International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

Suitability of Gum Arabic as a Plasticizer in Self-Compacting Concrete: Fresh Concrete Properties

[1]P.W. Zakka, [2]P.D Bang, [3]H. S. Yohanna, [1]O.F. Job and [1] N.A. Anigbogu
[1]*Department of Building, Faculty of Environmental Sciences, University of Jos*
[2]*National Film Co-orperation of Nigeria (NFC), Jos*
[3] *Department of Building, Faculty of Environmental Sciences, Bells University Otta*

ABSTRACT

In the production of self-compacting concrete, superplaticizers and viscosity modifying agents play an important role in the performance of the concrete. However, these superplarticizer as well as viscosity modifying agents are expensive and their environmental friendliness cannot be guaranteed as most manufactures keep their composition secret. Gum arabic is an abundant and available material found in about 12 states in Nigeria, and is non-reactive or harmful to the environment. The study therefore investigated empirically its suitability as a plasticizer in self-compacting concrete. The research identified the most suitable mix proportion for the self-compacting concrete using gum arabic as a plasticizer. The study made use of a fine/coarse aggregate content of 55:45% content which represents a 1:2 ½: 2 Mix. The water/cement of 0.40 and 0.45 were used as well as a superplasticizer content of 0.9 and 1.5% the weight of cement were used. It was observed that the concrete made with a water cement ratio of 0.45 and a gum arabic content of 0.9% the weight of cement had a slump flow of 560mm, a V-funnel of 9 secs, an L-box value of 0.65 and 0% segregation. The concrete made with a water/cement ratio of 0.40 and a gum Arabic content of 1.5% had a slump flow of 590mm, a V-funnel time of 7 secs, an L-box value of 0.76 and 0% segregation. The concrete made with a water/cement ratio 0.45 and a gum arabic content of 0.9% the weight of cement had a slump flow of 660mm, a V-funnel time of 5.5 secs, L-box value of 0.80 and 0% segregation. The concrete made with a water/cement ratio of 0.45 and a gum arabic content of 1.5% the weight of cement had a slump flour of 680mm, a V-funnel time of 5 sec, L-box value of 0.80 and 0% segregation. The concrete made with 0.45 w/c and a gum arabic content of 1.5% the weight of cement meets all the criteria for self-compacting concrete while the other three mixes met 75% of the requirements. Gum arabic has a low viscosity and thus alters the viscosity of water and improves the workability and flow of self-compacting concrete. The samples of the fresh self-compacting concrete belong to the slump flow class SF1 with a slump flow range of 520-700mm. The viscosity test showed that the concrete belongs to the VF1 class, since their time of flow through the V-funnel was less than 10s. The concrete made with a water cement ratio of 0.45 had more passing ability than the one made with a water/cement ratio of 0.40. There was no form of segregation observed in any of the concrete mixes. The concrete made with a water/cement ratio of 0.40 had a lower slump flow and flowability than the one made with a water/cement ratio of 0.45. The SCC made with Gum Arabic as a plasticizer meets the minimum standard required for SCC after its properties were evaluated.

Keywords: *Suitability, Gum Arabic, Plasticizer, Self-Compacting Concrete, Fresh, Properties.*

INTRODUCTION

Realizing the lack of uniformity and complete compaction of concrete by vibration, researchers at the University of Tokyo, Japan, started out in late 1980's to develop SCC. By the early 1990's, Japan has developed and used SCC that does not require vibration to achieve full compaction (Ouchi, Nakamura, Osterson, Hallberg, and Lwin, 2003). Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete (The European Guidelines for Self

Compacting Concrete, 2005). Sustainability and ecological demands on concrete, adoption and development of workable construction methods have remained a persistent challenge to researchers and developers of concrete admixtures. Therefore, the development of an "ecological concrete" is the only way to meet these challenges. An "ecological concrete" is a concrete which according to ecological criteria has an optimized composition of the individual components (sand/coarse aggregate, cement, water, concrete admixture, additives) as well as high technical specifications (Haner, Galli, Schluep, Madar and Germann, 2004). To make durable concrete structures, sufficient compaction by skilled workers is required. However, the gradual reduction in the number of skilled workers in construction industry has led to a similar reduction in the quality of construction work. One solution for the achievement of durable concrete structures, independent of the quality of construction work, is the use of the SCC, which can be compacted into every corner of a formwork, purely by means of its own weight and without the need of vibrating compaction (Iureş and Bob, 2010).

