INFLUENCE OF FLYASH ON THE STRENGTH AND SWELLING CHARACTERISTICS OF BENTONITE

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF

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SUBMITTED BY:
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CERTIFICATE

This is to certify that the thesis entitled, "**INFLUENCE OF FLYASH ON THE STRENGTH AND SWELLING CHARACTERISTICS OF BENTONITE**" submitted by **NEERAJ SONI** (107CE019) in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Civil Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any Degree.

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ABSTRACT

Swelling soil like Bentonite causes many problems more for lightly loaded structures than moderately loaded structures. Through consolidation under load and changing volumetrically along with seasonal moisture variation, these problems are proved through swelling, shrinkage and unequal settlement. It leads to damage of foundations, structural elements and architectural aspects which defeats the purpose for which the structures are erected. So to avoid these types of failures research is done and some methods have been proposed. Pre-stabilization is very effective method in tackling expansive soil. Therefore a many laboratory experiments are conducted to ascertain host of soil engineering properties of a naturally available expansive soil before and after stabilization. Pre stabilized and post stabilized results are compared to arrive at conclusion that can thwart expansive soil problems. Such structures are requiring renovation of foundation by under pinning. New structural shall need special techniques for control of swelling and shrinkage.

Index properties of expansive soil like Atterberg limits and shrinkage limit with and without fly-ash have been compared. Grain size distribution has also been determined by experiments. The swelling potential of this soil has been determined for various percentage of fly-ash. Maximum dry density (MDD) and optimum moisture contents (OPC) have been found out by the proctor compaction test and the graphs are drawn. The strength of swelling soil is determined for soil specimens with different fly-ash concentrations through Unconfined Compression Test and the results are compared through the graphs.

The above results of experiments are compared among them to obtain a percentage concentration of fly-ash with swelling soil which gives best results for lower value of swelling potential and higher strength.

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CHAPTER- I

INTRODUCTION

INTRODUCTION

For a long time, we are facing problems like failures of small and big structures. The biggest problem behind this is swelling soil. This is very unstable soil. Its property varies from hard to soft and dry to wet. It exhibits swelling and shrinkage with different water content. As a result the many structures usually face excessive settlement and differential movements, which results in damage to foundation systems and structural elements. We are aware about this situation for a long time, but unable to make improvements due to absence of technologies till now. So now our main aim is to improve the properties of swelling soil like Bentonite. The purpose was to check the scope of improving bearing capacity value and reduce expansiveness by adding additives like fly ash, lime fly ash, ordinary Portland cement etc.

Expansive soils are found in many part of the world like Burma, south Africa, Western USA, Cuba, Spain, Russia and Indonesia etc.. In India it found in Madhya Pradesh, Maharashtra, Gujarat and Orissa.

In many countries, coal is the primary fuel in thermal power plant and other industry. The fine residue collected from field is known as fly ash and considered as a waste material. The fly ash is tossed out of either in the dry form or mixed with water and discharged in slurry into locations known as ash ponds. Production of flyash worldwide is huge and increasing day by day. Four countries, namely, China, India, United State and Poland are producing more than 270 million tons of fly ash every year. It is causing hazards to our environment. Therefore it is used as admixture for expansive soil like Bentonite, to stabilize it which is easy, ideal and cheap technique.

India at present produces around 120 Million Ton of Ash per annum. The requirement of power in the country is rapidly increasing with increase in growth of the industrialization. India depends on Thermal power as its main source (around 80% of power produced is thermal power), as a result the Ash quantity produced shall also increase. Indian coal on an average has 35 % Ash and this is one of the prime factors which shall lead to increase in ash production and hence, Ash utilization becomes major problem for the country.

Today we are studying the stabilization effect of fly ash on Bentonite. The following tests were conducted for this investigation:

1. Specific gravity test for Bentonite and fly ash
2. Atterberg limits (liquid limit and plastic limit) of Bentonite and flyash Bentonite mix(at all %)
3. Free swelling index test for bentonite and flyash bentonite mix.
4. Proctor compaction test for determining maximum dry density and optimum moisture content of
    a) Fly ash only
    b) Bentonite only
    c) Fly ash bentonite mix (for all % of flyash at 10% interval)
5. Unconfined compression test for remoulded and re-moulded fly ash bentonite mix from 0 to 100%(at 10% interval)

On the basis of above mentioned tests results, graphs were plotted.

CHAPTER-II

LITERATURE REVIEW

REVIEW OF LITRATURE

2.1 Origin and occurrence of expansive soils

Clay mineral is the key element which passes on swelling characteristics to any ordinary non-swelling soil. Montomorillonite has the maximum swelling potential among several types of clay minerals. The origin of such soil is sub aqueous decomposition of blast rocks, or weathering in situ formation of important clay mineral takes place under alkaline environments. If there is sufficient supply of magnesium of ferric or ferrous oxides and alkaline environments along with sufficient silica and aluminum due to weathering condition, it will favor the formation of Montomorillonite. The depth is shallow at the place of formation for Bentonite with the parent rock underneath. The alluvium deposits can be much deeper in low lying areas, where these soils are transported and deposited.

2.2 Clay mineralogy

Generally clay-minerals are divided into three groups on the basis of their

Crystalline arrangements like:

- Kaolinite group
- Montomorillonite group
- Illite group

2.2.1. Kaolinite mineral

Kaolinite [$Al_2Si_2O_5(OH)_4$] is a clay mineral. It is a layered silicate mineral having one tetrahedral sheet linked by oxygen atom to one octahedral sheet of alumina octahedral. Rocks which are rich in Kaolinite are known to be china clay. The stacked layers of Kaolinite have thickness of 7Å. Thus kaolin group of minerals are most stable and water can’t enter between the sheets and expands the unit cells.

