Improvement of fine grained soil using liquid polymer and cement kiln dust

Authors:

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Abstract: Soil stabilization is a common technique to increase the strength, durability and reduce the swell-shrink behavior of foundation or subgrade soil in pavement and for improvement of soil in regions where small scale construction is to be laid. During manufacturing of cement a waste by product, known as cement kiln waste(CKD) is generated which accounts for 5-10% of the cement clinker production. So using CKD as an admixture to improve the properties of soil involves economic and environmental advantages. Also, nowdays many stabilizers (e.g, polymer,bio-enzyme,ionic solutions etc) are used in soil. In the present study, the use of cement kiln dust alongwith liquid polymer was used on fine grained soil classified as CL with varying proportions of CKD from 5% to 30% with each increment of 5% in the soil and liquid polymer was used in 0.5%,1%,2%,3%,4% of 20% CKD alongwith optimum value of CKD. A decrease in UCS value is significant with further addition after 3% liquid polymer in soil.

Keywords: unconfined compressive strength, cement kiln dust, liquid polymer

In the developing India, the stabilization of soil had begun in 1970's due to huge shortage of aggregates to be used at sites to attain the required strength, so the option of replacement of the poor subgrade was to be avoided at each cost. In the present 21st century, with increase in the population and more demand of infrastructure, soil improvement had become indispensable and industrial wastes such as coal ash, blast furnace slag, rice -husk ash, coconut coir, brick dust, cement kiln dust etc. had took stabilization to new era. After the blending of limestone and shale when the material is poured in heat exchange process a waste by product, known as cement kiln dust (CKD) is generated which accounts for 5-10% of the cement clinker production. So, using CKD as an admixture to improve the properties of soil involves economic and environmental advantages. The variation in strength of soil can be seen within a region of small area especially in rocky regions where improvement becomes obligatory at slopes to avoid the slope falls in the region during the rainy periods.

Literature review

Use of various industrial wastes for large number of purposes has been increased in last few years. Use of liquid polymer for strengthening the clayey soil is very effective when used with cement. So it will be equally useful in case of cement kiln waste, as it will reduce the harmful affects on environment and can generate cost of waste for cement plants too. The cement industry specifically identifies the nation's development and is foremost in deciding the improvement of the nation. With a present creation limit of around 366 million tons (MT), India is the second biggest manufacturer of cement on the planet and as per development, the limit can increase to around 550 MT by 2020.

Ahmed et al. (2017) Studied improvement of poor subgrade soils using cement kiln dust. Increment in CBR value is seen with increase in percentage of CKD upto 30%. Increase in CKD shown dual behaviour with decrease in swelling potential upto 20% CKD and then increment with increase of CKD percentage. Also the optimum value of CKD is recommended in this paper 20% as highest rate of increase in CKD value is seen at 20%.The subgrade without any treatment had shown a value of 3.4% of CBR with corresponding value of resilience modules M_r of 5100 psi.

The CBR value after treatment with optimum value of CKD is 48% provides subgrade resilience modules (Mr) of 17000 psi. From this a decrease of 80 mm was denoted in the asphaltic layer thickness in comparison to untreated subgrade. In addition, the base thickness was decreased from 250mm to175mm for untreated and treated subgrade cases respectively.

Mohammad et al. (2017) Performed experimental work on liquid polymer along with addition of cement kiln dust had shown that the axial stress had shown a tremendous increase of nearly 300% from value of 155Kpa on addition of 0.5% liquid polymer only. Although increase in axial strain is seen from 0.74% to 1.2% at peak stress of 600Kpa and 650Kpa at 0.5% and 1% addition of liquid polymer. In case of unconfined compressive strength with 5% cement content and at liquid

polymer content of 0.2% the value increased from 80kpa to 200kpa while it increased to 275kpa when liquid polymer content is 1%. The value of UCS for 15% cement increased from 300kpa to 875 kpa at 0.2% liquid polymer content and this value increased to 1100 kpa when liquid polymer content used is 1%. Liquid polymer increases the fresh mixture workability.

