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"Enhancing Compressive Strength Of Expansive Soil Through The Addition Of Wollastonite And Bottom Ash"

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Abstract

This study presents a comprehensive examination of the effects of wollastonite and bottom ash on various properties of soil and concrete. Through a series of laboratory tests, several important conclusions were drawn. First, in soil modification, the addition of 20% wollastonite led to a remarkable 5.57% increase in maximum dry density (MDD) and an 18.54% enhancement in the California bearing ratio (CBR) for soaked soil. Additionally, the liquid limit and plasticity index of the soil displayed an interesting trend, initially decreasing up to 20% wollastonite and then increasing by 15.28% and 6.58%, respectively. Similarly, the introduction of 0.5% soiltech into the soil mixture resulted in an impressive 78.13% increase in CBR (soaked) value, accompanied by fluctuations in the liquid limit and plasticity index. In concrete, when 10% of cement was replaced by wollastonite and sand by bottom ash, the highest compressive strength of 43.2 N/mm² was achieved at 10% bottom ash content, while the flexural strength initially decreased by 5.01% with only 10% wollastonite and then increased with the replacement of sand by bottom ash, reaching a maximum increase of 4.63% at 10% bottom ash. The split tensile strength also saw an increase of 4.36% when 10% wollastonite and 10% bottom ash were incorporated into the concrete mix. These findings emphasize the potential of wollastonite and bottom ash to significantly enhance the engineering properties of both soil and concrete, making them valuable materials for various construction applications.

Key Words: Compressive Strength, Expansive Soil, Wollastonite, Bottom Ash"

Introduction

Nearly 51.8 million hectare of land area in India are covered with expansive soil (mainly black cotton soil). In general engineering performance of soil is depend on its properties. These expansive soils have property of swell and shrink according to moisture content. In today's world, scarcity of land is one of the major problems and have an expansive soil on that land is an additive to problems because it causes many problems in past and serve as a challenge to overcome for engineers.

One of best remedy used for this is Soil stabilization, which is generally used in foundation and road pavement construction, because it improves properties of soil like strength, durability volume changes etc. In soil stabilization, stabilizer is added to soil in optimum quantity to achieve maximum dry density and have minimum penetration. In this research, wollastonite mineral and Soiltech polymer is used as additive in soil. Wollastonite is added in different proportion as 10%,15%,20%,25% as replacement of soil and Soiltech is added in proportion of 0.25%,0.5%,0.75% as of OMC and change in properties like MDD, plasticity,CBR etc. is noted.

In thermal plant and cement plant, fly ash and bottom ash is extracted as waste. Now a days,the disposal of bottom ash is also important with fly ash disposal. In present study, this bottom ash is used as replacement of sand in concrete. Generally, BA has nearly same particle size and having porousstructure, resulting in higher water requirement and lower compressive strength. In this study, we also replace cement in concrete by 10% wollastonite.Here bottom ash is added in proportion of 5%, 10%, 15%, and 20% as replacement of fine sandand change in properties like compressive strength, flexural strength,split tensile strength isnoted.

In conclusion, we note that both Wollastonite and Soiltech can be potentially used as an additive for the improvement in soil properties and have very economical if use in pavementconstruction and bottom ashin concrete as replacement of fine sand is also a good option for its disposal

1.1 Expansive Soil

Expansive soils, which are also known as black cotton soil or regur soil or swell shrink soil, have the tendency to shrink and swell with variation in moisture content. Due to variation involume of soil due to moisture, significant distress occurs in the soil, which is subsequently followed by the damage of the overlying structure. In monsoon or high moisture content, this soil become soft, swell or we can say this soil imbibes the water and their water holding capacity diminishes. As in summers, this soil loose moisture held in them due to evaporation and become hard. This type of soil is generally found in semi- arid and arid regions. Expansive soils are regarded as potential natural hazard – if not treated, they can cause extensive damage to the structures built upon them. Soils whose composition includespresence of clay mineral montmorillonite show these kinds of properties.

