ANALYSIS ON IMPROVEMENT OF SOFT CLAYSOILS BY PARTIAL REPLACEMENT OF CNS (Cohesive NON-Swelling Soils)

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ABSTRACT

Geo-Technical Engineers all over the world fare enormous problems, when the soils founding those structures are expansive in nature. Depending upon the use of soft clay soils as foundation support or construction materials. Their properties need careful study to estimate their potential for damages based on volume changes, with reference to imposed structural loads and tolerance of structure for maximum settlement Among several techniques adopted to overcome the problems, lime stabilization gained prominence during past few decades due to its abundance and adaptability The main objective of this project is to improvement of soil property of soft clay soil without using any admixtures i.e., by using CNS (Cohesive NON- Swelling soils). An attempt has been made to use these materials for improving the swell, plastics compaction, and strength and penetration characteristics of problematic clay soil which also prove environment friendly.

Keywords: Soft clay soils, Black cotton soil, settlement ,Cohesion NON- Swelling Soil……

1.INTRODUCTION

General Soil stabilization is a method of improving soil properties by blending and mixing other materials. Soil stabilization is the process of improving the shear strength parameters of soil and thus increasing the bearing capacity of soil. Stabilization of soil fall into two categories. They are Chemical stabilization and Mechanical stabilization. Soil Stabilization in the field Soil stabilization enhances the resistance to deformation and controls the swelling and shrinkage properties of soil. Thus stabilization increases the ability of weak ground loads, strongly supports the base and reduce subsidence on the foundation. Stabilization is commonly used to hand le all types of soils, from clay to coarse grained soil. The most common improvements are achieved through stabilization, including better soil assessment, lower roasting and increase in soil strength. It is becoming increasingly important to stabilize the soil and improve the engineering properties of soil, as it is not always possible to have good soil near the site of construction. Soil stabilization using cohesive non-swelling (CNS) used in the construction of road infrastructure as well as in earthen embankment.

1.1 Advantages of Soils Stabilization

Soil stabilization usually has many advantages over weak soil characteristics. The advantages of soil stabilization include increasing the shear strength of the soil and increasing the load carrying capacity of the soil. Soil stabilization can be used to stabilize embankments in the soil. Stabilization reduces the compressibility of soil and prevents the penetration of water into the soil, thereby losing the engineering strength of soil. Stabilization contributes to soil changes as a result of climatic change, such as temperature and moisture content.

1.2 Significance of Research Chemical admixtures create some environmental issues when they are used to stabilize the weak soils. Chemical additives produce negative environmental impacts. Some of the vital chemical stabilizers such as Lime, Portland cement, Fly ash and Bitumen are used for stabilization processes and these chemicals may have a chance to pollute the surrounding environments, stabilized area if it is not protected from runoff which may leach into surrounding area and have the possibility of polluting the vegetation growth. Mechanical stabilization is the process of improving the properties of the soil by changing its gradation. This process includes soil compaction and densification by application of mechanical energy using various sorts of rollers, rammers, vibration techniques and sometimes blasting. Mechanical stabilization using Cohesive non-swelling (CNS) soil is the most economical and expedient method of altering the existing material. It is an alternative method for the improvement of engineering properties like Maximum Dry Density (MDD), Shear strength parameters, California bearing ratio (CBR) value of locally available weak soil

2.1 LITERATURE REVIEW

General In this chapter, previous works carried on analysis on improvement of soft clay soils by partial replacement using cohesive non-swelling soil are discussed. Improvement of site with weak or high compressible or high swelling or any other such problematic soils and replacing them with more component ones such as compacted gravel, crushed rock or light weight aggregates to increase the load bearing capacity. Although this is considered a good solution, usually has the drawback of high cost due to the cost of the replacement materials. In India, expansive soils are found in region where the annual rainfall ranges from 300 to 900mm.

(A. Srirama Rao and M. Rama Rao, 2010) studied and suggested several innovative foundation techniques to overcome the problems associated with expansive soils. Belled pier and under reamed pile are some of the foundation practices adopted in these soils. Besides overburden in the form of a sand cushion or a cohesive non-swelling (CNS) soil cushion has also been tried for arresting heave. But, most of them suffer from one short coming or the other. In order to overcome the drawbacks of the existing foundation practices, fly ash cushion, stabilized with lime or cement, has been tried. The principle of this technique is same as that of a CNS cushion. This proved to be very effective in arresting heave. However, its efficiency over a few cycles of wetting and drying needs to be established since CNS cushion, which was found to be effective in arresting heave during the first cycle of wetting and drying was ineffective during the subsequent cycles. The present study relates to the behavior of expansive clays under lime- or cement stabilized fly ash cushion subjected to several wetting and drying cycles

(Jagadish Prasad Sahoo and Pradip Kumar Pradhan, 2010) An experimental investigation was undertaken to study the effects of lime stabilized soil cushion on the strength behavior of expansive soil. In this investigation, a series of laboratory tests (unconfined compressive strength (UCS) tests and California bearing ratio (CBR) tests) were conducted on both expansive soil and expansive soil cushioned with lime stabilized cohesive non-swelling soil. Both expansive soil and lime stabilized soil cushion were compacted to standard proctors optimum condition with thickness ration 2:1. Tests on cushioned expansive soil were conducted at different curing and soaking periods i.e., 7, 14, 28 and 56 days. The test results revealed that maximum increase in strength was achieved after 14 days of curing or soaking period with 8% of lime content.

(Dr. CH. Sudha Rani and G. Suresh, 2013) studied the plasticity and compaction characteristics of soil mixtures with and without addition of different percentages of cohesive non-swelling soil. This work emphasized on investigating of soil mixtures comprising of three expansive soils mixed with cohesive non-swelling soil. After conducting the tests the Liquid limit (LL), Plastic limit (PL) and Plasticity index (PI) values of all the soil mixtures decreased with the increase in percentage of cohesive non-swelling soil. There is decrease in Optimum moisture content (OMC) with increase in cohesive non-swelling soil. The Maximum dry density (MDD) of soil mixtures increased slightly with increase in percentage of CNS soil

(Kola Srinivas et. al. 2016) proved that cohesive non-swelling soil mixed with natural soil has met with considerable success as observed in both laboratory and field scale tests. Heave was reduced significantly and the surrounding soil was found improved. Swelling pressure, Liquid limit (LL), Plastic limit (PL), Shrinkage limit etc., are different at each site and there is no correlation of properties of each site. Swelling pressure increases with increase in dry density and decreases with increase in moulding water content. It was also observed that, cohesive nonswelling soil prevents ingress of water in the underlying expansive soil layer, contracts swelling and secondly even if the underlying expansive soil heaves, the movement will be more uniform and consequently more tolerable.