Kolay et al. (2016) Conducted research on two types of soils having high plasticity and low plasticity along with liquid polymer varying from 0.5% to 3% with optimum value of UCS at 1.5% and increased upto 2% of liquid polymer for soil classified as CH. Two types of soils used in this research shows varying results, the soils with more clay content has shown higher increase in UCS value as compared to soil with smaller clay content. The increase in UCS value is seen upto 4% for the soil with smaller clay content. A significant increase in CBR value is also seen in both types of soils with the use of liquid polymer.

Wang et al. (2016) Effect on strength properties with the use of cement kiln dust on expansive soils was seen. The value of cohesion had increased upto 10% cement kiln addition and then declined with further addition. Exponential relation in increase of shear strength is seen with the curing time on sample treated with cement kiln dust varying from 5% to 20%. It is also seen that the expansive properties are reduced with the use of cement kiln dust.

Rahman et al. (2011) Made experimental investigation revealing that increase in strength in various types of soils has inverse relation with plasticity index. when testing was done for different CKDs it shows that soils having higher free lime and moderate alkalies shown good results. The research revealed that 12% to 50% of cement kiln dust is recommended for the dune sand stabilization and shows good stabilization with curing duration of 56 days. CKD varying from 0% to 40% was used for two types of blocks revealed that there was increase upto 20% of CKD and then a decrease with 30% CKD.

methodology

UCS samples were first prepared for virgin soil only and then soil with cement kiln dust by adding different percentage of cement kiln dust. And optimum value of CKD was selected at which there was maximum increase in value of UCS the selected value was then further used in testing with liquid polymer in both direct shear test and UCS test. Whole of testing done in UCS are with remoulded state of soils.

material

soil

The soil used in the proposed study was obtained from local village, of Distt. Ludhiana. The amount of approximately 200 kg of locally available clayey soil is classified as clay with low plasticity.

Table.3.1: Properties of virgin soil used determined by laboratory tests.

Sr.No	Properties	Results
1.	liquid limit(%)	35.70
2.	Plastic limit(%)	25.20
3.	Plasticity index(%)	10.50
4.	Optimum moisture content(%)	13.60
5.	Maximum dry density(kN/m^3)	18.20
6.	Specific gravity	2.67
7.	Unconfined compressive strength(kN/m^2)	51.75
8.	Cohesion(kN/m^2)	13.83
9.	Angle of internal	21.70
10.	Soil classification	CL

Paticle size distribution of soil used.

