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Influence of Gum Acacia Karroo on Some Mechanical Properties of Cement Mortars and Concrete

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Abstract—Natural admixtures provide concrete with enhanced properties but their processing end up making them very expensive resulting in increase to cost of concrete. In this study the effect of Gum from Acacia Karroo (GAK) as set-retarding admixture in cement pastes was studied. The possibility of using GAK as water reducing admixture both in cement mortar concrete was also investigated. Cement pastes with different dosages of GAK were prepared to measure the setting time using different dosages. Compressive strength of cement mortars with 0.7, 0.8 and 0.9% weight of cement and w/c ratio of 0.5 were compared to those with water cement (w/c) ratio of 0.44 but same dosage of GAK. Concrete samples were prepared using higher dosages of GAK (1, 2 and 3% wt of cement) and a water bidder (w/b) of 0.61 were compared to those with the same GAK dosage but with reduced w/b ratio. There was increase in compressive strength of 9.3% at 28 days for cement mortar samples with 0.9% dosage of GAK and reduced w/c ratio.

Keywords—Compressive strength, Gum Acacia Karroo, retarding admixture, setting time, water-reducing admixture.

I. Introduction

TODAY'S concrete is made up of cement, aggregates, water, chemical and mineral admixtures. Use of chemical admixtures has grown considerably in the last four decades [1]. They have become an essential part of modern day concrete. Asia pacific region is currently the biggest market for chemical admixtures for concrete. In Africa though the usage of admixtures is currently very low, it is expected to increase due to increase in construction of new infrastructures such as new residential buildings, roads, bridges and water retention structures. There is need to increase growth in the area of usage of admixtures which is slow due to high prices of chemical admixtures and lack of awareness in construction industry.

A. Background

Admixtures improve mechanical and chemical properties of both concrete and mortar. Properties such as setting time, compressive strength and durability can be improved by use of admixtures. Quality of construction can also be improved by reducing water usage and construction time. This will result to more durable structures. Today the most commonly used admixtures in concrete production contain either set-retarding chemicals or set-accelerating chemicals. They compromise of a wide variety of chemicals which enhance intended properties in fresh or hardened state of mortars and concrete. Other factors such as composition of cement, ambient temperature, dosage of admixtures, have a major effect on performance of admixture and mechanical properties of concrete.

Among the organic admixtures used in concrete are natural gums. Gum Arabic and tragacanth gum which are natural gums are good flocculants as well as good thickeners [2]. Natural gums are described as [3] Viscosity Enhancing Admixtures (VEAs) and anti-washout admixtures which are water soluble polymers that increase cohesion and stability of cement based materials. Most of these VEAs are water soluble polysaccharides that enhance the water retention capacity of concrete. According to Kawai [4] water soluble polymers can be classified as synthetic, semi-synthetic and natural polymers. Among the natural polymers used as admixtures are gum Arabic, xanthan gum and welan gum. Research has been carried out on most of these polymers but very little has been done on gum Arabic as a set retarding admixture.

Organic Viscosity Modifying Agents (VMAs) have been used in Self Consolidating Concrete. Most effective is welan gum which is a natural water soluble polysaccharide in the same class with gum arabic. Welan gum is produced by bacteria from Alcahgenes species in an aerobic submerged fermentation. When introduced into cementious material it substantially increases water retention capacity and improves workability [5]. Other organic thickening admixtures like cellulose-ethers with different molecular weight, guar ether and starch ether have been used in concrete and have been found to increase water retention [6]. All the above admixtures are biodegradable.

Gum Arabic used in this study is a sticky natural fluid which oozes from Acacia Karroo Haynes trees. Gum Arabic comes from two species of Acacia tree ie Acacia Senegal and Acacia Seyal. Gum from Seyal and Senegal is of high quality and mostly used in food industry. It mainly comes from gum belt in Africa situated in sub-sahara countries in Africa [7]. Gum from Acacia Karroo comes the countries South of River Zambesi which includes South Africa. It is of lower grade [8].

The motivation to study gum Arabic as an admixture in concrete was due to the fact that gum Arabic is a polysaccharides [9] , [3]. It contains similar sugars [10] like

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most lignosulphates [11]. It is widely available in South Africa [12], has no major commercial use, it easily dissolves in water and has low reactivity. It does not interfere with blended product due to its pale colouration and is does not react with most minerals. A similar study conducted by [13] using Acacia gum from Seyal species reported increase in compressive strength. However, no research can be traced in literature having used the gum from Acacia Karroo Hayne species in concrete.