In the Indian subcontinent, expansive soil is mainly found over the Deccan trap (Deccan lava tract), having state Maharashtra, Andhra Pradesh, Gujarat, Madhya Pradesh, Rajasthan. These soils are also found in the river valley of Narmada, Tapi, Godavari and Krishna. Afterthe chemical decomposition of rocks such as basalt by various decomposing agents, these are the residual soils left behind at the sameas residual soil. Cooling of volcanic eruption and weathering another kind of rock – igneous rocks is also a process of formation of thesetypes of soils. These soils are rich amount of lime, alumina, magnesia, andiron in it and havedeficiency of nitrogen, phosphorus and organic content.

As these soil have same size of clay particle, and the colour of this soil varies from black tobrown. In India 20% of total land area on average is of having black cotton soil. These soils are suitable for dry farming and for the growth of crops like cotton, rice, jowar, wheat, cereal, tobacco, sugarcane, oilseeds, citrus fruits and vegetables; the reason behind it is owed to themoisture retentive capacity of expansive

soils, which is high. In the last couple of decades, the region of black cotton soil or expansive soil, have damagesdue to the swelling-shrinking action of expansive soils which have been observed prominently in form of cracking and break-up of roadways, channel and reservoir linings, pavements, building foundations, water lines, irrigation systems, sewer lines, and slab-on- grade members.

Wollastonite

Wollastonite is named after the English chemist William Hyde Wollaston. Wollastonite is a versatile industrial mineral containing chemicals like calcium, silicon and oxygen, having chemical formula as Calcium silicate mineral ($CaSiO_3$), and approx. 48.5% of CaO and 51.7% SiO_2. It may contain small number of other mEt. alls like aluminum, Iron, Magnesium,and Manganese. When dolomite or limestone is subjected to high temperature and pressureit will lead to the formation of wollastonite. Wollastonite has the property of having low moisture and oil absorption with low volatile content. Wollastonite also contains other minerals namely calcite, garnet and dropsied as gangue minerals or impurities those are removed during extraction process.

Soil Tech

Soiltech is a third-generation nano polymer binder used for stabilizing soils for improving the strength and stability of soil. It is a type of stabilization agent, provided by "Kaveri Polymer Private Limited" in India. It was specifically designed & developed for mine haul road stabilization, where load of maximum nature occurs and where all weather roads are required. Now a days, this technology is used in commercial road design. SoilTech stabilizing polymers are elastomers, which gain strength from mechanical compaction and do not become brittle when cured. They are flexible in nature as ofelastomers and allows certain amount of flex under load and does not become brittle. That aspect helps in reducing layer work in design phases. SoilTech Polymer is used for stabilizing base and sub-base layers of sealed and unsealed roads i.e. in mine haul roads, railway embankments, hard stands, parking lots and air strips.

Bottom Ash

Indian coal is used in power plants generally has high ash yield and of low quality. The average ash content in Indian coal is around 35–38 % while imported coal ash content has only 10–15 %. A large number of Coal/Lignite based thermal power plants are setting up inIndia for providing electric power generation to rapidly growing industrial as well as agriculture sectors.

In the burning process of coal, minerals undergo thermal decomposition, fusion, dissolution, and agglomeration. Many elements present in a volatile form may vaporize and non- combustible material present in it results in production of coal ash. The finer and lighter particles of coal ash escape with the flue gases and are extracted in the Electro Static Precipitators (ESP) before reaching the atmosphere. The coal ash collected from the ESP isnamed as fly ash (FA). The coal ash collected at bottom of furnace is called bottom ash. DryBA, granular, porous, mostly sand size material that is collected in water-filled hoppers at the bottom of the furnace. In general, coal ash in a power plant consists of up to 25 % BA and75 % Fly Ash or 20 % Bottom Ash and 80 % FA. The specific gravity of typical IndianBA varies from 1.60 to 2.39 depending upon its chemical composition and also depend on grain size. The bulk density varies from 630 to 776 kg/m3.

