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A Case Study on Geological Influence for Effect of Variation in Index and Engineering Behaviour of Black Cotton Soil Contaminated with Acidic Effluent through Comparative Variation Number

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Abstract: *In semi-arid region like South India, the geotechnical properties of soil is highly influence by the weathering process, type of soil and history of rock. From GIS lithology map as well as GIS soil map of Kadur and Devanahalli it is observed that rock varies from granite to laterate and basalt and soil varies from sand clay to sandy clayey loam. GIS litholigy map shows that Kadur soil having traces of acid volcanic with iron ore. Hence that soil is selected for research and also from the GIS soil textural map, it is observed that void ratio of Devanahalli region soil is more and are also know that surrounding Devanahalli, especially Vijayapur, large number of silk dyeing industries in operation. But unethical way of discharge is in practice in that region. To know the ill/beneficial effect of effluent on soil, the effluent is collected and optimal combination soil with acidic effluent is inundated to simulate the field contaminate condition in the laboratory. The laboratory tests were conducted for liquid limit, compaction and Unconfined Compressive Strength as per IS: 2720 guidelines. Test results shows that, soil with 60% acidic effluent is beneficial even though it is present in soil or rock.*
Keywords– Maximum Dry Density, Comparative Varying Number, Maps.

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I. Introduction

In semi-arid region in South India in particular and arid and semi-arid regions in the world in general, soil contamination is one of the most critical environmental problems due to adverse effect of soil/rock permeability and rapid industrialization. Satellite remote sensing of land affected by such soil, rock or industrial contamination especially industrial by-product effluent like acid and alkali can be predicted at its initial stage, thus satellite remote sensing is useful tool for decision support through GIS. In the present study lithology map of Kadur taluk, Chikkamagaluru district, as well as Devanahalli taluk, Bengaluru rural district, Karnataka is selected through Bhuvan open source software supported by ISRO. From this lithology map it is observed that, Kadur soil is having acid volcanic traces of iron formation, which indicates rock strata of that zone is acid contaminated. From GIS map of Devanahalli taluk it is observed that there is a accountable traces of lateritic formations which is highly porous structure and this allows the effluent to pass through them. From GIS soil tecture maps of both districts it is observed that the soil is sandy clayey loam which also permit effluent to pass through them. Thus form GIS maps we finalised collection of soil (which is a disintegration of rock from chemical weathering) from Kadur taluk and effluent from Devanahalli taluk and soil is inundated in the laboratory at their optimal combination to arrive the effect of effluent on geotechnical properties of soil thereby one can predict the influence on soil or rocky strata.

II. Review Of Literature

Amulyaet al., (2015) says that Black Cotton Soil contaminated with sulphuric acid has changed the mineralogy and micro structure behaviour of soil[1]. Abdellatif and Lounis (2012) say that, satellite remote sensing is a best tool for identifying salinity ground[2]. From photo.1, it has clearly indicated, detection of salt affected soil in their study map captured in Oran region of Algeria and in their investigation they also projected a photo reflecting salt affected soil with different techniques like LANDSAT, ISOCLOST analysis etc., From these maps they concluded that salt affected soils are spread across the world especially in semi-arid and sub humid regions. They also said that the soil salinity is through natural or human induced processes and it is a major environmental hazard. They also conclude that RS and GIS is an effective tool in comparing salinity of the land and its percentage before and after interference. Photo.2 shows salt affected soil in different spots of Oran. Mallikarjuna et al., (2008) says that structural change in clay due to the influence of textile dye waste on clayey soil, affects the engineering properties of soils[3]. Madhi et al. (2014), have studied the application of remote sensing technique in geoenvironmental engineering through a field spectral reflectance measurements to identify naturally hydrocarbons contaminated soil and also carried out field tests for ground truth [4]. They found a good comparison of results between spectral reflectance from field measurement and analyzing the satellite imagery and the method improves to save cost, time, effort and manpower. Masashi et al., (1997), the effect of acid rain on physic-chemical and engineering properties of soil shows that the unconfined compressive strength has generally increased with soak time[5]. Rao and Indiramma (2009) have reported that, the textile effluent is found to be effective in reducing liquid limit as well as swelling properties, increasing strength and compaction characteristics and stability of soil mass increased due to increase in the textile effluent concentration[6]. Ramesh et al. (2010) have expressed their various test results in terms of Strength Gain Number-SGN[7]. Taha et al. (2015), concluded that soil salinization is one of the crucial environmental problems and due to this, adversely affects on agricultural productivity and sustainable development especially in arid and semi-arid region of the world[9]. They also said that remote sensing and GIS maps as well as modeling outperformed the traditional methods in superimposing the same ground before and after salinization. They shows that these maps are very good estimators in case of exposed soil or soil with low scattered vegetation. Umesh et al., (2012) have studied the adverse effect of acid concentration on geotechnical properties of Black Cotton Soil and found that water holding capacity play a role in strength reduction[10].