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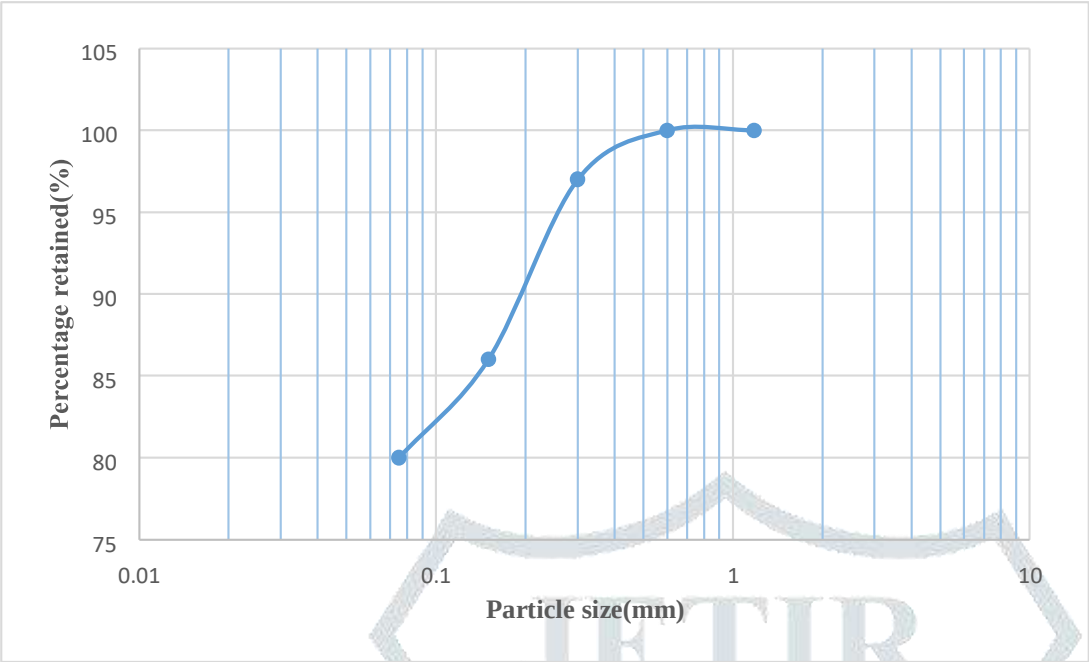
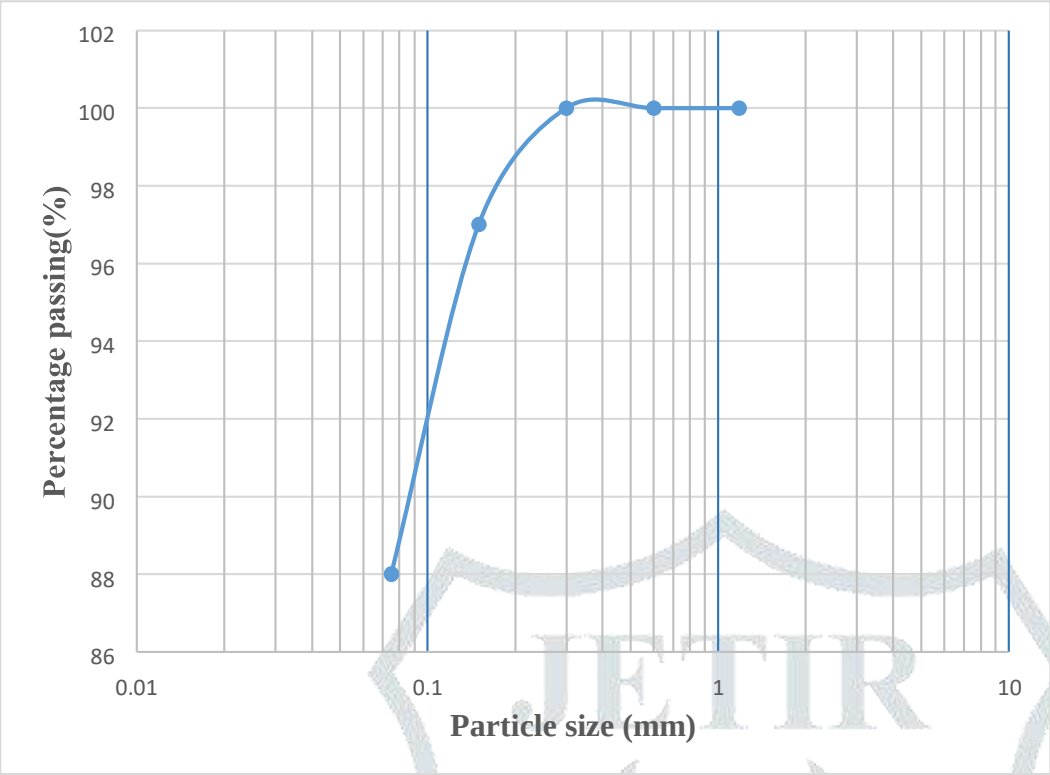


Cement kiln dust

Cement kiln dust used was collected from ACC plant of himachal Pradesh.
Chemical properties of cement kiln dust.

Sr. No	Chemical Composition	Percentage present
1	Cao	52.52
2	Si_2O	11.9
3	Al_2O_3	9.9
4	Fe_2O_3	3.4
5	SO	1.48
6	MgO	1.7
7	Na_2O	0.5
8	K_2 O	0.1
9	Loss on ignition	4.7

Particle size distribution of cement kiln dust.

