

# Characterization of Gum Arabic As Viscosity Modifying Agent (VMA) for Producing Self-Compacting Concrete (SCC)

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**ABSTRACT** This study aims at finding alternative indigenous Sudanese material for concrete admixtures that are necessary for casting concrete in hot weather of the Sudan. The objective of this study to classify Gum Arabic (GA) namely, Acacia Senegal (known locally as Hashab Gum) as viscosity modifying admixture (VMA) for lowering powder content in self compacting concrete (SCC). The methodology of the study is based on the European standards BS EN 934-2 & BS EN 480-15 that are used as a paradigm to classify GA as the VMA. Three trial SCC test mixes containing different quantity of cement, namely (400, 370 and 350) Kg/m<sup>3</sup> as powder content. A dose of GA 0.2% by weight of cement is applied after being dissolved in water at a concentration of 30% by water weight. The water/cement ratio (W/C) is kept constant as 0.45 for all mixes. The results of this study showed that the 0.2% GA dosage is appropriate and satisfied all criteria set by BS EN 934-2: 2009 for VMA. Using 0.2% GA as VMA lower the powder of SCC from 400kg to 350kg/m<sup>3</sup> while maintaining the SCC fresh properties.

**Keywords:** Gum Arabic, Viscosity Modifying Agent, SCC.

## 1. INTRODUCTION

According to BS EN 206-9:2010 [1]. Self Compacting Concrete (SCC) is defined as "Concrete that is able to flow and compact under its own weight, does not require vibration for placing, without segregation or bleeding[2], fill the formwork with its reinforcement, ducts, boxouts etc., whilst maintaining homogeneity". The SCC may be classified into three types: the powder type, VMA type and the blend of the two types [3].

- *The powder type SCC* is characterized by the large amounts of powder (all material with size < 0.125 mm) which is usually in the range of (550 to 650 kg/ m<sup>3</sup>).
- *In the VMA type SCC*, the powder content may be lower (350 to 450 kg/m<sup>3</sup>). The segregation resistance is mainly controlled by a

VMA and the yield point by the addition of superplasticizer.

- *In the combination type of SCC*, the powder content is between (450 to 550 kg/m<sup>3</sup>) but in addition, the rheology is also controlled by a VMA as well as an appropriate dosage of the superplasticizer.

The powder type of SCC requires high cement content. This leads to increase in cost and will be problematic if used in the tropical weather of the Sudan by increasing risk of thermal cracks and delayed ettringite formation in deep section, hence reduces durability of concrete.

Adding VMA for SCC to improve the stability to allow for variations during construction, as SCC is very sensitive to variation of ingredients properties, and increase cohesion and segregation resistance[4]. Most VMA's are supplied as dispersed in a liquid to make dosing easier and improve dosing accuracy. The dosage depends on

the application but typically ranges from 0.1 to 1.5% by weight of cement but can be varied for specific applications [3]. Sudan imports all its chemical admixtures from abroad and this drains hard currency which is very scarce. The use of imported admixtures is costly also manufactured admixtures have short shelf-life and require special storage conditions (normally 12 months) [5].

Raw GA can be used as a viable alternative as it does not have an expiry date and is indigenously cultivated in the Sudan. Natural gums are described as Viscosity Enhancing Admixtures (VEAs) and anti-washout admixtures that are water-soluble polymers that increase cohesion and stability of cement-based materials [6].

This paper is the first up to our knowledge to use the BS EN 480 [15] and BS EN 934-2 [7] codes and specification to classify GA as VMA.

The aim of this study is to classify GA namely, Acacia Senegal (known locally as *Hashab*) as VMA, and then lower the quantity of powder used in SCC production. The approach to achieving this study is summarized as follows:

- Collection of samples of GA (Acacia Senegal known locally as *Hashab*) from local sources.
- Classification of the GA as VMA according to BS EN 934-2 [7] requirements following methods listed in BS EN 480 [15], concrete reference will be used and designed using the empirical design method that is based on data and limits values stated in EFNARC [3].
- Preparation of mixes containing GA as VMA with the same dosage 0.2% of cement weight based on levels and lowering powder contents reported in [8-12].
- Conducting testing and check conformity according to BS EN BS EN 934 [6] and interpreting results of fresh and hard properties of self-compacting concrete. This paper consists of four sections: Introduction (Section 1), materials and Methods (Section 2), Results and Discussion (Section 3) and Conclusions and Recommendation (Section 5).