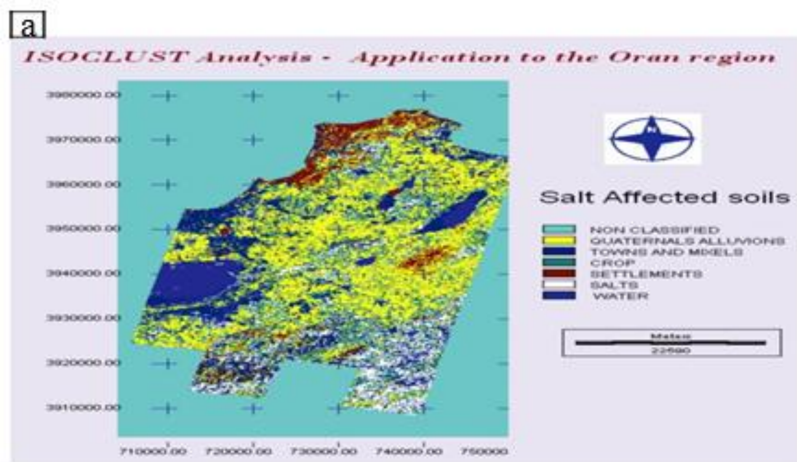

Photo.1 Salt affected soil with different techniques- LANDSAT & ALI-EO-1 Oram [Courtesy: Abdellatif and Lounis (2012)]

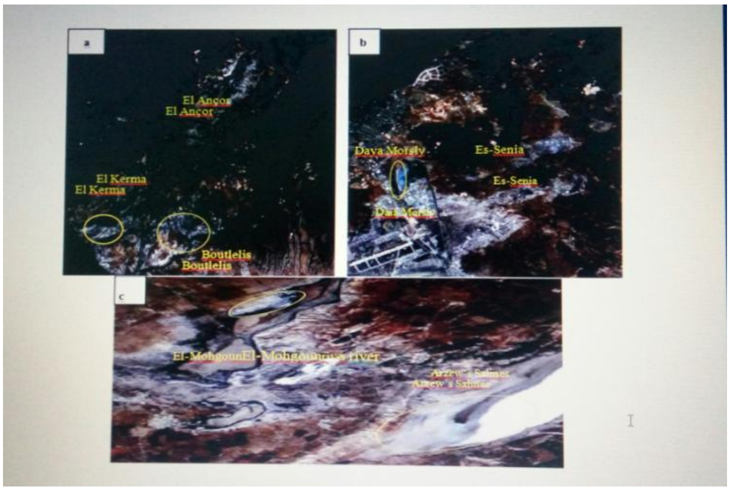

Photo.2 Detection of Salt affected soil (represented with white bluish colour) in different Spots of Oram [Courtesy: Abdellatif and Lounis (2012)]

Form the above remote sensing and GIS literatures, it is observed that, these maps will clearly indicates geology of rock formation; soil texture and its contamination are projected environmental hazards due to movement of chemicals. Hence remote sensing and GIS approaches are used in this paper for selecting study area in which this area may affected by chemicals like silk dyeing acidic effluent in future.

Several researchers has collected the soil and effluents randomly and conducted some of the geotechnical property tests. However, from the literature review of remote sensing and GIS papers as well as traditional papers it has concluded that modern methods implemented papers has not discussed effect of contaminants on soil, on the other hand traditional researchers have not logically given justification through modern techniques like remote sensing & GIS regarding the purpose of collecting soil or effluent from the same or different locations. Hence this paper act as a bridge between modern techniques of remote sensing and GIS approaches in decision making in selection of study area and carryout various tests through traditional methods.

