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Stabilization of an Expansive Soil with Addition of Bitumen and Cement

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Abstract: ***This study examined the effectiveness of stabilizing Expansive soil with combination of bitumen emulsion and cement. The research employs laboratory-scale model studies to simulate the behavior of expansive soil subjected to varying levels of bitumen and cement stabilization. Clayey soils naturally shrink and swell, which can have a major impact on buildings due to differential settlements. In semi-arid and arid regions of the world, expansive soils present a significant maintenance challenge for geotechnical engineers. Soil samples were obtained from bore hole 1 below 3M ground level, located at Ambedkar Colony, Tirupathi in Andhra Pradesh, and laboratory experiments such as dry density, Atterberg limits, Swelling, unconfined compression tests and California bearing ratio test (CBR) were performed with and without varied Bitumen percentages (2%, 4% ,6 %) and (2 %) Cement percentage. Experimental results indicate that the incorporation of bitumen and cement enhances the mechanical properties of expansive soils, reducing settlement and improving stability. Additionally, the study evaluates the long-term performance and environmental impacts of bitumen and cement stabilization techniques.***
Keywords: Expansive Soil, Bitumen, Pavement Subgrade, Cement.

I. INTRODUCTION

Expansive soils, characterized by its expansive nature and high compressibility in response to variations in moisture content, present formidable challenges in civil engineering projects, particularly in the construction of embankments, slopes, and foundations. In recent years, alternative materials such as Bitumen and Cement have garnered attention in geotechnical engineering for their potential to improve soil stabilization performance while offering environmental benefits.Bitumen is a black, sticky, Visco-elastic material obtained from crude petroleum. The research examines how different bitumen - cement contents affect the soil's liquid limit, plastic limit, plasticity index, expansion index, permeability, dry density, and compressive strength. By evaluating the impact of bitumen -cement stabilization on soil strength, stability, and workability, this study advances construction practices.

II. LITERATURE REVIEW

W. H. Kwan; C. B. Cheah; M. Ramli; Y. K. Al-Sakkaf: Four types of stabilizers were used in the study, namely, cement, slaked lime, bitumen emulsion and calcium silicate.Meanwhile, bitumen emulsion and calcium silicate were incorporated at various percentages together with 10% of cement.

AYININUOLA Gbenga Matthew and ABIDOYE Shola Paul: Three percentages of additives were considered: 4%, 6% and 8%. The bitumen emulsion and cement contents were combined in percentages: 100:0, 75:25, 50:50, 25:75 and 0:100 to form five additives. The corresponding values for UCS were 0.64, 0.66, 1.21, 1.27 and 1.33. It was observed that both the UCS and CBR values increased as the cement component increased for both soil samples.

Beshoy M. Hakeem: This paper investigates the effect of using six different percentages of bitumen to improve the properties of expansive soils in Egypt. The results indicated that, when bitumen content was increased to 15%, the liquid limit decreased by 41.5%, 37.23%, and 35.21% for very high potential expansiveness, high potential expansiveness, and medium potential expansiveness, respectively. Also, free swell, swelling potential, and swell pressure decreased by 68%, 65.5%, and 70% for very high potential expansiveness when bitumen content was increased to 15%.

Apichat Suddeepong , Artit Intra, Suksun Horpibulsuk , Cherdsak Suksiripattanapong, Arul Arulrajah, Jack Shuilong Shen:
The durability of RAP when blended with crushed rock (CR) and stabilized with Portland cement was investigated in this paper.

Ali Reza Ghanizadeh, Morteza Rahrovan, Kazem Barkhordari Bafghi: The present study was conducted using two different types of aggregate soils. Compaction and unconfined compressive strength (UCS) tests were carried out on different ratios of RAP to aggregates of 0/100, 20/80, 40/60, and 60/40. Four cement contents of 3, 4, 5, and 6 percent were added and the samples were cured for 7 and 28 days after compaction.