The self-compacting concrete differs from conventional concrete in the following three characteristic features, namely, appropriate flowability, non-segregation, and no blocking tendency. An increase in the flowability of concrete is known to increase the risk of segregation. Therefore, it is essential to have a proper mix design (Ravindrarajah, Siladyi and Adamopoulos, 2003). Most of the modern concretes possess additives, either in the mineral form or synthetic form. Admixtures such as water reducers and set controllers are invariably used to enhance the properties of fresh and hardened concrete. The use of superplasticizers (high range water reducer) has become quite a common practice. This class of water reducers was originally developed in Japan and Germany in the early 1960's and later introduced in the United States in the mid 1970's (AllahBakash and Reddy, 2013).
In order to obtain the characteristic properties of self-compacting concrete (SCC) highly effective water reducing agents (superplasticizers) based on polycarboxylate esters (PCE) are necessary. Compared to conventional concrete, higher concentrations of superplasticizer (1-2 % relative to cement) are added. The added superplasticizers are not considered as biologically easily degradable (Herterich, Volland, Wüstholz, Stegmaier, 2004).

The composition is in many cases ill-defined and kept secret for proprietary reasons by the manufacturer. The chemical composition from batch to batch may also vary even in the same product of one producer (Ervanne and Hakanen, 2007). Concrete plasticizers must correspond to the general requirements in EN 934-1 and the additional requirements of EN 934-2. A concrete plasticizer is defined here as: "An admixture that allows the water content of a specific concrete mixture to be reduced without impairing its consistency or to increase its slump without changing the water content or to achieve both effects at the same time." Super plasticizers must correspond to the general requirements in EN 934-1 and the additional requirements of EN 934-2. A super plasticizer is defined here as: "An admixture that allows the water content of a specific concrete mixture to be considerably reduced without impairing its consistency or to considerably increases its

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

slump without changing the water content or to achieve both effects at the same time" (STATE-OF-THE-ART-REPORT, 2011). There are several studies on the environmental concentrations of super plasticizers, but there is a lack of detailed study on their budget and estimates of leaching amounts especially from concrete structures. The evaluation of budget is difficult since there are in most cases several sources, which make their contribution to the total flow unclear.

Gum arabic is a leguminous tree species that is well adapted to sudan and sahalian agro-ecology of Africa. There are over 300 species in this family. Notable among them is *Acacia senegal* because it produces grade 1 quality gum. Its distribution is localized in Africa. Studies have shown that genetic variability exists among the *Acacia senegal* genotypes growing across Africa. For example, it has four different varieties found in Africa. In Nigeria and Sudan variety *senegal* is relatively abundant, whereas in Kenya and Senegal, the variety *karensis* exists, in South Africa and Zimbabwe, variety *rostrata* is found while the fourth variety, *leirhochis* is found in most other African countries. The other species of note also found in Africa is *Acacia seyal* that produces grade II gum (Mokwunye and Aghughu, 2010). The gum from *Acacia senegal* is a water-soluble polysaccharide of the hydrocolloid group and comprised mostly of arabinogalactan and protein moiety, in addition to some mineral elements (Williams and Phillips, 2000). It has considerable variation in physicochemical, functional and toxicological properties according to different locations, type of soil and age of the tree (Anderson, Dea, Karamalla and Smith, 1968). Chemically, gum Arabic consists mainly of high-molecular weight polysaccharides made up of rhamnose, arabinose, galactose, gluronic4-o-methoxyglucuonic acid and the salt of calcium, magnesium, potassium, and sodium of the two acids. The major gums of economic importance are gum Arabic, gum talha and Acacia polycantha gum (Tewari, 2010).

Table 1. Chemical Properties of Gum Arabic

Property/Composition	A. Senegal	A. seyal
% galactose	44	38
%arabinose	27	46
% rhamose	13	4
%glucutonic acid	14.5	6.5
4-o-methyl glucuromic acid	1.5	5.5
%nitrogen	0.36	0.15
Specific rotation/degrees	-30	+51
Average molecular weight (MW)	500-600	800K-1.5m

(Source: Williams and Philips, 2000; MNS, 2008; Rabah, 2011 and Yusuf 2011).