## 2. MATERIALS AND METHODS

### A. Raw Materials Testing

Sakhr Al-Sudan cement is used in the mix which is a locally OPC produced by Al-Takamol company. OPC cement class 42.5N conforming to

BS EN 197-1. The specific gravity of the cement was measured. Uncrushed coarse aggregate conforming to 14 mm graded sized of BS-EN882-1992 & natural sand conforming to BS5075-1:1982 for fine aggregate, the specific gravity of the coarse and fine aggregate was measured 2.65, 2.63 respectively. Water and GA (Hashab type) were used. High range water reducing Yaracon SP650 conforms with BS 5075, BS: EN 934-2, ASTM C494 Type F and relative density of SP was 1.15 at 25°C. All raw materials were tested in accordance with requirement of BS EN 480-1:2000, except the aggregates which were tested in accordance with requirements of BS 480-15 Table 1. The OPC has initial & final setting time of 157 & 196 minutes respectively and compressive strength of 45N/mm<sup>2</sup> at 28 days. The tests carried out on coarse and fine aggregates for concrete mixes by using procedures conforming to the correspondent parts of BS EN1097 [13] & BS EN 933-1 [14] included: particle density, water absorption, moisture content and sieve analysis. The tests were carried out on the sand by using procedures conforming to the correspondent parts of BS 1097 included: water absorption and moisture content.

### B. Mix Proportions

There are many mix design methods of SCC. The best estimation of SCC proportion was based on trial mixes to fulfil requirement of Table 2 in BS EN 480 [15] and adjustment of initial mixture. European guideline [4] determined indication of the typical range of constituents in SCC by weight and volume. According to BS EN 480 [15] requirements, concrete reference was used and designed using Empirical method as shown in Table 1. Three trial test mixes containing different quantity of cement, namely (400, 370 & 350 kg/m<sup>3</sup>). A dose of GA 0.2% by weight of cement was carried out after being dissolved in water. This dosage was based on dosages reported by J.J in [8]. The water/cement ratio 0.45 for all mixes, the water content of the test mixes varied between same amount as reference mix and reduced amounts in order to achieve equal consistence. The amounts of cement reduction in mix 3-370 kg and mix 4-350 kg were replaced by CA and FA while maintaining the proportion ratio of CA: FA in control mix.

TABLE1: MIX PROPORTIONS OF SCC ACCORDING TO EMPIRICAL DESIGN METHOD

Mix	CA kg/m <sup>3</sup>	FA kg/m <sup>3</sup>	Cement kg/m <sup>3</sup>	Water kg/m <sup>3</sup>	W/C	SP kg/m <sup>3</sup>	GA kg/m <sup>3</sup>
Reference Mix1	820	1020	400	180	0.45	7	0.0
Mix2-400 kg/GA	820	1020	400	180	0.45	7	0.8
Mix3-370 kg/GA	835	1038	370	167	0.45	7	0.74
Mix4-350 kg/GA	852	1060	350	157	0.45	7	0.7

### C. Test Methods & Mixing procedure

The Forced pan mixer was used to make mixes, Unlike the mixing procedure stated in BS EN 480[15], the mixing began by dry mixing of sand with powder for about 2 minute. Two-thirds of the total water content was slowly poured while the mixer was running. Then CA was added with the remaining third of water, then third of SP was added and mixed for 2 minutes. Finally BS EN 480[15], two third of SP and GA solution was slowly poured and mixed for extra 7 minutes [16]. Tests carried out on the reference concrete was performed as comparative tests and compared to Table 13 of BS EN 934-2:2009 requirements [7].

In this study, according to BS EN 206-9:2010 [1] and BS EN 12350-8 [17] the following tests were used, slump flow test, and sieve segregation to measure and classification the fresh properties of SCC. Moreover, compressive strength was measured (28days) according to BS EN 12390-3:2000[18] using cubes (150\*150\*150) mm cast without compaction.

