STRENGTH CHARACTERISTICS OF CLAY PROCESSED WITH POZZOLANA (FLY ASH) AND RECRON 3S FIBRE

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ABSTRACT: The major target of this research was to enhance the strength of clay& to obtain an ideal amount of soil- pozzolana (fly ash) – recron 3S fibre mix. The objective of study was to increase the strength of clayey soil using pozzolana(fly ash)& recron 3S fibre. As we know pozzolana (fly ash) act as a cement material & recron 3S fibre act as a reinforcing material. As clay shows high shrinkage, swell characteristics & low bearing capacity. There is a need to improve the strength characteristics. So the main focus of this research was to increase the strength characteristics of soil. The tests performed in laboratory was Pycnometer test for specific gravity, Casagrande's test for liquid limit, plastic limit test, Standard proctor test for determination of OMC& MDD, unconfined compression test & Direct shear test. Proportional of the recron 3S used was 0.2, 0.4, 0.6, 0.8 & 1.0 % and proportional of pozzolana,(fly ash) was 10, 15,20,30,40 & 50%. The fly ash was optimised at 15% & UCS value for virgin soil was 215.6KN/m2& by adding fly ash in different proportions i.e., 10, 15, 20,30,40,50. The UCS values were 409.10, 460.1, 378.7, 345.2, 242.01 &234.06 in KN/m2, so the maximum was at 15% pozzolana (fly ash).After adding recron 3S in different proportions i.e., 0.2, 0.4, 0.6, 0.8 & 1.0 %. The UCS values were 512.46, 566.49, 625.23, 672.1 &654.35 in KN/m2 for 1 week curing. So the maximum was at 0.8% & for 2 weeks curing UCS values was 587.085, 625.23, 676.81, 710.2 &672 in KN/m2 & again was maximum for 0.8%. The results of direct shear test for virgin soil was - cohesion intercept 24.6 KN/m2 & angle of shearing resistance 19.20& was increased by adding pozzolana (fly ash)& Recron 3S fibre at 15% fly ash & 0.8% recron3S It was 62.2 KN/m2 & 29.10.From this study it was concluded fly ash works as a cementing material & Recron 3S as a reinforcing material & provides strength to the soil as well as fly ash. The best proportion obtained was; 84.2% soil – 15% fly ash – 0.8% Recron 3S fibre. Also the method used in this research was randomly distributed fibre reinforcement soil also turned as RDFS. Also from Proctor test it was found that OMC increases & MDD decreases with increase in pozzolana (fly ash)& Recron 3S fibre.

I. INTRODUCTION

Soil means earth's upper layer, where plants and organic matter develop. It is a black or dark brown material typically consisting of a mixture of organic remains, clay and rock particles. The word soil is derived from solium a Latin word. Soil is a material naturally available in universe. The cheapest available construction material is also soil, on the same hand it is very complex material too. Study of soil mechanics is complex thing too in itself. The high variability in characteristics and composition makes soil a complex material. The behaviour of soil varies from place to place and also with the change in the naturally occurring conditions changes the behaviour of the soil. The very first duty of geotechnical engineer is to check whether the engineering property of soil matches to the design requirements of an engineering structure or not.

Because of complex behaviour of the soil with respect to the engineering properties the soil has rendered it to following limitations.

- Theory of elasticity cannot be applied due to the non linear stress strain relationship.
- Strength and behaviour of soil depends on drainage, pressure, environment and many other factors, because of this same soil show different strength and dissimilar conditions.
- Soil at different locations is different in characteristics and composition so the results of soil at one place are different from other place.
- Interpretation of the results of tests not possible.
- Soil being a particular material the properties of soil changes as the particles shifts the positions.

Necessity for the improvement of available soil for engineering use

- This is very common problem now days the engineering properties of soil do not come up to the design requirements of the standards. The further step taken must be made whether to;
- Use the site material as it is present and makes changes in the design to meet the existing quality standards of the soil.
- Replacement of site material with some superior material.
- Modify the properties of the existing soil so as to create a new improved material meeting the requirement of the designed standards.
- Now times, in this fast developing world it is quite impossible to impose restrictions on the design requirements. The purpose of the structure to be built on such soil is not served.
- Secondly it will be uneconomical to replace the soil when vast quantities are involved. So the last left alternative of improving the engineering behaviour of the available soil. This method of improving soil properties is known as stabilization of soil.

