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The Use of Plant Extract as Shrinkage Reducing Admixture (SRA) to Reduce Early Age Shrinkage and Cracking on Cement Mortar

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ABSTRACT: Concrete shrinkage is a main concern of engineers due to its direct relation to cracking. Shrinkage and shrinkage cracks jeopardize durability and increase maintenance as well as rehabilitation cost. To enhance the durability, normally shrinkage reducing admixtures is used, but the chemical admixtures are not eco-friendly and economical. The chemicals are patented and manufactured in developed countries and soled to developing countries at exorbitant price. The manufacturing also emits toxic chemicals which significantly contribute to global warming. To alleviate this situation, research work was undertaken to determine the suitability of plant extract (Blue Gum extract) as shrinkage reducing admixture (SRA) for concrete. Extracts from the bark of blue gum tree was prepared by boiling the bark in water. Mortar slabs were prepared for different percentage of dosage and flow level, which were then exposed to the environment, thus permitting measurement of shrinkage and cracks for different times (5hour, 3day, 7 day & 28 day). Results obtained indicate that the use of Blue Gum plant extract reduced shrinkage and cracks due to shrinkage on cement mortar.

KEYWORDS: Eco-Friendly, Plant Extract, Shrinkage, Cracking, Shrinkage Reducing admixture.

1 INTRODUCTION

The durability of concrete is affected by the presence of cracks. Concrete cracking is mainly due to shrinkage. Crack in concrete due to shrinkage make ways for aggressive substances from the environment to percolate and dissolve the concrete, and hence, later on degrade the concrete and diminish the service life of the concrete. During hydration, the cement undergoes volumetric contraction due to chemical reaction and, the water moves towards the external surface due to surface tension. The movement of water towards outside leaves the cement paste, mortar or concrete in unsaturated condition leading to drying and shrinkage. Chemical shrinkage is also early age shrinkage due to cement reaction [1]. In concrete a map-like cracks exist due to the inhibition of volumetric reduction of the outer layer by the inner part [2]. Drying shrinkage occurs after the concrete set and is due to the exposure to different environment which contributes to the volumetric change of concrete [3]. Plastering with cement mortar was an essential part of finishing concrete structures. One of the problems in finishing is crack due to early age or later age shrinkage. Cracks in the finished layer decrease the beauty and quality of the structure [4]. Different promising researches were done on different shrinkage reducing supplementary materials. Replacement of cement with fly ash decreased both plastic and drying shrinkage, but mostly autogenous shrinkage. As the replacement of cement with fly ash increased, the shrinkage of the concrete decreased, however the effect was not much for drying shrinkage. The reduction in shrinkage was more effective when using shrinkage reducing admixture. The use of silka control 40(shrinkage reducing admixture) was more efficient in reducing all types of shrinkage [5]. When shrinkage reducing admixtures added to concrete during batching stage, it significantly reduced both early and long term drying shrinkage. Glycol ether is one of shrinkage reducing admixture and mainly they are glycol derivatives [6]. Polypropylene glycol reduced authgenous and drying shrinkage by 85% and 50% respectively. Shrinkage reducing admixture (polypropylene glycol) reduced shrinkage and shrinkage cracking by reducing the surface tension at the [7].

2 Materials And Methods

2.1 Materials

2.1.1 Plant Extract

The plant extract used as an admixture was prepared by boiling Blue Gum bark in water. The bark of Blue Gum was cut into very small pieces and then 1kg of the bark was boiled with four litters of water for two hours under pressure. From successive boiling an average of 700ml/kg was obtained. The elemental analysis of the boiled plant extract was done by X-ray fluorescence and the results are shown in the Table 1

Table 1: Chemical concentration in ppm or µg/g

Element	Bark of Blue Gum Extract	Element	Bark of Blue Gum Extract
Potassium (K)	837 ±29	Copper (Cu)	<0.10
Calcium (Ca)	31.6 ±1.2	Zink(Zn)	0.514 ±0.030
Titanium (Ti)	<0.15	Arsenic(As)	0.334 ±0.022
Vanadium(V)	<0.10	Bromine(Br)	<0.01
Chromium(Cr)	<0.10	Rubidium(Rb)	1.38 ±0.06
Manganese (Mn)	22 ±0.80	Strontium(Sr)	5.14 ±0.19
Iron(Fe)	2.74 ±0.12	Yttrium(Y)	0.280 ±0.020
Nickel	<0.10		0.343 ±0.027

The elemental analysis shows the extract was not toxic to human body. The level of bromine, rubidium, arsenic and nickel are insignificant as compared to their toxic level.