1) Experimental: Ordinary Portland Cement (OPC) CEM-I (grade 52.5) donated by Pretoria Portland Cement (PPC) was used for all cement pastes, cement mortar and concrete specimens. For concrete specimens OPC was blended with 25% unclassified fly ash. X-ray Fluorescence (XRF) was used to determine the composition of cement shown on Table I. Clean tap water was used. Gum Acacia Karoo was picked from Pretoria Botanical Garden . The tears (picture shown in Figure 1) were hand picked, cleaned by removing pieces of bark and any foreign matter, ground and sieved through a 200 μm sieve and stored in a cool dry place to avoid moisture. Dosages of 0.3,0.4 0.5,0.6,0.7, 0.8,0.9 and 1.0% weight (%wt) of cement were used. Mortar without GAK was used as control. The powder form was used for cement pastes and cement mortar. The tears for concrete samples were dissolved in part of gauge water and left overnight Figure 2.

Soluble sugar content (fructose, glucose and sucrose) in GAK was determined using 80% Ethanol and Chloroform reagents. An average of sugar content for five samples was tested and was found to be 70%.

Fig. 1. Gum Arabic Tears oozing from the bark

Crusher sand was used with 19 mm coarse aggregates both donated by Raumix Aggregates from Rosslyn Quarry in Pretoria. Grading of sand used for concrete was determined in accordance with South African National Standard SANS(1083, 2002). The coarse aggregate was crushed from Norite rock. Design mix of 34 MPa was used.

Fig. 2. Gum Acacia dissolved in water

TABLE I
CEMENT COMPOSITION

Constituents	Composition (g per 100g
SiO_2	20.17
Al_2O_3	3.96
Fe_2O_3	2.35
Mn_2O_3	0.753
TiO_2	0.29
CaO	60.57
MgO	2.71
P_2O_5	0.09
Cl	96.8 ppm
SiO_3	2.39
Na_2O	0.148
K_2O	0.37
CaO_2	1.50
Denisty(g/cm^3)	3.12
Blaine surface(cm^2/g)	3240

B. Testing procedures

The following tests were carried out.

1) Setting time: The entire setting time test for cement pastes was carried out at temperature of 23$\pm$2 degrees C at Pretoria Portland Cement Company Limited Laboratory in Pretoria. The humidity was controlled at 90$\pm$ 2%. Automatic setting time apparatus conforming to EN(196-3, 2005) with temperature controlled bath at (20$\pm$1 degrees) was used to store the samples during the setting time test.

2) Compressive strength test: Compressive strength was performed on mortar samples according to [SANS 50196-1]. 500g of cement was mixed with 1350g of standard sand and 255g of distilled water. Samples were prepared using water cement ratio (w/c) of 0.5 and 0.44 and with 0.7,0.8 and 0.9 (%wt)of cement. These dosages were used for this study since their compressive strength was slightly less than the control. The cement together with the GAK was directly measured in the dry mixing bowl and mixing started immediately. Gauging water was added and lastly the sand. After vibration, the moulds were covered and stored in a humidity chamber (99 $\pm$ 1%) for 20 to 24 hrs from time zero. The specimens were tested at ages 2, 7 and 28 days and the failure load recorded. An average of six samples per test was recorded.

Compressive strength test for concrete samples was carried out according [SANS 5863, 2006]. Concrete cubes measuring 100$\times$100$\times$100 mm were prepared. Concrete specimen with water content of 0.61 but using high dosages (1, 2 and 3% wt of cement) of GAK were prepared. Concrete without GAK was used as control. At high dosages concrete became watery and water was reduced till a slump of 75 mm was achieved. Mix with no GAK was used as control. The specimens were tested at ages 7,28 and 56 days. Average compressive strength for three specimens was recorded to the nearest 0.5 MPa.

II. Results

The initial and final setting time of cement paste with and without GAK was compared and displayed in Figure 3. The initial setting time for samples with GAK was generally higher than the control Sample. The setting time measured was dependent on the dosage of admixture. The highest initial setting time for GAK was at 0.5% dosage of GAK and extended initial setting time by 3.2 hours above the control. Both initial setting time and setting duration were extended. When 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 1 % dosage was used the initial setting time was extended by 2.0, 2.2, 3.2,2.7, 1.7, 1.8 and 1.0 hours respectively above control. Increase in GAK dosage increased the extended time for setting with 1% dosage having an extension of 238 minutes. Observed retardation in setting time of cement paste may be attributed to retarding effect of GAK. The presence of sugar in GAK could have delayed the hydration process. [14] [15] used beet molasses which contain sucrose and glucose and reported delayed setting time. These sugars are good retarders who form salts that adsorb on the cement grains and poison the hydrates surfaces. This causes longer induction period, longer nucleation and reduced growth of hydration products [11].