## 3. RESULTS AND DISCUSSION

This section presents the results obtained from the testing program and discusses the effect of GA in SCC concrete mix and knowing the extent to which the powder can be reduced while maintaining the properties of the SCC when using GA as VMA. Also, it includes comparison between these results and specific requirements according of BS EN 934-2:2009 to classify the GA as VMA. The results were obtained from the slump flow test, T<sub>500</sub> test, air content and compressive strength test. Three different quantity of cement with 0.2% of GA were tested (400,370&350 kg/m<sup>3</sup>). The result obtained by conducting the test methods on the fresh mixes and hardened concrete.

### A. Influence of GA addition on Slump Flow (SF)

Fig.1 shows the slump flow spread obtained from slump flow testing of SCC)

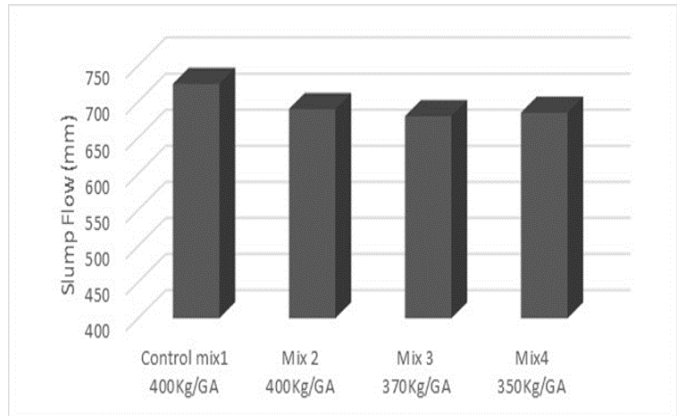


Fig 1: Slump Flow of different Mix (mm)

Fig 1 shows that the Control Mix1 and test Mix2 with addition of GA by 0.2% by weight of cement decreases the slump flow. However, when the quantity of cement was reduced in the presence of GA as in test mixes Mix3 and Mix4 until (370,350 kg/m<sup>3</sup>) respectively, it was found that the slump flow increased by a small amount and satisfied requirements and specification in BS EN 206-9-2010[1]. This indicates that there is no remarkable effect on slump flow when the cement was reduced to the above quantity.

### B. Influence of GA addition on viscosity (flow rate Test, T<sub>500</sub> time)

Fig.2 shows the T<sub>500</sub> obtained from slump flow testing of SCC) Mix2, Mix3 and Mix4 containing 0.2% of GA had higher spread time (T<sub>500</sub>) compared to Control Mix1, which is due to extensive cohesion and viscosity exhibited by these mixes.

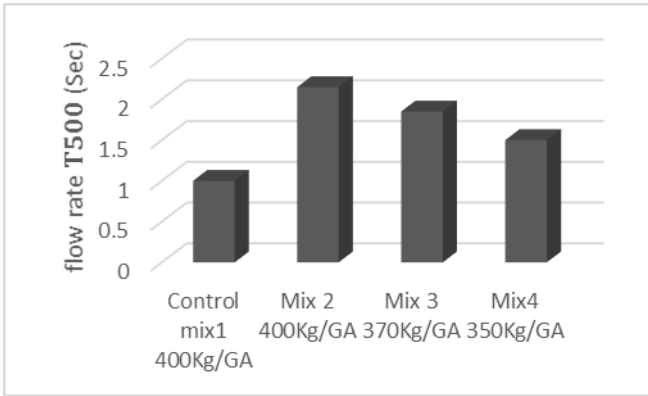


Fig 2: flow rateT500 of mixes

That makes the paste slow and limit the viscosity noticeably which means increasing of filling time ability. This agrees with [20] who observed the addition of GA increased the T500, i.e. decreased the rate of flow. This means the GA is enhancing the viscosity and acts as VMA.