Improvement of soil strength by stabilizing

Process of improving the engineering properties of the soil to make it stable is known as soil stabilization. Soil stabilization is the prevalent and usual methods in use to improve the engineering properties of soil. The main purpose of practice of stabilization is to reduce the permeability and compressibility of the soil mass in the earth arrangement and to amplify its shear strength.

Methods of soil stabilization

Soil improvement mainly comes under three types viz Elimination of undesirable materials, control of ground water, strengthening the geological materials and reclaimed materials. These methods are mainly focuses to change the unfavourable conditions into those more suitable for the support of structures in shallow foundations or to reduce pavement thickness requirements etc.

The properties of soil may be improved by following ways, which are;

- Cement stabilization
- Lime stabilization
- Chemical stabilization
- Bituminous stabilization
- Grouting concrete stabilization
- Geotextile stabilization
- Reinforced earth stabilization

Pozzolana (fly ash) in India

Fly ash is a fine powder produced from the burning of coal in a coal fired burner. It is a fine grained particulate material that is carried off in the flue gas and collected from the flue glass by means of electrostatic precipitators, bag houses etc. In actual there are three types of ash produced by a thermal plan viz 1, fly ash 2, bottom ash and 3. Pond ash. Bottom ash is collected from boilers. Fly ash and bottom ash are mixed together to yield pond ash. Besides thermal power plants the steel, copper and aluminium industries contributes a substantial amount of the fly ash/pond ash . Fly ash is on average finer than the Portland cement and lime. It consists of silt sized particles which are generally spherical; usually ranging between 10 and 100 microns. In microscopic view they look like similar to bubbles of various sizes.

Characteristics of Pozzolana (fly ash)

Fly ash is classified in two categories viz class c (lignite ash) and class F (bituminous ash) as per the composition given in the table 1.4 given by FERGUSON (1999).Class c is more convenient for soil stabilization FERGUSON (1993). Average particle size of lignite fly ash is considerably coarser than the bituminous variety. The most produced fly ash in India is bituminous ashes i.e. class F fly ash.

Table No. 1.1: Classification of Fly ash

S.NO.	Compound	Class of Fly ash	
		Class F	Class C
1	Silica	54.9	39.9
2	Alumina	25.8	16.7
3	Iron oxide	6.9	5.8
4	Calcium oxide	8.7	24.3
5	Magnesium oxide	1.8	4.6
6	Sulphur	0.6	3.3

Table 1.2(a): List of industries producing Pozzolana (fly ash)/pond ash in India

THERMAL POWER PLANTS

Name of Industry	Name of the state situated	Name of the place
Kothagendem	AP	Nellore
Ramagundam	AP	Vijyawada
Bongaigaon	Assam	Lakwa
Barauni	Jharkhand	Bokaro
Chandradurg	Bihar	Muzzafarpur
Indraprasta	Delhi	Rajghat
Utraw	Gujrat	Gandhinagar
Singrauli	UP	Mirjapur
Korba	MP	Satpura
Guru nanakdev	Punjab	Ropar
Ennoere	Tamil nadu	Tuticorin
Trombay	Maharashtra	Nasik
Durgapur	West Bengal	Bundle

Table 1.2(b): List of Aluminium Industries

B) ALUMINIUM INDUSTRIES

Name of the Industry	Name of the state situated
BALCO	MP
NALCO	ODISHA

Use of pozzolana (fly ash)

Fly ash can be used for various purposes. Some of the applications are the following;

- For land fill
- For structural fill for reclaiming low areas
- For manufacturing of Portland cement
- For soil stabilization
- In soil conditioning
- Manufacture of bricks
- For stowing materials for mines

II. MATERIAL AND METHODS

In the present experimental study, the soil's properties are improved by the addition of fly ash and recron 3S fibre. Fly ash will be used as stabilizing agent to improve some properties and the recron 3S will be acting as the reinforcement's material. Both fly ash and recron 3S fibre worked well to improve the properties of soil which are unconfined compressive strength

Soil samples were taken from Srinagar.

