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Effect of Different Admixtures on Strength of Cement Grouted Soil

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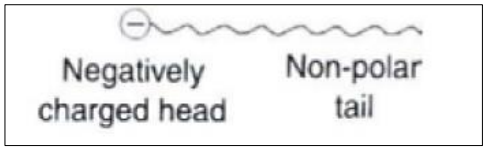
Abstract
Grouting is mainly used for filling the empty voids or replacing the fluids inside voids with grout so that engineering properties of soil and rock medium, become better. Cement grouting is most common and also most important technique in construction industry for reducing permeability of mass and also increasing strength of formation. When cement hydrates and cures it make strong interlocking crystals and become almost impermeable. In civil engineering, there are many uses of grouting and now many materials are also available in market. Cement is still the most popular grouting material but to enhance its property is big concern. By adding some admixtures the performance can be improve. In this study admixture like accelerator, retarder and antibleeder is studied for strength aspects. For experiment direct shear test was done to find relation between normal stress and maximum shear stress. From the straight line slope we get angle of shearing resistance and vertical intercept give cohesion value for soil with and without admixture for 7 day curing.

Keywords: Cement grouting, soil stabilization, admixtures, shear strength, direct shear test

Introduction
Cement grouting is very common in civil works for decreasing permeability and increasing strength of soil formations. Sometimes extra admixture are mixed with cement to enhance its behaviour. Many chemical admixtures are there in market for example Calcium Chloride, sodium silicate and sodium aluminate works as accelerator, cellulose ether and aluminium sulphate as antibleeder. Other admixtures also available in this report we tried to see if such admixtures reduce or affect strength of cement grout. The report shows investigation result on this matter. Shear strength test show that both cohesion intercept and shearing angle of soil is improved after cement grouting. Ground improvement mean any technique used for making soil stronger, less compressible and less permeable so that it can be used for project work. Many methods are present for improvement up to 20 m deep like, drainage, preloading, reinforcement, grouting, chemical or thermal methods. Method selection depend on type of soil, cost and time. If, soil depth less than 3 m and water table also low then replacement is cheaper. But if water table is high then costly dewatering required. Vibro compaction is useful for loose sands but not when fines more than 20 percent. Grouting is one very popular technique in foundation engineering, used in seepage control below dams, tunnelling, cut off walls etc. Its main aim is filling the voids by grout and replacing fluids so that permeability goes down and strength goes up.

Literature Review
In early days concrete had small addition of organic or inorganic matter. Admixture is different from additive or additions, because admixture are mixed separately to change cement property for example gypsum added in manufacture is additive, but chemical admixture added at site is admixture; Last 30 to 35 years research on admixtures has increased much with concern on strength and durability of concrete. Many researchers studied this and found confidence in chemical admixtures technology. Different admixtures can be used in grout. Littlejohn (1982) shown sodium silicate and Calcium Chloride as accelerator, sugar and tartaric acid as retarder, aluminium sulphate and cellulose ether as antibleeder. But earlier works only studied viscosity or stability, no one properly check strength property. This report give experimental result on effect of admixture on strength of cement grout.

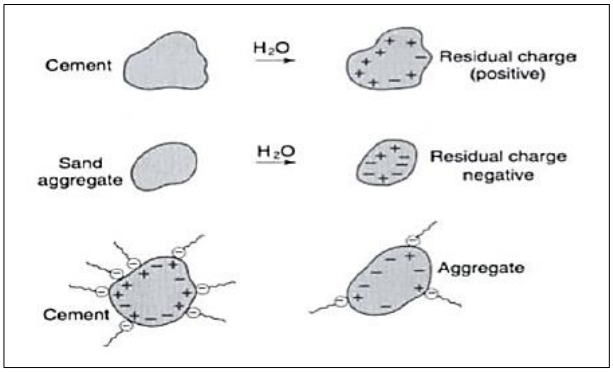
A. Antibleeder
These admixtures having a polar group which work at the air, water interface of cement paste and they help in keeping the air which is trapped during mixing process more stable. The process start with dissolution, then dissociation and then orientation and adsorption they also change the viscosity of cement paste. When adsorption happens viscosity goes up paste become more water repellent and particle attraction also increase. At first the small air bubbles stay in paste and they make bridges between cement particles, this leads to higher viscosity and less bleeding in cement paste;