(P. Sanjay Chandra and G. Venkatarathnam, 2016) studied and determined the thickness of CNS soil layer for canal lining. IS code prescribed the specifications of cohesive non-swelling soil stating that these soils should possess the cohesive property over and above 0.10kg/cm2 depending upon cohesive non-swelling soil. A series of tests are conducted and results are observed. The swelling pressure of expansive soil samples are tested in soil mechanics lab. The swelling pressure of tested samples are in the range of 0.2kg/cm2 and 0.32kg/cm2. Hence a - 8 - minimum thickness of 10cm – 15cm cohesive non-swelling soil layer is to be provided for the canal lining.

(K.S. Subba Rao, 2018) made attempts to study cohesive non-swelling soil as cushion to black cotton soil. The purpose of cushion is to see that both swelling and swelling pressure of black cotton soil are effectively reduced and do not get wholly transmitted to the structure. From the results of laboratory tests conducted and the observations made it was concluded that the specifications of cohesive non-swelling (CNS) soil are not so rigorous. Some variations from the specifications do not make much difference in the cyclic swell-shrink behavior of BC-CNS system. For the CNS soil to be fully effective, its placement should be at its proctor maximum conditions. Advantage of CNS soil as cushion is felt mostly in the first cycle. CNS soil becomes less and less active and effective with cycles. After a few cycles, it loses its life as a cushion. After it reaches this stage, it needs to be completely removed and replaced with fresh cohesive non-swelling soil

3 RESEARCH MATERIALS

3.1 Black Cotton Soil

The Black cotton soil used in this project is collected from an agricultural field in Medchal, up to a depth of 1.5m from the ground level. The collected sample is then carried to Geo Technical Engineering Lab of CMRCET. The soil is then pulverized into small grains and kept in oven for 24 hours at 110 degrees centigrade. The basic experiments conducted for this dry black cotton soil are specific gravity, unconfined compressive test. Based on the test results of sieve analysis, liquid limit (LL), plastic limit (PL), the natural soil is classified as per IS classification. The results obtained are discussed in

3.2 Cohesive Non-Swelling Soil

The cohesive non-swelling soil used in this project is collected from a construction site in Malakpet up to a depth of 4-5m from the ground level. The collected sample is then carried to Geo Technical Engineering Lab of CMRCET. The soil is then crushed into small grains and kept in oven for 24 hours at 110 degrees centigrade. The experiments conducted are standard proctor compaction test and CBR test for different percentages (4%, 8%, 12%, 16%, 20%, 30%) of cohesive non-swelling soil blended with black cotton soil.

3.3 Methodology/Experimental Procedure

In this point-by-point strategy which is embraced for blending cohesive nonswelling soil with black cotton soil and procedure of directing analysis are displayed. Prior to that, experimental procedures for basic properties of black cotton soil such as Sieve analysis, Specific gravity and Atterberg limits are classified. Further, Methodology which is adopted for finding out engineering properties, for example, Max Dry Density (MDD), Optimum Moisture Content (OMC), Shear Strength parameters and CBR resistance values of both black cotton soil and cohesive non-swelling soil are exhibited.

Laboratory experiments such as standard proctor compaction test, unconfined compressive strength (UCS) test and CBR tests are performed for black cotton soil mixed with different percentages (4%, 8%, 12%, 16%, 20% and 30%) of cohesive non-swelling soil by weight.

Rundown of analysis led in the laboratory as per IS codes are in Table 3.1. The strategies and techniques for blending cohesive non-swelling soil with black cotton soil are discussed in the following sub areas

Table 3.1 Experiments performed in the study.

S.no	Black Cotton Soil	CNS Soil Blended With Black Cotton Soil
1	Specific Gravity Of Soil Solids (IS:2720-Part 3-1980)	Compaction Test
2	Particle Size Analysis (IS:2720-Part 4-1985)	California Bearing Ratio Test
3	Atterberg/Consistency Limits (IS:2720-Part 5-1985)	
4	Compaction Test (IS:2720-Part 7-1980)	
5	Unconfined Compressive Strength (IS:2720-Part 10-1991)	
6	California Bearing Ratio Test (IS:2720-Part 16-1987)	

3.4 Specific Gravity of Soil

In which, Specific Gravity of cotton soil is determined according to the method given by IS:2720-Part 3- 1980.Specific gravity is commonly characterized as the proportion of the mass of dry soil for a given volume to the mass of water at equivalent volume that of soil at 4 degree centigrade. Specific gravity of soil soils can likewise be Characterized as the proportion of unit weight of soil solids to the unit weight of water at equivalent volume that of soil.

Specific gravity is the vital and helpful factor which is required for computing the soil properties, for example, void ratio of a soil, unit weight /density and degree of saturation of agiven soil.Results of specific gravity test are exhibited in the chapter 4. Based on the testoutcomes, discussions and conclusions are made.

3.5 Dry Sieve Analysis

Dry sieve analysis is done for coarse granular soils whose soil grain sizes are larger than 0.075mm according to the test methodology given by IS:2720- Part 4 -1985. In which set of sieves are utilized to pass. The finer soil particles which being less in diameter that of sieve sizes. A series of sieves with different openings are arranged in ascending order of bigger size opening at top and smaller size opening at bottom. A collector like a pan with no openings is kept at the bottom of the arrangement of sieves to gather fine soil particles under 0.075mm in size and a lid is kept at the top of the sieves to held firmly by the machine associated on it.

Before that, the soil sample to be tested is dried in oven for around 24 hours at a temperature of 110 degree centigrade, at that point any bunches if present in soil mass arebroken. Then the soil sample is placed on top of sieve in set of sieves and passed through the arrangement of sieves by shaking which might be done by automatic sieve shaker or using hand worked. The shaking of sieves should be about 10-15 minutes is viewed as satisfactory. It is all around expected that bigger soil particles are gotten on the upper sieves, while the smaller size soil particles passed are gotten on one of the smaller sieves underlying on the larger sieves.