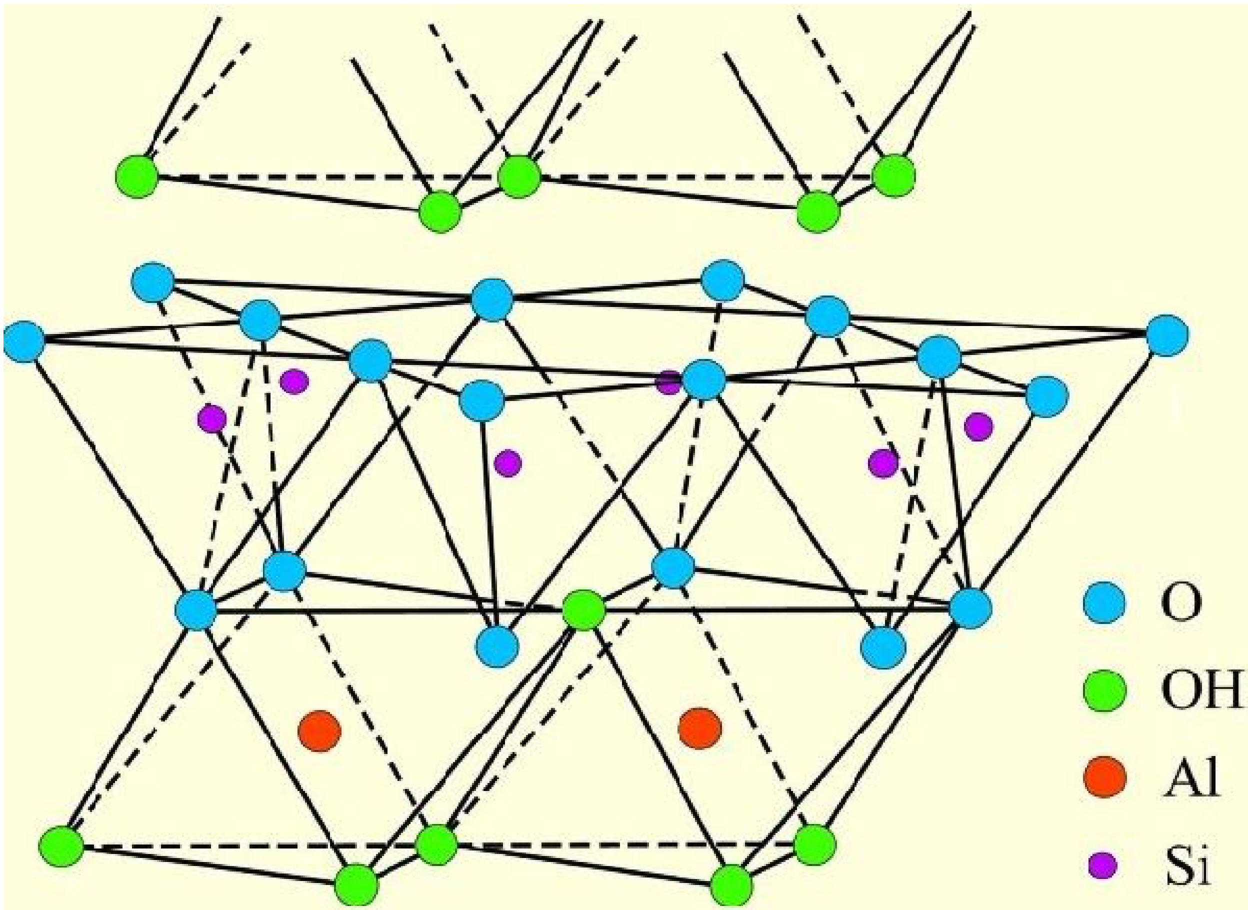

Fig1: Structure of kaolinite layer

2.2.2. Montomorillonite minerals

This Crystals form weaker bond between them. Soils containing higher percentage of Montomorillonite mineral exhibits high swelling and shrinkage characteristics; Structural arrangement of Montomorillonite mineral is composed of units which are made of two silica tetrahedral sheets to the central aluminum octahedral sheet. The silica and gibbsite sheets are added in such a way that the tips of the tetrahedrons of each silica sheet and one of hydroxyl layers of octahedral sheet forms a common layer. The atoms which are common to both gibbsite and silica layers never participate for swelling. Water enters between the sheets causing them to expand significantly and these structures can breaks into 10Å thick structural units. Thus soil with Montomorillonite minerals exhibits high shrinkage and swelling characteristics depending upon the nature of exchangeable cation presence.

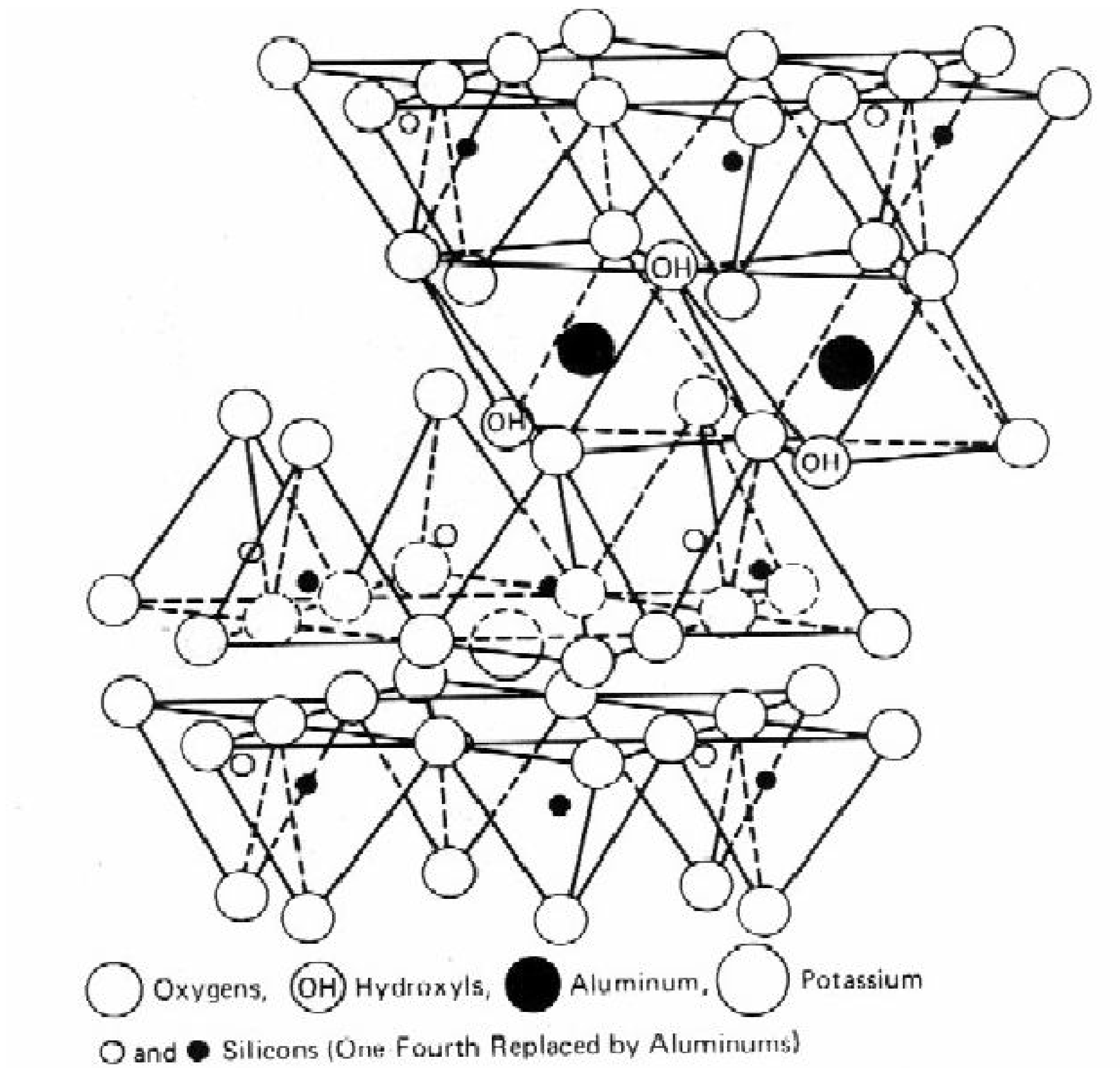

Fig-2: Structure of Montomorillonite layer

2.2.3. Illite group

Illite is a 2:1 clay mineral. The spacing between the element silica and gibbsite silica sheets depends upon the amount of water availability to occupy the space. For this reason Illite is said to have expanding lattice. Every thin platelet attracts other flat surface and a layer of absorbed water about 200Å thick which separates palates with a distance of 200 Å under zero pressure. When there is abundance of water is present, the mineral cause splitting into about individual unit layers of 10Åthick.