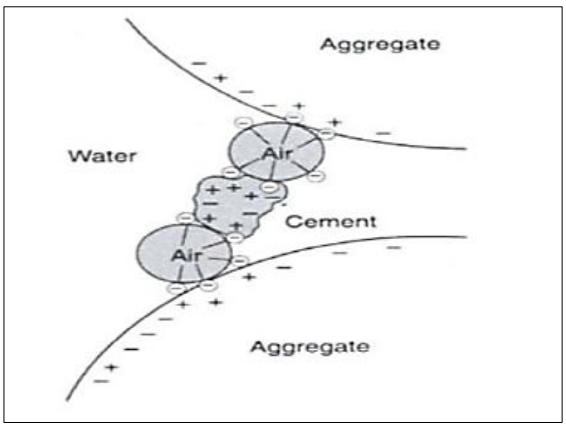
Dissolution: Sodium alkyl benzenesulphonate when mixed in water, it break into sodium ion and alkyl benzene sulphonate part which has one hydrophilic side and other hydrophobic side.

Orientation: The hydrocarbon chain part is hydrophobic and one end is hydrophilic this chain arrange itself towards the air inside bubble. This reduces surface tension of water because of intermolecular repulsion and so bubbles are formed easily.

Adsorption: In cement mortar or concrete, these air bubbles repel each other since they having same charge, so they do not combine. This make the air bubbles stable.



Overall the result is like aggregate-air-water-aggregate type bridge which improve cohesion of the mix and keep the air void system stable. Finally, the cohesion of mixture become more. Because of adsorption viscosity increase, inter particle attraction also go up and bleeding of cement paste is reduced directly.



B. Accelerator

This kind of admixture do both work; it reduce water content and also speed up the cement hydration the simple type is made from mixture of calcium lignosulphonate and Calcium Chloride. When chloride free accelerator needed then calcium formate or sodium nitrite can be used. Many of the chloride free accelerators also give enough water reducing so they also come in this group.

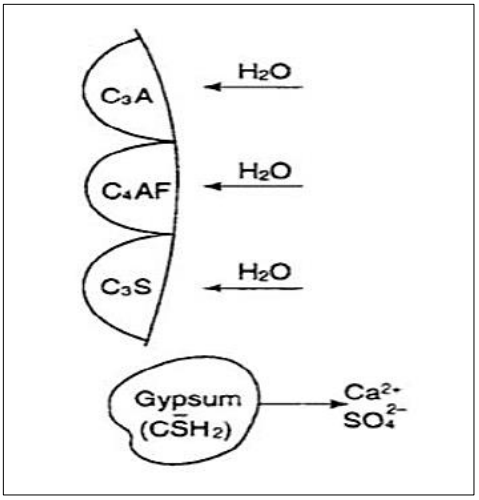
Mainly they are used in concreting during cold weather and in precast works where mould has to be reuse quickly. Because of water reducing property, higher strength can be achieved compare to using only normal accelerator like Calcium Chloride.

Calcium Chloride work like a catalyst in hydration of C_3S and C_2S. It can also reduce alkalinity of solution which promote hydration of silicates. The hydration of C3A little delayed but overall cement hydration process remains same.

C. Retarder

This type of admixture mostly made from hydro carboxylic acids. Their main work is delaying the setting time of concrete without much affecting water-cement ratio. Another type is calcium lignosulphonates where sugar content is high because of crude sulphite. Sugar is strong retarder, but here high dose required compared to hydro carboxylic type. This type also cause more air entrainment, but it can be balanced by adding air detainer. Generally water reducing admixtures are useful for mature concrete property. But if used only for workability improvement then accelerating types can cause little more drying shrinkage and creep.

Retarders get strongly adsorbed on cement particle surface. The hydration rate sometimes increase because of fine dispersion, which produce early hydration product and make cement setting time longer.