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Shravan A. Kanalli and Mohan H. Badiger: This study aims to investigate the stabilization of black cotton (BC) soil using mine waste (MW) and steel slag (SS) to enhance properties of the subgrade for pavement construction. CBR test results showed that optimal mix of 60% BC soil, 40% MW and 30% SS exhibited a CBR value of 7.8% and an effective CBR of 5%. The durability test results show that the stabilized mix with SS has a weight loss of 10.8% after 12 cycles of wetting and drying, within the permissible limit of 12%.

Zia Ur Rehman1 · Muhammad Rauf3 · Jiang Chaozhe1 · Fang Xu2 · Arshad Jamal4 · Ataur Rahman5 · Jamil Iqbal: The purpose of this research investigates the influence of cement on the stabilization of clayey soil. Soil samples were obtained from four different sites in the KPK province, and laboratory experiments such as dry density, Atterberg limits, permeability, and unconfined compression tests were performed with and without varied cement percentages (1–5%).

III. MATERIALS AND METHOD

A. Soil

Soil is collected at Ambedhkar colony Tirupati District of Andhra Pradesh. It was collected from a depth of 5m below the natural ground level which is dug out for construction of building by open excavation. The soil is dried and pulverized to perform the various experimental studies.

Table-3.1 Tests Conducted On Untreated Soil And Their Results

S.NO	Property	Values	IS codes
1	Specific gravity of total soil fraction	2.58	IS: 2720(Part-3/sec 2) – 1980
2	Liquid limit	112%	IS: 2720(Part-5) – 1985
3	Plastic limit	22.97 %	IS: 2720(Part - 5) – 1985
4	Plasticity index (Ip)	89.03 %	
5	Free swell index	290%	IS: 2720(Part-40) – 1977
6	Gravel Sand Silt + Clay	0.5 % 41.1% 58.4 %	IS: 2720(Part-3)- 1985
7	I.S. Soil classification	CH	IS: 1498 (1970)
8	Optimum Moisture Content (OMC)	14%	IS: 2720(Part-7) – 1980
9	Maximum Dry Density (MDD)	1.78 g/cc	IS: 2720(Part-7) – 1980

B. Bitumen

In this study, utilized VG 30 penetration grade bitumen emulsion was used for stabilising the expansive soil. VG 30 is a viscosity-graded bitumen with a viscosity range of 2400–3600 poise at 60°C, commonly used in road construction.

TABLE-3.2 Physical properties of Bitumen

S.NO	PROPERTY	TEST RESULTS
1	Specific gravity @ 27 ˚C	1.01
2	Penetration value	64.9
3	Flash point	189
4	Fire point	235
5	Softening point	51

C. Ordinary Portland Cement

Ordinary Portland Cement [OPC] 53 grade used in this study were purchased from the Dhanalakshmi Nagar,R.C. road local Tirupati, OPC 53 Grade Cement (Ordinary Portland Cement 53 grade) is a high-strength cement widely used in structural concrete works in India.

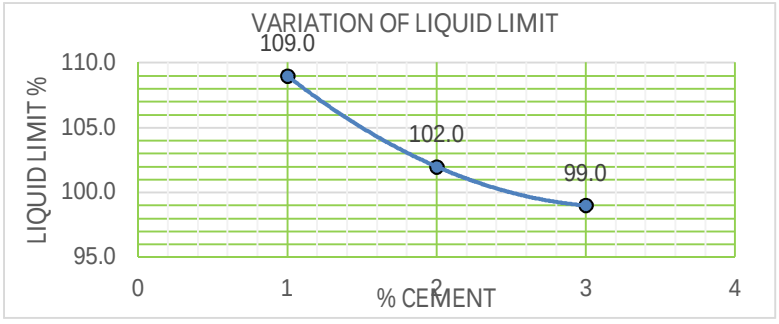
Table- 3.3 Physical properties of Cement