2.1.2 Cement

The cement used was Ordinary Portland cement (OPC) of grade 42.5. It was manufactured by Bamburi cement Ltd, Kenya. The product conforms to European Norm EN 197 cement.

2.1.3 Fine Aggregate

Locally available river sand was used. The aggregate was graded through sieving and curve plotting according to BS 812:1992. The physical properties of fine aggregate were done based on their respective BS standard: The specific gravity (BS 812-102:1995), Bulk density (BS 812-2:1995), water absorption (BS 813-2:1995) and moisture content (BS 812-109:1990). The results are shown in Table 2.

Table 2: Physical properties and sieve analysis of fine aggregate

Sieve Designation mm	Weight retained (gm)	percent weight retained	Cumulative percent weight retained	percent weight passing
5	2.5	0.5	0.5	99.5
2.36	5	1	1.5	98.5
1.18	58.75	11.75	13.25	86.75
0.6	142.5	28.5	41.75	58.25
0.3	172.5	34.5	76.25	23.75
0.15	98.75	19.75	96	4
Residue	20	4	100	-
Physical properties: Grading = Zone II Fineness modulus = 3.3 Specific gravity = 2.62 Bulk Density = 1470 kg/m^3 Water Absorption = 8.63% Moisture Content = 8.1%				

2.1.4 WATER

The water used for concrete mix and curing the specimen was the water available in the laboratory form the tap.

2.2 METHODOLOGY

2.2.1 SHRINKAGE AND CRACKS DUE TO PLASTIC SHRINKAGE ON CEMENT MORTAR

To measure shrinkage, and cracks due to plastic shrinkage on mortar slabs, a wooden molds of size 500x500x15mm was prepared. A total of 10 mortar slabs were cast for two different mix ratios and three different percentage plants extract dosage. The mortar mixtures were proportioned with cement to sand ratio of 1:3 and 1:4. The mortar slabs were cast for the same flow level but different percentages of plant extract (0, 5, 10 & 15%) dosage. Three mortar slabs for a mix ratio of 1:3 (Cement: sand) were exposed to direct heat from the sun and, four mortar slabs for each mix ratio of 1:3 and 1:4 (cement: sand) were kept away from direct heat. The shrinkage and cracks were measured using the aid of measuring scale and use of magnifying lens. The data's were recorded for plastic shrinkage at 5 hours and drying shrinkage at 3, 7, and 28 days.

3 RESULTS AND DISCUSSION

3.1 THE EFFECT OF BLUE GUM EXTRACT ON SHRINKAGE

The shrinkage was measured as the sum of all types of shrinkage occurred on the specimen. The shrinkage was measured based on the change in length of the test specimen over time and presented in the figure 1-6 below. Figure 1&2 shows the effect of the blue gum extract on the shrinkage of the mortal slab with a mix ratio of 1:3 (cement: sand) controlled from direct heat of the sun. The average wind speed, temperature and humidity were measured within the 5 hours from the cast and were 16km/h, 26^{0}C and 51% respectively. The use of blue gum extract decreased both early age shrinkage as well as shrinkage through time. Since the mortar slabs were kept away from direct heat of the sun, the variation in early age shrinkage was not much. However, for the later age or drying shrinkage, as the dosage of blue gum extract increased the shrinkage also decreased. A dosage of 15% plant extract decreased the early age and drying shrinkage in average by 15 and 25% respectively for controlled case. Figure 2 shows shrinkage for different time interval and dosage. Shrinkage for early age and later was very less for the slab mortar with plant extract as compared to the control. The shrinkage increased from 5 hours to 3 days, but followed a constant trend then after, hence showing that drying shrinkage was also affected by early age shrinkage. For the controlled case the early age shrinkage and drying shrinkage have a direct relation. For different percentage dosage blue gum extract, early age and later age shrinkage decreased as compared to the control.