Fly ash was taken from dealer situated at Rajbagh Srinagar.

Recron 3S was taken from the market. Recron 3S is manufactured by Reliance Industries.

Tap water was used for laboratory work.

SOIL

Source of soil

The soil used in this study was taken from a village Rajbagh District Srinagar. The soil shows expansive properties when came in contact with water. The clayey soil is light brown in colour. The properties of clay are shown in the following table.

Table No. 2.1: Properties of Soil Used in the study

S.No.	Characteristics	Value
1	Specific Gravity	2.68
2	Atterberg's limits: Liquid limit (%) Plastic limit (%) Plasticity index (%)	 34.4 20.2 9.15
3	Colour	Light brown
4	IS classification	CI
5	Standard proctor compaction test results: Optimum moisture content (%) Maximum dry density (kN/m^3)	 16 16.9
6	Unconfined compressive strength (kN/m^2)	215.6kN/m^2
7	Shear strength parameters: Cohesion intercept (kN/m^2) Angle of shearing resistance (in degree)	 24.6 19.2

Pozzolana (fly ash)

Source of Pozzolana (fly ash)

Fly ash used here in this study was collected from the R.G Contactors Srinagar. The samples were made dry in oven at temperature of 100o C.The fly ash brought was then passed through the sieve to remove the solid heavy foreign particles. The dried and sieved fly ash was packed in polythene air tight bags for further usage to protect from the moisture. Properties and composition of fly ash are provided by the manufacturer i.e., R.G ContractorsSrinagar (Kashmir).

Table No. 2.2: Engineering properties of Pozzolana (fly ash)

S.No.	PROPERTIES	VALUES
1	Colour	Dark Grey
2	Standard proctor compaction test Optimum moisture content (%) Maximum dry density (kN/m^3)	 32.2 13.5
3	Specific gravity	1.92

Table No. 2 RECRON 3S Fibre Source of recron 3S fibre

Recron 3S, name of geo-fibre used in present study was bought from market. The material was packed in a pack of 125 gm. The fibre used in this study of length 12mm. Recron 3S is also available in different sizes as 6mm, 12mm and 24mm but here 12mm is used as in previous studies 12mm was found successful. The recron 3S fibre is made from polymerization of pure Terapthalic acid and Mono Ethylene Glycol using a catalyst. These fibres are found to be used widely in concrete technology. The fibre has a special triangular cross section. The equivalently diameter of fibre was about 32-55µm. The special triangular cross section is good for the anchoring and the interaction with soil fly ash mix. The physical properties of the recron 3S, as provided by the manufacturer are as shown in table no.3.4

2.3: Chemical Composition of Pozzolana (fly ash)

S. No.	Constituents	Percentage
	SiO_2	58.48
	Al_2O_3	29.68
	Fe_2O_3	6.98
	CaO	1.69
	MgO	1.36
	Na_2O	0.27
	K_2O	1.21
	P_2O_5	0.31

Role of recron 3S fibre

- Controls cracking
- Reduces water permeability
- Increases flexibility
- Safe and easy to use

Primary applications of recron 3S fibre

- Wall plastering and plain concrete
- Foundations , footings and tanks
- For improvement of the properties of soil
- Dams and bridges
- Roads and pavements

METHODS USED IN PRESENT STUDY

Reinforced earth stabilization:

Method chosen here in present study is reinforced earth stabilization. Due to the availability of variety of materials commercially at cheaper rates has takenmomentumof use of reinforcement in improving the strength parameters of geo materials. Earth reinforcement involves the basic principles which are simple and are used by mankind for centuries. The essential characteristics of earth reinforcement are that it is made up of two kinds of elements, reinforcement and soil grains. The basic mechanism of earth reinforcement is the generation of the frictional forces between the reinforcement and soil. Previous research has been done to find out the suitability of compacted fly ash in geotechnical construction

like retaining walls, embankments etc. on the other hand these structures are needed to be protecting from getting wet in case to prevent the inherent strength of compacted pond ash, which is difficult to do in fields. Having this issue in mind fly ash soil has modified the stress – strain behaviour of destabilized material, reinforcement has been used in the form of recron 3S fibre. Effect of fibre reinforcement on the stress – strain behaviour, strength parameters of the compacted mixes has been evaluated through a series of unconfined compressive stress tests, direct shear tests. From the results shown that the addition of fibre reinforcement is very proficient in increasing the failure load.

