.4%, 0.6% and 0.8% of Gum-Arabic. Generally, it is observed that the strength of all the concrete mixes decreases gradually with an increase in Gum-Arabic but increases with curing age.

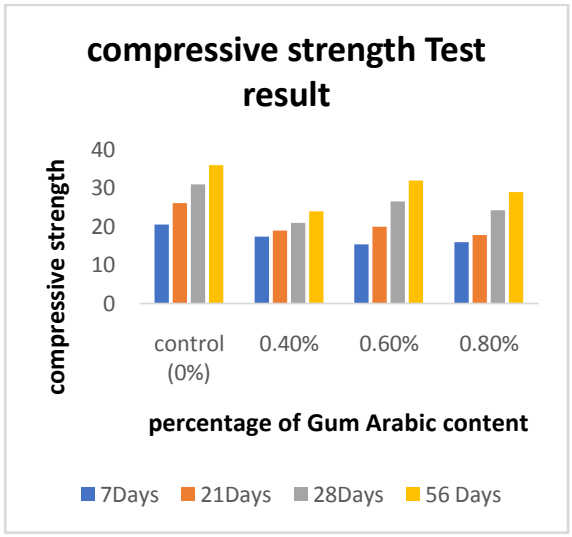

Figure 5. compressive strength result at different curing days

3.6 Water Absorption

The conducted experimental result on water absorption (moisture content) is presented in figure 6. The Gum-Arabic concrete was found to have a lower absorbing capacity than normal concrete, also the higher the Gum-Arabic concentration the lower its water-absorbing capacity. As established by previous research, concrete durability especially reinforced concrete in a moist environment is partly dependent on the rate at which it absorbs harmful chemicals. (Kelham, 1988;Shi et al., 2012)Therefore, Gum-Arabic concrete is suitable in a prone to moisture environment, especially for a reinforced concrete element.

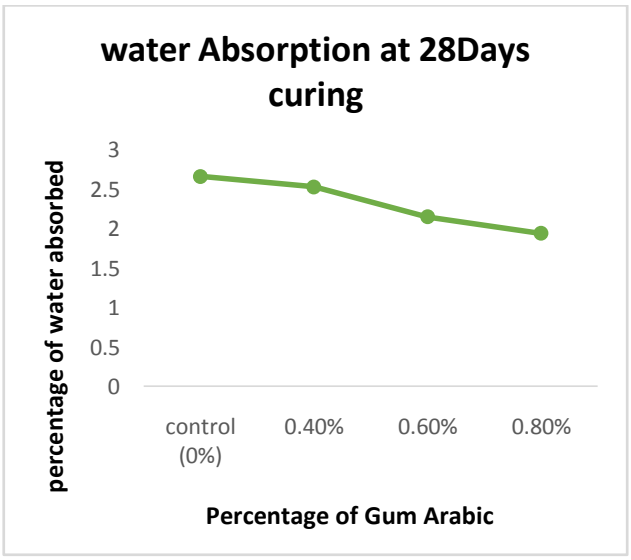

Figure 6. water absorption test result

IV.CONCLUSION

This experimental study which aims at finding the possibilities of using Gum-Arabic as set retarding admixture presented test results of both fresh and hardened concrete with different percentage of Gum Arabic content. Based on this study, the following conclusions are derived:

- Gum-Arabic increases the workability of concrete with an increase in percentage addition. Concrete workability enables proper placement and consolidation which has among many an advantage of properly filling forms completely and surrounding the reinforcement and other embedded items.
- Gum Arabic retard setting time of concrete by 68% on average of 0.4%,0.6% and 0.8% addition experimented in this study. In hot climates, retarders are used to reduce the rapid hydration of cement (Justnes, 2008)
- Gum Arabic decreases the compressive strength of concrete but regains strength with an increase in curing age.
- Gum Arabic reduces the moisture absorbing rate of concrete; therefore, it is recommended for moisture controls in concrete

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