It has a low reactivity, an excellent emulsifying, and foam stabilizing adhesive properties and does not interfere with blended product due to its pale colouration, odourless, and tasteless properties (Nuhu and Abdullahi, 2009). Ominijei (2003), cited in Nuhu and Abdullahi (2009) found it useful as admixture in concrete mortar. This research seeks to ascertain the suitability of using the Nigerian Acacia Species (Gum Arabic) as plasticizer in self-compacting concrete.

MATERIALS AND METHODS

Design of self-compacting concrete (SCC) is typically achieved by use of a cement and fines content greater than regular concrete, and admixtures that increase flowability. Some advantages of using SCC over regular concrete are higher passing ability, and the ability to consolidate without the need for mechanical vibration. The higher cement content results in a higher SCC unit cost than regular concrete. SCC remains a viable option because of less required labor and an improved finish. Potential drawbacks to using SCC include risk of segregation and batch variability (Johnson, Johnson and Robertson, 2010). The research adopted seven mix compositions with different proportions of materials and water/cement ratio. The research explored the aggregate proportion as recommended by the European Guidelines for Self Compacting Concrete which recommends a 48-55% fine aggregate content. The most suitable proportion adopted from the trial mixes when using gum Arabic as a super plasticizer that met the test requirements for fresh self-compacting concrete was 55/45% of fine and coarse aggregate which gives a proportion by weight of 1 : 2 1/2 : 2. A water/cement ratio of 0.4 and 0.45 were adopted for the research as they were found to be the most suitable for the mix and gum arabic content from the trial mixes carried out. The plasticizer proportion adopted was 0.9% and 1.5% by weight of cement. Also, an optimum fly ash content of 20% by volume of cement was found to be the most suitable for this research.

The first mix was a normal concrete mix of 1:2:4 and a water/cement ratio of 0.55 to serve as the second control. The second and third controls had the same mix of 1:2 1/2:2, but with varying water/cement ratios of 0.4 and 0.45 respectively. The three controls were chosen because the proportioning for normal concrete used on site for structural members usually has more coarse aggregates than fine aggregates. The second and third control have the same composition of cement, fine aggregates and coarse aggregates as the self-compacting concrete. The test methods adopted were from the European Guidelines for Self Compacting Concrete (2005) and Specification and Guidelines for Self-Compacting Concrete (EFNARC, 2002) in accordance to the provisions of BS-EN 12350-1 and BS-EN-12350-2.

Table 2. Summary of Materials Needed Per M^3 of Concrete in Kg.

Material	Mix ratio		
	1:2:4	**1:2 1/2:2**	**1:2 1/2: 2**
Cement	309	399	399
Sand	647	1047	1047
Gravel	1242	804	804
Water (litres)	170	160	160
W/C	0.55	0.40	0.45
Fly ash	-	80	80
G.A (0.9%)	-	4	4

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

G.A (1.5%)	-	6	6

Tests on Fresh Concrete

Slump flow test and T50cm test

This method was first developed in Japan for use in assessment of underwater concrete. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of the concrete. This is a simple, rapid test procedure, though two people are needed if the T50 time is to be measured. It can be used on site, though the size of the base plate is somewhat unwieldy and level ground is essential. It is the most commonly used test, and gives a good assessment of filling ability. It gives no indication of the ability of the concrete to pass between reinforcement without blocking, but may give some indication of resistance to segregation. It can be argued that the completely free flow, unrestrained by any boundaries, is not representative of what happens in practice in concrete construction, but the test can be profitably be used to assess the consistency of supply of ready-mixed concrete to a site from load to load.

V funnel test and V funnel test at T 5minutes

The test was developed in Japan and used by Ozawa et al. The equipment consists of a V-shaped funnel. An alternative type of V-funnel, the O funnel, with a circular section is also used in Japan. The described V-funnel test is used to determine the filling ability (flowability) of the concrete with a maximum aggregate size of 20mm. The funnel is filled with about 12 liter of concrete and the time taken for it to flow through the apparatus measured. After this the funnel can be refilled concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time will increase significantly. Though the test is designed to measure flowability, the result is affected by concrete properties other than flow. The inverted cone shape will cause any liability of the concrete to block to be reflected in the result – if, for example there is too much coarse aggregate. High flow time can also be associated with low deformability due to a high paste viscosity, and with high inter-particle friction. While the apparatus is simple, the effect of the angle of the funnel and the wall effect on the flow of concrete is not clear.