This decrease in the flow rate (or increase in viscosity) is due to the GA having a high-molecular-weight polysaccharide composed of one or a few different mono-saccharide repeating units joined together by glucosidal bonds. The multiple hydroxyl groups in the structure of these molecules allow hydrogen bonding between GA molecules, a mechanism that is responsible for building viscosity in solution [20].

#### C. Influence of GA addition on Air Content

Fig 3 shows the air content of the control mix and the three test mixes containing 0.2% dosage of GA. The air content value of the control concrete Mix1 as 1% by volume of concrete. The air content

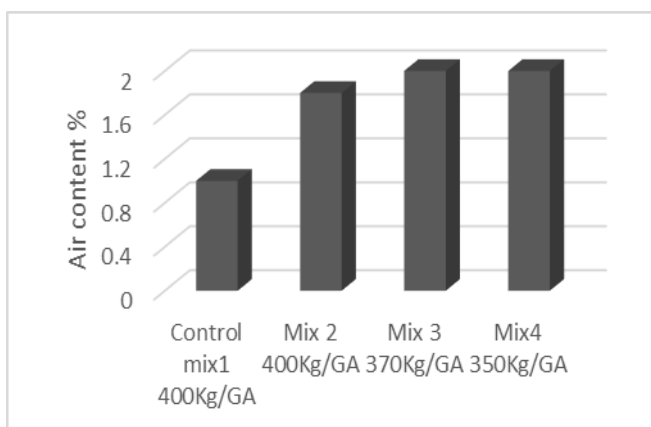


Fig 3: Air content of mixes

of Mix2 was 1.8% and for Mix3 & Mix4 was 2% higher than the control mix. It can be concluded that GA increased the air content. This agrees

with the comment of Ramachandran [19] about pumping aids admixtures containing natural gums. These admixtures have inherent surfactant properties that lower the surface tension of the aqueous phase of the mix. Consequently, dosages above optimum levels will entrain unjustified air. It is worth noting that during preparing the GA admixture (by dissolving in mixing water) air bubbles were observed. Li *et al* (2009) [21] had been reported that the air bubbles formed in concentrated aqueous GA solutions (30%) seem to also have a significant effect on the rheological behavior especially in the low shear rate range. It could indicate that besides VMA, GA could be used as air-entraining admixture; however, further investigation is required in this aspect.

#### D. Influence of GA addition on segregated portion (SR)

It is noted from Fig 4 that adding GA by 0.2% of the cement weight to SCC reduced the segregated portion percent (SR) when comparing control Mix1 with test Mix2. This means that adding GA increases and enhances the resistance of the SCC to bleeding, segregation and surface settlement.

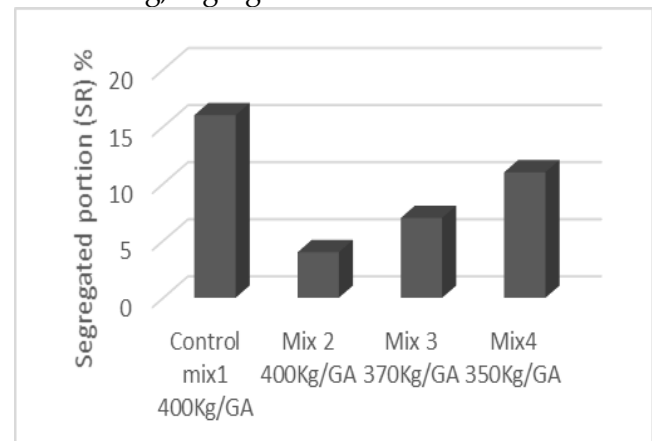


Fig 4: Segregated portion of mixes (SR)

Although all of the above mixes are stable and resistant to bleeding, it is observed in Mix3 and Mix4, i.e. with decrease in powder with the presence of GA reduces the resistance of SCC to segregation compared to Mix2, but still lower than the control Mix1 without GA and having higher powder content. This agrees with comment of Khayat [20] about the effect of VMA on stability of SCC who attributed this stability is due to the incorporation of GA molecules. He mentioned that the GA can adsorb some of the

free water in the system, thus reducing bleeding and surface settlement. The enhanced yield stress and plastic viscosity, as well as the structural build-up of the static yield stress with rest due to the addition of VMA. The VMA can improve the capacity of the liquid phase to suspend solid particles and decrease the rate of sedimentation (Stokes' law) [20].