Figure 3 and 4 shows the effect of the blue gum extract on shrinkage of the mortar slab with a mix ratio of 1:3 (cement: sand) exposed to direct heat from the sun. The average wind speed, temperature and humidity were measured within the 5 hours from the cast and were 13km/h, 22^{0}C and 57% respectively. The effect of plant extract on early age shrinkage was very high. The use of blue gum extract decreased the early age and drying shrinkage in average by 20 and 14% respectively for mortar slab exposed to direct heat from the sun. The use of plant extract reduced excessive loss of the moisture from the surface of the concrete by its ability of reducing surface tension. In addition the plant extract was effective in reducing the movement of water towards the outside surface by decreasing the surface tension in the capillary tube.

Figure 5&6 shows the effect of plant extract on shrinkage of the metal slab with a mix ratio of 1:4 (cement: sand) controlled from direct heat of the sun. The average wind speed, temperature and humidity were measured within the 5 hours from the cast and were 16km/h, 26^{0}C and 51% respectively. As compared to mix ratio of 1:3, the shrinkage for mortar slabs with a mix ratio of 1:4 was very small. The shrinkage of the mortar slab for 5% blue gum extract was greater than that of control and less for 10 and 15% dosage. From the graph there is no direct relation between dosage and shrinkage. For a mix ratio of 1:4 by cement to sand ratio, the amount of binder in the mortar mix is very small i.e. Shrinkage decreases as the quantity of binder material decrease and quantity of aggregate increase. Due to the above reason the effect of plant extract on shrinkage was not effectively seen as the dosage increase.

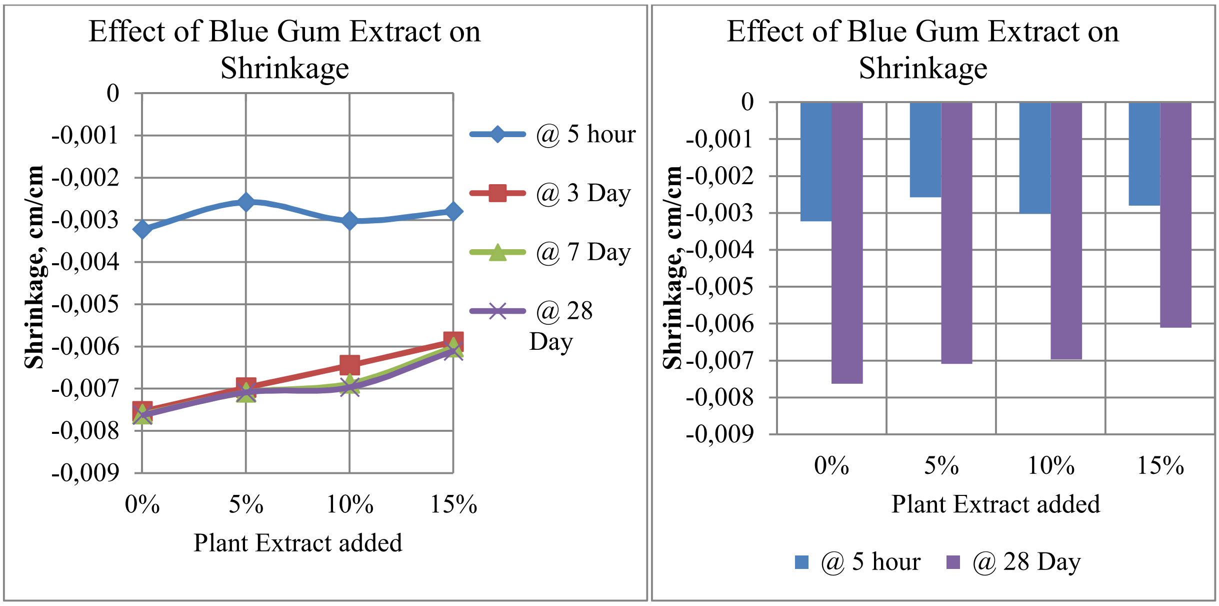


Figure 1: The Effect blue gum extract on shrinkage for controlled from direct heat from the sun