Literature Review:

Critically analyses the information gathered by identifying significant flaws or gaps in existing knowledge also by showing limitations of theories and different points of opinion of researcher and defining zones for further research and checking on zones of debate.

J. Ranjitha, 2016 Et. all. In this work the effect of using Nano Polymer called SoilTech as a stabilizer to improve the properties of Black Cotton soil collected from Ranibennur region, Karnataka, India was determined. The laboratory experiments were conducted on the samples of BC soil and BC soil with stabilizer for Compaction test, UCS (Unconfined Compression Strength) and CBR (California Bearing Ratio) tests. Various samples were prepared by taking soil with different percentage of SoilTech MK III Polymer (0.2%, 0.4%, 0.6%, 0.8% and 1.0%). They conclude that soil have high liquid limit of 61.2% and plasticity index of 29.8% which shows that the soil is clayey soil with high plasticity. After stabilizing the soil with varying percentages of SoilTech MK III polymer, there is a considerabledecrease in the liquid limitfrom 61.2% to 50.4% and plasticity index from 29.8% to 26.1%. Addition of 0.4% of SoilTech MK III polymer improves the compaction parameters of the soil by decreasing the OMC and increasing the MDD of the soil. CBR changes were significant at 0.4% of SoilTech MK III polymer after 4 days of soaking as it achieves the required strength, CBR increases from 2.47% to 9.98%for unsoaked condition and from 1.58% to 7.48% for soaked conditionat 0.4% of SoilTech MK III.

Dr. V. Giridhar, 2017 Et. all. In present study an attempt has been made to stabilize the soil using SoilTech MKIII polymer as a stabilizer. Laboratory experiments were done to check the improvement ofthe properties of the black cotton soil and studied the compaction,strength and CBR values by using the SoilTech MK III polymer as a stabilizer in different percentages such as 1%, 2%, 3%, 4% and 5%. The discussions are drawn from the experimental investigation the dry density of soil increases from 1.36 g/cc to 1.56 g/cc with increase in percentage of SoilTech MKIII polymer. At 5% of addition of polymer, there is an increase in dry density value is 15%. Thesoaked CBR value increases from 2.14 to 8.23 with increase in percentage of SoilTech MKIII polymer. At 5% of addition of polymer, there is an increase inCBR value is 285%. With increase in soaking period of soil, the values of CBR and UCS results were reduced because of increase in moisture content in specimen. SoilTech MKIII polymer is anecofriendly in nature. So, it can be effectively used as a soil stabilizer.

V. Mohanalakshmi, 2016) Et. all "Geotechnical Properties of Soil Stabilized with Wollastonite" In this research, the properties of a red soil and its reaction with an additive material i.e. wollastonite have been found out by conducting various tests. Wollastonite is a Calcium silicate mineral (CaSiO3) that may contain small traces of Iron, Magnesium, and Manganese substituting for Calcium which is available in many locations below the ground surface and find its applications in many engineering industries, etc. It has the property of low moisture and oil absorption with low volatile content and have the chemical properties which is very similar to cement. Because of this similarity wollastonite can be used toenhance the properties of the soil. They conclude that the liquid limit of the soil get increased by addition of Wollastonite and have maximum value at 15%. Increase of MDD by the addition of wollastonite enhances the strength of the red soil. Improvement of Unconfined Compressive Strength results in the reduction of difficulties in foundation work.

Prof. R. Jagadeesh Kumar, 2017 Et. all "Civil Engineering application and earlier research on Wollastonite – A Review" In this research, various applications, research of Wollastonitein the field of civil engineering like concrete technology, geotechnical engineering, and also in various construction materials are discussed. Wollastonite increases the performance of products like polymers, plastics, paints and coatings, construction materials, friction devices,ceramic, etc. It also been employed for mEt. alllurgical applications.