III. Materials And Methods

This paper has been prepared by conducting laboratory test on compaction and strength behaviour of soil treated with acidic effluents and results were compared to soil treated with tap water. Black Cotton Soil, silk dyeing effluents were used for the present investigation. Black Cotton Soil is collected from open method of soil exploration at location Kadur, Chikkamagalur district, Karnataka state, India at a depth of 1.6m from normal ground level. The obtained soil is pulverised and soil passing through the 425µ IS sieve used for the present investigation. The acidic effluent is collected at the outlet point in the silk dyeing industry at Vijayapura, Bengaluru, India.

3.1.1 Sample preparation

Pulverised Black Cotton Soil has soaked in soaking containers, containing silk dyeing acidic effluent for a period of four days in order to simulate field soil contamination condition. The soil which is collected from the soaked containers were air dried and oven dried in a thermostatically controlled oven, there after soaked soil samples were taken for conduction of compaction and Unconfined Compressive Strength test. Typical soaking containers are shown in photo 3.0. Two stages of experiment were conducted for both compaction and Unconfined Compressive Strength test. In the first phase oven dried field soil mixed with tap water to simulate uncontaminated ground condition. In the second phase, to stimulate varying concentration of effluent in soil, the collected acidic effluent has diluted from 10% to 90% and these diluted effluent preserved in separate cans as shown in photo 4.0. At each stage of experiment instead of distilled /tap water, diluted effluents which are preserved in respective cans are used for compaction and Unconfined Compressive Strength test. The physical and chemical properties of Black Cotton expansive soil shown in Table 1.0 and Table 2.0. Chemical properties of effluents are shown in Table 3.0.

Photo 3 Typical pictorial representation of Black CottonSoil treated (soaked) in Acidic effluent

Photo 4 Diluted Acidic effluent stacked in containers

Table 1 Physical properties of Expansive soil

Soil Index	Values
Natural moisture content(%)	8.5
Liquid Limit (%)	77.00
Plasticity Index (%)	54.00
Gravel (%)	0.40
Sand (%)	23.40
Silt size fraction (%)	34.20
Clay size fraction (%)	42.00
Classification of soil	CH
Compaction test OMC (%) MDD (kN/m^3)	 25.80 15.40
Unconfined Compressive Strength (kN/m^2)	230

Table 2 Chemical properties of Expansive Black Cotton Soil

Parameters	Results
Calcium Oxide as CaO, (% by mass)	2.80
Magnesium Oxide as MgO, (% by mass)	1.2
Silicon Dioxide as SiO_2, (% by mass)	64.1
Iron Oxide as FeO_3, (% by mass)	5.6
Aluminium Trioxide as Al_2O_3, (% by mass)	8.43
Loss on Ignition, by mass at 900^0C	8.8
Sodium Oxide as NaO_2, (% by mass)	0.086
Potassium Oxide as K_2O, (% by mass)	0.35
Manganese Oxide as MnO, (% by mass)	0.03

Table 3 Chemical properties of effluent

Properties	100% concentrated Effluent	60% concentrated Effluent	Water (Tap)
Pb (μg/l)	16.83	2.32	0.14
Cd (μg/l)	18.01	3.85	0.02
Al (μg/l)	18.22	3.32	0.06
Na (mg/l)	92.00	58.90	28.00
K (mg/l)	6.00	4.20	1.30
Cr (mg/l)	0.11	0.01	0.01

IV. Results And Discussion

The main variables controlling the wastewater movement in the soil are litology and geological structure.

Litological Mapping: Lithology refers to an individual rock type, which is a basic geological unit. In the unconsolidated/semi-consolidated sediments and some volcanic rocks which have primary porosity and permeability. Remote sensing provides the basis for discrimination and differentiation of rock types with minimum ground survey and more accurately. Lithology maps Kadur and Devanahllli used in this study are shown in Fig. 1 and Fig. 2 respectively.