Principles of reinforced earth

Soil mass in general is a discrete system consisting of soil grains. And it is unable to withstand tensile stresses and this is particularly in the case of cohesion less soil like sand. Soil cannot stay stable on steep slopes, a relatively large strains will be caused when the external loads are imposed on them. Reinforced earth is a combined material, a combination of reinforcement and soil placed suitably to withstand the development of tensile stress. Presence of reinforcement `modifies the stress field giving a hold back mostly in the form of adhesion or friction so that minimum strains are induced and tension is avoided.

III. REINFORCING MATERIAL

General:

A number of materials like steel, glass fibre, geofabrics, wood, rubber etc. have been reported to be used successfully as reinforcement materials. Developed countries prefer using polypropleyene based synthetic fibres due to their available with desired properties and durability. The reinforcement can be used in the form ofgrids, strips, rope and other combinations.

The artificial polymers have high resistance to alkalis, acid and bacteria. Degradation characteristics of polymers are shown in table 1.2.Polyamides posse's very good mechanical characteristics including excellent resistance to abrasion to rotting.

Fibre reinforced soil (ply soil)

Randomly distributed fibre reinforcement soil- also termed as RDFS is one of the latest ground improvement practice, here fibres of desired quantity and type are added in soil, mixed randomly and then compacted properly. The method of RDFS is similar to other conventional stabilization methods. In reinforced earth, reinforcement is in the form of sheets, strips, fibre etc is laid horizontally at specific intervals, but in case of RDFS fibres are mixed randomly in soil thus making a homogenous mass and maintain the isotropy in strength. Now days, modern geotechnical engineering has focused on planner reinforced example; metal strips, sheet of synthetic fabric.

This concept of involving the reinforcement of soil using fibres has been used since ancient times, although the reinforcing mechanism may not be understood. Even at the time of Great Wall of China the clay soil was mixed with tamarisk branches. The improvement of soil by tree roots is same as of fibres. Gray (1947, 1978), Waldron (1977) and Wu et al.(1998) reported that the plant roots help in increasing the shear strength of soil and consequently the stability of natural slopes. Synthetic fibres were introduced since 1980s, after the initial studies using polymeric fibres were conducted.

Advantages of fibre-reinforced soil

RDFS offers many advantages as listed below;

- It increases shear strength with the maintenance of isotropy.
- It increases durability
- It reduces post peak strength
- It increases seismic performance
- It helps in erosion control
- It reduces shrinkage and swell pressure of expansive soil
- It is beneficial for all types of soil

Natural fibres

In India a number of natural fibres are present like coir, hemp, munja, bamboo etc. if the cost of the ply soil is to kept low then the locally available fibres should be considered in design. But on the same time stability and life of structure should be given prime focus as the life of the structure depends on the durability. Most of the natural fibres are tested under various tests and results are obtained that they lose the strength when they are subjected to alternate wetting and drying environment.

Due to low strength and lack of durability natural fibres are not widely usedfor reinforcement but are preferred for erosion control.

Factors affecting the strength characteristics of RDFS

The factors on which strength characteristics and other engineering properties of RDFS depend are as follows;

- The type of soil includes soil gradation expressed in terms of uniformity coefficient (Cu) and mean grain size (D50).
- The type of fibre monofilament or fibrillated.
- Denier of fibre, its weight of 9000m long fibre, weight is in gm.
- Length of fibre
- The ratio of fibre to its diameter i.e. aspect ratio.
- Fibre soil surface friction.

Applications

During designing the civil engineering structures, function to be performed needs to be analysed first, after that the suitable material and the products are selected. Table 1.3 illustrates the applications of geosynthetics.