S.NO	Physical Testing	Results Obtained	Requirement Of Is 269 :2015
1	Fineness of Cement Sp.Surface (m²/kg)	 320	 225 nimum
2	Soundness Le-Chatelier Expansion (mm) Autoclave Expansion (%)	 1.00 0.053	 10 Maximum 0.8 Maximum
3	Setting Time Initial (in Minutes) Final (in Minutes)	 180 220	 30 Minimum 600 Maximum
4	Normal Consistency	28.75	-

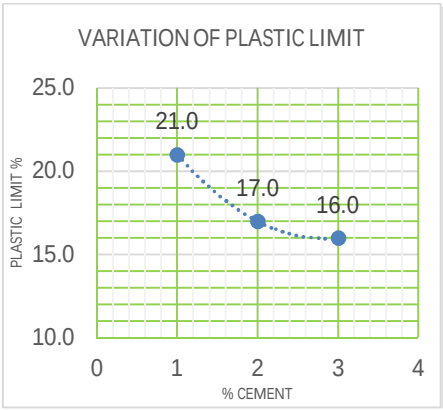
IV. RESULTS AND DISCUSSION

A. Plasticity Characteristics

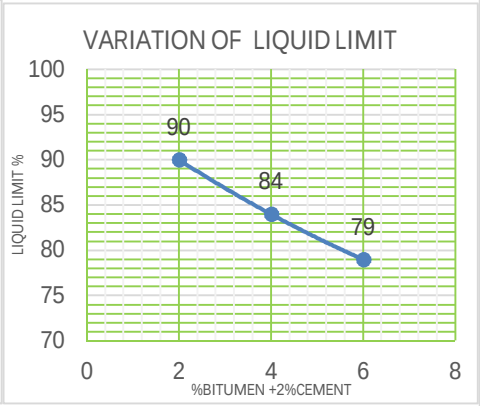
The addition of bitumen also reduces the liquid limit, mainly due to its water-repellent nature. The addition of cement generally reduces the liquid limit of clayey soils. The addition of bitumen generally increases the plastic limit slightly & the addition of cement increases the plastic limit of soil.