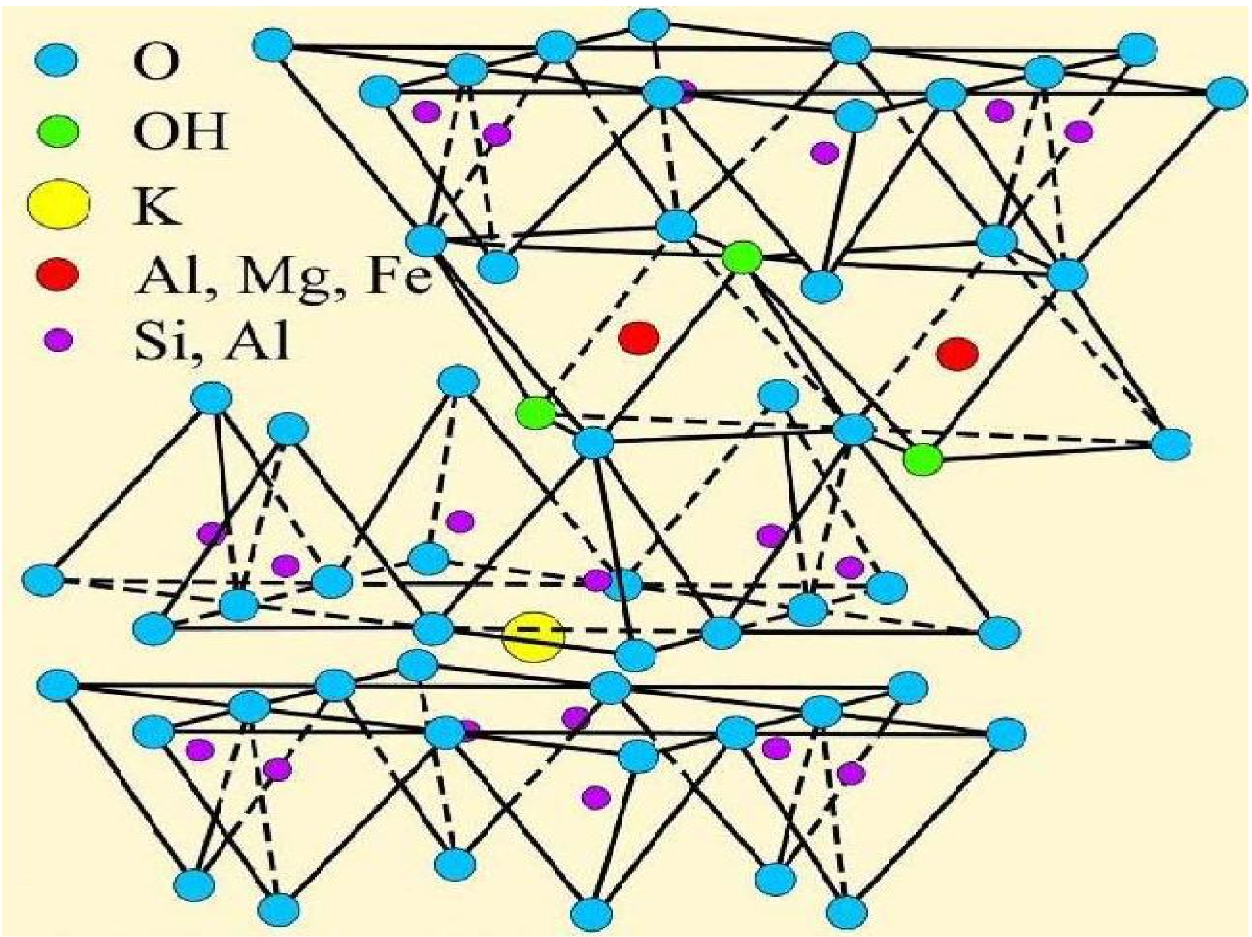

Fig-3: Structure of Illite/mica layer

2.3 Identification and classification of swelling soils

2.3.1 Tests conducted for identification

For identification of swelling soils, many laboratory tests are there. By presence of Montomorillonite in clay minerals, the expansiveness of the soil can be found out. But the tests are technical. Free swell test is the simple way to find expansiveness of soil in laboratory. This test performed by slowly filling 10CC of dry soil, passing through 425 µ sieve, in two 100 CC of graduated jar among which one is filled with kerosene and other one with water. Swelling will takes place in the flask filled with water, hence noting down the swelled volume of the soil after which it comes to rest (after 24 hours). The free swell index values are calculated in percentage. The code for free swell index test is IS:2720-II.

Free swell value [I_n] (in %age) = [(final volume-initial volume)/ initial volume] x 100

Holtez Gibbs reported that high swelling Bentonite having a free swell values from 1200% to 2000% are of good grade and the soils having free swell values as low as 100% may exhibits considerable volume change, when go under light loading, and caution should be made. Soils having free swell values below 50% exhibits significant volume changes, even for very light loadings. But these limits are also considerably gets influenced by the surrounding climatic conditions. The free swell test should be combined with other engineering properties of the soil. A liquid limit and plasticity index together indicates the swelling characteristic of the soil for large clay content. Shrinkage limit can be used for estimating the swelling potential of a

Bentonite. A low shrinkage limit value shows that a soil could have appreciable volume change at low moisture content. In general the swelling potential of a soil can be related to plasticity index. Various degrees of swelling capacities of soil and the corresponding range of plasticity index are shown below through table.

Table-1: Swelling potential Vs plasticity index

Swelling potential	**Plasticity index**
Low	0-15
Medium	10-35
High	35-55
Very high	55 and above

Soil having high swelling potential actually exhibits swelling characters are depending on several other factors. Difference between field soil moisture content at the time of the construction and the equilibrium moisture content that is finally achieved under the conditions with the complicated structure is of greatest importance. If the latter is considerable and higher than field moisture content, then the soil is having high swelling capacity and vigorous swelling may occur by upward heaving of soil by the development of large swelling pressure.

2.3.2 Methods of recognizing expansive soils

There are three methods for identification of expansive soils

- Mineralogical identification
- Indirect method, such as index properties free swell, soil suction etc.
- Direct measurement

Methods for mineralogical identification are important for showing the basic properties of clays, but are uneconomical and impractical in practice. The other two methods are generally used, out of which the direct measurement is offering most useful data. Potentially expansive soils are usually recognized in the field by their shattered condition and obvious structural damage caused by such soils to existing buildings. The potential expansion or the degree of expansion is a convenient term used for classifying expansive soils. Through which soil engineers can tell how good or bad the potentially swelling soils are. The following tables give the various criteria proposed for classifying expansive soils.