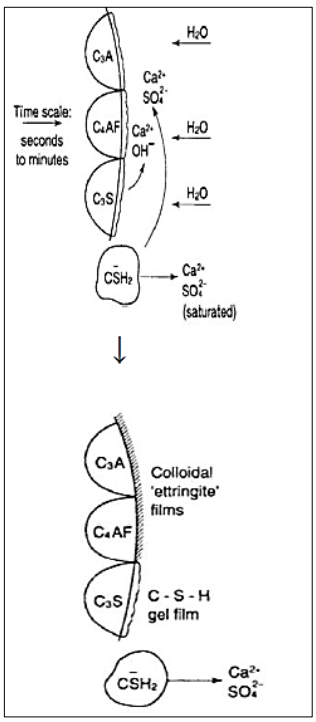
$2Ca_3Al_2O_6 + 21H_2O \rightarrow 2Ca_3[Al(OH)_6]_2 + 9H_2O$

$2Ca_3SiO_5 + 6H_2O \rightarrow Ca_3Si_2O_7 .3H_2O + 3Ca(OH)_2$

$Ca_3Al_2O_6 + Ca(OH)_2 + 12H_2O \rightarrow 2[Ca_2Al(OH)_6]_2(SO_4)_3 .26H_2O + Ca(OH)_2$

$CaSO_4 \rightarrow Ca^{+2} + SO_4^{2-}$

Formation of CSH bridge constitute the welding points between the granules and in result lengthening of setting time in concrete.



Materials Used
To do the experiments the materials were used followings-
Cement (43 Grade OPC)
1. Sand
2. Water (normal tap water) and some Admixtures

A. Properties of Cement
Normal consistency of cement paste was tested using Vicat Apparatus and found to be 28%.

B. Properties of Sand
The sand used in the test was passed through 4.75mm IS sieve. From particle size distribution curve, details were noted as:
D_{10}=0.002mm, D_{30}= 0.017mm and D_{60}= 0.25 mm
Therefore, the value of Cu=D_{60}/D_{10}=125 and Cc =$D_{30}^2/(D_{60}\times D_{10})$= 0.58
So, the used sand is poorly graded.

C. Proctor Compaction Test
Proctor compaction test was done to find the optimum moisture content (OMC) and the maximum dry density (MDD) of the soil which we used.

Table 1: Variation of Dry Density with Moisture content

Compacted Soil - Sample no.	1	2	3	4	5
Actual average water content, w%	8.0	10.0	12.0	14.0	16.0
Mass of compacted soil and mold (g)	3457.2	3721.2	3909.0	3782.5	3715.2
Mass of mold (g)	1849.5	1849.5	1849.5	1849.5	1849.5
Wet mass of soil in mold (g)	1524.2	1788.2	2176.0	2149.0	2082.0
Wet density (g/cm^3)	1.6	1.8	2.0	1.9	1.8
Dry density (g/cm^3)	1.5	1.7	1.8	1.6	1.6