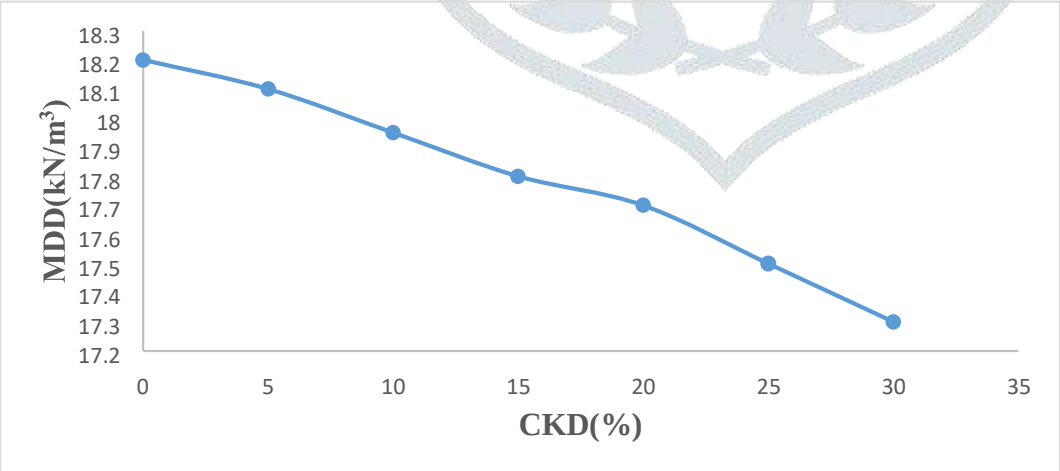


Liquid polymer

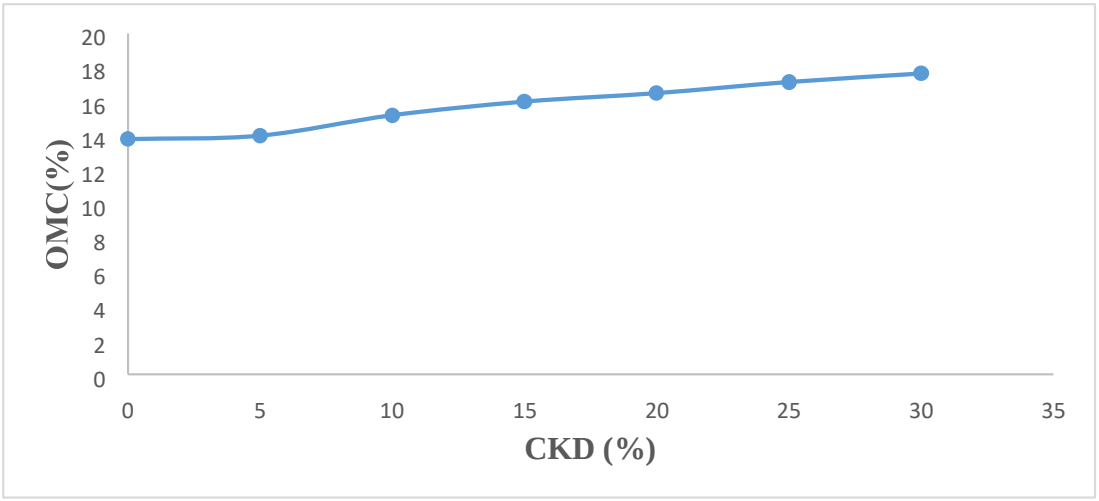
Acrylic bond material having an aqueous emulsion of acrylic co-polymer having cationic nature specially articulated for usage with cement is brilliant bonding agent and high strength material in milky white state. The specific gravity of the material is very low in comparison to the soil used

COMPACTION TEST RESULTS

Use of standard proctor compaction test was made in testing in reference with IS:2720 part-7-1980 on clayey soil sample along with several variation of CKD with addition of 5% in each test.