After the shaking process is finished, arrangement of sieves are to be taken out from the sieveshaker machine and each sieve is isolated from the get together.Weight of each sieve containing with soil particles is then determined utilizing electronic balance and values are noted. Empty weights of each sieve is required to be calculated so that weight of soil particles which are kept down by each sieve is obtained by subtracting the weights of sieves with soil particles minus the weight of corresponding empty sieves. From the information, percentage of finer soil particles in each sieve size is determined and the particle size distribution curve is plotted against particle diameter of the soil.

The dry sieve analysis test results are exhibit in chapter 4 and corresponding discussions and conclusions are made.

3.6 Liquid and Plastic Limit of Black Cotton Soil

Liquid limit and plastic limit of black cotton soil are determined according to the strategy given by the IS: 2720-part 5-1985. Liquid limit (LL) can be defined as the water content at which the soil changes from liquid state to plastic state.

3.7 Compaction Test

The method which is adopted for standard proctor test is as per the procedure given by IS:

2720-Part 7-1980. From compaction test water content – dry density relationship is obtained.

At first, the standard proctor test is conducted for black cotton soil. The soil used for compactiontest should pass through 20mm sieve.

Then the soil is mixed by adding sufficient amount of water i.e., 4% by the weight of soil. Compact the soil in three equal layers by a rammer. Each layer is given 25 blows. Furtherproctor test is performed as per IS code given.

Later, a series of standard proctor tests are conducted for the cohesive non-swelling soil blended with black cotton soil using different percentages (4%, 8%, 12%, 16%,20% and 30%) of CNS soil by weight.

3.8 Unconfined Compressive Strength Test

The methodology which is adopted for unconfined compressive strength test is as per IS 2720 Part 10 – 1991. The confined compressive strength is the load per unit area at which the cylinder specimen of a cohesive non-swelling soil falls in compression

Fig 3.1 Unconfined Compressive Strength Test Apparatus

The undrained shear strength of soil is equal to the one half of the unconfined compressive strength.

3.9 California Bearing Ratio Test

In this section, a methodology which is adopted for California bearing ratio test on black cottonsoil is presented. First, unsoaked California bearing ratio test is performed on black cotton soil and later, a series of unsoaked CBR tests are performed on black cotton soil blended with varying percentages (4%, 8%, 12%, 16% and 20%) of cohesive non-swelling soil as per the IS2720 Part 16 – 1987 procedure for light compaction.

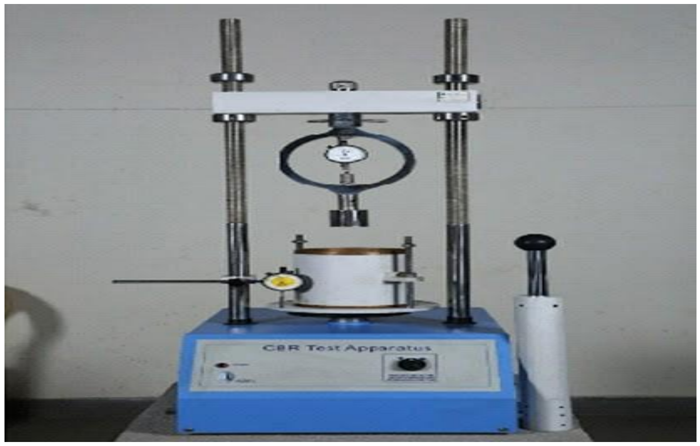

Fig 3.2 California Bearing Ratio Test Apparatus

At first, black cotton soil is blended with CNS soil to 5kg by weight, and then mix the soil sample with suitable water thoroughly until homogenous mixture is obtained. The mouldcontaining the test specimen placed on the lower plate of the testing machine with the base plate in position and the top surface is exposed. The plunger kept under a load of about 4kg so that fullcontact is ensured between the surface of specimen and plunger.

4.RESULTS AND DISCUSSIONS

Methodologies which are adopted for Compaction test, Unconfined Compressive Test and California Bearing Ratio (CBR) Tests have been discussed in chapter 3. Test procedures for Specific Gravity of soil solids, Dry Sieve Analysis, Liquid Limit and Plastic Limit are discussed in chapter 3. In this section, detail test results for both black cotton soil and cohesive non-swelling soils are presented. First, results for specific gravity and basic properties or index properties (Sieve Analysis, LL and PL) of black cotton soil are presented. Based on the index properties results, soil classification of black cotton soil has been done as per IS soil classification system. Detailed results and discussions for each mentioned tests are presented. Results for black cotton soil mixed with different percentages (4%,8%,12%,16%, 20% and 30%) of cohesive non-swelling soil are presented. Based on the each test results corresponding discussions and recommendations are presented.

Further, for each all tests with different percentages of cohesive non-swelling soil corresponding tables and graphs are presented. Based on the nature of graphs, discussions are made .Percentage of increase in properties of cohesive non-swelling soil blended with black cotton soil are presented and the comparison between them are shown.

4.1 Results for Black Cotton Soil

In this section, the test results and corresponding is cussion for black cotton soil are presented. The following sub- sections present the results for Specific Gravity, Sieve Analysis, Liquid Limit (LL), Plastic Limit (PL), Compaction Test, Unconfined Compressive Strength and California Bearing Ratio (CBR) test.

4.2 Specific Gravity of Soil:

The test procedure and related theory regarding specific gravity of soil solids have been discussed in the previous chapter. In this section, the test results of specific gravity of soil solids by pycnometer method is presented .From the pycnometer method, the specific gravity of soil solids is found to be Gs=2.50.

4.3 Dry Sieve Analysis:

Test procedure for dry sieve analysis are described in previous chapter. In this section, testresults and classification of the soil are presented.

Table4.1 Results for Grain Size Analysis of natural soil.