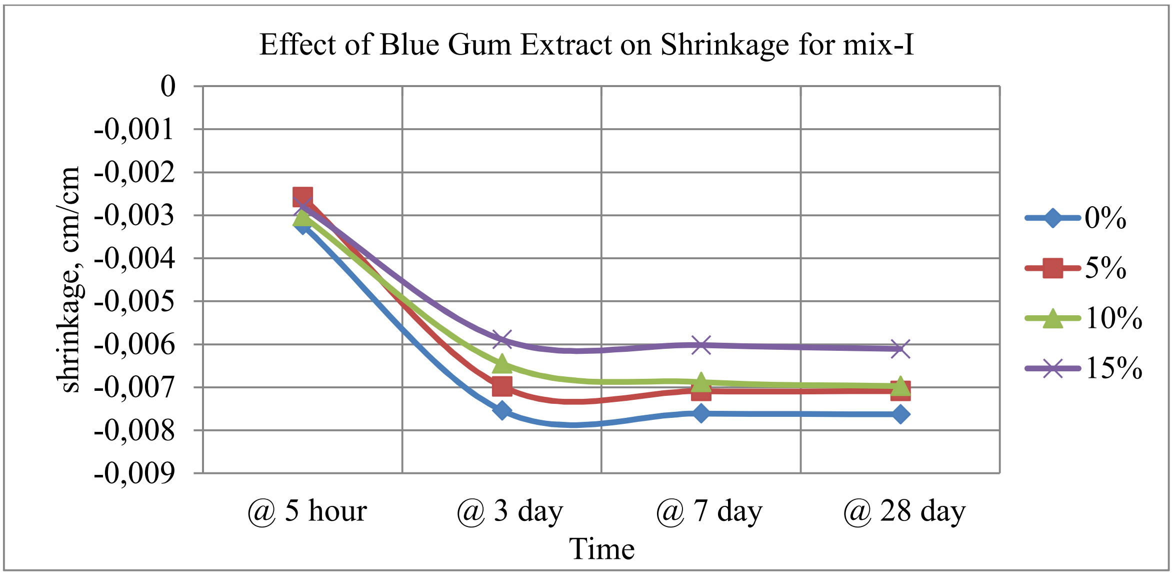


Figure 2: Shrinkage through time for different dosage for controlled from direct heat from the sun