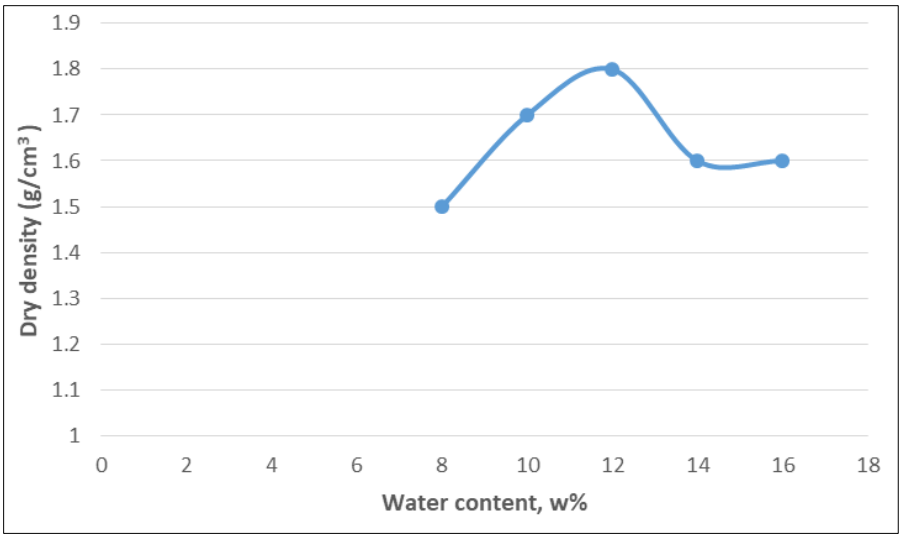


Fig 1: Relation between Dry Density and Water content

From the graph between dry density and water content, the values are calculated.
Optimum Moisture Content (OMC) = 11.9 %
Maximum Dry Density (MDD) = 1.80 g/cm³

D. Properties of Water
In this experiment normal tap water is used which have pH nearly 7. This water is suitable for mixing in cement.

Experimental Investigations
To observe the effect of admixture on shear strength, grout was placed inside the pores of sand bed by hand mixing. Soil samples were made by adding cement about 10% by weight of sand and mixed properly with trowel.

Required percentage of admixture (as per weight of cement) was first dissolved in water (about 10% by weight of sand and cement both together) and then added in the mixture of cement and sand. This gives uniform mixing of all materials. The mix was filled in split moulds of size 60 × 60 × 25 mm in layers to get same density. The samples were kept in room temperature for one day and then cured in water tanks for 7 days before testing.

A. Test Using Accelerator
One sample of size 60 × 60 × 25 mm was taken and direct shear test was carried out after 7 days curing. The graph shows variation of shear strength with different percentage of Calcium Chloride in cement grouted soils. The addition of Calcium Chloride first decrease the shear strength of grouted soil.

Table 2: Variation of Shear strength with % $CaCl_2$

% $CaCl_2$ by weight	σ=100kN/m^2	σ=150kN/m^2	σ=200kN/m^2
0	284.14	353.21	422.28
0.5	228.70	295.05	301.40
1	230.90	292.89	354.86
1.5	249.17	298.76	358.35
2	252.45	312.67	372.90
2.5	251.40	309.16	366.88
3	259.40	315.17	370.90

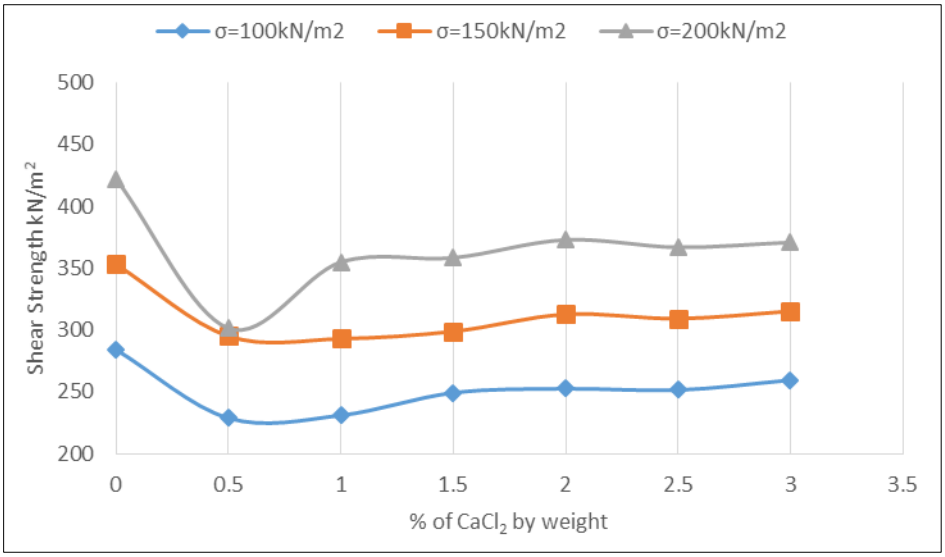


Fig 2: Variation of Shear strength with % $CaCl_2$

B. Test Using Retarder

Sugar is one of the common retarder used in cement grouting the graph below indicate the effect of sugar percentages on shear strength of sand grouted with cement. The behaviour is nearly same like, in case of Calcium Chloride. For small percent (till about 0.15%) the shear strength goes down, but after that it again increase and almost achieve the original value.

