IMPROVING THE ENGINEERING PROPERTIES OF SOIL USING NYLON FIBRE WITH GROUND GRANULATED BLAST FURNACE SLAG

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Abstract - Among the major issues facing the engineering community are the development of economically viable ground improvement techniques and the safe and efficient disposal of industrial pollutants. In this work, an effort has been made to look at the viability of using GGBS with fibers. These hazardous industrial waste materials are used to stabilize soil because they can be used in large quantities for geotechnical projects including building embankments, earth dams, and paving for roads and airports. The process of increasing the soil's engineering qualities and making it more stable is known as soil stabilization. When the construction-ready soil is unfit for the intended use, it is necessary. Stabilization, in its broadest definition, encompasses preconsolidation, drainage, and many other similar processes. However, the term "stabilization" is typically used to refer to a procedure where the soil material is changed in order to improve its qualities. For the purpose of stabilizing a natural soil, a cementing substance or chemical is added. In earth structures, soil stabilization is utilized to increase shear strength and decrease permeability and compressibility of the soil mass. To strengthen the foundation soils' bearing capability, soil stabilization is necessary. Stabilization is mostly used to enhance the natural soils for the building of roads and airports. The grading of soils and aggregates used to build the bases and sub bases of highways and airports are governed by the principles of soil stabilization.

***Key Words*:** Compaction test, CBR, UCS, Nylon Fibre, GGBS

1. INTRODUCTION

An expansive soil is mostly covers nearly 20% of the land (with a large part of central india and a portion of south india) in India and includes approximately the entire Deccan Plateau. Expansive soil is mainly a clay soil which has high compressibility and lower strength when contact with water. These soils are very sensitive to variations in water content and show excessive volume changes (i.e. prone to high volume changes or variations). This expansive nature of the soil may create cracks and damage on the pavements, highway embankments, building foundations etc. soils which has montmorillonite and bentonite minerals composition, shows maximum changes in volumes. In other words the mineral structure of these soils is mainly responsible for the the absorption of water on great extent.

In a flexible or rigid pavement, subgrade layer is the lowest portion in the pavement structure underlain by surface course, base course and sub-base course. Being the lowest layer Subgrade is the natural ground level and it may have loose earth crust. When the subgrade layer is consists of expansive soil and when it came in contact with the water by rain or water table capillary action, it will changes its volume largely. This volume changes in subgrade soil will reflect on to the pavement layers and ultimately reach to the surface of the pavement. A flexible pavement failure occurs by formation of pot holes, ruts, cracks, localized depressions and settlements. The localized depression normally is followed with heaving. The sequence develops undulations on the pavement surface. Pavement unevenness may itself be considered, as a failure, when it is excessive.

Therefore on of the main cause of flexible pavement failure is excessive changes of volume in subgrade soil. This can be easily noticed in the form of excessive undulations or waves and corrugations in the pavement surface. The lateral shoving of pavement near the edge along the wheel path of vehicles is due to insufficient bearing capacity or shear failure in subgrade soil. Inadequate stability may be due to inherent weakness of the soil itself or excessive moisture or improper compaction of the soil. Stability is the resistance to deformations under the stress, which means if the stability of the soil is good, than the soil will be able to resisit the volume changes. Excessive stress application on the soil which causes deformation of the pavement is due to inadequate pavement thickness or loads in excess of the design capacity of the pavement.

2. Literature Review

Nazmul Ummahat, S.M. Ashik al aziz et al (2020) Nylon fiber reinforced concrete has introduced a new role in the construction arena. Among all other responsible factors for transferring stress between matrix and fibers aspect ratio has a great influence on the mechanical properties of the concrete composite. This paper aims to compare the effects of using three different lengths (19mm, 25mm, 50mm) of nylon fibers on the mechanical properties of concrete. Moreover, this research work compared the result of using different percentage (0.25%, 0.37% & 0.50%) of dosages of nylon fiber with the plain concrete by conducting the tests (compressive strength, Tensile strength and flexural strength). it was observed that the Compressive strength was maximum at 0.25% fiber dose and 19mm length, the splitting tensile strength was maximum at 0.25% fiber and 25mm length & the maximum flexural strength was achieved at 0.25% fiber and 25mm length. The tests indicates that the presence of Nylon fiber
tends to increase the strengths in lower fiber percentage and shorter length. But it decreases at higher fiber percentage and longer length; however some irregular behaviours were also noted. the research work results raise a hope that NFRC (Nylon Fiber Reinforced Concrete) can be used in areas where small tensile reinforcement is expected and also in the construction of temporary structures. The low cost, reduced weight and reduction in other concrete constituents also indicate the economic advantage of NFRC.