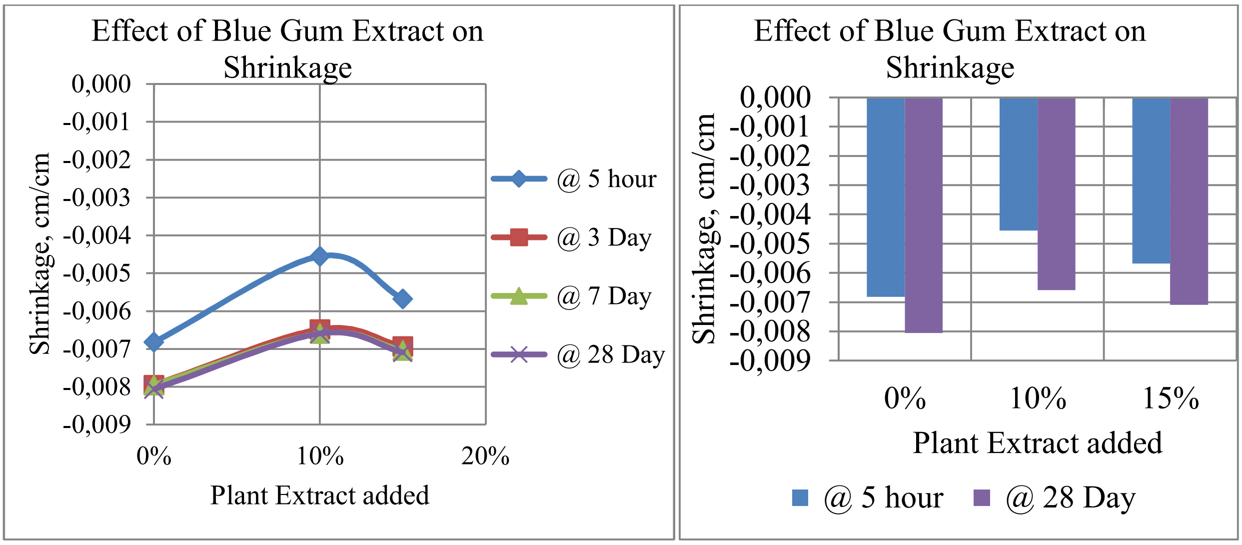


Figure 3: The Effect on shrinkage for exposed to direct heat from the sun

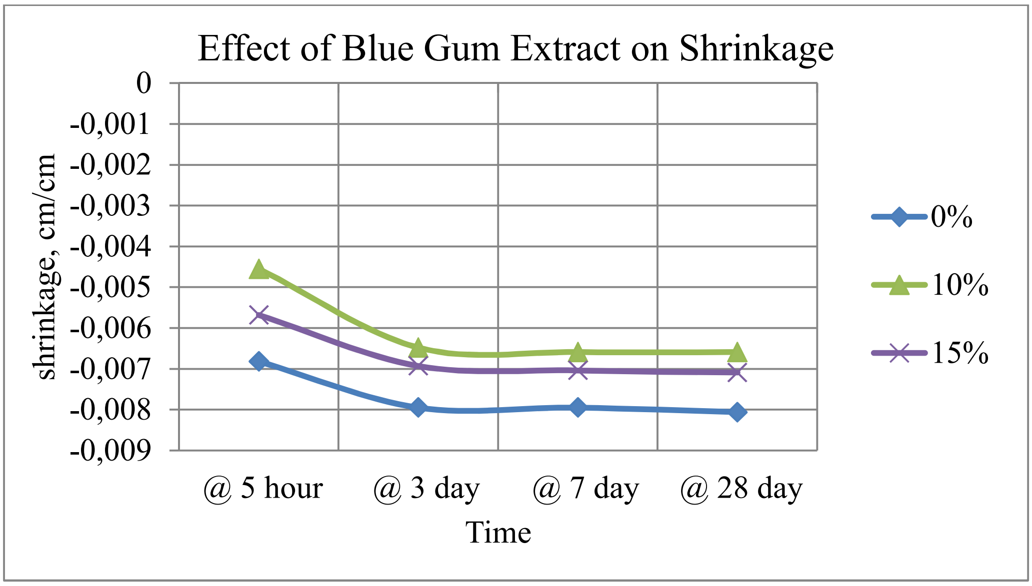
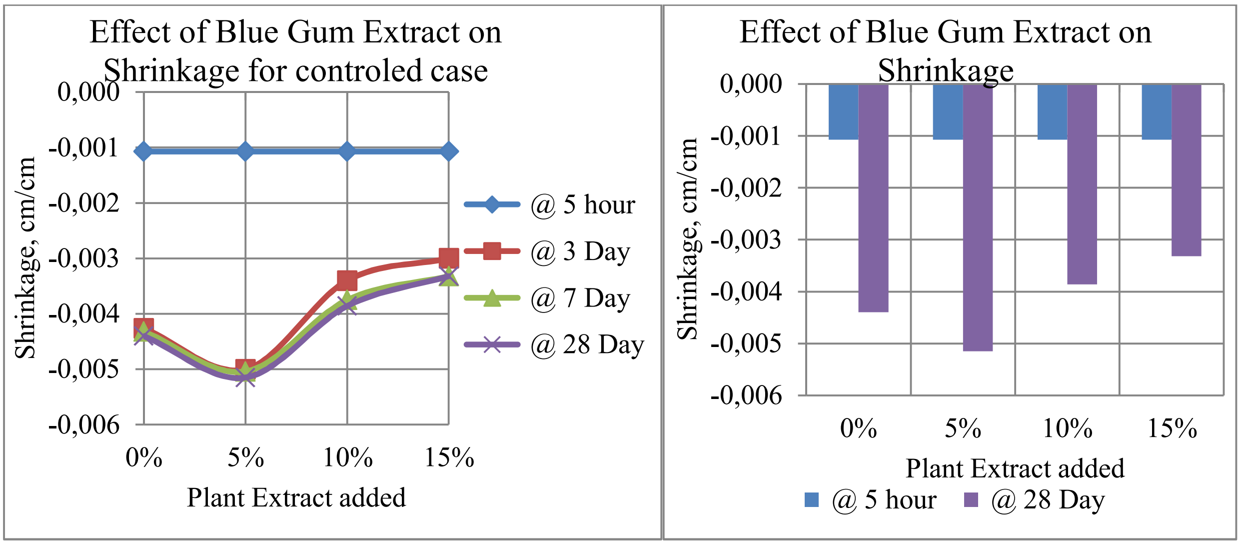