S.NO.	Particle diameter (mm)	Percentage finer(%)
1.	4.75	100
2.	2.36	98.8
3.	1.18	96.2
4.	1.6	92.35
5.	0.425	87.94
6.	0.3	81.024
7.	0.15	73.20
8.	0.75	63.63

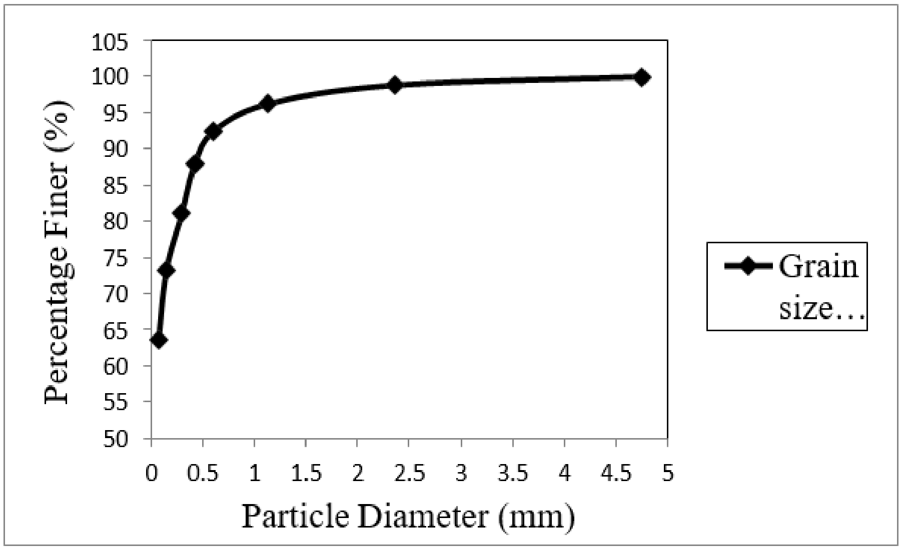

Fig 4.1 Grain Size Distribution Curve

From the above graph it is observed that more than 50% of soil is passing through0.075mm sieve, hence the given soil is classified as fine grained soil.It is also observed from the graph that D10, D30, and D60values cannot be determined as more than 50% of soil is passing through 0.075mm IS sieve. Therefore, coefficient of curvature (Cc) and coefficient of uniformity (Cu) cannot be determined.Further to classify the soil, it is compulsory to conduct liquid limit (LL) & plastic limit (PL) tests and the results represented in the following section.

4.4 Liquid Limit and Plastic Limit Tests:

In thissection, test results of Liquid limit test and Plastic limit test are presented. Based on the LL &PL, the soil classified as per IS classification system as discussed below.

From the flow curve shown in the above graph, liquid limit of the soil is determinedas the water content corresponding to 25 of blows sand it is given as LL□w_L□=61.70%.

Plastic limit (PL) of soil = 29.68% and the plasticity index value for the obtained liquid limit and plastic limit is 32.02%.

Fine grained soils are classified as per IS Classification system and the correspondingPlasticity chart.

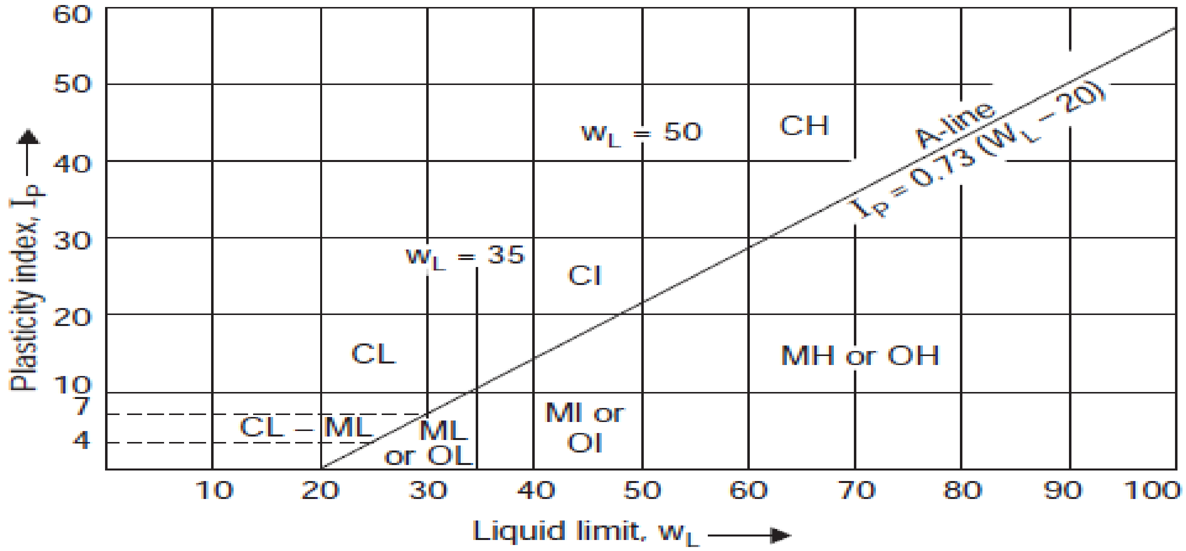

Fig4.2. Plasticity Index Chart

Plasticity index obtained from A-line = 30.44%. Since obtained LL is 61.70% and as per plasticity index it lies in the high region of plasticity. As the plasticity in the x value lies above the A-line the natural soil is classified as Clay with High Compressibility (CH).

4.5 Compaction Test:

Test procedure for conducting standard proctor test has been discussed in the previous chapter.In this section, standard proctor test results are presented for black cotton soil and corresponding discussions have been made.

Table4.2 shows the standard proctor test results of natural soil in which dry densities andwater contents are presented

Table 4.2.Compaction Test Results.