Table-2: Potential expansion Vs shrinkage limit and linear shrinkage

Shrinkage limit (in %age)	Linear Shrinkage (in %age)	Potential expansion or Degree of expansion
>12	0-5	Non critical
10-12	5-8	marginal
<10	>8	Critical

Table-3: Classification system, as per (HOLTZ 1959)

Colloid content (in %age)	Plasticity index (in %age)	Shrinkage limit (in %age)	Probable expansion of total volume of clay (in %age)	Potential expansion or Degree of expansion
<5	<18	<15	<10	Low
13-23	15-28	10-16	10-20	Medium
20-31	25-41	7-12	20-30	High
>28	>35	>11	>30	Very high

Table-4: I.S. Classification system, as per (IS: 1498)

Liquid limit (in %age)	Plastic Limit (in %age)	Shrinkage limit (in %age)	Free swell Index (in %age)	Degree of expansion	Degree of severity
20-35	<12	<15	<50	Low	Non critical
35-50	12-23	12-30	50-100	Medium	Marginal
50-70	23-32	30-60	100-200	High	Critical
70-90	>32	>60	>200	Very high	Severe

Note: Potential expansion provided for a confined sample with vertical pressure equal to Over burden pressure in terms of percentage of sample weight.

During estimation of expansion in the design of foundation it becomes necessary to consider the following factors:

- Climate
- Natural moisture content or rather than degree of saturation.
- After construction of building, there is a possibility of alteration of surface drainage. If the moisture content of the soil is at shrinkage limit, maximum utter could occur on wetting, but if the soil is at its plastic limit the utter will be much less.

2.4 Causes of swelling

The Mechanism of swelling is still unclear. There are different theories, and no resemblance have found till now. One of the reasons universally accepted for swelling of soil is the presence of high percentage of clay, had the swelling characters.

2.5 Swell Pressures

Expansive soils when come in contact with water exerts pressure. This pressure exerted by the expansive soil is called swelling pressure. It is required to estimate the swell pressure and the likely heave for the design of a structure on such a soil like Bentonite, or taking a canal through this type of soil, or construction of road embankment.

2.6 Factors affecting swelling:

The most important influencing factor is the molding water content and initial moisture content in case of re-molded soil sample.

As per findings of Gibbs and Holts, “the remolded clays are behaving much as undisturbed clays”.

For a given dry density, the initial water content will determine the swell pressure and water thirst of a given soil sample. For the swelling to start, clay should have minimum initial moisture content (w_n) from which swelling begins under a pre-paved and sub-grade, given by:

$w_n(\%) = 0.2\, w_1 + g$……………………………………(1)

where, w_1 = liquid limit

As per SAVOCHAN (1970) soil surface rises during the swelling with time. Rate of this rise of soil surface is governed by fluctuation of temperature gradient in both bottom and top layers. Irrespective of higher swelling potential, this expansion activity is also confined to an upper restricted zone of the soil. If the moisture content of the clay remains unchanged there will be no further volume change. A slight change of moisture content is enough to cause detrimental swelling. A clay sample with low water content has very high swelling capacity and hence higher swelling pressure than the soil with higher water content. A soil element close to the surface, swell more with the more intake of water, but the same soil unable to swell if it is below the surface over an overburden load which neutralizes the swelling pressure of the dry soil. Factors which are responsible for swelling are as follows:

- Location of expansive soil sample from the sample form the surface
- Initial water content

- Volume change
- Unit weight of sample
- Stress history
- Shape size and thickness of sample
- Nature of pore fluids
- Temperature
- Time etc.

2.7 Problems associated with expansive clay

For all type of engineering construction over expansive soils are not suitable since they creates problems. But due to persistence of these types of soils in different parts of India, different irrigation projects are needed to be developed on these deposits. Moreover examples of similar problems have also been recognized in many other parts of the world. Structures found on these soils are subjected to differential deflections which causes distresses on swelling clays and produce hazardous damage to the buildings and superstructures .Reduction of moisture content cause shrinkage by the evaporation of vegetation whereas continuous increase in moisture content causes heave in expansive soil like Bentonite. The rise of water table has got a notable effect on the movement of foundation on expansive soils.

Whether a mass of clay has been compacted by nature or by artificial means, it is unlikely to expand as much vertically as horizontally. Experiments have shown that the compacted clay soils exhibits greater value of swelling in the horizontal direction than in vertical direction. So magnitude of difference in swelling soil being very low, the vertical swelling pressure is calculated to uplift forces on structure. Due to evaporation in dry season the surface gets reduced surrounding a building which was erected on clayey layer, but a very little evaporation under the structure. Thus there will be uneven settlement at plinth level causing danger to structures.

If a structure is built around dry season with foundation lying within the unstable zone, the foundation base experiences swelling pressure as the partially saturated soil starts intake of water during wet season. This swelling pressure has developed due to its constraint offered by their foundation for free swelling. If imposed pressure on the foundation is less than the swelling pressure by its structure, the structure is likely to get lifted up locally which will lead to cracks in the super structure and on the other hand if imposed bearing pressure is greater than the swelling pressure than structure will be safe. If a structure is built around wet season, it will be experiencing settlement as the dry seasons will comes whether the bearing pressure is low or high. The imposed bearing pressure should be within the allowable bearing pressure in the wet season for the soil. Therefore better practice for the structure is be constructed during dry season and should be finished before wet season.

2.8 Swelling time

When the compacted clay is exposed to water requirement of time is there for movement of water into the soil sample under the hydraulic gradient. The process is in many ways similar to the process of consolidation where movement of water in loaded clay is retarded by its low permeability. The amount of water taken in, by the swelling soil at various time periods is different, as corresponding to void ratio. Intake rate gradually decreases during next 100 minutes. Beyond 100 minutes, intake rate is very slow.

The initial high intake rate may be due to the high order of capillary potential gradient between water and soil. After swelling the wetting height is determined from the relation

Equation: $H_t = a.t$ …………………………………….(2)

Where; a = a constant (found out experimentally)

t = time of swelling

2.9 Swelling behavior of compacted clay related to Index properties

Numerous and widely different methods have been proposed by various research workers all over the world for the characterization of soil in lab for the purpose of prediction of their behavior under field conditions. All these methods broadly can be classified in the two methods:

2.9.1 Direct method

Direct method features the direct measurement of swell percent, swelling components and swelling pressures and a great deal of such data is now available in published literature.

2.9.2 The indirect method

Indirect method includes methods in which measuring soil properties are related to swell percentage and swelling pressure of the soil by semi-empirical mathematical expressions, empirical or graphical illustrations.

2.10 Bearing capacity

Bearing capacity is the capacity of soil to handle the loads applied on the ground. The bearing capacity of expansive soil is maximum average contact pressure between the soil and foundation which should not produce shear failure in the soil.

2.11 Construction techniques in expansive soils:

In general, 3 basic approaches may be considered for foundations on expansive clays. Altering the condition of swelling soil

• By passing the swelling clay through the insulating of the foundation from its effects.