Figure 4: Shrinkage through time for different dosage for slab exposed to direct heat from the sun



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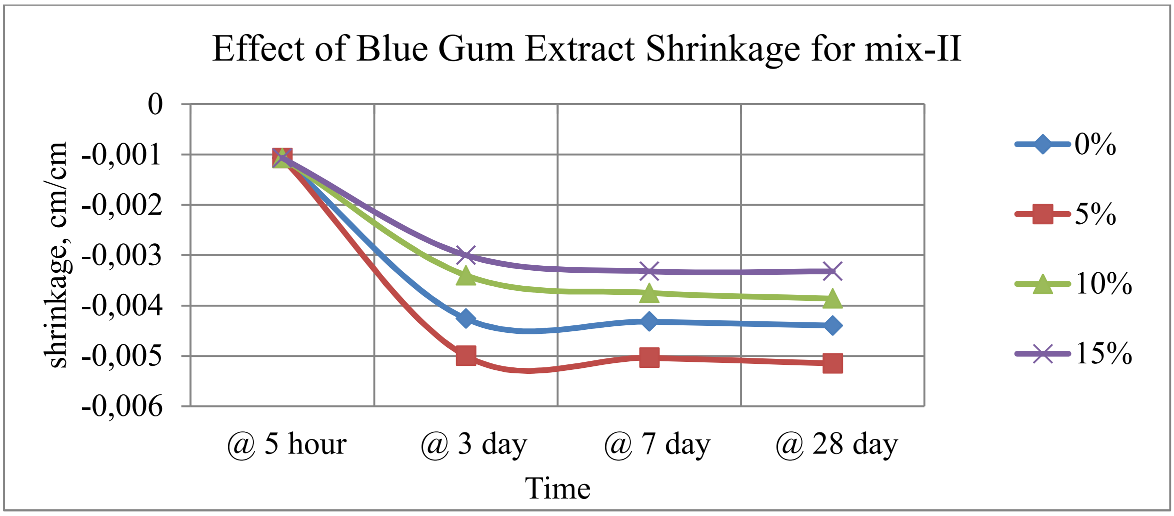

Figure 6: Shrinkage through time for mix-II controlled from direct heat from sun

3.2 THE EFFECT OF BLUE GUM EXTRACT ON CRACKING DUE TO SHRINKAGE

The cracks formed on the surface of mortar slab were due to early age shrinkage. The crack width and length was measured for early age at 5 hour and later at 3, 7 and 28 days. The result shows all the cracks occurred due to early age shrinkage and not increased through time.

Table 3 shows a mortar slab cast for mix-I and cured away from direct heat of the sun. The average wind speed, temperature and humidity were measured with in the 5 hours from the cast and were 16 km/h, 26^{0}C and 51% respectively. The results from 5 hour measurement, one crack were seen on the surface of the mortar slab with 5% blue gum extract and two cracks on control (mortar slab without plant extract). The two cracks on control mortar were measured at 5 hour and have a (width, length) of (1, 130) mm and (1, 170) mm. Cracks due to shrinkage were also measured for 3, 7, 28 day and have the same dimension (width, length) of (1, 133) and (1, 175). The mortar slab with 5% plant extract cracked due to shrinkage. The crack was measured for both early and drying shrinkage in (width, length); and were (0.5, 58) and (0.75, 60). The crack was occurred due to early age shrinkage and not increasing much through time. The shrinkage was reduced for a mortar slab with plant extract as compared to the control (Mortar slab without plant extract).