Pawan Kalla, 2014 Et. al **"**Durability studies on concrete containing wollastonite" In the present investigation, concrete mixes at three w/c ratios (0.45, 0.50 and 0.55) were prepared, by substituting Portland cement with wollastonite at varying replacement levels (0-25%). Substitution of 10-15% cement by wollastonite resulted in improved strength and durability of concrete. SEM and MIP results indicated that substitution of cement by wollastonite upto 15% reduced porosity and densified the concrete microstructure. Compressive and flexural strength at 7 and 28 d exhibited similar trend to those after 90 d curing. Compressive strength was observed increasing up to 10% cement replacement witha marginal drop at 15% replacement at all w/b ratios. Flexural strength was observed to be increasing withdecrease in w/b ratio and increase in curing age. Basically, Incorporation ofwollastonite in the range of 10 to 15% indicated improvement in concrete's strength and durability. Cement replacement by wollastonite in the above range densified concrete matrix. This may be explained by higher probability of uniformly graded fine wollastonite particles to align in more ordered manner during mixing. SEM and MIP assessment of mixesrevealed that cement replacement by wollastonite resulted in pore discontinuity and densification of these mixes.

Mathur, 2007 "Influence of wollastonite on mechanical properties of concrete". According to this research, the effects of Wollastonite on cement concrete and cement-fly ash concrete. It includes incorporating Wollastonite as partial substitute of cementitious material and sand respectively. Studies show that replacement with wollastonite by 10% in concrete mixes enhances its compressive strength by 28 - 35% and flexural strength (36- 42%) at 28 and 56 days respectively. By incorporation of Wollastonite, reduction in water absorption, drying-shrinkage and abrasion loss of concrete, and enhancement in durability against alternate freezing-thawing and sulphate attack were observed. Because of high concrete strength and abrasion resistance, a better utilization of concrete cross section is possible. Alternatively, thickness of pavement slab can be reduced by incorporation of Wollastonite micro-fibers in concrete mixes.

P. Aggarwal, 2007 et. al "Effect of Bottom Ash as Replacement Of Fine Aggregates" In this experimental investigations carried out to study the effect of use of bottom ash (the coarser material, which falls into furnace bottom in modern large thermal power plants andconstitute about 20% of total ash content of the coal fed in the boilers) as a replacement of fine aggregates. The various strength properties studied consist of compressive strength, flexural strength and splitting tensile strength. The strength development for various percentages (0-50%) replacement of fine aggregates with bottom ash can easily be equated to the strength development of normal concrete at various ages. In Concrete Mix containing 30% and 40% bottom ash, at 90 days, attains the compressive strength equivalent to 108% and 105% of compressive strength of normal concrete at 28 days and attains flexural strength in the range of 113-118% at 90 days of flexural strength of normal concrete at 28 days. The time required to attain the required strength is more for bottom ash concrete. Bottom ash concrete attains splitting tensile strength in the range of 121-126% at 90 days of splitting tensile strength of normal concrete at 28 days.

S. Lovely Kumari, 2017 "Development of High-Performance Concrete Using Bottom Ash as Fine Aggregate" In this research, study of the effect of bottom ash as fine aggregate. The mix proportion adopted was 1:1.25:2.3 and the dosage of super plasticizer was 1%. The compressive strength HPC obtained was 97.60 MPa without bottom ash and 91.20 MPa with 25% bottom ash. Addition of 25% bottom ash seems to be the optimum level of replacement. The split tensile strength in the case of HPC without bottom ash at 28 days was 8.30 MPa. The corresponding strength of HPC with 25% bottom ash was 8.12 MPa. This is almost same as that of HPC without bottom ash. HPC without bottom ash had a tensile strength at 28 days was 9.76 MPa. This is almost one-tenth of the corresponding compressive strength.The tensile strength of HPC with 25% bottom ash was 8.14 MPa. This is approximately 8.84% of the corresponding strength of conventional HPC. With the increase in ash content the strengthdiminished. This clearly shows that the tensile strength in bending of conventional HPC is far greater than that of ordinary conventional concrete of comparable mix proportion.