Table 2.5 Geosynthetics application summary table

Application	Primary function	Products
Sub grade stabilization	Separation/reinforcement/filtration	Geotextiles/geogrids
Rail road track bed Stabilization	Drainage/ Separation/filtration	Geotextiles/geogrids

Sedimentation	Sediment retention	Geotextiles
Fence	Separation/filtration	Geotextiles/geogrids
Asphalt overlay	Stress reliving layer/water proofing	Geotextiles/geogrids
Soil reinforcement	Reinforcement	Geotextiles/geogrids
Erosion control protection	Protection/cushion	Geomembrane
Subsurface drainage	Separation/filtration	Prefabricated drainage
Surface erosion control	Turf reinforcement	Erosion control mats

IV. RESULTS AND DISCUSSIONS

This chapter gives detailed experimental process for the present study, including the material processing, optimization of fly ash, their proportion of mix to be used for further tests on soil- fly ash- recron 3S mix. The results of tests of properties of the soil selected are shown here and also the results of standard proctor test, unconfined compressive strength test and direct shear test are also elaborated in this chapter.

PROCESSING OF MATERIALS

The soil samples were collected form Khansahib District Budgam. The soil was crushed to break lumps with the help of wooden hammer and dried in air under covered area. The crushed soil was sieved through 2.36mm IS sieve and mixed carefully. The sieved soil was stored in bags. For each test the required amount of soil was taken out and was dried in oven at 105oC for hours. Then dried soil was allowed to cool down at room temperature.

Fly ash brought from R.G Contractors (Kashmir) was also dried in oven at 100o C and was allowed to cool down before the test.

Tests performed in Laboratory:

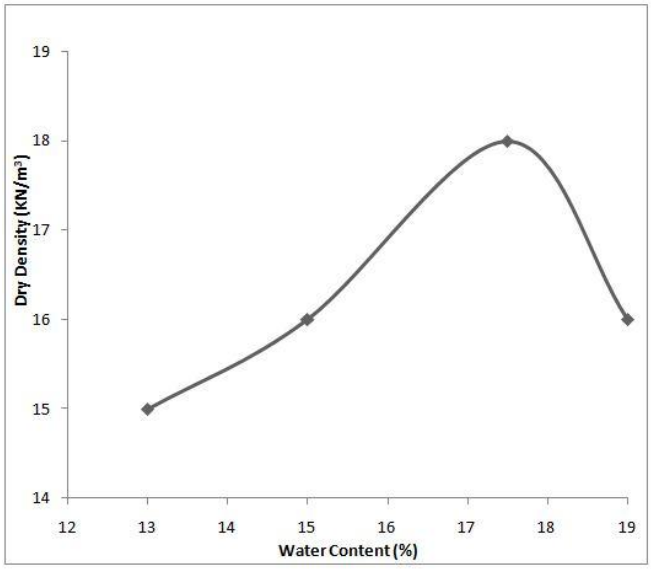
The following were tests performed for the present study in Laboratory

- Pycnometer test for specific gravity
- Casagrande's test for liquid limit.
- Plastic limit test.
- Standard proctor Test for determination of O.M.C and MDD
- Unconfined compression Test.
- Direct Shear Test.

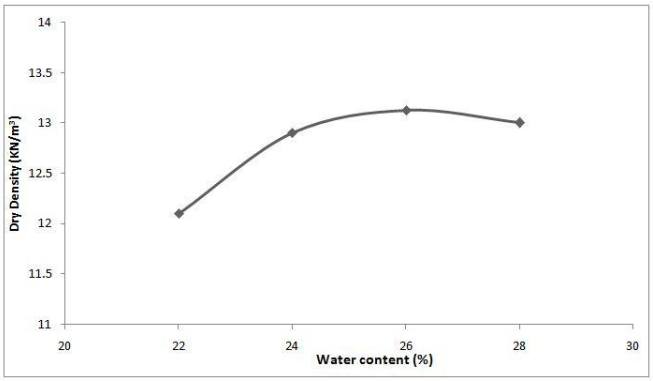
EXPERIMENTAL RESULTS

This section contains the test results on the soil, for properties of the virgin soil i.e. standard proctor test (OMC and MDD), unconfined compressive strength and the direct shear test results. After obtaining the properties of virgin soil the tests were done on soil and fly ash mixes, from here the amount of fly ash was optimized by UCS test. The optimized value of fly ash and soil was mixed with different proportions of recon 3S fibre. Then the soil, fly ash and recon 3S samples of different ratios were tested under the unconfined compressive strength and direct shear tests after 7 days and 14 days curing period.