S.NO.	Water Content (%)	Max Dry Density(g/cc)
1.	10.03	1.29
2.	13.6	1.36
3.	17.93	1.38
4.	19.11	1.39
5.	22.74	1.4
6.	23.65	1.38

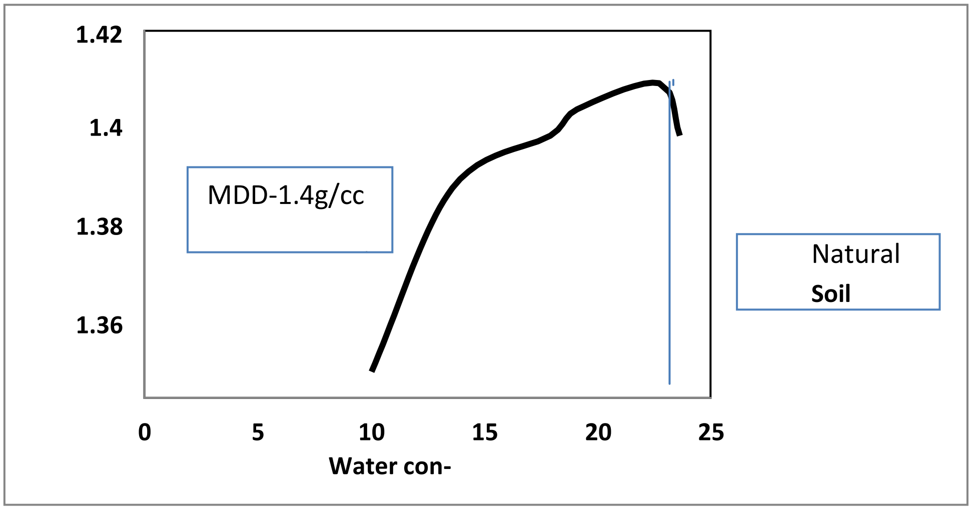

Fig 4.3 Compaction Curve for Natural Soil

From the above graph it is noted that the Maximum Dry Density (MDD) and Optimum MoistureContent (OMC) of black cotton soil are 1.4g/cc and 22.74% respectively.

4.6 California bearing ratio (CBR) Test for Black Cotton Soil:

The test procedure for California Bearing Ratio (CBR) test is discussed in previous chapter. In this section, Un-soaked CBR test results are presented for black cotton soil. From CBR test, the resisted load on black cotton soil specimen is calculated for 2.5mm and 5mm depth of penetration. Based on the standard loads corresponding to 2.5mm and 5mm depth of penetration, CBR values are determined and greater CBR value of 2.5 mm and 5mm is adopted for design.

Table4.3.California Bearing Ratio Test Results for Natural Soil

S.NO.	Penetration Depth(mm)	Resisted load on Soil P_t(kg)	Standard load P_s(kg)	CBR (%)
1	2.5	26.35	1370	1.92
2	5	34.1	2055	1.65

From the Table it is observed that CBR valueismorefor2.5mm and it is adopted for designing.\

4.7 Unconfined Compressive Strength (UCS):

The test procedure for Unconfined Compressive Strength (UCS) test is discussed in previouschapter. In this section, UCS test results represented for black cotton soil.

Table4.4 Unconfined Compressive Strength test results for Natural Soil.

S.NO.	Stress	Strain
1.	0.006	0.037
2.	0.012	0.053
3.	0.024	0.068
4.	0.03	0.084
5.	0.036	0.096
6.	0.039	0.104
7.	0.042	0.114
8.	0.042	0.11

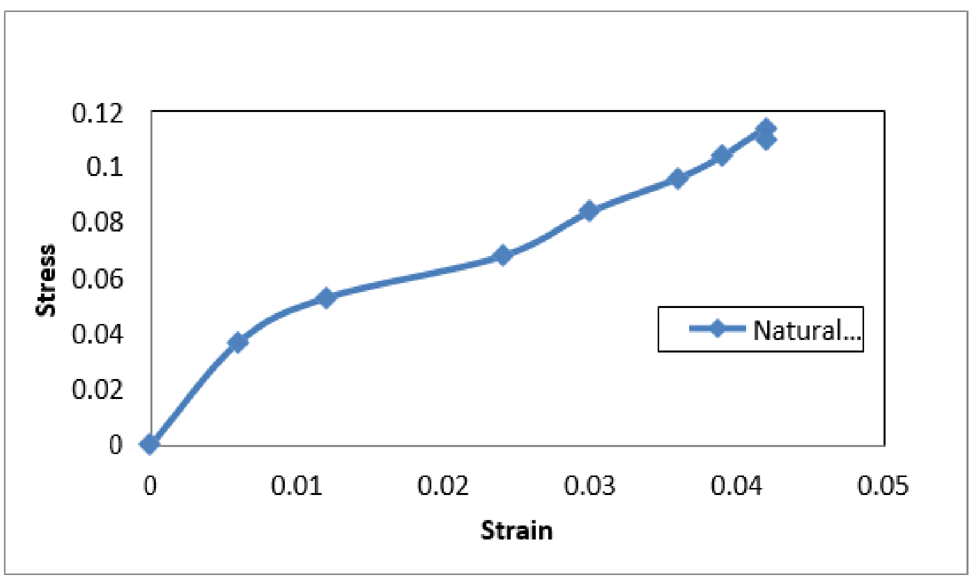

Fig 4.4 Stress Strain Curve for Natural Soil.

From the graph we observe that the unconfined compressive strength of black cotton soil is 0.114 kg/cm^2.

4.8. Summary of Results for Black Cotton Soil:

So far, Test results for natural soil are presented in above sections with detailed discussionson results. In this section, all test results are grouped and presented.

Table4.5 Index and Engineering properties of Natural Soil.

S.NO	Property of Black Cotton Soil		Value
1	Specific Gravity(G_S)		2.5
2	Particle Size Distribution	Gravel(%)	
		Fine Sand (%)	
		Silt(%)	
		Clay(%)	
3	Consistency Limits	LL(%)	61.70
		PL(%)	29.68
		PI(%)	32.02
4	Compaction Properties	MDD(g/cc)	1.4
		OMC(%)	22.74
5	Un-Soaked CBR Test	CBR(%)	1.92
6	Unconfined Compressive Strength(kg/cm^2)		0.114

4.9 Results for Cohesive Non-Swelling Soil Blended with Black CottonSoil:

In the previous section, test results and discussions are presented for black cotton soil. In this section, results of compaction test and California bearing ratio (CBR) test arepresented for cohesive non-swelling soil blended with black cotton soil. Black cotton soilis mixed with different percentages (4%, 8%, 12%, 16%, 20% and 30%) of cohesive non-swelling soil and the changes in engineering properties are observed. After that, comparisons are present educing graphs for different percentages of cohesive non- swelling blended with black cotton soil with respect to engineering properties of black cotton soil.