• Providing a shallow foundation capable to withstand differential movements and mitigating their effects in super structure.

2.11.1 Alteration of soil condition:

Alteration the condition of expansive soil which includes stabilization of expansive soils, moisture control, compaction control and replacement of these soils is to reduce or eliminate its volume change on drying and wetting.

• Moisture barriers:

Most moisture control methods are applied around the perimeter of structure in order to minimize edge wetting and drying of foundations and for maintaining uniform water conditions beneath the structure. According to recent study which suggests that vertical trenches, about 15 cm wide by 1.5 m deep and filed with gravel. Capillary barrier, lean concrete, limes and fly ash serves as quite effective moisture barrier.

• Pre-wetting

Pre-wetting is done to raise the moisture content of the nearby suitable clays prior to placement of the structure. In some cases it has been found effective, especially for minimizing sub grade heaving under highways. A well maintained garden is also recommended in different cases. This will assist for maintaining equilibrium of moisture movement from and toward the structure.

• Compaction control

It has been found that expansive class expands very little when compacted at high moisture and low densities conditions. GROMLEO recommends compaction at 2% - 5% above the optimum moisture content(OMC) compaction of expansive foundation soil, to contain low densities for allowing slight swelling, however may be desirable because these procedures greatly reduces swelling pressure.

• Replacements

A simple and worthy solution for footing sand slabs on expansive soils is to replace the foundation soil with non-expansive soils. Experience indicates that there is no danger of foundation movement of the subsoil which consists of more than 1.5 m of non swelling soil under lying by high expensive s

• **Cohesive non-swelling layer (C.N.S Layer):**

The CNS layer techniques have been recently introduced in India for canal lining, buildings on expansive soils and foundation of cross drainage structures. Form a layer number of experiments it has been seen that the shear strength of cohesive non-swelling soil layer is highly effective in facing the swelling pressure of its underlying expansive soil. Generally, it causes the reduction of apparent cohesion, loss of shear strength and henceforth bearing capacity of the soil is also reduced drastically. Therefore it is necessary to study the soil behavior at saturation.

CHAPTER-III

PRESENT EXPERIMENTAL PROCEDURES

PRESENT EXPERIMENTAL PROCEDURES

3.0 Experimental Procedures

As we have came to known about the swelling soil, that it can be stabilized with an admixture for making it suitable for our work. So to make it stabilize, the following experimental were done and results were observed.

Different proportion of fly ash is mixed with Bentonite varying from 0% to 100% (with interval of 10%) and following experiments were performed.

3.1 Free Swell Index Test

The free swell index for swelling soil as well as **Bentonite + fly ash** mix (0% to 100%, with interval of 10%) was determined as per IS:2720 (part-II). The procedure involved is to take two oven dried soil samples (passing through 425µ IS sieve), 20g each sample were placed separately in two 100ml graduated soil sample. In one cylinder distilled water was filled and in other kerosene (non-polar liquid) is filled up to 100ml mark. The final reading of volume of soil was taken after 24hours to calculate free swell index.

The percent free swell index was calculated as

Free Swell Index (in %) = [(Vd – Vk)/ Vk] * 100

Where Vd= The volume of sample noted from the graduated cylinder containing distilled water

Vk= The volume of sample noted from graduated cylinder containing distilled kerosene.

Free Swell Index of Bentonite- fly ash mixes was determined from the tests and tabulated.

3.2 Specific gravity

The specific gravity of Bentonite and fly ash were determined by density bottle method according to IS: 2720(part-III/sec-I) 1980. It was the most suitable for determining specific gravity.

The mass M1 of the empty, dry, bottle is first taken. A sample of our soil was taken and kept it in bottle, and the mass M2 is taken. The bottle is then filled with distilled water (or kerosene) gradually and removing the entrapped air either by applying vacuum or by shaking the bottle. The mass M3 of the bottle, soil and water (full on the top) was taken. Finally, the bottle is emptied completely and thoroughly washed, and clean water was filled to the top, and mass M4 is taken. Based on these four readings specific gravity is calculated.

G = (Dry mass of soil/ mass of water of equal volume) = [(M2-M1)/ {(M4-M1)-(M3-M2)}]

3.3 Determination of Atterberg Limits

The liquid limit(L.L) and plastic limit(P.L) of Bentonite- fly ash mixes at different percentages is determined as per IS:2720(Part-IV) 1970.

3.3.1 Liquid Limit

The liquid limit was determined in the laboratory by the help of standard liquid limit apparatus. About 120g of the specimen passes through 425μ sieve was taken. A groove was made by groove tool which IS: 9259-1979 designates. One brass cup was raised and allowed to fall on a rubber base. The water content correspond to 25 blows was taken as liquid limit.

3.3.2 Plastic Limit

This test is done to determine the plastic limit of soil as per IS: 2720 (Part V) – 1985. The plastic limit of fine-grained soil is the water content of the soil below which it ceases to be plastic. It gets crumble when rolled into threads of 3mm dia.

3.3.3 Plasticity Index

We calculate Plasticity index from the relation

$Ip = W_L - Wp$

Where "Ip" is known as plasticity index in %,

W_L is liquid limit in %

W_P is plastic limit in %

3.4 Proctor Compaction Test

The Optimum moisture content and dry density of Bentonite with various percentage of flyash (0 to 100% with 10% interval) was determined by performing the "standard proctor test" as per IS: 2720(part VII) 1965. The test consist of compacting soil at various water contents in the mould, in three equal layers, each being given 25 blows of 2.6 kg dropped rammer from a height of

31cm. The collar removed and the excess soil is trimmed of to make it level. The dry density is determined and plotted against water content to find OMC and corresponding maximum dry density.

3.5 Unconfined compression test

This test was conducted on various sample with fly-ash concentration (0% to 100% with 10% interval) prepared at OMC, which is subjected to unconfined compression test. The test so conducted with reference to IS: 2720 part-10(1991) & 4330-5(1970).

CHAPTER-IV

APPENDIX -TABLES

Table-5

Free Swell Index (in %) of different Bentonite- flyash mixes

Percentage of flyash mixed with Bentonite	Free Swell Index
0	610
10	533.3
20	478.5
30	437.3
40	400
50	331.8
60	282.6
70	273.9
80	200
90	211.53
100	214.87

Table-6

Specific gravity of Flyash Bentonite mixes

Percentage of flyash mixed with Bentonite	Specific gravity
0	2.620
10	2.612
20	2.603
30	2.592
40	2.582
50	2.577
60	2.571
70	2.565
80	2.559
90	2.554
100	2.550

Table-7

Liquid Limit (in %) of different Flyash Bentonite mixes

Percentage of flyash mixed with Bentonite	Liquid Limit (in %)
0	228
10	157
20	152
30	115
40	106
50	97
60	89
70	71
80	61
90	41
100	38

Table-8

Plastic Limit (in %) of different Flyash Bentonite mixes

Percentage of flyash mixed with Bentonite	Plastic Limit (in %)
0	63.4
10	55.2
20	51
30	47.2
40	42.5
50	40
60	33.3
70	32.4
80	31.2
90	-
100	-