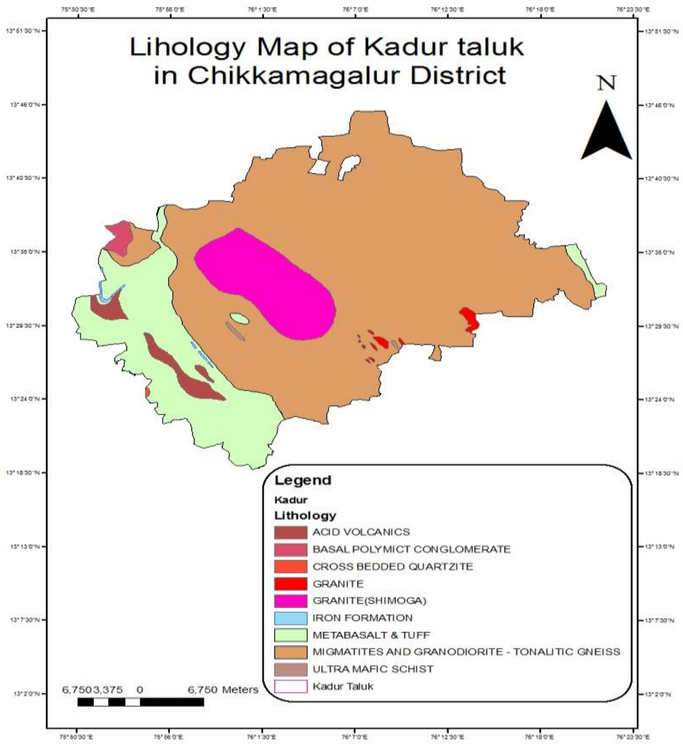

Fig. 1 Lithology Map of Kadur taluk in Chikkamagalur District

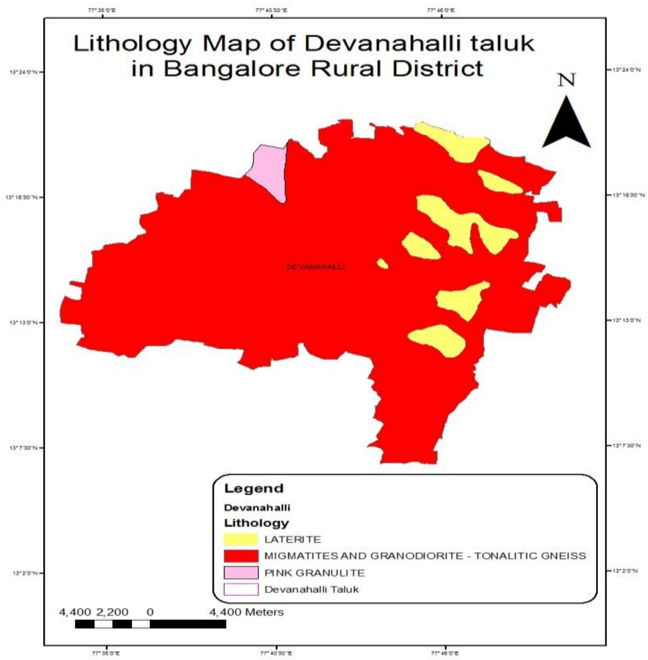

Fig. 2 Lithology Map of Devanahalli taluk in Bengaluru District

Geolgical structures: In the hard rock areas the movement and occurrence of groundwater depends mainly on the secondary porosity and permeability resulting from structural discontinuities like lithologic contacts, bedding and cleavage planes, unconformities, folds, faults, fractures, joints etc. These structurally weak planes act as conduits for wastewater movement and introduce an element of directional variations in hydraulic conductance. Fig. 3 and Fig. 4 shows the geological structure maps referred in this paper.