4.9.1 Compaction Test:

The standard proctor test procedure for cohesive non-swelling soil blended with black cotton soil is discussed in the methodology part chapter 3. In this section, the standard proctor test results of CNS soil are presented. Series of standard proctor tests are conducted and results are presented for natural soil mixed with varying percentage of CNS soil (4%, 8%, 12%, 16%, 20%and 30%).

The Standard Proctor Test is conducted for black cotton soil and the results are discussed in the previous section. The compaction properties of natural soil obtained from standard proctor test are MDD= 1.4g/cc sand OMC= 22.74%. These results are used to evaluate the percentage of increment or decrement in compaction properties for standard proctor test results of CNS soil.

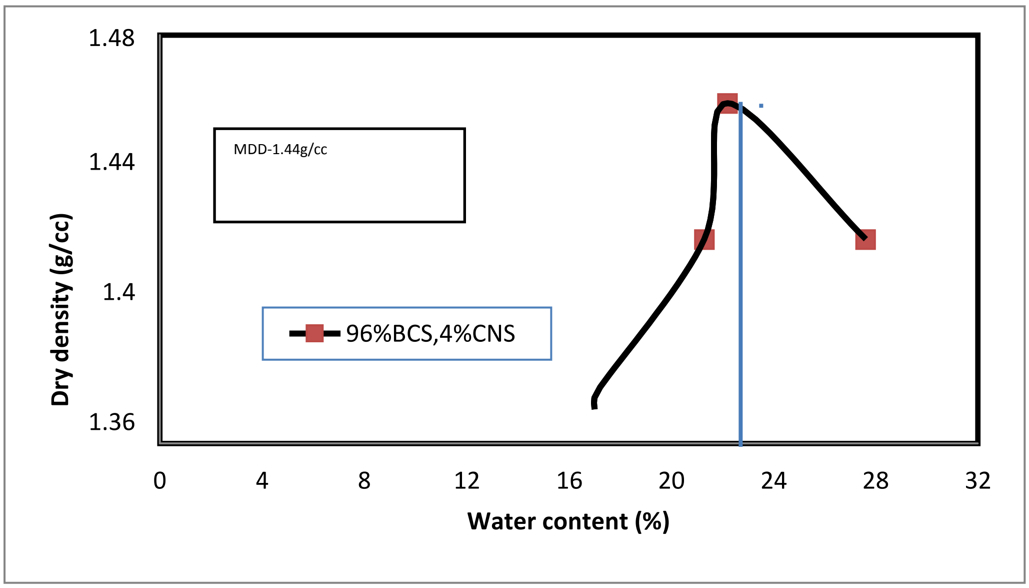

Fig 4.5 Compaction Curve for 96% BCS and 4% CNS Soil.

Its observed that percentage in increment of Maximum Dry Density (MDD) for 4% cohesivesoil blended with black cotton soil is 2.85% as the value of MDD for black cotton soil is found to be 1.40g/cc and is increased to 1.44g/cc at 4% cohesive soil blended with black

cotton soil. It is also observed that Optimum Moisture Content (OMC) for 4% cohesive non-swelling soil blended with black cotton soil is decreased from 22.72% to 22.21%.

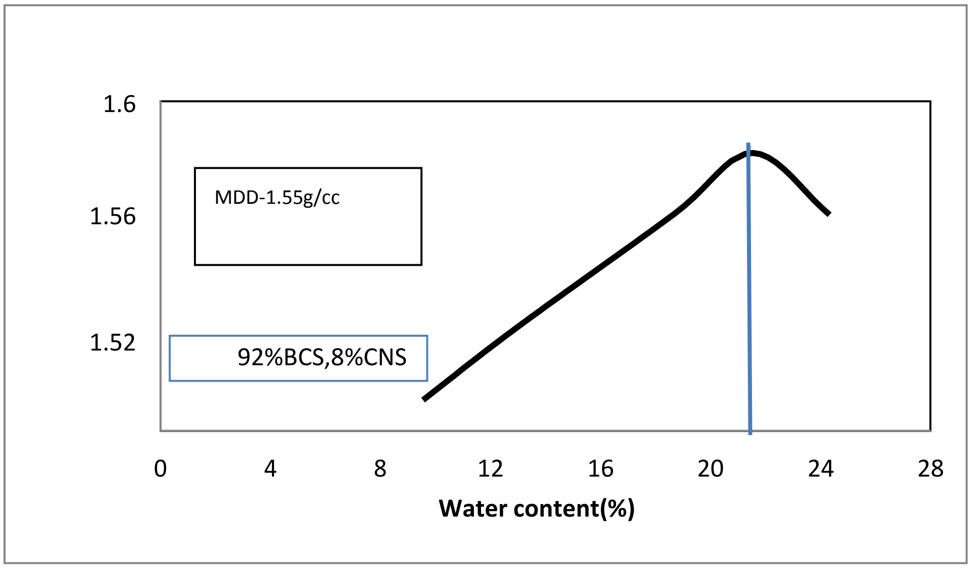

Fig4.6 Compaction Curve for 92% BC Sand 8% CNS Soil.

From the above fig. it is observed that percentage of Maximum Dry Density (MDD) for 8% cohesive soil blended with black cotton soil is 7.86 % as the value of MDD for 4% CNS soil blended with blackcotton-soilisfoundtobe1.44g/ccandisincreasedto1.55g/ccat8%CNS soil. It is also observed that Optimum Moisture content (OMC) for 8% cohesive non-swelling soil blended with black cotton soil is decreased from 22.21%to 21.54%.