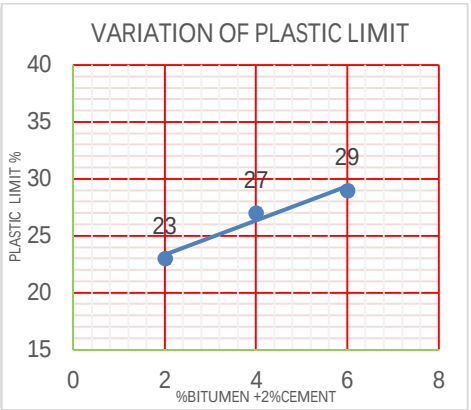
Graph 4.01



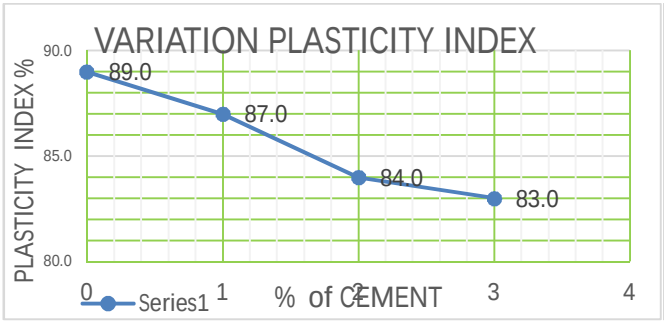
Graph4.02



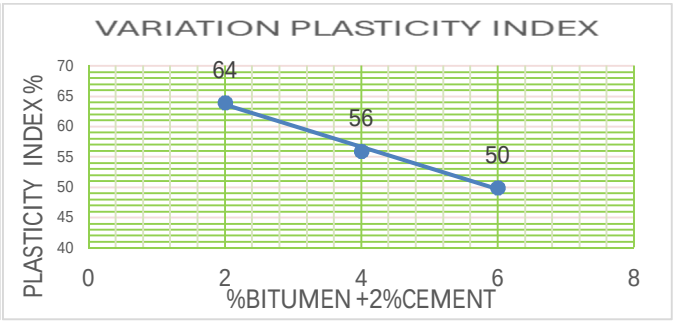
Graph 4.03



Graph 4.04



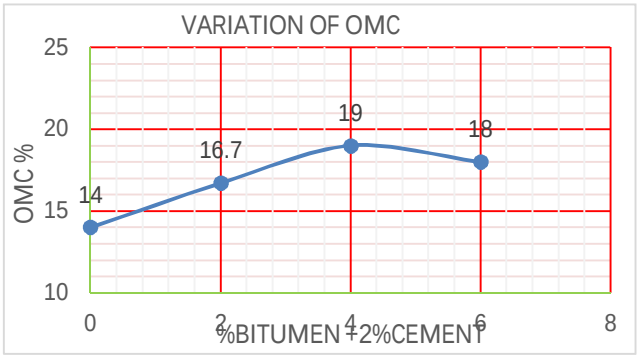
Graph 4.05



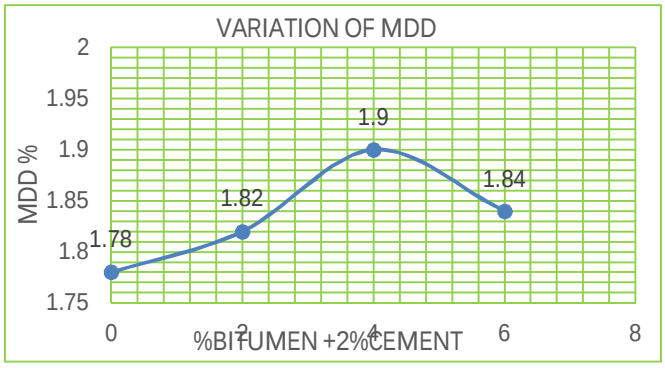
Graph 4.06

B. Standard Proctor Test

when we look at the bitumen mixes it can be observed that with the increase in bitumen content and cement content, OMC is increased while MDD is increased. It can be seen from the graph that the OMC is increased and MDD of the treated soil increases up to 4% of bitumen content, 2% of cement and 94 % of soil. The MDD obtained at 2% cement and 4% binder is 1.90 gm/cc.