Graphs showing curves obtained from standard proctor test for soil- fly ash mix



MDD and OMC for soil: fly ash (85:15)



Results of MDD and OMC for soil- Pozzolana(fly ash) mix

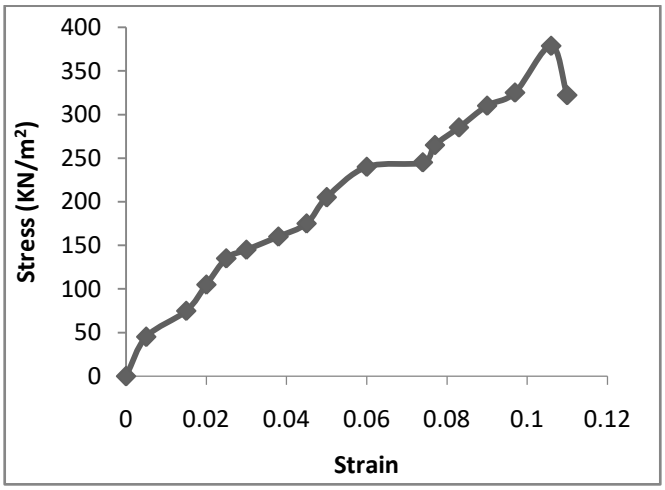
S.No.	Proportion Soil- fly- ash	MDD (KN/m³)	OMC (%)
1.	100-0	18	17.5
2.	90- 10	20.18	18
3.	85- 15	19.01	18.5
4.	80- 20	16.07	19
5.	70- 30	15.09	21
6.	60- 40	14.01	24
7.	50-50	13.13	26

Results of MDD and OMC for soil- fly ash and recron 3S mix

S.No.	Proportion Soil- fly ash-recron 3S	MDD (kN/m³)	OMC (%)
1.	84.8 – 15 – 0.2	16.04	18
2.	84.6 – 15 – 0.4	15.95	18.20
3.	84.4 – 15- 0.6	15.77	20
4.	84.2 – 15- 0.8	15.5	22.75
5.	84 – 15- 1	15.4	24.50

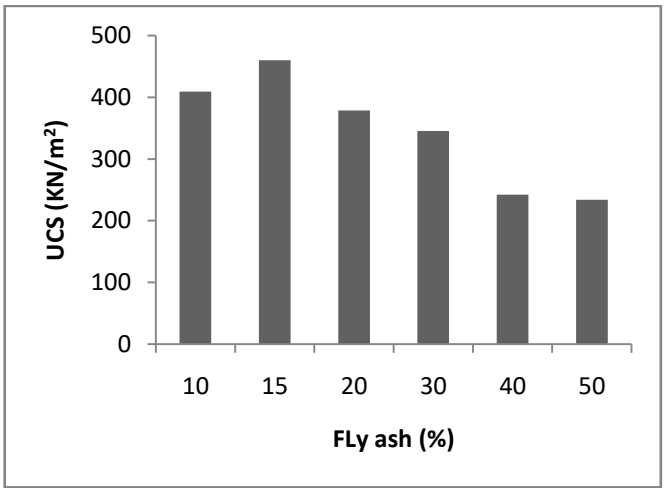
UNCONFINED COMPRESSIVE STRENGTH

The results obtained from U.C.S test shows increase in strength of virgin soil by adding fly ash in the beginning when added 10% but when this amount was increased to 20, 30, 40 & 50 % the strength decreases. Then a value of 15% fly ash was chosen as the maximum strength was achieved there.