Dr. Siddhartha Rokade et al (2017). Addition of nylon fibre along with fly ash to measure the change in the strength parameters of black cotton soil. The CBR of the soil was determined by conducting three series of tests. Tests were carried out on the BC soil mixed with varying percentage of fly ash, from 10% to 40% out of which 20% came out to be cptimum. Then,nylon fibre with aspect ratios (length/ diameter) 20, 40, 60 and 80 and fiber contents were varied from 0.25% to 1.5% with 0.25% interval, out of which 0.75% of fibre content is considered as optimum on the basis of MDD and maximum CBR value

Pallavi et al (2016): They studied the stabilization of black cotton soil using fly ash and nylon fibre. In their study, they used different combinations of fly ash as 10%,20%, 30% & 40%. 20% was their optimum value. After which they calculated the optimum value of nylon fibre from various values as0.25%, 0.50%, 0.75%, 1%, 1.5%. From which 0.75% nylon fibre comes to be the optimum. The CBR value of soil+20% fly ash+0.75% fibre was maximum of all other readings. And the MDD was also maximum of this mix proportion.

RangaSwamy et al(2015): In this paper utilization of GGBFS and lime is done to improve the compaction and unconfined strength properties of clayey soil.clay is replaced by 20% GGBS by weight of soil and Lime is added (0%, 4%, 8%, 12%, 16% and 20%) by dry weight of soil. In the resultsit has been found from Unconfined compressive strength (UCS) test, 20% GGBS replacement and 16% Lime addition to dry weight of soil gave optimum results.

AbhlilashDevano et al (2014): In this geotechnical properties of clayey soil has been noticed by the addition of GGBFS.Different dosages of blast furnace slag i.e. 10,20,30,40 and 50% were used to stabilize the expansive soil. California bearing ratio (CBR) and Unconfined compressive strength Test (UCS). Based on strength performance tests, it was observed that replacement of blast furnace slag increases the strength of expansive soils.

B.R. Phanikumara et al (2013): This paper presents the swell-consolidation characteristics of remoulded expansive clay specimens reinforced with randomly distributed nylon fibre.In the case of nylon fibre, the length of the fibre (l) was varied at 15 mm and 20 mm. As the diameter of the fibres was 1mm, the aspect ratio of the fibres used was equal to 15 and 20, respectively. The fibre content (fc) used in the testing programme was varied at 0%, 0.05%, 0.1%, 0.15%, 0.2%, 0.25% and 0.3% by the dry weight of the soil. Their result shows that the swell potential (S%) and the vertical swelling pressure also decreased with an increasing fibre content (fc) for a given fibre length. & thesecondary compression decreased with an increasing length of fibre. The value of the secondary consolidation coefficient (C_α) for fibre-reinforced specimens was less than that for the unreinforced specimen.

NoorinaTarannum et al (2013) : In this paper effects of GGBFS on the properties of black cotton soil has been noticed by performing different experiments on different soil mixes. The oven dried black cotton soil, lime (5%) and blast furnace slag(5%, 10%, 15%, 20%, 25%) are mixed in proportions by weight to form different mixes.it is observed that the liquid limit is decreasing with the increase in GGBFS and shrinkage limit is increasing with the increase in GGBFS and the plasticity index is gradually decreasing.

LaxmikantYadu et al (2013): in this paper influence of GGBFS in the Engineering behavior of the stabilized soft soil. In this they studied the effect of mixing GGBFS on the consistency ,compaction characteristic and strength of laterite soil. The GGBFS content varied from 0% to 15% by dry soil weight. Both the liquid limit and the plastic limit decreases with the increase in GGBFS content and an increase in plasticity index is observed with the increase in GGBFS content.

KameshwarRaoTallapragada et al.(2009): Their work is undertaken to research the benefits of fiber reinforced subgrade. They used two fibres: nylon fibre and monofilament. The main tests performed were CBR test & UCS test to check the strength. Three proportions were prepared as 0.75%, 1.5% & 2.25%. Their result shows CBR value of Black Cotton soil also increases considerably due to addition of the fibers in soil. From UCS test it was found that Maximum Stress value of soil increases with increasing aspect ratio of nylon fibre.

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3. Materials

3.1 SOIL

Source of soil

The soil used for the experiment purpose, which is clay soil (CI) was taken from the local area near Jammu. The amount of soil that was taken for the experiment purpose was around 130 kg, including the impurities in the soil (like hard particles, pebbles, organic impurities etc.). After bringing the soil to the working area, the lumps and the organic impurities in the soil were removed by using tools like Hoe and Rake.

Table no. 1 Properties of soil used in the study

S.NO.	PROPERTIES	RESULTS
1.	Liquid Limit	40.5 %
2.	Plastic Limit	24.3 %
3.	Plasticity Index	16.2 %
4.	Optimum Moisture	12.8 %
5.	Maximum Dry	18.93 kN/m³
6.	Specific Gravity	2.59
7.	CBR (soaked)	2.83 %
8.	U.C.S	93.25 kN/m²
9.	Indian Soil	CI

3.2 GGBS

The Blast Furnace Slag for the work was collected from the Mandi Gobindgarh (Distt Patiala).