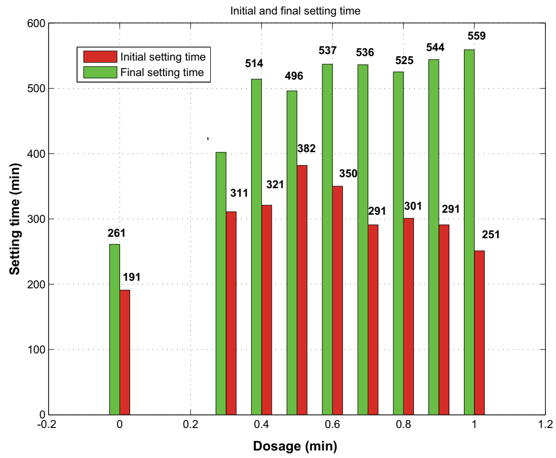

Fig. 3. Initial and final setting times of cement paste samples with different dosage of GAK

Addition of GAK to both concrete and mortar decreased the compressive strength at 2, 7 and 28 days for both cement mortar and 3,7 and 56 days for concrete shown on Table II. The compressive strength when 0.7, 0.8 and 0.9 % dosages were close to the compressive strength of control sample but the values never reached the control sample. Therefore these three dosages were chosen to study the effect on compressive strength Figure 4 when the w/c ratio was reduced. Compressive strength (for all samples with w/c ratio of 0.44 increased more than the samples with 0.5 w/c ratio including the control. It was interesting to note that after water reduction

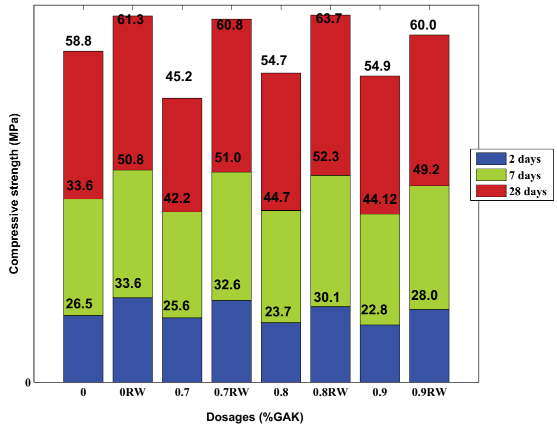

Fig. 4. Compressive strength of cement mortars with different w/c ratio

TABLE II
Increase in Compressive Strength for mortar and concrete samples

Sample	0	0.7%	0.8%	0.9%	1%	2%	3%
2 days	26.7	22.9	34.22	27.2	0.6	75	
7 days	9.5	10	13.2	11.4	5.4	-2.5	60.7
28 days	4.3	3.4	8.6	9.3	-12.1	7.4	62.8
52 days	-	-	-	-	-23.7	-17.6	37.03
w/c	0.5	0.44	0.44	0.44	0.48	0.48	0.48

the percentage increase of samples with GAK was higher than the control and even surpassed it at all ages of testing. At 28 days when no admixture was used there was increase by 4% due to reduction of w/c ratio. For mixes with 0.7,0.8 and 0.9% dosage GAK and reduction of w/c ratio of 0.44 there was 3.4,8.6 and 9.3% increase in strength respectively.

For concrete, higher dosages of GAK were used which produced concrete that was flowing. To achieve 75 mm slump for concrete, with 1, 2 and 3% dosage of GAK, there was w/b ratio decrease from 0.61 to 0.56,0.53 and 0.48 respectively. All samples with the high dosages yielded concrete with compressive strength below the design mix of 34 MPa as shown in Figure 5. However when the w/b ratio was reduced there was increase in compressive strength for samples having 2 and 3% dosage of GAK by 7.4 and 62.8% respectively compared to the control. For 1% dosage the compressive strength even with a w/b of 0.56 was less than than the control at 28 days and at 56 days but it was higher by 5.4% than the control at 7 days. The highest compressive strength was achieved with 3% dosage of GAK with w/b ratio of 0.48 which increased strength by 60.7, 62.8 and 37.03% compared to the control. Decrease of strength with increase in retarding admixture dosage was also reported by [16].