L-box test method

The test assesses the flow of the concrete, and also the extent to which it is subject to blocking by reinforcement. The apparatus consists of a rectangular-section box in the shape of an 'L', with a vertical and horizontal section, separated by a moveable gate, in front of which vertical lengths of reinforcement bar are fitted. The vertical section is filled with concrete, then the gate lifted to let the concrete flow into the horizontal section. When the flow has stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (H2/H1in the diagram). It indicates the slope of the concrete when at rest. This is an indication passing ability, or the degree to which the passage of concrete through the bars is restricted. The horizontal section of the box can be marked at 200mm and 400mm from the gate and the times taken to reach these points measured. These are known as the T20 and T40 times and are an indication for the filling ability. The sections of bar can be of different diameters and spaced at different intervals: in accordance with normal reinforcement considerations, 3x the maximum aggregate size might be appropriate. The bars can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete. This is a widely used test, suitable for laboratory, and perhaps site use. It assesses filling and passing ability of SCC, and serious lack of stability (segregation) can be detected visually. Segregation may also be detected by subsequently sawing and inspecting sections of the concrete in the horizontal section. Unfortunately there is no agreement on materials, dimensions, or reinforcing bar arrangement, so it is difficult to compare test results. There is no evidence of what effect the wall of the apparatus and the consequent 'wall effect' might have on the concrete flow, but this arrangement does, to some extent, replicate what happens to concrete on site when it is confined within formwork. Two operators are required if times are measured, and a degree of operator error is inevitable.

U-box Test Method

The test was developed by the Technology Research Centre of the Taisei Corporation in Japan. Sometimes the apparatus is called a "box-shaped" test. The test is used to measure the filling ability of self-compacting concrete. The apparatus consists of a vessel that is divided by a middle wall into two compartments. An opening with a sliding gate is fitted between the two sections. Reinforcing bars with nominal diameters of 13 mm are installed at the gate with centre-to-centre spacing of 50 mm. This creates a clear spacing of 35 mm between the bars. The left hand section is filled with about 20 liter of concrete then the gate lifted and concrete flows upwards into the other section. The height of the concrete in both sections is measured. This is a simple test to conduct, but the equipment may be difficult to construct. It provides a good direct assessment of filling ability – this is literally what the concrete has to do – modified by an unmeasured requirement for passing ability. The 35mm gap between the sections of reinforcement may be considered too close.

Fill-box Test Method

This test is also known as the 'Kajima test '.The test is used to measure the filling ability of self-compacting concrete with a maximum aggregate size of 20mm. The apparatus consists of a container with a flat and smooth surface. In the container are 35 obstacles made of metal plate with a diameter of 20mm and a distance centre to centre of 50mm. At the top side is put a filling pipe (diameter 100mm height 500mm) with a funnel (height 100mm). The container is filled with concrete through this filling pipe and the difference in height between two sides of the container is a measure for the filling ability. This is a test that is difficult to perform on site due to the complex structure of the apparatus and large weight of the concrete. It gives a good impression of the self-compacting characteristics of the concrete. Even a concrete mix with a high filling ability will perform poorly if the passing ability and segregation resistance are poor.

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

Sieve stability test (Reference method for resistance to segregation)
The test aims at investigating the resistance of SCC to segregation by measuring the portion of the fresh SCC sample passing through a 5 mm sieve. If the SCC has poor resistance to segregation, the paste or mortar can easily pass the sieve. Therefore the sieved portion indicates whether the SCC is stable or not.

RESULTS AND DISCUSSION

Workability

The workability of concrete is the ease with which concrete is mixed, transported and placed. This property is influenced by the water/cement ratio as well as the aggregate content in the concrete. The compaction factors as well as the slump of the concrete used as control was measured. C1 had a slump of 55mm, C2 had a slump of 65mm and C3 had a slump of 65mm. C1, C2 and C3 all had a compaction factor of 0.97 which falls within the range for good workability and ideal for structural concrete.