Table 4 show a mortar slab cast for mix-II and cured away from direct heat of the sun. No crack occurred on the surface of the mortar slab and the shrinkage was very small compared to that of mix-I. No crack was occurred for both mortar slabs with and without plant extract. Shrinkage and shrinkage cracks are dependent on concrete constituent and hence, increased in quantity of sand decreased shrinkage in mortar slabs.

Table 5 shows a mortar slab cast for mix-I and were measured at 5 hour. The wind speed, temperature and humidity from the mix to measurement were in average 13 km/h, 22^{0}C and 57% respectively. The cracks were occurred on both control and mortar slab with 10% blue gum extract. The crack (width, length) on a control mortar slab and with 10% blue gum extract was measured at 5 hour and were (1, 150)mm and (0.5,55)mm. The cracks were also measured for 3, 7, 28 day for both control and with 10% blue gum extract. The cracks (width, length) were not increased in dimension and were (1, 155) mm and (0.75, 70) mm for control and with 10% blue gum extract respectively. The crack was occurred due to early age shrinkage and not increased much through time. No crack occurred on mortar slab with 15% blue gum extract and shrinkage was reduced for a mortar slab with plant extract as compared to the control (Mortar slab without plant extract).

Table 5.3: Crack due to shrinkage for mortar slabs of mix-I controlled from direct heat from the sun

Crack width and length for different percentage of blue gum extract added				
Mix-I: 1:3, N= number, L = length and W = width				
% Plant extract added	@ 5 hour	@ 3 day	@ 7day	@28 day
	Crack (N,L,W)	Crack (N,L,W)	Crack (N,L,W)	Crack (N,L,W)
	mm	mm	mm	mm
0	2, (130, 170), (1,1)	2, (133, 175), (1,1)	2, (133, 175), (1,1)	2, (133, 175), (1,1)
5	1, 58, 0.5	1, 60, 0.75	1, 60, 0.75	1, 60, 0.75
10	No Crack	No Crack	No Crack	No Crack
15	No Crack	No Crack	No Crack	No Crack

Table 5.4: Crack due to shrinkage for mortar slabs of mix-II controlled from direct heat from the sun

Crack width and length for different percentage of blue gum extract added				
Mix-II: 1:4 , N= number, L = length and W = width				
% Plant extract added	@ 5 hour	@ 3 day	@ 7day	@28 day
	Crack (N,L,W)	Crack (N,L,W)	Crack (N,L,W)	Crack (N,L,W)
	mm	mm	mm	mm
0%	No Crack	No Crack	No Crack	No Crack
5%	No Crack	No Crack	No Crack	No Crack
10%	No Crack	No Crack	No Crack	No Crack
15%	No Crack	No Crack	No Crack	No Crack

Table 5.5: Crack due to shrinkage for mortar slabs of mix-I exposed to direct heat from the sun

Crack width and length for different percentage of Blue Gum extract added				
Mix-I: 1:3 , N= number, L = length and W = width				
% Plant extract added	@ 5 hour	@ 3 day	@ 7day	@28 day
	Crack (N,L,W)	Crack (N,L,W)	Crack (N,L,W)	Crack (N,L,W)
	mm	mm	mm	mm
0%	1, 150,1	1, 155, 1	1, 155,1	1,155,1
10%	1,55, 0.5	1, 70, 0.75	1, 70, 0.75	1, 70, 0.75
15%	No Crack	No Crack	No Crack	No Crack

4 CONCLUSIONS

Based on the experiments carried out and the results on the effect of plants extracts on shrinkage and cracks due to shrinkage, the following conclusions are made:

a) The plant extract decreased shrinkage and, hence blue gum extract can be used as shrinkage reducing admixture in concrete.

b) Cracks in concrete is a main concern of engineers and plant extract has a capability of reducing early age cracks and hence, it can be used as shrinkage reducing admixture in concrete to reduce cracks.

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