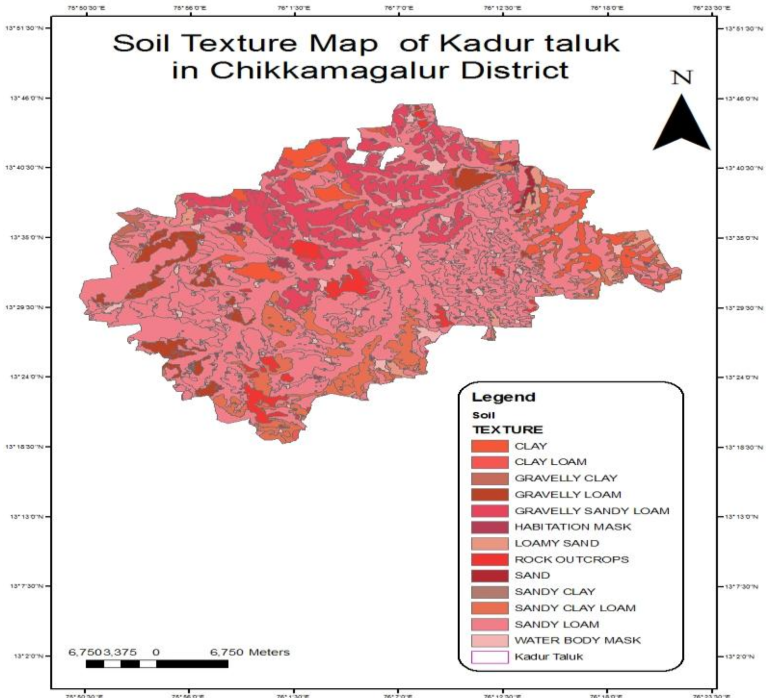

Fig. 3 Soil texture Map of Kadur taluk in Chikkamagalur District

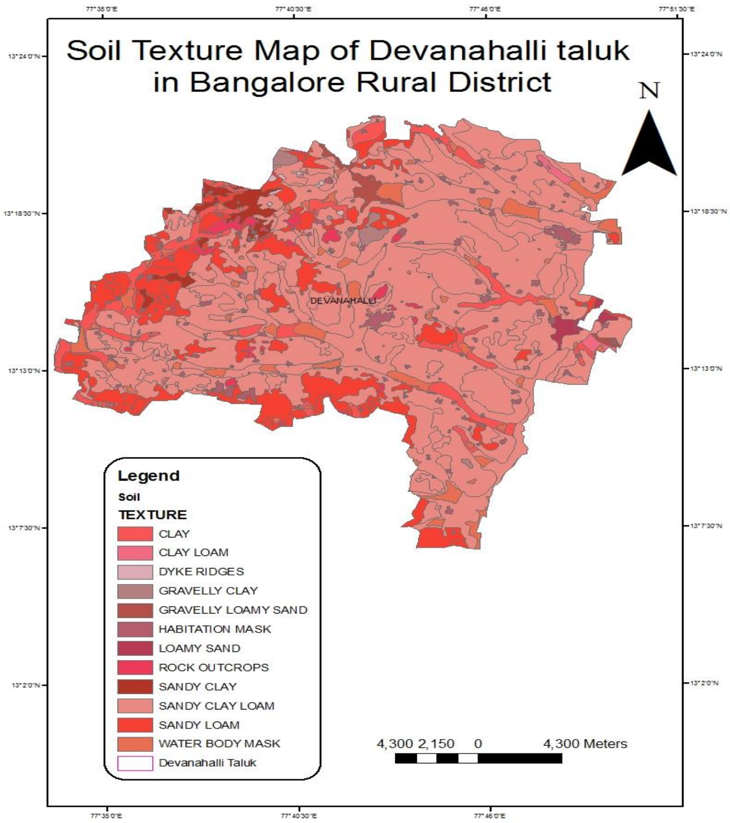

Fig 4 Soil texture Map of Devanahalli taluk in Bengaluru District

From Fig 5 it is observed that addition of acidic effluent reduces the liquid limit from 7% to 14% when Black Cotton Soil is contaminated with 10% to 100% with an increment of 10% by weight of soil. However, in comparison with other percentage of acidic effluent, 30% of acidic effluent in Black Cotton Soil having liquid limit value nearer to Black Cotton Soil alone. From Fig. 6 it has been observed that Black Cotton Soil treated with varying percentage of acidic effluent substantially improves the strength in terms of Comparative Variation Number (CVN) for all combination except for Black Cotton Soil with 30% acidic effluent.