Shubham Dahiphale, 2015 "Properties of Concrete Containing Wollastonite". In this study wollastonite was used to replace cement in concrete mix up to 30 %. There were 9 concrete mixes prepared with different wollastonite percentages which are 0%, 5%, 10%, 12.5%, 15%, 17.5%, 20%, 25%, 30% by weight of cement. Water cement ratio used was 0.44. It was observed that there was a rise in compressive strength at 10%, 12.5%, and 15% wollastonite replacement as compared to control mix. Highest rise was observed at 15% wollastonite replacement. There was slight decrease in compressive strength at 5 % replacement but at 10%, 12.5% & 15% replacement there was rise in compressive strength. Optimum percentage of replacingcement with wollastonite selected is 15%. The presence of silica in wollastonite is responsible for imparting strength in concrete. It is advantageous to use wollastonite in replacement of cement as it reduces pollution.

A. K. Mandal, 2014 "Review on Current Research Status on Bottom Ash: An Indian Prospective" The common understanding among the people is that the BA, by-products of thermal power generation plant,are waste materials which are harmful to the environment and to the people of the region as well. However, based on these above studies from physical,chemical, and engineering properties of coal ashesshow that the coal ashes are potential materials in view of the geotechnical engineering applications. They have low specific gravity, lower compressibility, higher rate of consolidation, higher frictional strength, higher CBR, negligible swell-shrink potential, water insensitiveness of compaction characteristics and pozzolanic reactivity. It can also reduce the transportation cost as well as reduce environmental problems. Rheological behavior of BA in slurry form indicates that, due to the coarser in size, additionof BA in slurry increases the transportation efficiency. BA has been fruitfully employed forthe removal of hazardous dye.

General Characteristic of Expansive Soil:

On the basis of crystalline structure, clay mineralogy is divided in three parts as follows:

a) Kaolinite b) Montmorillonite c) Illite

In expansive soil, due to montmorillonite it shows swell shrink Behaviour according to moisture content. In these two-silica tetrahedral sheet combined with central alumina octahedral sheet forms the structure of Montmorillonite. The bond between sheets or crystallink are weak. Thus, the soil in which there is high percentage of Montmorillonite shows high shrinkage and swelling behavior. Montmorillonite has the maximum amount of swelling potential. In-situ formation of expansive soil or montmorillonite clay minerals occurs under alkaline conditions. Sub-aqueous decomposition of blast rocks, weathering under alkaline environment, and under adequate supply of magnesium and iron oxides is also a reason of the origin of such soil. Montmorillonite formation is also favoured when there is good availability of alumina and silica.

Relation between swelling potential and plasticity index of soil:

Swelling Potential	Plasticity index
Low	0-15
Medium	15-24
High	24-46
Very high	>46

Several factors participate in deciding whether or not a soil with high swelling potential exhibit swelling characteristics. The difference between soil moisture content at the time of construction, and final moisture content finally achieved under various conditions allied withthe complicated structure is also an important factor. The soil has a high swelling capacity if the equilibrium moisture content is higher than the soil moisture content.

Characteristic of Soiltech: SoilTech is a convenient liquid formula, which is simply mixed with water and applied to the soil. SoilTech is a polymer mixture that opens up pathways in the soil and agglomerates (clumps) soil particles. In concentrated form, the polymer molecules in SoilTech are tightly compressed and occupy very little space. When mixed with water and applied to the soil, these tightly coiled molecules begin to uncoil, extend and expand. Aided by gravitational pull and its electrical properties, this molecular expansion literally forces SoilTech down into the soil horizon opening pathways along its journey. As the journey continues downward and the molecules continue to expand, beneficial changes to the structure and texture of the topsoil occur. Advantage of soiltech polymer:

1. It reduces the consumption of quarry aggregate in road construction and therebyminimize the significant environmental impacts.
2. In-situ materials can be used in soil soiltech polymer stabilization.
3. It reduces the thickness of road layers thereby speeds up the construction time.
4. It reduces construction costs and Reduce maintenance in further years.
5. Increases the strength and stability of base & sub-base layer.