Table-9

Plasticity Index of different Bentonite Flyash mixes

Percentage of flyash mixed with Bentonite	Plasticity Index(in %)
0	164.6
10	101.8
20	101
30	67.3
40	63.5
50	57
60	55.7
70	38.6
80	30.8
90	-
100	-

Table-10

Maximum Dry Density (in gm/cc) of different Bentonite- flyash mixes obtained from Proctor Compaction Test

Percentage of flyash mixed with Bentonite	MDD(in gm/cc)
0	1.245
10	1.318
20	1.489
30	1.473
40	1.438
50	1.401
60	1.391
70	1.372
80	1.365
90	1.325
100	1.298

Table-11

Optimum Moisture Content (OMC) of different Bentonite flyash mixes

Percentage of flyash mixed with Bentonite	OMC (in %)
0	26.9
10	29.2
20	27
30	24.85
40	25.7
50	27.05
60	28.01
70	28.78
80	33.89
90	38.85
100	40.98

Table-12

Unconfined Compressive Strength of different samples of Bentonite Flyash mixes

Percentage of flyash mixed with Bentonite	Unconfined Compressive Strength(in kg/cm^2)
0	1.62
10	2.41
20	2.30
30	1.99
40	3.48
50	3.89
60	1.7
70	1.75
80	1.46
90	.51
100	.36