Table 2 Chemical composition of Blast furnace slag

Sr. No	Constituent	Composition (%)
1	CaO	40 – 52
2	SiO_2	10 – 19
3	FeO	10 -40 (70 – 80% FeO, 20 - 30% Fe_2O_3)
4	MnO	5 – 8
5	MgO	5 – 10
6	Al_2O_3	1 – 3
7	P_2O_5	0.5 – 1
8	S	< 0.1
9	Metallic Fe	0.5 – 10

3.3 NYLON FIBRE

The nylon fibre 6 used for the work was bought from the dealer in Delhi and it was made by Gujarat State Fertilizers & Chemical Limited. ISO 9001, ISO 14001 & OHSAS 18001 certified company.

S.No.	Property	Value
1.	Density	1.14gm/cc
2.	Melting point	215℃
3.	Length	20mm
4.	Specific gravity	0.90
5.	Diameter	0.50mm
6.	Aspect ratio	40

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

CLAYEY SOIL- NYLON FIBRE AND GGBS MIXES

Table no. 3: Results of OMC and MDD for mix proportions of Nylon Fibre and GGBS

SOIL:NF:GGBS	MDD (kN/m³)	OMC (%)
77.5: .5:22	18.56	13.5
77:1:22	18.38	13.9
76.5:1.5:22	18.31	14.3

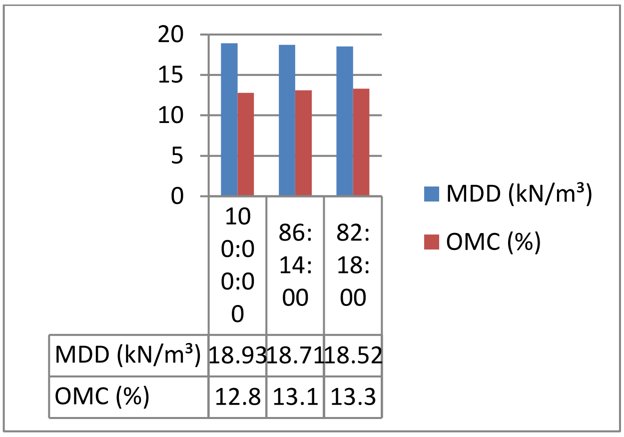

Fig:-1 Differences b/w MDD and OMC of Nylon Fibre and GGBS in various ratios

Table 4: Results of UCS of Nylon Fibre and GGBS

(S:GGBS:NF)	Curing period (days)	UCS value (KN/m²)
77.5:22:0.5	7	204.30
77:22:1	7	228.54
76.5:22:1.5	7	216.78

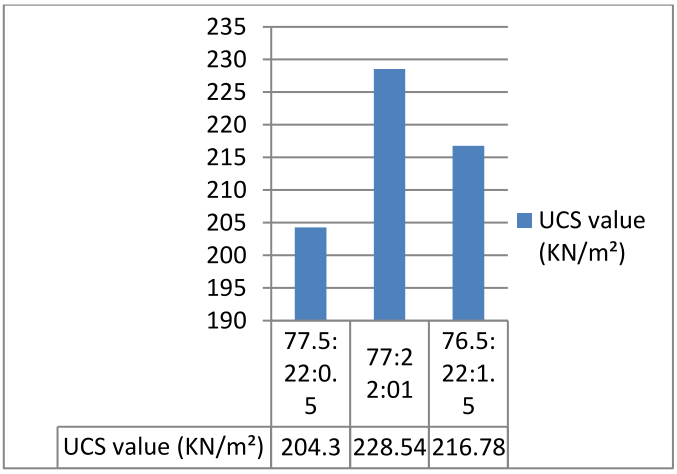

Fig:-2 various ratios of Nylon Fibre and GGBS are shown in the UCS graph.