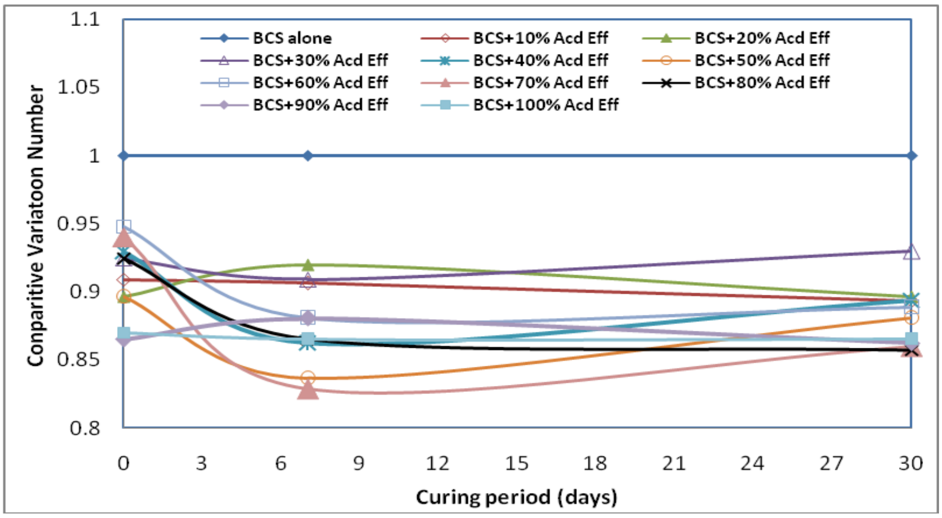

Fig 5 Liquid Limit of Black Cotton Soil (BCS) treated with varying concentration of acidic effluent

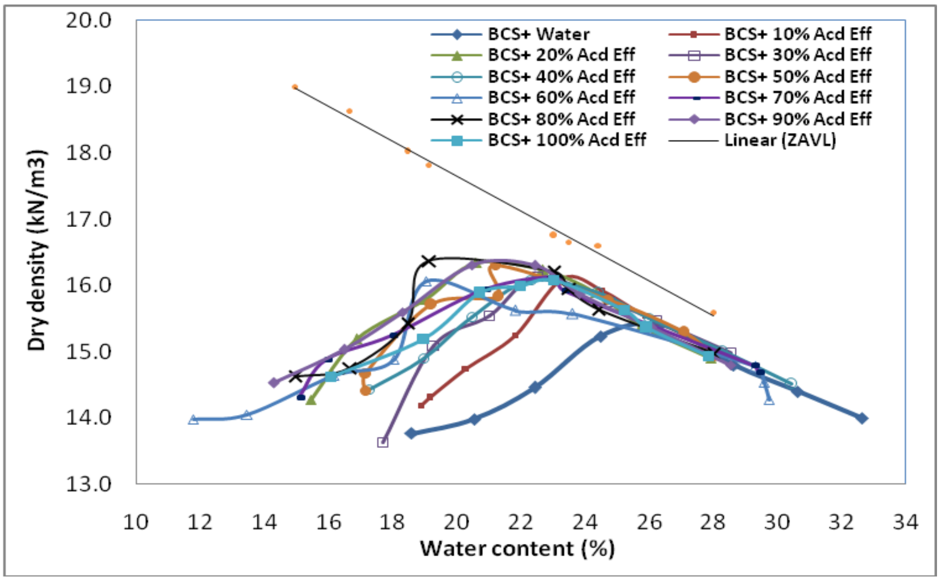

Fig 6 Unit weight – water content relationship of Black Cotton Soil (BCS) treated with Varying percentages of acidic effluent concentration

Fig 6 shows that, Black Cotton Soil treated with varying percentage of acidic effluent increases the maximum dry density and reduces optimum moisture content for all the acidic effluent (Shivaraju et al., 2011) concentrations[8]. It is also been observed that addition of acidic dyeing effluent shifted compaction curve to the left side of optimum on compared with soil treated with tap water. This may be due to the increase in workability of matrix in presence of acidic effluent. Comparative study has been carried out by comparing soil treated with tap water, acidic effluent in their isolated condition.