CHAPTER-V

APPENDIX -FIGURES

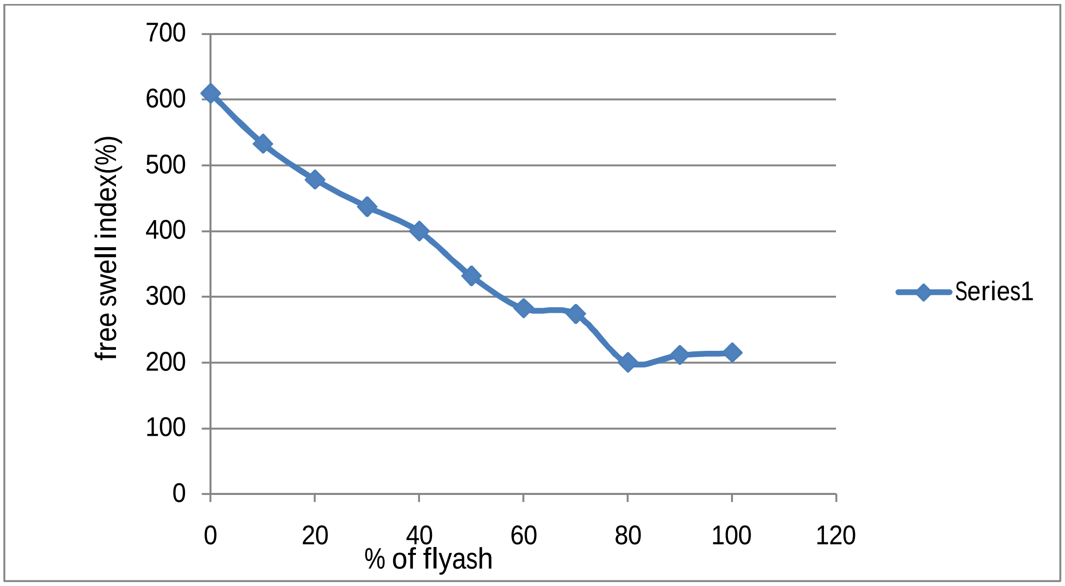

Figure 4- Variation of Free Swell Index

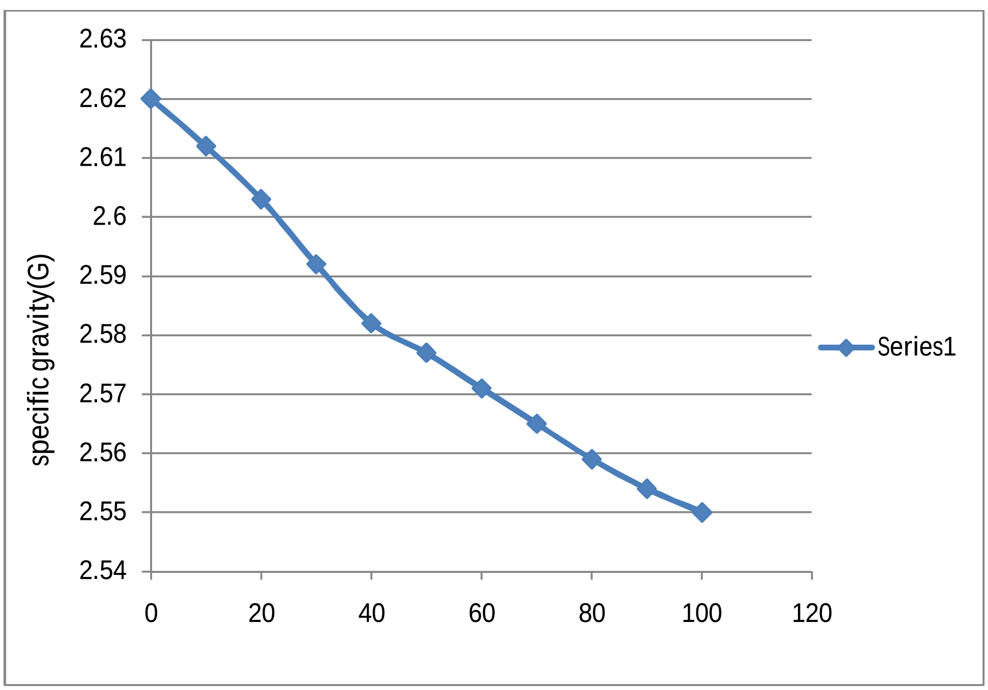

Figure 5- Variation of Specific gravity

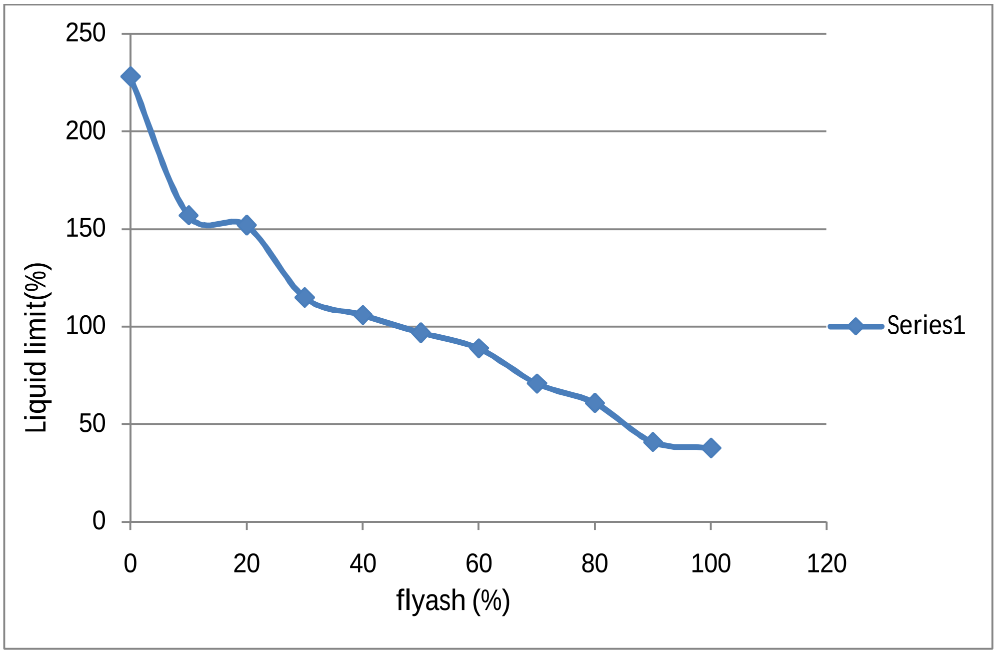

Figure 6- Variation of Liquid Limit

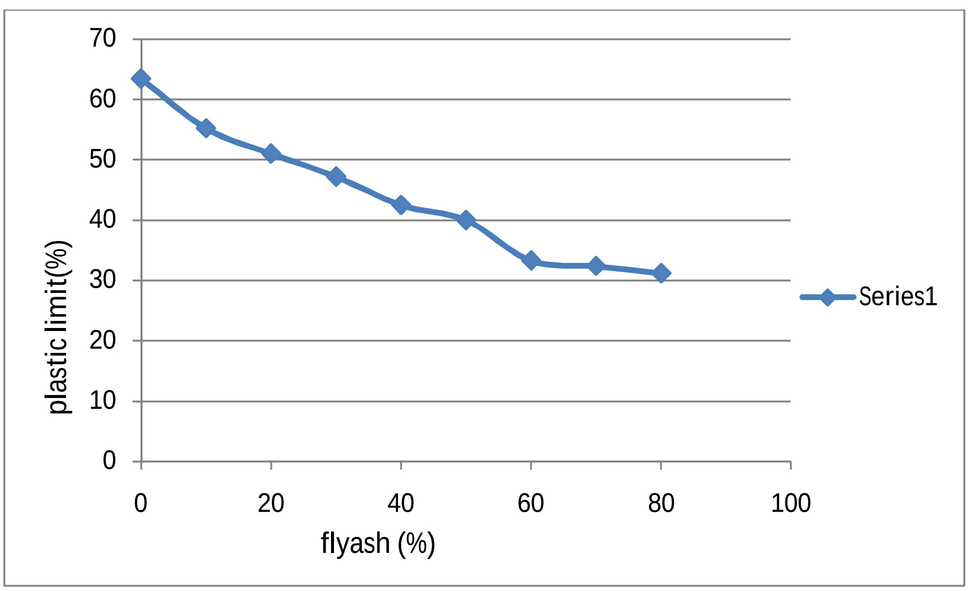

Figure-7 Variation of Plastic Limit

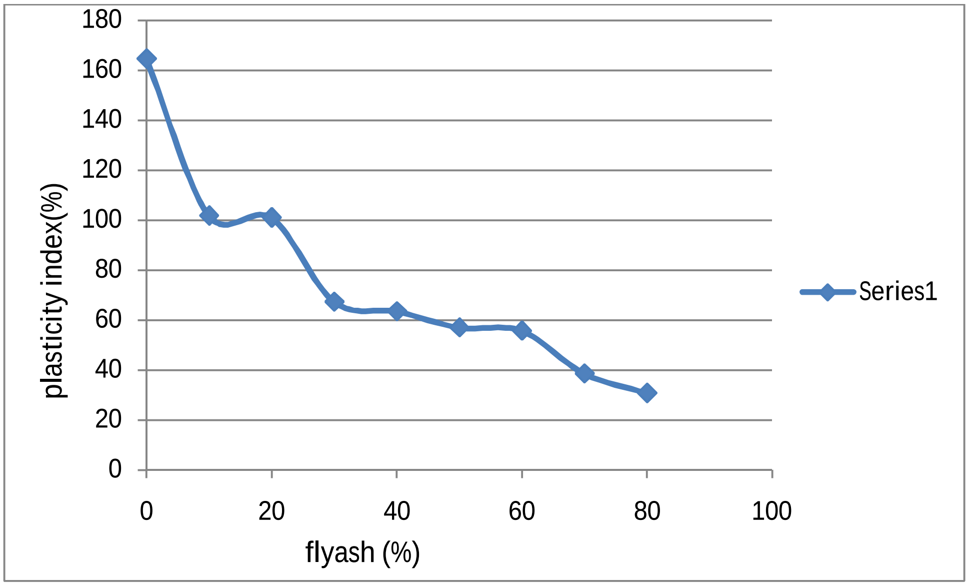

Figure-8 Variation of Plasticity Index

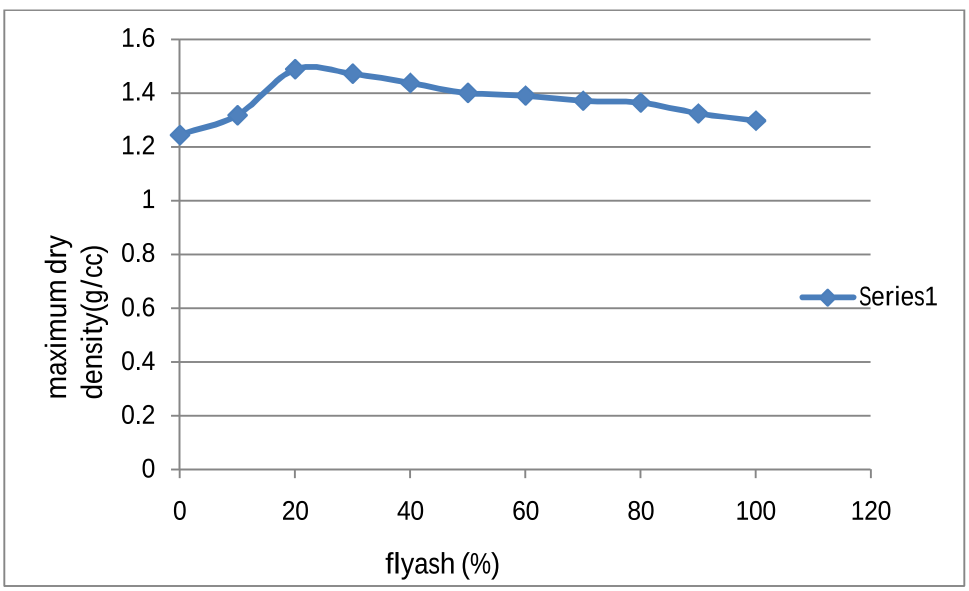

Figure-9 Variation of Maximum Dry Density

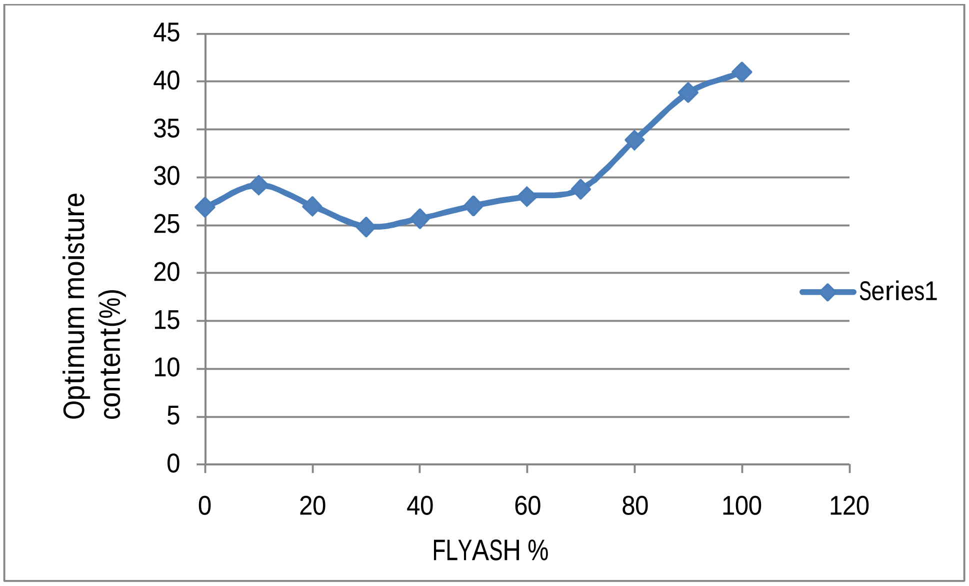

Figure-10 Variation of Optimum Moisture Content

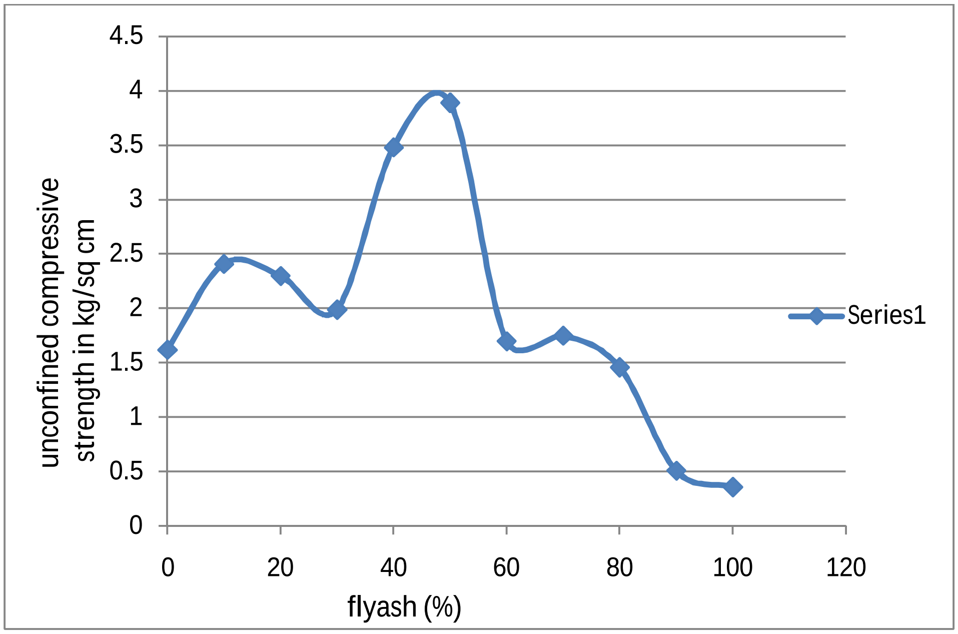

Figure-11 Variation of Unconfined Compressive Strength

CHAPTER-VI

IMPORTANT INDIAN STANDARD SPECIFICATIONS

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• **Methods of test for soil**: Prepare of dry soil sample for various test

IS: 2720(part-I)-1973

• **Methods of test for soil:** Determination of water content

IS: 2720(part-II)-1973

• **Methods of test for soil**: Determination of specific gravity

IS: 2720(part-III/section-1)1980

• **Methods of test for soil:** Determination of liquid limit and plastic limit

IS: 2720(part-V)-1986

• **Methods of test for soil:** Determination of California bearing ratio

IS: 2720(part 31)-1990

• **Methods of test for soil**: Determination of free swell index

IS: 2720(part 40)-1977

• **Methods of test for soil**: Measurement of swell pressure of soils

IS: 2720(part 41)-1977

CHAPTER-VII

RESULTS AND DISCUSSION

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4.1 As we have discussed in the previous chapter, Bentonite is mixed with varying percentage of flyash (i.e. from 0% to 100% with 10% interval) by weight to know the effect of flyash on Bentonite for different engineering properties like free swell index, Atterberg limits, proctor compaction test etc.

4.1.1 It was found through experiment that free swell index of Bentonite decreases drastically from 0 to 60%, then at 80% we are getting minimum free swell, then again it increases slightly from 80% to 100%.

4.1.2 The graph of specific gravity indicates that with increasing flyash content, specific gravity decreases steadily and get minimum at 100% flyash.