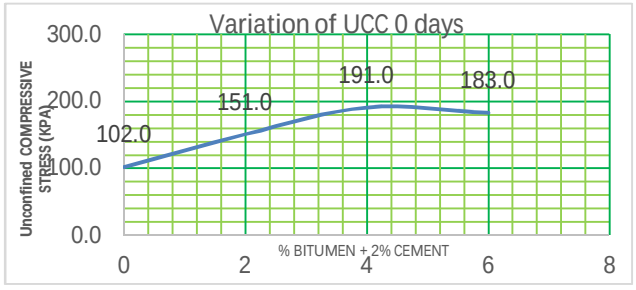
Graph 4.08



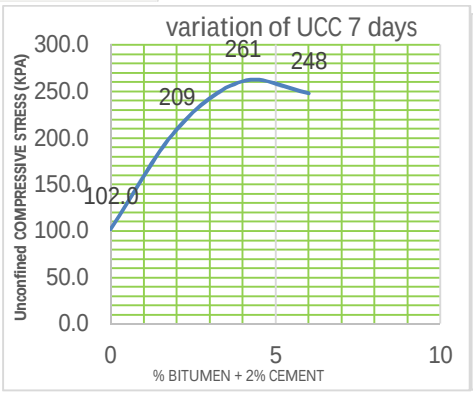
Graph 4.09

C. Unconfined Compressive Strength Test

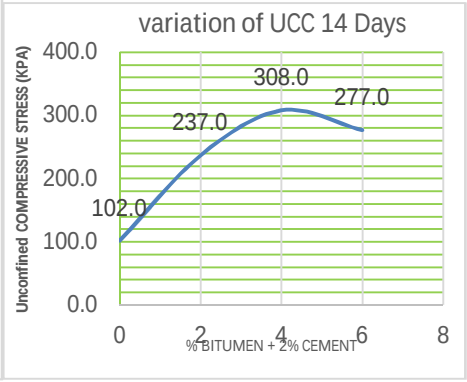
The tests were carried out for different curing periods, i.e. 7, 14, 28 days. Following graphs shows the variation of the unconfined compressive strength (UCS) of treated expansive soil for different curing periods in relation to the percentage of cement and bitumen content.



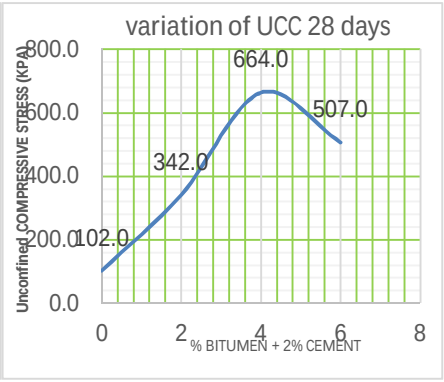
Graph 4.14



Graph 4.15



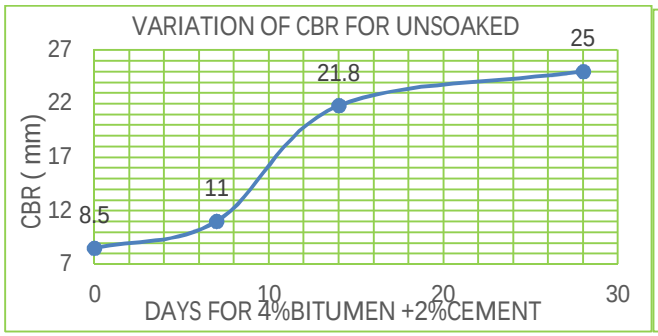
Graph 4.16



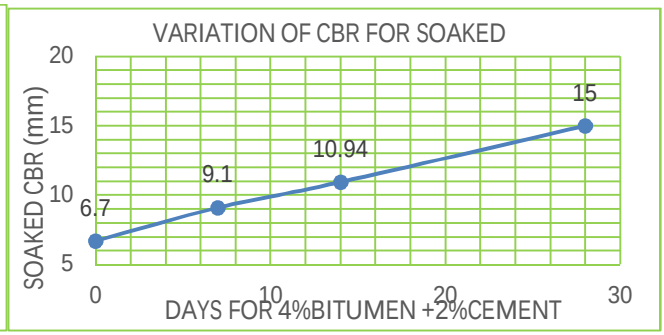
Graph 4.17

D. California Bearing Ratio (CBR)Test

In order to asses the strength development of the optimum combination of soil+ 4% bitumen and 2% cement samples over time, the tests were carried out for different curing periods, i.e. 7, 14, 28 days. The maximum value of CBR was obtained as 25 % at 4% of bitumen and 2% of cement content which is 6 times that of virgin soil. The formation of the cementitious compounds in the soil binder matrix is responsible for the increase in the CBR strength of the stabilized soil.