III. Conclusion

1 There was increased initial setting time and extended setting time in cement pastes. As the dosage of GAK increased, the initial setting time and setting duration increased

2 Higher dosages of GAK decreased the compressive

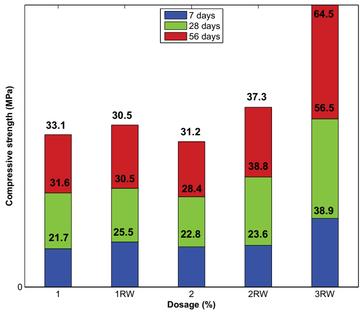

Fig. 5. Compressive strength of concrete with different dosages and different w/b ratio

strength in both cement mortar and concrete but reduced w/c ratio increased compressive strength all samples.

3 GAK can be used for economic production of concrete in hot weather conditions by delaying the setting time without using high cost admixtures.

4 Use of GAK in concrete as a water reducing admixture will result in reduction of cement demand which in turn reduces carbon emission and energy used thereby providing construction industry with a cleaner, greener and environmental friendly admixture.

5 If well developed, this can provide a source of income for the local communities where Acacia Karroo grows wildly.

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REFERENCES

[1] J. Stark, "Recent advances in the field of cement hydration and microstructure analysis," *Cement and Concrete Research*, vol. 41, no. 7, pp. 666–678, 2011.

[2] K. H. Khayat and A. Yahia, "Effect of welan gum-high-range water reducer combinations on rheology of cement grout," *ACI Materials Journal*, vol. 94, no. 5, pp. 365–372, 1997.

[3] K. H. Khayat, "Viscosity-enhancing admixtures for cement- based materials- an overview," *Cement and Concrete Composites*, vol. 20, pp. 171–188, 1998.

[4] T. Kawai and T. Okada, "Effect of superplasticizer and viscosity-increasing admixture on properties of lightweight aggregate concrete," *ACI Special Publication*, vol. 119, 1989.

[5] L. Ma, Q. Zhao, C. Yao, and M. Zhou, "Impact of welan gum on tricalcium aluminate–gypsum hydration," *Materials Characterization*, vol. 64, pp. 88–95, 2012.

[6] M. Cappellari, A. Daubresse, and M. Chaouche, "Influence of organic thickening admixtures on the rheological properties of mortars: Relationship with water-retention," *Construction and Building Materials*, vol. 38, pp. 950–961, 2013.

[7] D. Verbeken, S. Dierckx, and K. Dewettinck, "Exudate gums: occurrence, production, and applications," *Applied Microbiology and Biotechnology*, vol. 63, no. 1, pp. 10–21, 2003.

[8] J. J. Coppen, "Gums, resins & latexes of plant origin. non-wood forest products," 1995.

[9] N. A. Ademoh and A. Abdullahi, "Determination of the physio-chemical properties of nigerian acacia species for foundry sand binding applications," *Research Journal of Applied Sciences, Engineering and Technology*, vol. 1, no. 3, pp. 107–111, 2009.

[10] S. Al-Assaf, G. O. Phillips, and P. A. Williams, "Studies on acacia exudate gums: part ii. molecular weight comparison of the vulgares and gummiferae series of acacia gums," *Food Hydrocolloids*, vol. 19, pp. 661–667, 2005.

[11] V. S. Ramachandran, *Concrete admixtures handbook: properties, science and technology*, 2nd ed. Ottawa, Canada: Noyes Publication, 1995, no. ISBN0-8155-1373-9.

[12] R. Dyer, "Acacia karroo in southern africa," *Bothalia*, vol. 10, no. 2, pp. 385–401, 1971.

[13] N. Abdeljaleel, A. Hassaballa, and A. R. E. Mohamed, "The use of gum arabic liquid and modified liquid in concrete mixes," *Innovative Systems Design and Engineering*, vol. 3, no. 12, pp. 1–11, 2012.

[14] A. Jumadurdiyev, M. Hulusi Ozkul, A. R. Saglam, and N. Parlak, "The utilization of beet molasses as a retarding and water-reducing admixture for concrete," *Cement and concrete research*, vol. 35, no. 5, pp. 874–882, 2005.

[15] B. Khan and B. Baradan, "The effect of sugar on setting-time of various types of cements," *Science Vision*, vol. 8, no. 1, 2002.

[16] S. Alsadey, "Effects of super plasticizing and retarding admixtures on properties of concrete."

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