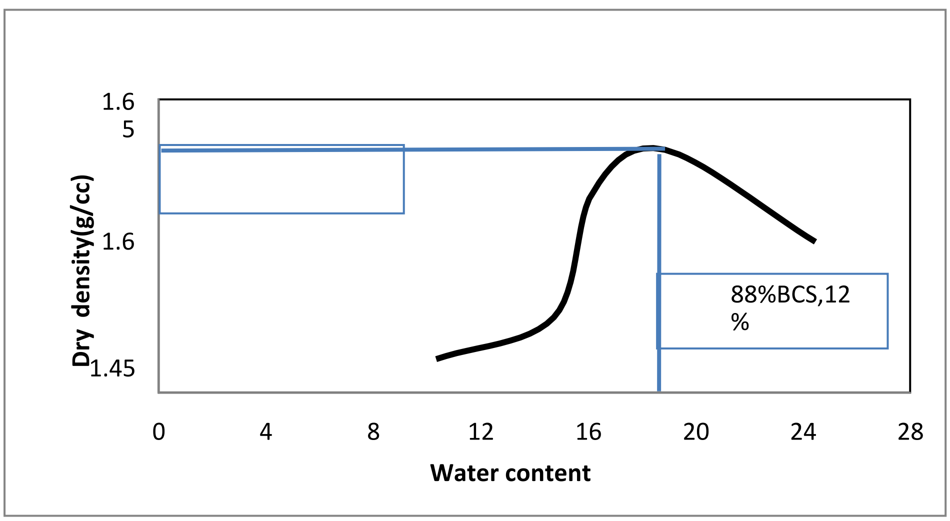

Fig4.7 Compaction Curve for 88% BC Sand 12%CNS Soil.

From the above fig. it is observed that percentage in increment of Maximum Dry Density (MDD) for 12% cohesive non-swelling soil blended with black cotton soil is 2.79% as the value of MDD for 8% CNS soil blended with black cotton soil is found to be

1.55g/cc and isincreased to 1.59g/cc at 12%. It is also observed that OMC for 12% cohesive non-swelling soil blended with black cotton soil is decreased from 21.54% to 18.87%.

From the above fig. it is observed that percentage in increment of Maximum Dry Density (MDD)for 16% cohesive non-swelling soil blended with black cotton soil is 1.5% as the value of MDD for 12% CNS soil blended with black cotton soil is found to be 1.59g/cc and is increased to 1.6g/cc at 16%. It is also observed that OMC for 16% cohesive non-swelling soil blended with black cotton soils decreased from 18.87% to 18.23%.

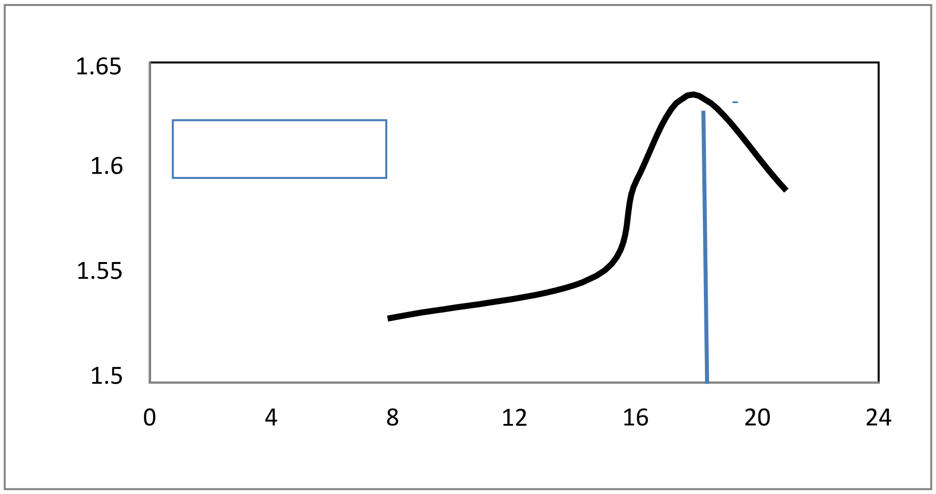

Fig 4.8 Compaction Curve for 80% BC Soil and 20% CNS Soil.

From the above fig. it is observed that percentage in increment of MDD for 20% cohesive non-swelling soil blended with black cotton soil is 0.71% as the value of MDD for 16%CNS soil blended with black cotton soil is found to be 1.6g/cc and is increased to 1.62g/cc at20%. It is also observed that OMC for 20% CNS soil blended with black cotton soil is decreased from18.23% to 17.9%.

It is observed that percentage in increment of MDD for 30% cohesive non-swelling soil blended with black cotton soil is 3.49% as the value of MDD for 20% CNS soil blended with black cotton soil is found to be 1.62g/cc and is increased to 1.67g/cc at 30%. It is also observed that OMC for 30% CNS soil blended with black cotton soil is decreased from 17.9%to17.7%.

From the above variation curves, it is observed that the Maximum Dry Density (MDD) is gradually increased with increase in percentage of cohesive non-swelling soil and the Optimum Moisture Content (OMC) is decreased gradually with increase in percentage of cohesive non-swelling soil.

Table4.6. Compaction Test Results for Cohesive Non-Swelling Soil.

S.NO.	Percentage of Black Cotton Soil (%)	Percentage of Cohesive Non-Swelling Soil (%)	Maximum Dry Density (MDD)(g/cc)	Optimum Moisture Content (OMC) (%)
1.	100	0	1.4	22.74
2.	96	4	1.44	22.21
3.	92	8	1.55	21.54
4.	88	12	1.589	18.87
5.	84	16	1.61	18.23
6.	80	20	1.62	17.9
7.	70	30	1.67	17.7

From the table it is concluded that there is a gradual increment in the values of Maximum Dry Density (MDD) with the increase in percentage of cohesive non-swelling soil blended with black cotton soil and the Optimum Moisture content (OMC) decreases with theincrease in percentage of cohesive non-swelling soil.

4.9.2 California Bearing Ratio (CBR) Test:

The California Bearing Ratio (CBR) test procedure for cohesive non-swelling soil blended with black cotton soil is discussed in the methodology part of chapter3. In this section CBR test results of CNS soil blended with black cotton soil are presented. Series of CBR tests are performed and results are presented for black cotton soil with varying percentages (4%, 8%,12%,16%and 20%) of cohesive non-swelling soil.

The CBR test is conducted for black cotton soil and the results are discussed in the previous section. The CBR values of black cotton soil obtained from CBR test at 2.5mm and 5mm depth of penetration are 1.92% and 1.65% respectively. The higher value of those CBR values is generally adopted for design purpose, so the CBR value for black cotton soil is found to be 1.92%. This CBR value to evaluate the percentage of increment or decrement in CBR values

for CBR test results of cohesive non-swelling soil blended with black cottonsoil and evaluated percentage increments and decrement in CBR values are presented.
From the table, it is observed that percentage in increment of CBR value for 4% cohesive non-swelling soil blended with black cotton soil is 3.12% as the value of CBR for black cotton soil is found to 1.92% and is increased to 1.98% at 4% of cohesive non-swelling soil blended with black cotton soil.
From the above graph it is observed that percentage in increment of CBR value for 8% cohesive non-swelling soil blended with black cotton soil is 5.72% as the value of CBR for 4% cohesive non-swelling soil blended with black cotton soil is found to be 1.98% and is increased to 2.03% at 8% cohesive non-swelling soil blended with black cotton soil.