Graph 4.20

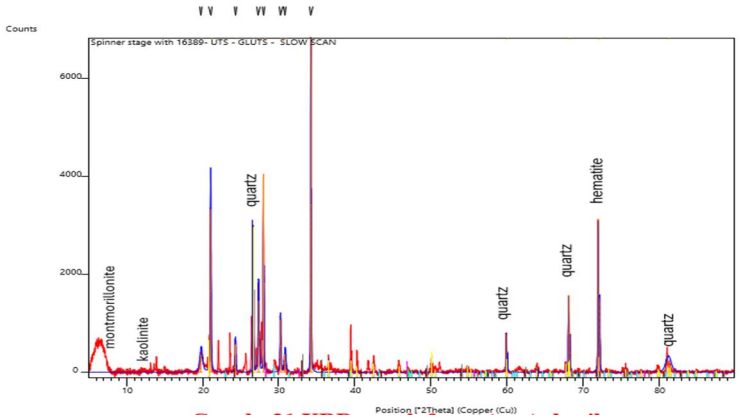


Graph 4.21

V. MICROSTRUCTURAL STUDIES

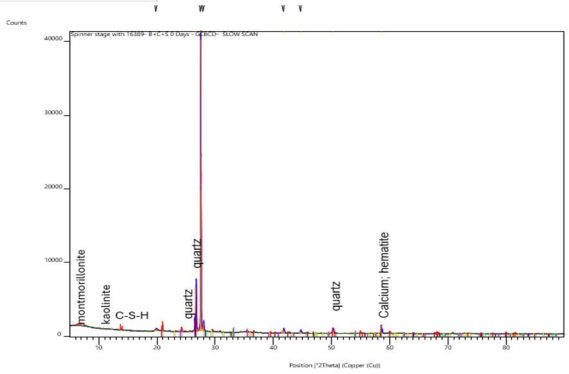
A. XRD Analysis

The properties of any soil depend greatly on mineralogical composition. Mineralogy is the primary factor controlling the size, slope, and physical and chemical properties of soil particles. This is the basic characterization technique used for the determination of crystal structure and other crystalline properties of the soils as well as bulk samples.

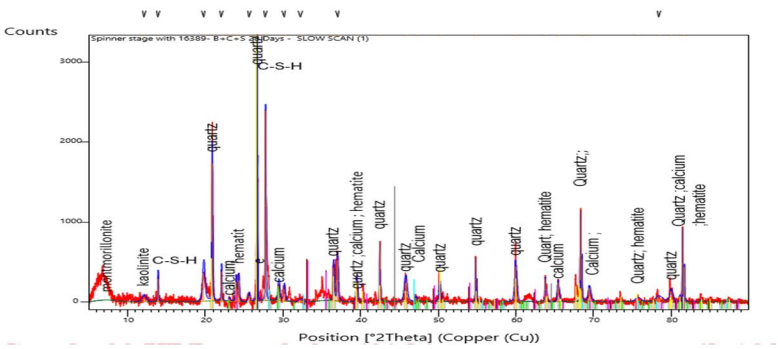


Graph 5.1 XRD graph for Untreated Soil

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Graph 5.2 XRD graph for Bitumen + Cement + Soil



Graph 5.3 XRD for Bitumen + Cement +Soil for 28 days

B. SEM ANALYSIS

The study aims to emphasize the importance of scanning electron microscope to explaining the differences in the physical and mechanical properties. Among several microscopic SEM is important because the soil microstructural formed by the clay particles and additives are observed.