Tests for Self-compacting Properties

The characteristic properties of SCC measured are; flow ability, filling ability, viscosity, passing ability and segregation resistance. The flow ability is measured using the Abraham's cone and flow plate to test the slump flow. The slump flow was measured and in terms of total spread and the time taken for the concrete to come to rest. The viscosity was measured using the V-funnel test and was measured in terms of the time it takes for the concrete to completely flow out of the funnel. The passing ability was measured using the L-box, U-box and Fill-box (Kajima test) and was measured in terms of passing ratio, height difference, percentage passing and time. The segregation resistance test was carried out using a BS 5mm sieve and was measured in terms of percentage laitance. The Table below shows the results for the self-compacting tests carried out on the samples of SCC produced.

SCC 1

The results in Table above reveal that the concrete had a slump flow of 560mm which makes it a Class SF1 slump flow. This flow satisfies the requirement for flowability. The time taken for the concrete to empty itself from the V-funnel equipment was 8s after the funnel gate was open. This places the concrete in a viscosity class VF1 and as such, adequate for self-compacting concrete. The values of the L-box, U-box and Fill-box show a low passing ability. The values are lower than the one recommended by the European Standard for Self Compacting Concrete. The concrete showed no sign of segregation, hence its compliance to segregation resistance.

SCC2

The Table below shows that the slump flow for this concrete was 590mm which places it in a class SF1 slump flow and meets the requirement for flowability. The time taken for the concrete to flow out of the V-funnel equipment was 7s and falls into the viscosity class VF1 and satisfies the test for viscosity. The L-box, U-box and Fill-box values from the table show that the concrete has a passing ability below the one required for self-compacting concrete. The concrete showed no sign of segregation, hence its compliance to segregation resistance.

SCC3

The Table below shows that the slump flow for this concrete was 660mm which places it in a class SF1 slump flow and meets the requirement for flowability. The time taken for the concrete to flow out of the V-funnel equipment was 5.5s and falls into the viscosity class VF1 and satisfies the test for viscosity. The L-box, U-box and Fill-box values from the table show that the concrete has a good passing ability like that required for self-compacting concrete. The concrete showed no sign of segregation, hence its compliance to segregation resistance.

SCC4

The Table below shows that the slump flow for this concrete was 680mm which places it in a class SF1 slump flow and meets the requirement for flowability. The time taken for the concrete to flow out of the V-funnel equipment was 5s and falls into the viscosity class VF1 and satisfies the test for viscosity. The L-box, U-box and Fill-box values from the table show that the concrete has a good passing ability like that required for self-compacting concrete. The concrete showed no sign of segregation, hence its compliance to segregation resistance.

The self-compacting properties of the four samples of SCC meet the minimum requirements proposed by the European Guidelines for Testing Self Compacting Concrete (2005) as shown in the Table below and are within the range of values found by Oliviera et.al., (2006). These results show the positive effects of gum arabic on the fresh properties of SCC.

Table 3. Results for Self Compacting Properties of Fresh Concrete.

Test Methods	Units	C1	C2	C3	SCC1	SCC2	SCC3	SCC4
Slump	mm	55	60	75	-	-	-	-
Compaction Factor	-	0.97	0.97	0.97	-	-	-	-
Slump Flow	T_{50} Time (s)	-	-	-	8.00	7.50	6.0	5.0
	Final Average Diameter(mm)	-	-	-	560	590	660	680
L-Box	T_{40} (s)	-	-	-	9.00	7.50	7.20	5.5
	H/H_1	-	-	-	0.69	0.76	0.80	0.80
Fill-Box		-	-	-	80	89	93	96
V-Funnel	Time (s)	-	-	-	9.00	7.00	5.5	5.0
U-Box	$H - H_1$	-	-	-	22	18	7	9
Sieve Test	%	-	-	-	No Segregation	No Segregation	No Segregation	No segregation

International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 4, Number 1, March 2019
http://www.casirmediapublishing.com

Table 4. Conformity Criteria for the Properties of SCC

Property	Criteria
Slump flow Class SF1	≥ 520, ≤ 700mm
Slump flow Class SF2	≥ 640, ≤ 800mm
Slump flow Class SF3	≥ 740, ≤ 900mm
Slump flow Class specified a target value	± 80mm of target value
V-funnel Class VF1	≤ 10s
V-funnel Class VF2	≥ 7s, ≤ 27s
V-funnel Class specified as a target value	± 3s
L-box Class PA1	≥ 0.75
L-box Class PA2	≥ 0.75
L-box Class specified as a target value	Not more than, 0.05 below the target value
Sieve segregation resistance Class R1	≤ 23
Sieve segregation resistance Class R2	≤ 23

(Source: European Guidelines for Self Compacting Concrete, 2005)

CONCLUSION

The self-compacting properties of the four samples of SCC meet the minimum requirements proposed by the European Guidelines for Testing Self Compacting Concrete (2005). These results show the positive effects of gum arabic on the fresh properties of SCC. Therefore, Gum Arabic is suitable for use in SCC as a plasticizer.