Table 3: Variation of Shear strength with % of Sugar

% Sugar by weight	σ=100kN/m²	σ=150kN/m²	σ=200kN/m²
0.0	283.60	352.4	421.27
0.1	191.63	351.4	420.27
0.3	209.64	277.2	344.78
0.5	264.00	322.3	379.87

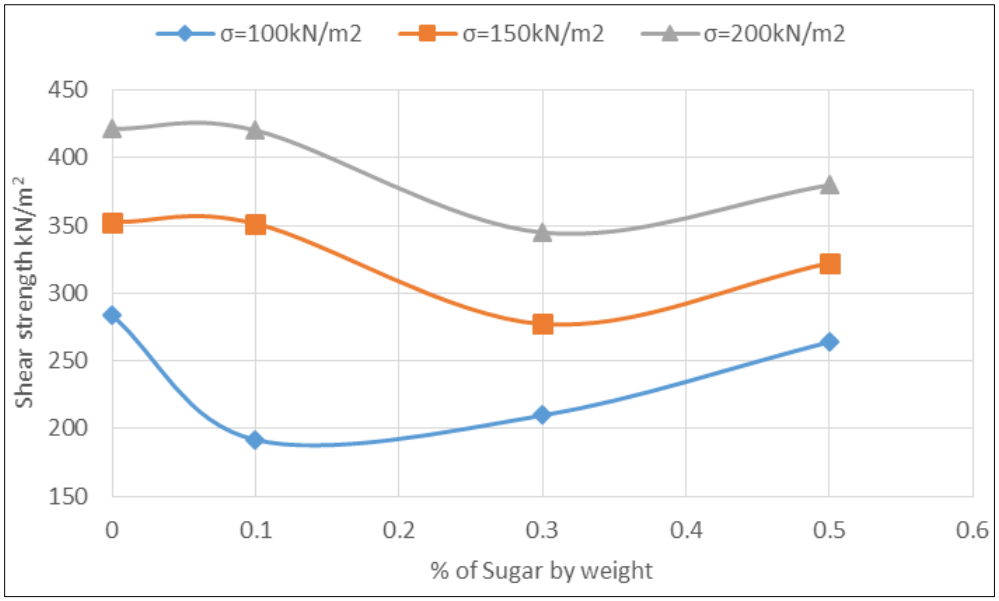


Fig 3: Variation of Shear strength with % of Sugar

C. Test Using Antibleeder

The graph showing how shear strength changes. Different percent of aluminium sulphate is mixed with cement grout. At first, there is small decrease in strength, but when the percentage is more, the shear strength again increases and even cross the original value.

Table 4: Variation of Shear strength with % Al2(SO4)3

%Al2(SO4)3 by weight	σ=100kN/m²	σ=150kN/m²	σ=200kN/m²
0	282.83	351.65	420.40
2	257.78	319.53	381.27
4	272.38	338.90	405.50
6	280.13	348.70	417.20
8	293.81	365.20	436.62
10	321.34	394.91	468.50