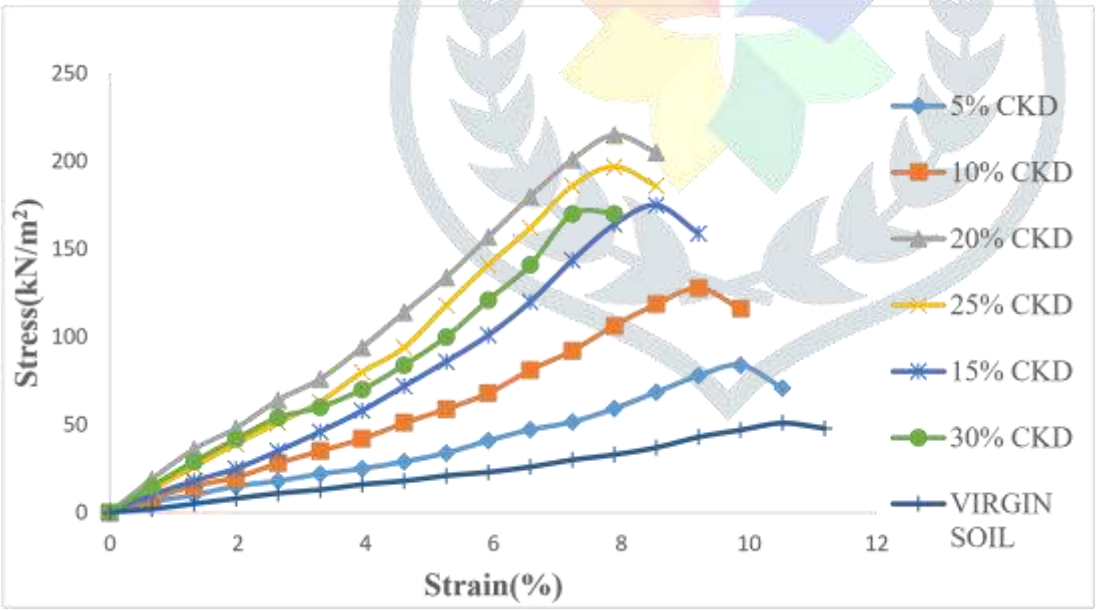
The increase of CKD from 5% to 30% had shown decreasing trends of dry density at similar rates with each addition with a small change in rate of decrement at 20% addition of C.K.D the M.D.D. value declines to 17.10 kN/m^3 with 30% C.K.D from 18.20 kN/m^3 of virgin soil.



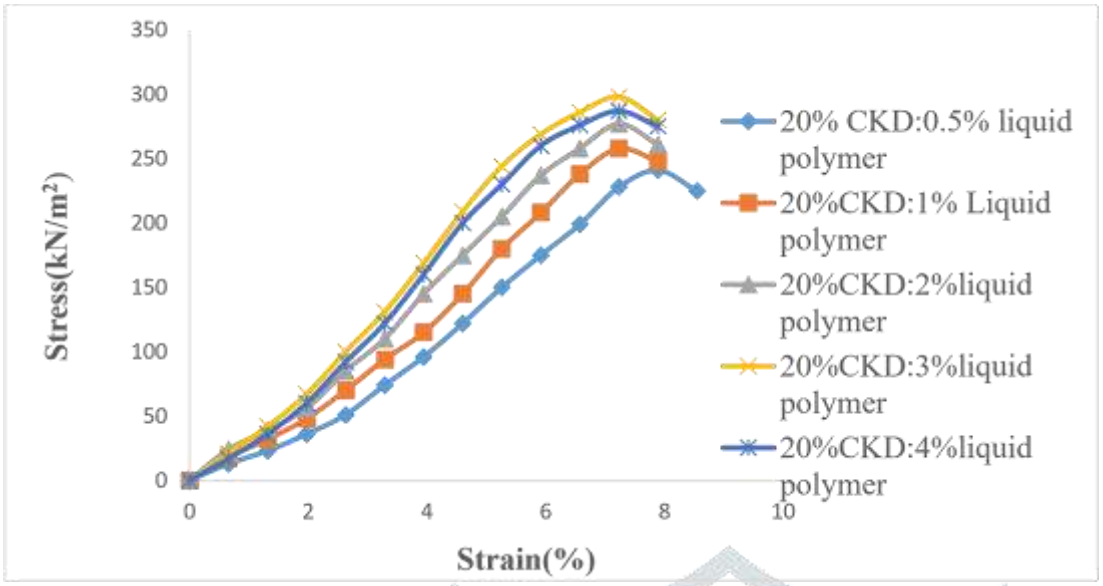
O.M.C. had shown increase with addition of C.K.D from 13.8% for virgin soil to and M.D.D. of virgin soil is 18.20 kN/m^3. A significant increase in value of optimum moisture content seen is due to hydration needed by the C.K.D. particles and due to increase in surface area. A small decrease in value of maximum dry density is seen with addition of CKD to virgin soil, the reason could be the proportional replacement of coarse particles by fine particles of CKD.