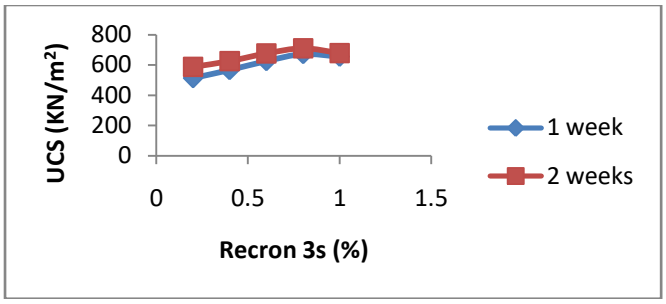


Results of unconfined compressive strength with increase in fly ash Quantity

S.No	Mix proportions (soil: fly ash)	Curing period (weeks)	Unconfined compressive Strength (kN/m²)
1.	100-0	1	215.6
2.	90- 10	1	409.10
3.	85- 15	1	460.1
4.	80- 20	1	378.70
5.	70- 30	1	345.26
6.	60- 40	1	342.01
7.	50-50	1	334.06



Variation of UCS with increase in fly ash (column view)



Variation of UCS with increase in Recron 3S (with 15% fly ash) for 1 and 2 week

Discussions

The mechanical behaviour of soil- fly ash- recron 3S mix was examined by conducting standard proctor test, UCS test and direct shear test. Numbers of samples were prepared on number of proportions. Also 1 and 2 week curing period was taken for unconfined compressive strength test.

2 Unconfined compressive strength test

The results obtained from U.C.S test shows increase in strength of virgin soil by adding fly ash in the beginning when added 10% but when this amount was increased to 20, 30, 40 & 50 % the strength decreases. Then after a value between 10% & 20% that was 15% was chosen and tested under SPT and U.C.S. At 15% the maximum strength was achieved and was found appropriate to be used for further work. The U.C.S test for soil – fly ash mix was performed on 7 days cured samples 4 samples were made for each proportion for best results. The strength of virgin soil was increased from 213.67KN/m2 to 409.10KN/m2 with 10% growth of fly ash and also with 15%, 20%, 30%, 40% & 50%. The strengths achieved were 460.1, 378.70, 345.26, 342.01 and 334.06 KN/m2 respectively shown in 4.3. The variation of U.C.S with increase in percentage of fly ashis shown in fig. 4.24 and 4.25. After optimizing 15% fly ash the recron 3S was introduced in amount of 0.2, 0.4, 0.6, 0.8 and 1% and the results after 1 week curing were 512.46, 566.49, 625.23, 686.1 and 654.35 KN/m2respectively and the results for 2 week curing were 587.085, 625.023, 676.81, 710.2, 678.08 KN/m2. This 1 week and 2 week curing results showed that the best proportion obtained is 84.2soil: 15 fly ash: 0.8 recron 3S as it gained maximum U.C.S for 1 week as well as 2 week period.

V. CONCLUSIONS AND SCOPE FOR FURTHER STUDY

Conclusions:

On the basis of the investigation, the following conclusions have been made:

- With the increase in quantity of pozzolana (fly ash) OMC value increases MDD decreases.
- When the recron 3S fibre quantity increases the OMC values increase and MDD decreases.
- 15% pozzolana (fly ash)was optimized for the further work.
- The best value obtained from results of UCS for 1 week and 2 week curing period is 672.1KN/m^2 and

710.2 KN/m^2.

- The best ratio obtained was 84.2% soil: 15% pozzolana (fly ash): 0.8% recron 3S fibre.
- With the increase of recron 3S in soil pozzolana (fly ash) mixes the cohesion intercept and angle of shearing resistance increases.
- The best value of cohesion intercept and angle of shearing resistance are 62.2KN/m^2 and 29.1^0 respectively.

2 Scope for further study:

- Here in this study compaction test, UCS test and direct shear test are performed, for further work CBR value, triaxial test, permeability, durability test should be performed.
- Other proportions should be tested for better use of fly ash and recron 3S.
- UCS test is performed here for 1 and 2 week, the curing period should be increased.
- Direct shear test should be performed with curing period.
- The work here is done on clay soil, work using recron 3S and fly ash should be performed on other type of soil.

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