REFERENCES

1. Ademoh, N.A. and Abdullahi, A.T. (2009). Determination of Physio-Chemical Properties of Nigerian Acacia Species for Fondry Sand Binding Applications. *Research Journal of Applied Sciences, Engineering and Technology. 1(3): 107-11*
2. AllahBakash, S. and Reddy, K., B. (2013). Increasing the Sustainability of Concrete by Using Superplasticizers- A Study. *International Journal of Advanced Structures and Geotechnical Engineering.*
3. Anderson, D.M.W., Dea, I.M., Karamalla, K.A. and Smith, J.F. (1968). Analytical Studies of Some Unusual Form of Gum from Acacia Senegal. Carbohydrates. Res., 6: 97-103.
4. BS-EN-12350-1 (2009). European Committee for Standardization. Testing fresh concrete: Part1: Sampling. Brussels, Belgium.
5. BS-EN-12350-2 (2009). European Committee for Standardization. Testing fresh concrete: Part2: Slump test. Brussels, Belgium.
6. European Project Group, *Specification and guidelines for self-compacting concrete,* United Kingdom, EFNARC, 2002.

7. Evvanne, H. and Hakanen, M. (2007). Analysis of Cement Superplasticizers and Grinding Aids.
8. Haner, A., Galli, R., Schluep, M., Mader, U. and Germann, A. (2005). Mass Flow Analysis of Two Superplasticizers. www.efcar.info. Retrieved in October, 2013
9. Herterich, U., Volland, G., Wustholz, T. and Stegmaier, M. (2004). Leaching Properties of Selfcompacting concrete. *Otto-Graf-Journal. Vol. 15.*
10. Iures, L. and Bob, C. (2010). The Future Concrete: Self-Compacting Concrete.
11. Johnson, D., Johnson, G., and Robertson, I.N (2010). Quantifying segregation in self – consolidating Concrete through image analysis
12. Market News Service. (2008). Gum Arabic. www.ngara.com.
13. Mokwunye, M., U., B. and Aghughu, O. (2010). Restoring Nigeria's Lead in Gum Arabic Production: Prospects and Challenges.
14. Oliviera, L., P., Gomes, J., P. and Pereira, C., N., G. (2006). Study of Sorptivity of Self- Compacting Concrete with mineral Additives. *Journal of Civil Engineering and Management 2006, Vol. XII, No. (3), 215-220*
15. Ouchi, Nakamura, Osterson, Hallberg, and Lewin. (2003). Applications of Self-Compacting Concrete in Japan, Europe and the United States.
16. Rabah, A., A. (2011). Rheological Characteristics of Sudanese *Acacia senegal* Gum: *UofKEJ Vol.1 Issue 2 pp. 58-62 (October 2011)*
17. Ravindrarajah, R., Siladya, D. and Adamopoulos B. (2003). Development of High-Strength Self-compacting Concrete with Reduced Segregation Potential. *Proceedings of the 3rd International RILEM symposium, Reykjavik, Iceland. 17-20 August.*
18. STATE-OF-THE-ART-REPORT. (2011). Concrete Admixtures and Environment. 5th Edition.
19. Tewari, A. (2010). An Overview on Chemistry and Applications of Acacia Gum: *Scholars research library.*
20. The European Guidelines for Self-Compacting Concrete. (2005). Specification, Production and Use.
21. Yusuf, A., K. (2011). Studies on Some Physicochemical Properties of the Plant Gum Exudates of *Acacia Senegal* (Dakwara), *Acacia Sieberiana* (Farar Kaya) and *Acacia Nilotica (*Bagaruwa). *JORIND 9(2) December, 2011. ISSN 1596 – 8308.*