#### E. Influence of GA addition on Compressive Strength

Fig 5 show that at equal W/C ratio with water reduction, adding 0.2% dosage of GA produced lower strength than the control mix, indicating that GA acts as strength retarder (i.e. hardening retarder).

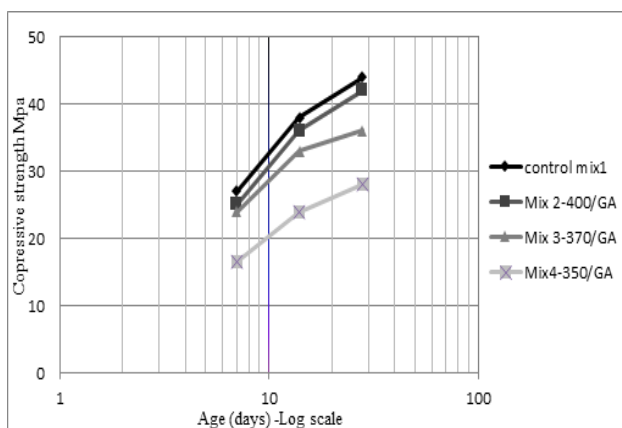


Fig5: Compressive strength of mixes

It is most likely that the retardation effect of GA for the strength is attributed to the actions of its sugars and glucuronic acids ingredients [21]. Figure 4-5 agrees with Mail vaganam [22] and ref [23] observations. The reduction of compressive strength with lowering the powder content albeit maintaining the same W/C ratio may be attributed to the decrease in cement/aggregate ratio.

#### F. Classification of 0.2% GA as VMA admixture

The results of SCC tests on control and 0.2% GA mixes at equal consistence were interpreted in accordance with Table 13 of BS EN 934-2:2009 requirements of admixtures. These interpretations are shown in Table 2.

## 4. CONCLUSIONS

From the tests results obtained it can be concluded that:

- At 0.2% GA dosage, satisfied all criteria set by BS EN 934-2: 2009 for viscosity modifying admixture (VMA).

- Using 0.2% GA as VMA can tolerate lowering the powder of SCC from 400 to 350kg/m<sup>3</sup> while maintaining the fresh properties that characterized SCC.
- Adding GA increases air content and decreases compressive strength of SCC that means the GA acts as strength retarder.
- Adding GA enhances the stability and resistant segregation of the SCC.

## 5. RECOMMENDATIONS

For future studies the following is recommended:

- Classification of other types of natural GA as VMA, such as Acacia Seyal (known locally as *Taleh*), guar gum and gum of Acacia Nileatoica .
- Further study should focus on preparation of GA solution to be used as admixture; this may need an optimization for chemical stabilization and storage environment.
- Further work in this field must be carried out using other types of super plasticizer and raw materials.
- The increase in viscosity when using GA hinders the sieve segregation test, so recommend using a column segregation test according to ACI 237R-07[24] measure stability.

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TABLE 2: PERCENTAGE OF TEST MIXES: CONTROL MIX RESULTS &amp; CLASSIFICATION STATUS OF 0.2% GA AS VMA ADMIXTURE.

Property	BSEN934-2:2009 Requirements	Control mix1		Testmix2GA=0.2		Note
		Value	Percentage	Value	Percentage	
Segregated portion (SR)	Control mix $\geq 15\%$ and SR $\leq 30\%$ Test mix SR $\leq 70\%$ of the value obtained with the control mix	16	100%	4	25%	25% < 70% OK
Compressive strength	At 28 days: test mix $\geq 80\%$ of control mix	44	100%	41	93%	93% > 80% OK
Air content%	Test mix $\leq 2\%$ (by volume) above control mix unless stated otherwise by the manufacturer	1	-	1.8	Increase 8% compared with control Limit = $2+0.8 = 2.8\%$	1.8 < 2.8% OK

\*OK= fulfilled the requirement

Table 7 shows that 0.2% GA satisfies all the criteria required for VMA classification.

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