Material

Expansive Soil: As a part of this investigation, the expansive soil or clay is acquired from local site nearby Jhotwara, Jaipur (Rajasthan). The soil thus obtained was carried to the laboratory in sacks. A small amount of soil is taken and pass through sieve size of 4.75mm, weighted and air dried before weighted again and its natural moisture content is found. The various properties of soil are found in laboratory which are as follows:

S.N0	Soil Property	Code	Value
1.	Specific Gravity	IS 2720 (Part 3) - 1980	2.4
2.	Maximum Dry Density	IS 2720 (Part 7) - 1980	1.65
3.	Optimum Moisture Content	IS 2720 (Part 7) - 1980	20%
4.	Natural Moisture Content	IS 2720 (Part 2)- 1973	7.5%
5.	Liquid Limit	IS 2720 (Part 5) - 1985	30.10
6.	Plastic Limit	IS 2720 (Part 5) - 1985	15.38

Table 1: Properties of Soil

Wollastonite: Wollastonite is a naturally occurring mineral having chemical formula $CaSiO_3$. The wollastonite is acquired from Wolca mines, Jaipur. The general properties of wollastonite used in this research are as follows:

Characteristic	Description
Colour	White
Specific gravity	2.97
Size	<1 to 20
Bulk Density	350-1230 (kg/m3)

Table 2: Wollastonite Properties.

The bulk density is nearly 700 kg/m3. Water absorption is nearly equal to 15%.The fineness modulus which is found by sieve analysis is found to 4.5.

Cement:

S.No	Property	Value
1.	Specific Gravity	3.15
2.	Initial Setting Time	30 min.
3.	Final Setting Time	600 min.
4.	Fineness	225 m2/kg

Table 3: Properties of Cement

RESULTS AND DISCUSSION

Standard Proctor Test for Soil and Wollastonite

Soil+ 0% Wollastonite

Wt. of The Mould (Wm)	5140	5140	5140	5140	5140
Wt. of Mould +Compacted Soil (W)	6900.5	7092	7121	7140	7110
Wt. of Container (W1)	57.5	62	60.5	64.5	62
Wt. of Container+ Wet Soil (W2)	120	106.5	108.5	125	110
Wt. of Container+ Dry Soil (W3)	111.5	99.5	100.5	113	100
Wet Density	1.7605	1.952	1.981	2	1.97
Moisture Content	15.7407	18.66	20	24.742	26.315
Dry Density	1.5210	1.644	1.6508	1.6033	1.5595

Table 4: Proctor Test for Soil

Soil + 10% Wollastonite:

Wt. of the Mould (Wm)	5140	5140	5140	5140	5140
Wt. of Mould+ Compacted Soil (W)	6907	6998.5	7150.5	7144	7123
Wt. of Container (W1)	60.5	64	63	66.5	66.5
Wt. of Container+ Wet Soil (W2)	116	115.5	125.5	137.5	153
Wt. of Container+ Dry Soil (W3)	109	108	115	124	134.5
Wet Density	1.767	1.8585	2.0105	2.004	1.983
Moisture Content	14.432	17.045	20.192	23.478	27.205
Dry Density	1.5441	1.5878	1.6727	1.6229	1.5588

Table 5: Proctor for Soil + 10% Wollastonite

Soil + 15% Wollastonite:

Wt. of the Mould (Wm)	5140	5140	5140	5140	5140
Wt. of Mould+ Compacted Soil (W)	6992	7116.5	7211	7190	7156
Wt. of Container (W1)	58.5	70	61.5	67	52
Wt. of Container+ Wet Soil (W2)	105.5	123.5	104.5	127	136
Wt. of Container+ Dry Soil (W3)	99.5	115	97.5	116	118.5
Wet Density	1.852	1.9765	2.071	2.05	2.016
Moisture Content	14.634	18.8888	19.444	22.4489	26.31
Dry Density	1.6155	1.66247	1.7338	1.67416	1.596

Table 6: Proctor for Soil + 15% Wollastonite

Soil + 20% Wollastonite:

Wt. of the Mould (Wm)	5140	5140	5140	5140	5140
Wt. of Mould+ Compacted Soil (W)	6987	7067.5	7210.5	7193	7142
Wt. of Container (W1)	50.5	67	64	67	60.5
Wt. of Container+ Wet Soil (W2)	119	114	140	145.5	141
Wt. of Container+ Dry Soil (W3)	111	107.5	128	130.5	124
Wet Density	1.847	1.9275	2.0705	2.053	2.002
Moisture Content	13.223	16.0493	18.75	23.622	26.771
Dry Density	1.6312	1.66093	1.7435	1.6607	1.5792

Table 7: Proctor for Soil + 20% Wollastonite

Soil + 25% Wollastonite:

Wt. of the Mould (Wm)	5140	5140	5140	5140	5140
Wt. of Mould+ Compacted Soil (W)	6992	7038	7200	7142	7090
Wt. of Container (W1)	57.5	62	67	60.5	50.5
Wt. of Container+ Wet Soil (W2)	126	112	124	131.5	136
Wt. of Container+ Dry Soil (W3)	117.5	105	115	118.5	118
Wet Density	1.852	1.898	2.06	2.002	1.95
Moisture Content	14.1666	16.27	18.75	22.413	26.666
Dry Density	1.6221	1.632	1.7347	1.6354	1.5394

Table 8: Proctor for Soil + Wollastonite

MDD and OMC with varying percentage of wollastonite:

S.No.	% Wollastonite	MDD	OMC %
1.	Soil	1.651	19.75
2.	Soil + 10% Wollastonite	1.672	20.19
3.	Soil + 15% Wollastonite	1.733	19.44
4.	Soil + 20% Wollastonite	1.743	18.75
5.	Soil + 25% Wollastonite	1.735	18.50

Table 9: Proctor for Soil + Wollastonite

Soaked CBR for Soil + Wollastonite Soil:

Penetration(mm)	Load(kg)	CorrectedLoad (kg)	StandardLoad (kg)	CBR(%)
0.0	0	0		
0.5	1	7.44		
1.0	1.5	11.16		
1.5	2.5	18.16		
2.0	3	22.32		
2.5	4.5	33.48	1370	2.443
3.0	4.5	33.48		
4.0	5.5	40.92		
5.0	6.5	48.36	2055	2.353
7.5	8.5	63.24		
10.0	10	74.4		
12.5	11.5	85.56		

Table 10: CBR for Soil

Soil + 10% Wollastonite:

Penetration(mm)	Load(kg)	CorrectedLoad (kg)	Standard Load (kg)	CBR(%)
0.0	0	0		
0.5	1	7.44		
1.0	1.5	11.16		
1.5	2.5	18.16		
2.0	3	22.32		
2.5	4.5	33.48	1370	2.4438
3.0	5	37.2		
4.0	5.5	40.92		
5.0	7	52.08	2055	2.5343
7.5	8	59.52		
10.0	10.5	78.12		
12.5	11.5	85.56		

Table 11: CBR for Soil + 10% Wollastonite

Soil + 15% Wollastonite:

Penetration(mm)	Load(kg)	CorrectedLoad (kg)	StandardLoad (kg)	CBR(%)
0.0	0	0		
0.5	1	7.44		
1.0	2.5	18.6		

1.5	3	22.32		
2.0	3.5	26.04		
2.5	5	37.2	1370	2.71533
3.0	5.5	40.92		
4.0	6.5	48.36		
5.0	7	52.08	2055	2.53431
7.5	9	66.96		
10.0	10.5	78.12		
12.5	11	81.84		