Compressive strength

Cement kiln dust content was varied with increment of 5% in each test with 14 samples prepared for 7 days to find the optimum value of CKD the maximum values of UCS were determined in each test and similar procedure was followed at 14 days of duration. Afterwards, using cement kiln dust 20%(which gave maximum value) samples made with varying proportions of liquid polymer from 0.5% to 4% along with optimum value of CKD(20%).

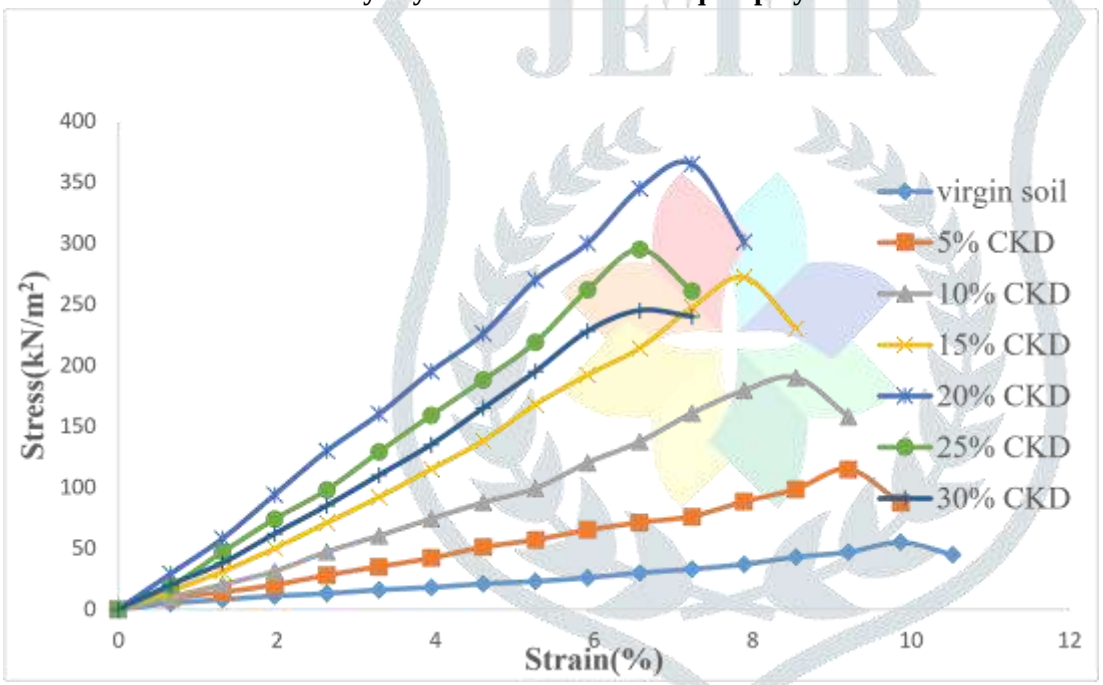


Graph illustrating increase in UCS value with CKD addition after seven days duration.