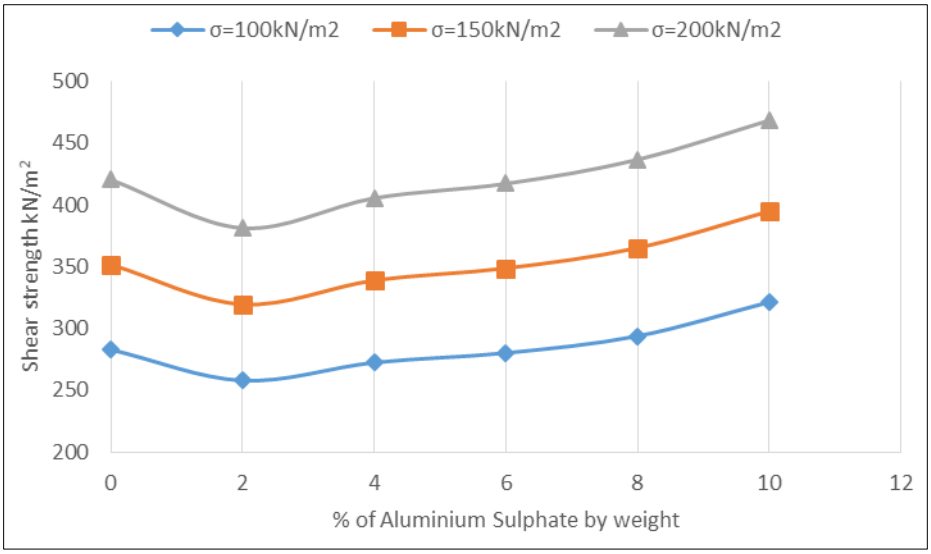


Fig 4: Variation of Shear strength with % of Aluminium Sulphate

Results and Discussion

A. Cement sand grout using Accelerator

The graph shows, variation of shearing resistance and cohesion intercept with different percentage of Calcium Chloride in cement grout. At very small percent (around 0.5%) the cohesion goes down, but later it again increase and reach almost same value as normal cement grout without admixture; There is also little reduction in angle of shearing resistance (nearly 1%) when accelerator is added. But this loss is balanced by the increase in cohesion intercept. Finally this balance is shown in the overall shear strength values.