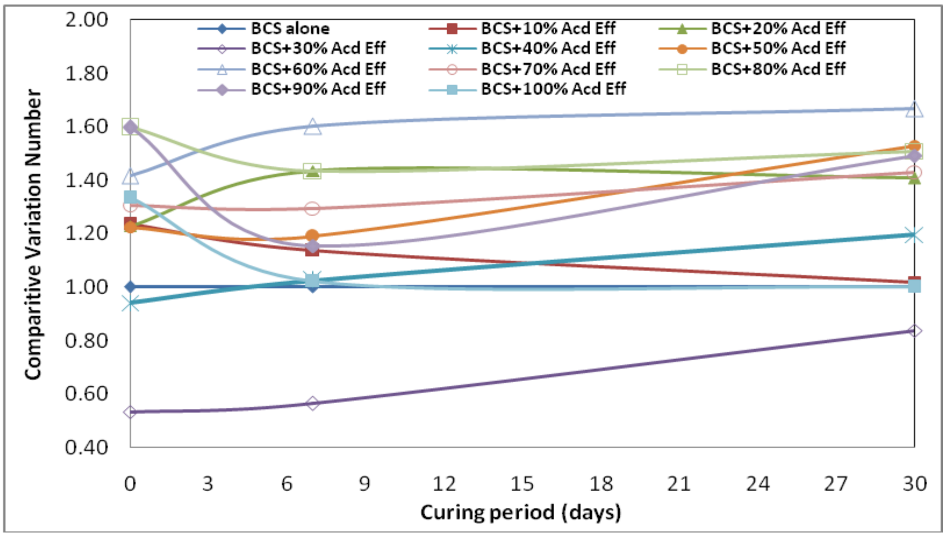

Fig 7 Unconfined Compressive Strength of Black Cotton Soil (BCS) treated with varying concentration of acidic effluent

From the Fig.5 and Fig.7 it has been observed that Black Cotton Soil with 30% acidic effluent having higher liquid limit, because of that diffused double layer of clayey soil in the range of $10A^0$ to $10.2A^0$ thickness. Hence upon application of unconfined compressive stress due to lack of conformity in conduction of unconfined compressive strength test with sudden collapse of diffused double layer upon application of compressive pressure leads to very high development of pore pressure which causes immediate failure, hence from Fig.5 and Fig.7, the Comparative Variation Number from liquid limit and unconfined compressive strength tests, it is concluded that Black Cotton Soil with 30% acidic effluent has higher liquid limit and lower unconfined compressive strength. Whereas form Fig.5, it is observed that Black Cotton Soil with 60% acidic effluent, the decrease in the liquid limit is 11.6% and for same combination, the unconfined compressive strength in terms of Comparative Variation Number is higher and it is also observed form the graph that Black Cotton Soil contaminated with 70% acidic effluent has lower liquid limit at 30 days curing period on compared with Black Cotton Soil alone, the decrease in liquid limit is 12.9%. But form Comparative Variation Number between Black Cotton Soil with 70% acidic effluent at 30 days curing even though it is having lowest liquid limit on compared to Black Cotton Soil alone whose Comparative Variation Number is 1.43, however, Black Cotton Soil with 60% acidic effluent having liquid limit lower than Black Cotton Soil alone and higher than 70% acidic effluent, but Comparative Variation Number is 1.66. Hence, there is a break point beyond which further reduction of liquid limit will not have appreciable improvement in unconfined compressive strength in terms of Comparative Variation Number. Hence it may be concluded that, Black Cotton Soil contaminated with 60% acidic effluent will treated as optimum.

V. Conclusions

Based on extensive review of literature followed by discussions on laboratory results following conclusions were drawn

1) From remote sensing and GIS maps Kadur taluk, Chikkamagalur district has shown traces of acid and iron volcanic during solidification of molten mass magma.
2) From remote sensing and GIS soil texture map, Kadur soil is highly clayey in nature whereas soil in Vijayapura of Devanahalli taluk, Bengaluru district is a mixture of gravelly clayey to sand clayey loam.
3) Kadur soil treated with 30% acidic effluent (by weight of soil) will have a liquid limit very close to Black Cotton Soil alone, whereas with 60% acidic effluent (by weight of soil) the liquid limit substantially reduced. Hence from Comparison Variation Number (CVN) with various curing period, it is observed that, higher the liquid limit lower the Unconfined Compressive Strength with lower CVN.
4) Soil treated with 60% acidic effluent has shown higher CVN in terms of Unconfined Compressive Strength, whereas other combination will have comparative CVN within upper and lower limits of above two cases. Hence Kadur Black Cotton Soil can be allowed for contamination through 60% acidic effluent.
5) As from remote sensing and GIS maps even though Kadur Black Cotton Soil is having acidic volcanic traces, intrusion of upto 60% of that traces in foundation soil having beneficial effect. This may be because of rich in very high strength carrying capacity of iron.

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