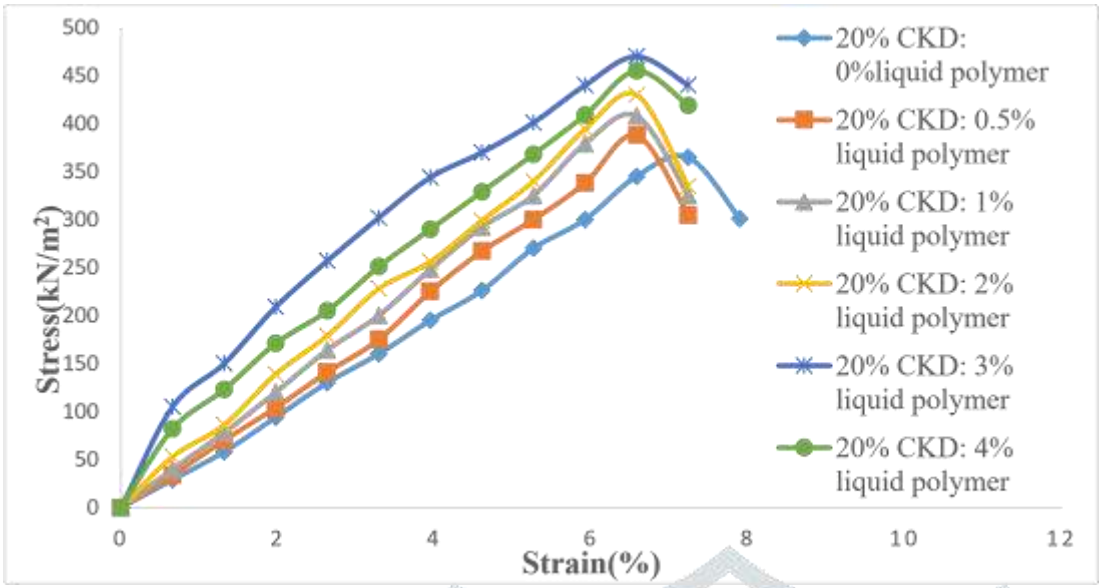


Graph illustrating increase in UCS value with liquid polymer + 20% CKD addition after seven days duration.

Increment shown after 14 days by CKD addition and liquid polymer



Graph illustrating increase in UCS value with CKD addition after fourteen days duration.



Graph illustrating increase in UCS value with liquid polymer + 20% CKD addition after fourteen days duration.

UCS value results

More than 4 times increase is witnessed in UCS value with 220kN/m^2 for 20% CKD content with 7 days which further increased to nearly 7 folds in comparison with virgin soil with value of 365 kN/m^2 for 14 days spell. Although increment in UCS value with addition of 1%,2%,3% liquid polymer alongside optimized cement kiln dust(20%) is at some decreased rates but it is quite recognizable. And maximum value is seen at 3% liquid polymer of 20% CKD and further addition of liquid polymer had shown small decrease in UCS value. Optimum mixture of Soil, CKD, liquid polymer is selected as 80%, 20%, 3% which gave UCS 302kN/m^2 with 7 days and gave UCS value of 470kN/m^2 with 14 days. UCS value had increased due to pozzolonic activity upto 20% CKD and decrease in UCS value is seen if excessive CKD is filled in samples. The decrease could be due to CKD which could not combine with soil particles and resulted in weak section in samples by occupying the space.

There is presence of Ca^{2+}, Si^{2+} and Al^{3+}cations in CKD, it react with water and ions present in soil had formed Calcium Silicate hydrate (CSH) and Calcium Aluminate hydrate (CAH). These chemical products formed are similar to the product formed in cement. Time spell and required water content favour the reactions and had resulted in increase in UCS values of soil. Although, according to IS: code recommendation required increase in value of compressive strength is achieved in the soil. But in comparison to literature the value of increment is much small. So, it can be concluded that UCS value increment in case of addition with CKD is inversely proportional to the plasticity index.

The strength achieved by using liquid polymer is not much time dependent as the increment at 14 days with use of liquid polymer increment is much comparable to that of 7 days results. So, it is concluded that samples treated using liquid has attained much earlier strength within first 7 days duration.

Conclusions

From the experimental study it is concluded that optimum proportions for soil :CKD :liquid polymer for unconfined test results are 80% soil,20% CKD, 3%liquid polymer of 20% CKD. In comparison of strength parameters with literature it can be established from present study that improvement in soil is inversely proportional to plasticity index of soil.UCS value had increased upto 302 kN/m^2 and 470 kN/m^2 at 7 days and 14 days with the optimum proportions.