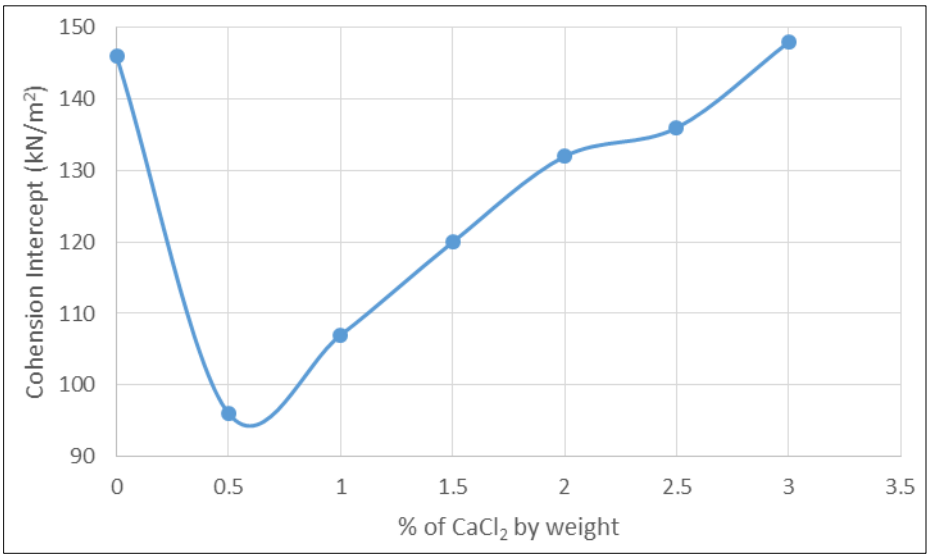


Fig 5: Variation of Cohesion with % $CaCl_2$ by weight

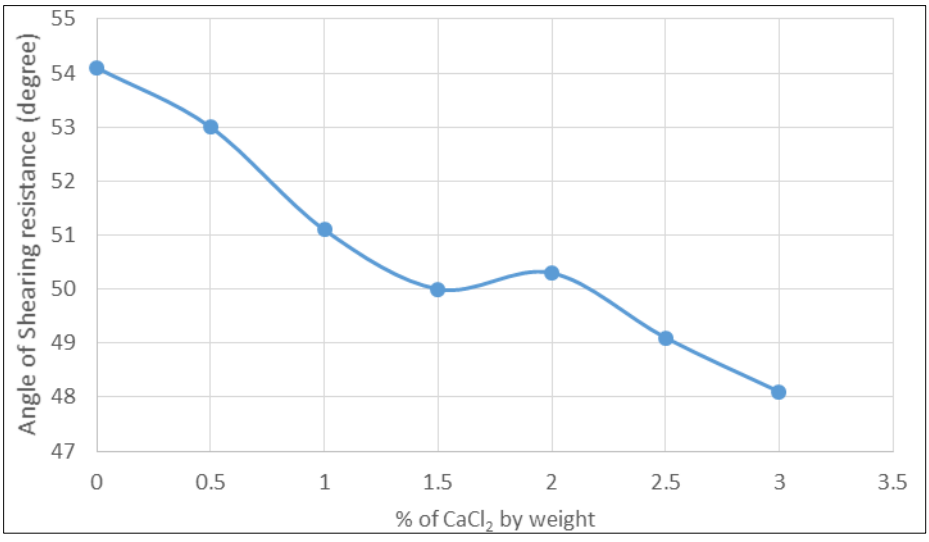


Fig 6: Variation of Angle of Shearing strain with % $CaCl_2$ by weight

B. Cement sand grout using Antibleeder

The graph show the change in cohesion intercept and angle of shearing resistance when Aluminium Sulphate is mixed with cement grouts and the main effect of Aluminium Sulphate is that it increases the cohesion. From the graph it can be seen that the angle of shearing resistance first reduce slightly at lower percent of Aluminium Sulphate but after that it keep on increasing as the percentage increases.

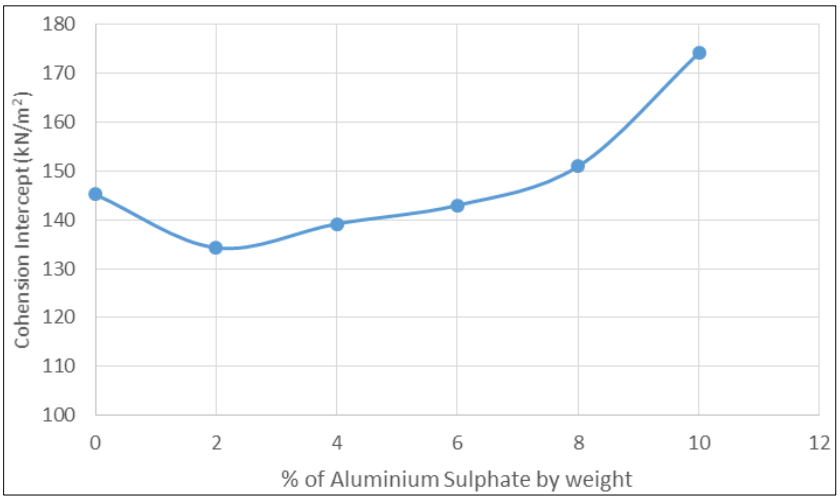


Fig 7: Variation of Cohesion with % of Aluminium Sulphate by weight

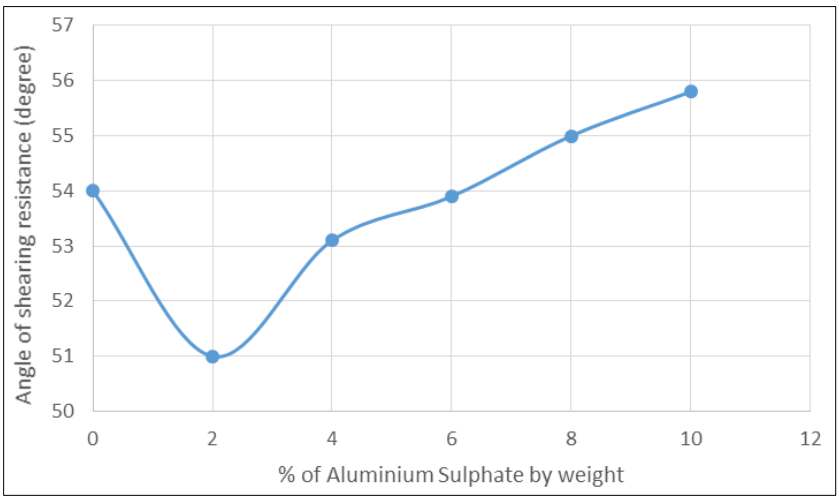


Fig 8: Variation of Angle of Shearing strain with % of Aluminium Sulphate by weight

C. Cement sand grout using Retarder

Graphs show the variation of cohesion intercept and angle of shearing resistance with the percentage of Sugar added to the cement grout. The variation of the cohesion intercept and the angle of shearing resistance are also similar to that of Calcium Chloride. The cohesion intercept initial decreases and then it even overtakes the initial value as the percentage of sugar increases. But angle of shearing resistance remains almost constant initially, but there is marginal decrease in the value with increase in the percentage of sugar.