4.1.3 In case of Liquid Limit also, like free swell index, it decreases but between 10 to 20% it remains same and then decreases.

4.1.4 Plastic limit of soil similarly decreases with increasing amount of flyash in Bentonite. It declines in a steady manner.

4.1.5 Plasticity Index drastically declined from 0% to 10%, and then after 20%, it again declines slowly for remaining flyash content like free swell index, which clears that swelling is proportional to the plasticity index.

4.1.6 From the graph of proctor compaction test on Bentonite flyash mix, it can be known that MDD increases slightly from 0 to 20% then it decreases gently for remaining percentage of flyash. Also the optimum moisture content increases slightly from 0 to 10%, and then it decreases up to 70%, and again steeply increases from 70 to 100%.

4.1.7 To gauge the combined effect of improvement of C and ø values, specimens were prepared at their maximum proper densities (at all % of flyash contents) for doing unconfined compression test at O.M.C. The graph takes peak initially at 10%, then a bigger one at 50% and then at 70 %, else it goes down.

CHAPTER-VIII

CONCLUSION

CONCLUSION

1. Till 60% of flyash addition, free swell index value decreases more than half than that of its value of only Bentonite.
2. Specific gravity decreases as straight line in a gentle manner and minimum at maximum content of flyash.
3. Liquid Limit value is decreasing with addition of flyash content like in free swell index, but decreases drastically from 0 to 10%.
4. Plastic limit value also decreases with addition of flyash.
5. Plasticity index also decreases with addition of flyash but abruptly from 0 to 10%.
6. Value of maximum dry density (MDD) is near about same but at 20% flyash content we are getting maximum MDD.
7. The Optimum moisture content increases slightly from 0 to 10% and then it decreases up to 70% and again get increases up to 100% of flyash content.
8. Unconfined compression strength of flyash Bentonite mixes shows peaks at 10%, 50% and 70%. But at 50% we are getting very high value of strength.

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   Evaluation of soil and rock properties; Author(s) P.J. Sabatini, R.C. Bachus

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