Table 5: Results of CBR for Nylon Fibre and GGBS

(S:GGBS:NF)	CBR (%)
77.5:22:0.5	5.11
77:22:1	5.31
76.5:22:1.5	5.23

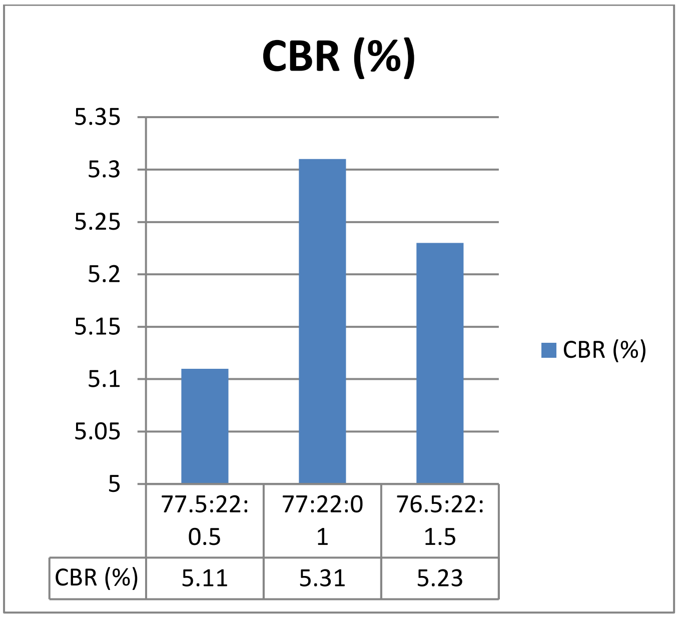

Fig:-3 CBR Graph of Nylon Fibre and GGBS with various ratios

5 DISCUSSIONS

5.1 STANDARD PROCTOR TEST:

- Test results shows an increase in Optimum Moisture Content from 12.8% to 14.6% and decrease of Maximum Dry Density from 18.93% to 17.92% respectively when GGBS is added to clayey soil in percentages of 14%, 18%, 22%, and 26%.
- The test results also shows an increase in OMC from 13.5% to 14.3% and decrease in MDD from 18.56% to 18.31% when the percentage of Nylon Fibre is varied as 0.5%, 1% and 1.5% and GGBS is fixed at 22% which is the content where soil shows maximum strength.
- The increase in OMC shows that with the addition of GGBS and Nylon Fiber, the soil now has more water retention capacity which in turns increases the load bearing capacity of soil without getting failed.
- The presence of lime and silica in GGBS reacts with water and form cementitous compound due to which more water can be absorbed which increases the OMC and strength of the soil increases.

5.2 CBR TEST

- The CBR value of virgin soil was 2.83 which was increased suddenly with the addition of GGBS, the CBR value increases till 22% of GGBS and after that the CBR value starts to decrease when CKD is increased to 26%.
- The optimum value of GGBS was found to be 22% which showed the maximum CBR value of 4.80.
- With the addition of Nylon Fiber in percentages of 0.5%, 1% and 1.5%, the CBR value increased from 2.83 to 3.9 at 1% Nylon Fiber and after that the value start to decrease.
- The increase in CBR with the addition of Nylon Fiber is due to its reinforcing properties which helps in binding the soil particles together and increases the shear strength of the soil.
- When both the materials are added in soil by keeping the GGBS content constant at 22%, soil showed increased CBR value of 5.31 at 1%

nylon fibre and after the addition of more fiber, the value start to decrease.

- This content of 22% GGBS and 1% Nylon Fiber was found to be the Optimum quantity in this test having the highest value which is about 2 times the value of virgin soil.

5.3 UCS TEST:

- UCS value of clayey soil came out to be 93.25 kN/m². After the addition of GGBS in different proportions, UCS value gets increased to 158.54 kN/m² at 22% GGBS. But after that the UCS value starts to decrease at 26% GGBS.
- With the addition of Nylon Fiber to virgin soil, the UCS value gets increased from 93.25 kN/m² to 123 kN/m² at 1% Nylon Fiber content. Increasing the fibre content beyond this decreases the UCS value.
- When the mixtures of GGBS and Nylon Fibre are mixed with soil while keeping the GGBS content constant at 22%, the UCS value gets increased to 228.54 kN/m² but at 1% Fiber content which shows that when both the compounds are used together the Fibre content is Optimum at 1%.
- The UCS value at 22% GGBS and 1% Nylon Fiber is 2.45 times more than that of virgin soil.

CHAPTER 6

CONCLUSIONS

Following conclusions can be inferred on the basis of the experiments performed:

1. Ground Granulated Blast furnace Slag is a waste product of steel manufacturing process.It is obtained by quenching molten iron slag which is obtained as a by-product of iron and steel making from a blast furnace. It can be effectively use in the process of stabilization ofsoil due to its cementitious properties that helps in increasing the strength of soil.
2. Nylon fiber on the other hand is a cheaply available material which can be added to soil in less quantities to make big changes in its strength parameters.
3. The optimum value of GGBS came out to be 22% while performing the CBR test and then it is kept constant in further experiments. So, keeping GGBS constant at 22%, Nylon Fiber is then varied and found the optimum content of fiber which came out to be 1%.
4. The Unconfined Compressive Strength of soil mixed with 22% GGBS and 1% Nylon Fiber came out to be maximum which is 2.45 times of virgin soil. So, the optimum mix also has the maximum strength which the soil can after treatment.
5. These materials help in improving the bearing capacity of soil effectively with very low cost and also make the soil suitable for construction works.

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