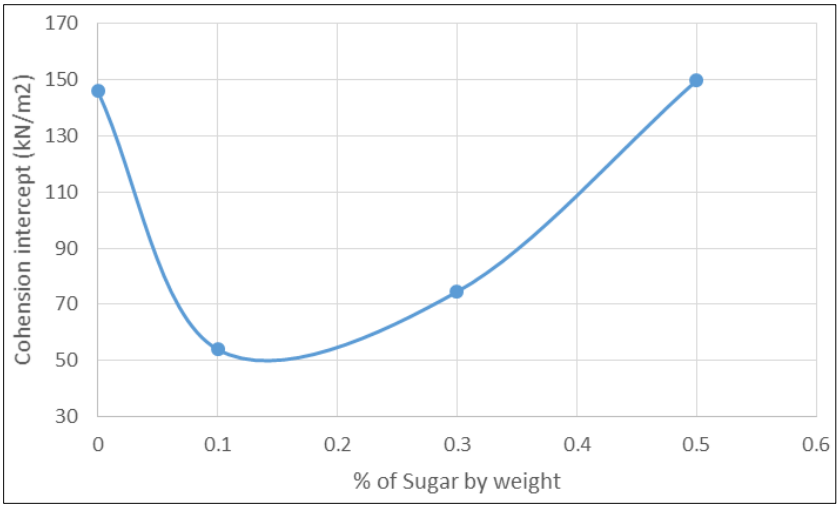


Fig 9: Variation of cohesion with % of sugar by weight

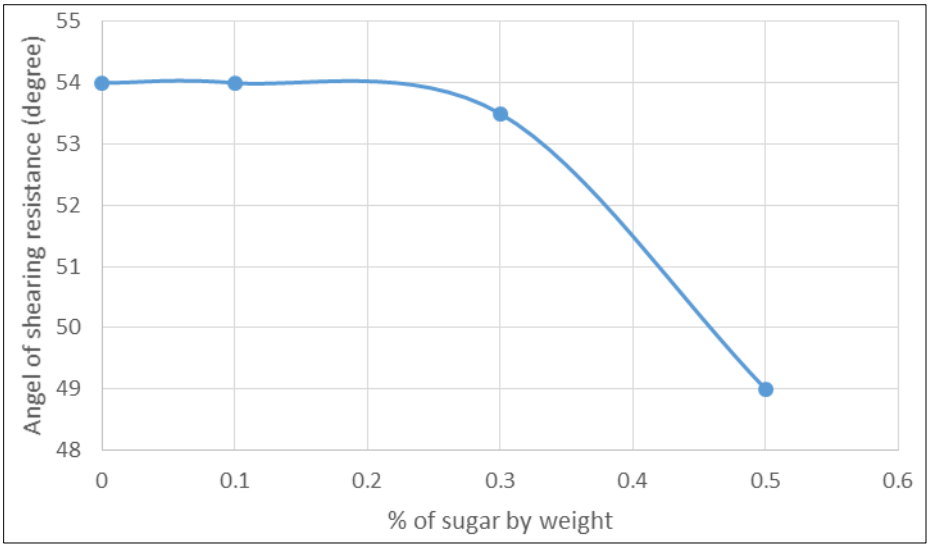


Fig 10: Variation of Angle of Shearing strain with % of sugar by weight

Conclusion

When admixtures are added in cement grouting, their effect on strength of grouted soil can be clearly seen in this study. We tested accelerator, retarder and antibleeder on cement grout strength. It was found that Calcium Chloride and Sugar decrease the shear strength little bit at small percent but later on the value again come close to original strength. So, addition of Calcium Chloride and Sugar does not affect badly on cement grouted soil strength. On the other side Aluminium Sulphate shows positive effect as it improve the shear strength of cement grouted soils.

Acknowledgment

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