From the above graph, it is observed that percentage in increment of CBR value for 12%cohesive non-swelling soil blended with black cotton soil is 14.58% as the value of CBR for 8% cohesive non swelling soil blended with black cotton soil is found to be 2.03% and is increasedto 2.2% at 12% cohesive non-swelling soil blended with black cotton soil.

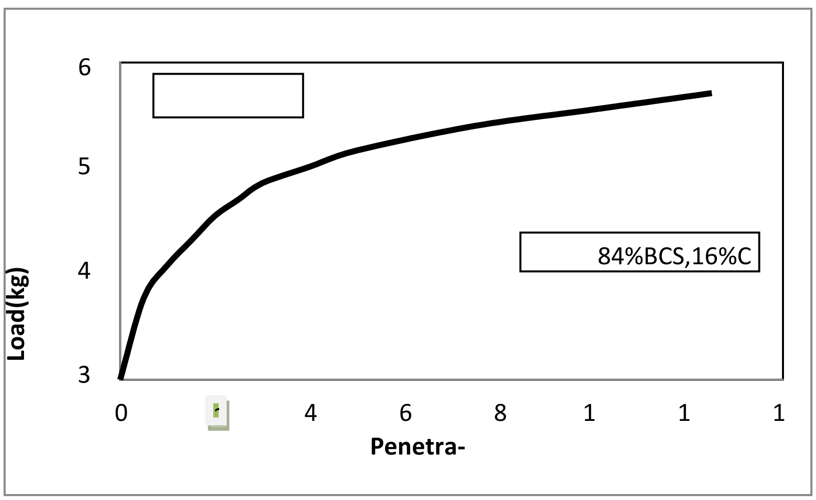

Fig.4.9 CBR Curve for 84% BC Sand 16% CNS Soil.

From the above graph, it is observed that percentage in increment of CBR value for 16% cohesive non-swelling soil blended with black cotton soil is 29.61% as the value of CBR for 12 % cohesive non swelling soil blended with black cotton soil is 2.2% and is increased to 2.48% for 16% cohesive non-swelling soil blended with black cotton soil. From the above graph, it is observed that percentage in increment of CBR for 20% cohesive non-swelling soil blended with black cotton soil is 35.41% as the value of CBR for 16% cohesive non-swelling soil blended with black cotton soil is found to be 2.48% and is increased to 2.6% at 20% cohesive non-swelling soil blended with black cotton soil.

Table 4.7 California Bearing Ratio test results for Cohesive Non-Swelling Soil

S.NO.	Percentage of Black Cotton Soil (%)	Percentage of Cohesive Non-Swelling Soil (%)	CBR Test (%)	Increase inPercentageof CBR values (%)
1	100	-	1.92	-
2	96	4	1.98	3.12
3	92	8	2.03	5.72
4	88	12	2.2	14.58
5	84	16	2.48	29.16
6	80	20	2.6	35.41

From the above table it is concluded that there is a gradual increment in the values of California Bearing Ratio (CBR) with the increase in percentage of cohesive non-swelling soil blended with black cotton soil. The CBR value will indirectly reduce the cost of pavement construction by reducing the thickness of sub-grade of pavement. Fig. shows the pavement thickness values against the CBR values for different traffic conditions.

Table 4.8. Application of CBR Values in the Field.

S.NO.	Percentageof Black Cotton Soil(%)	Percentage of CNS soil (%)	CBR values (%)	Percentage increase	Light Traffic (mm)	Medium Traffic (mm)	Heavy Traffic (mm)
1	100	0	1.92	-	-	-	-
2	96	4	1.98	3.12	-	-	-
3	92	8	2.03	5.72	540	600	690
4	88	12	2.2	14.58	530	590	680
5	84	16	2.48	29.16	500	560	650
6	80	20	2.6	35.41	480	540	630

From the above fig it can be observed that for 2.6% CBR value the corresponding pavement thickness is found to be 630mm for heavy traffic conditions, pavement thickness corresponding CBR value 2.03% of 8% cohesive non-swelling soil blended with black cotton soil is found to be 690mm. Black cotton soil and 4% cohesive non-swelling soil blended with black cotton soil are non tutilized in the construction of pavement as the CBR value is less than 2%. So, it may be concluded that for 20% cohesive non-swelling soil blended with black cotton soil, pavement thickness reduced to about 60 mm and thus cost of pavement can be minimized by reducing its thickness.

CONCLUSIONS

From the results and discussions of standard proctor test on cohesive non-swelling soil blended with black cotton soil, the Maximum Dry Density (MDD) is increasing on by increasing the percentage of CNS soil and it is also observed that Optimum Moisture Content (OMC) is decreased by increasing the percentage of cohesive non-swelling soil. The load bearing capacity of the soil is increased with the decrease in the optimum moisture content (OMC).

The Unconfined Compressive Strength of the Black Cotton Soil is 0.114kg/cm2. From theresults of California Bearing Ratio (CBR) Test, addition of cohesive non-swelling soil in percentages, CBR values increased from 1.92% (Black Cotton soil) to 1.98% (4% CNS soil), 2.03% (8% CNS soil), 2.2% (12% CNS soil), 2.48% (16% CNS soil) and 2.6% (20% CNS soil).Also, it is observed that increasing the percentage of cohesive non-swelling soil results in increase in the CBR values. It means that the thickness of pavement can be laid according to the values given in chapter 4.

It is concluded that by increasing the percentage of CNS soil there is increase in the Bearing Capacity and Maximum Dry Density (MDD). By increasing the percentage of CNS soil there is a considerable decrease in the Optimum Moisture Content (OMC). This can be used for the stabilization of pavement sub-grade, foundations and other fields of civil engineering as per needs. Thus, expensive methods for stabilization process can be replaced by the Cohesive Non- swelling Soil which will make construction economical and more ecofriendly safe structure.

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