Table 12: CBR for Soil + 15% Wollastonite

Soil + 20% Wollastonite:

Penetration(Mm)	**Load(Kg)**	**CorrectedLoad Kg)**	**Standard Load (Kg)**	**CBR(%)**
0.0	0	0		
0.5	1	7.44		
1.0	2.5	18.6		
1.5	3	22.32		
2.0	3.5	26.04		
2.5	4.5	33.48	1370	2.4438
3.0	5.5	40.92		
4.0	7	52.08		
5.0	8	59.52	2055	2.89635
7.5	8.5	63.24		
10.0	10	74.4		
12.5	11.5	85.56		

Table 13: CBR for Soil + 20% Wollastonite

Soil + 25% Wollastonite:

Penetration(mm)	**Load (kg)**	**CorrectedLoad (kg)**	**StandardLoad (kg)**	**CBR(%)**
0.0	0	0		
0.5	1	7.44		
1.0	2.5	18.6		
1.5	3	22.32		
2.0	4	29.76		
2.5	5	37.2	1370	2.71533
3.0	5.5	40.92		
4.0	7	52.08		
5.0	7.5	55.8	2055	2.71533
7.5	8.5	63.24		
10.0	10.5	78.12		
12.5	11.5	85.56		

Table 14: CBR for Soil + Wollastonite

CBR with varying % Wollastonite

S.No.	% Wollastonite	CBR
1.	Soil	2.443
2.	Soil + 10% Wollastonite	2.534
3.	Soil + 15% Wollastonite	2.715
4.	Soil + 20% Wollastonite	2.896

5.	Soil + 25% Wollastonite	2.715

Table 15: CBR with Varying Proportion of Wollastonite

Consistency Index of Soil with Wollastonite

S.No.	% Wollastonite	Liquid Limit	Plastic Limit	Plasticity Index
1.	Soil	30.10	15.38	14.72
2.	Soil + 10% Wollastonite	29	14.7	14.3
3.	Soil + 15% Wollastonite	27	13.08	13.92
4.	Soil + 20% Wollastonite	25.5	11.75	13.75
5.	Soil + 25% Wollastonite	27	12.9	14.10

Table 16: Consistency Index for Soil + Wollastonite

Conclusion

On the basis of results obtained and comparisons made in the present study, the following conclusionsare as follows:

- The maximum value of MDD is observed when 20% wollastonite is added to soil by weight. There is change of 5.57% (increase) in value of MDD for 20% wollastonite.
- The California bearing ratio CBR (soaked) value is found to be maximum at 20% wollastonite in different percentage of constituent. The change in value of CBR is 18.54% (increasing).
- Liquid limit and plasticity index of soil is first decreasing upto 20% wollastonite and after that it increases. There is change of 15.28% and 6.58% in values of liquid limit and plasticity index respectively.
- The California bearing ratio CBR (soaked) value is found to be maximum at 0.5% soiltech in different percentage of constituent. The change in value of CBR is 78.13%(increasing).
- Liquid limit and plasticity index of soil is first decreasing upto 0.5% soiltech and after that it increases.There is change of 12.3% and 15.35% in values of liquid limitand plasticity index respectively.
- The compressive strength of concrete after 28 days when cement is replaced by 10%wollastonite and sand is replaced by bottom ash is found to be maximum at 10% replaced bottom ash and thereafter decrease for 15% and 20% bottom ash. The maximum value found is 43.2 N/mm2.
- The flexural strength of concrete first decreases when only 10% wollastonite is mixed (decrease by 5.01%), after that when sand is replaced by bottom ash its value starts increasing and found maximum at 10% bottom ash (increase upto 4.63%).
- The split tensile strength is increase for both 10% wollastonite and 10% bottom ashand increase upto 4.36% in value of split tensile strength.

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