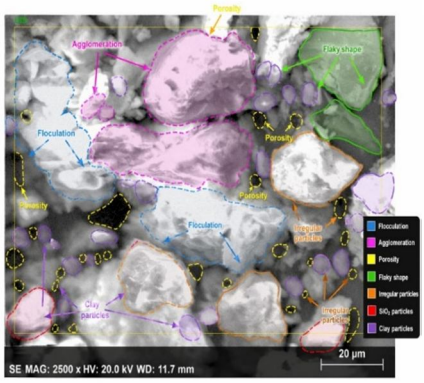


Fig 5.1 SEM image of soil

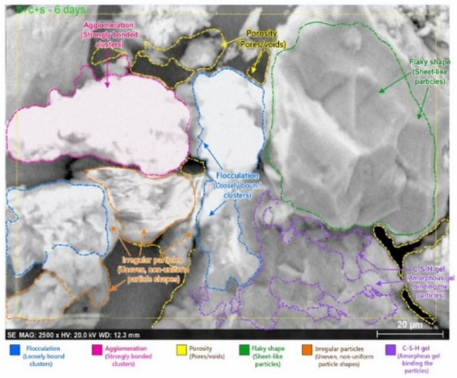


Fig 5.2 SEM of 4% bitumen + 2% cement+ soil

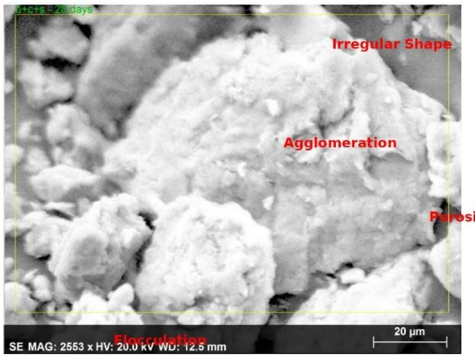
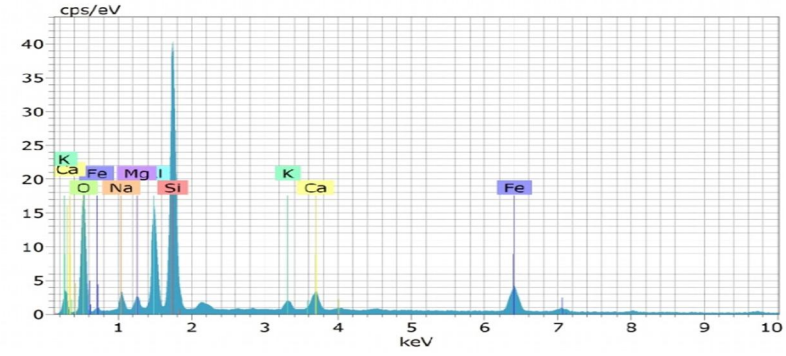


Fig 5.3 SEM of 4% bitumen 2% cement +soil (28-days curing)

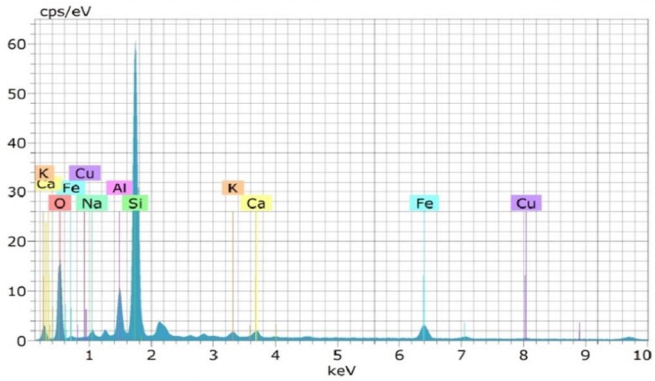
C. EDX Analysis

The colour is the most noticeable feature of soil that can be easily determined in field or laboratory. The main factors that influence soil colour are the organic matter and mineralogy, especially iron oxides. The below tables represent the Energy Dispersive Spectroscopy (EDS) table mentioned detection of different elements present in the normal soil and the soil treated with bitumen + cement.

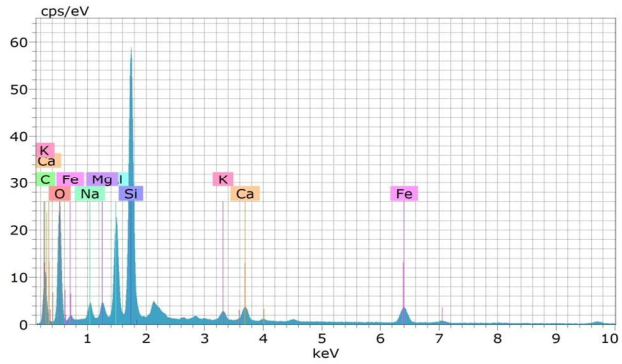


Graph 5.4 XRD graph for Untreated Soil

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Graph 5.5 XRD for Bitumen + Cement + Soil for (0 days)



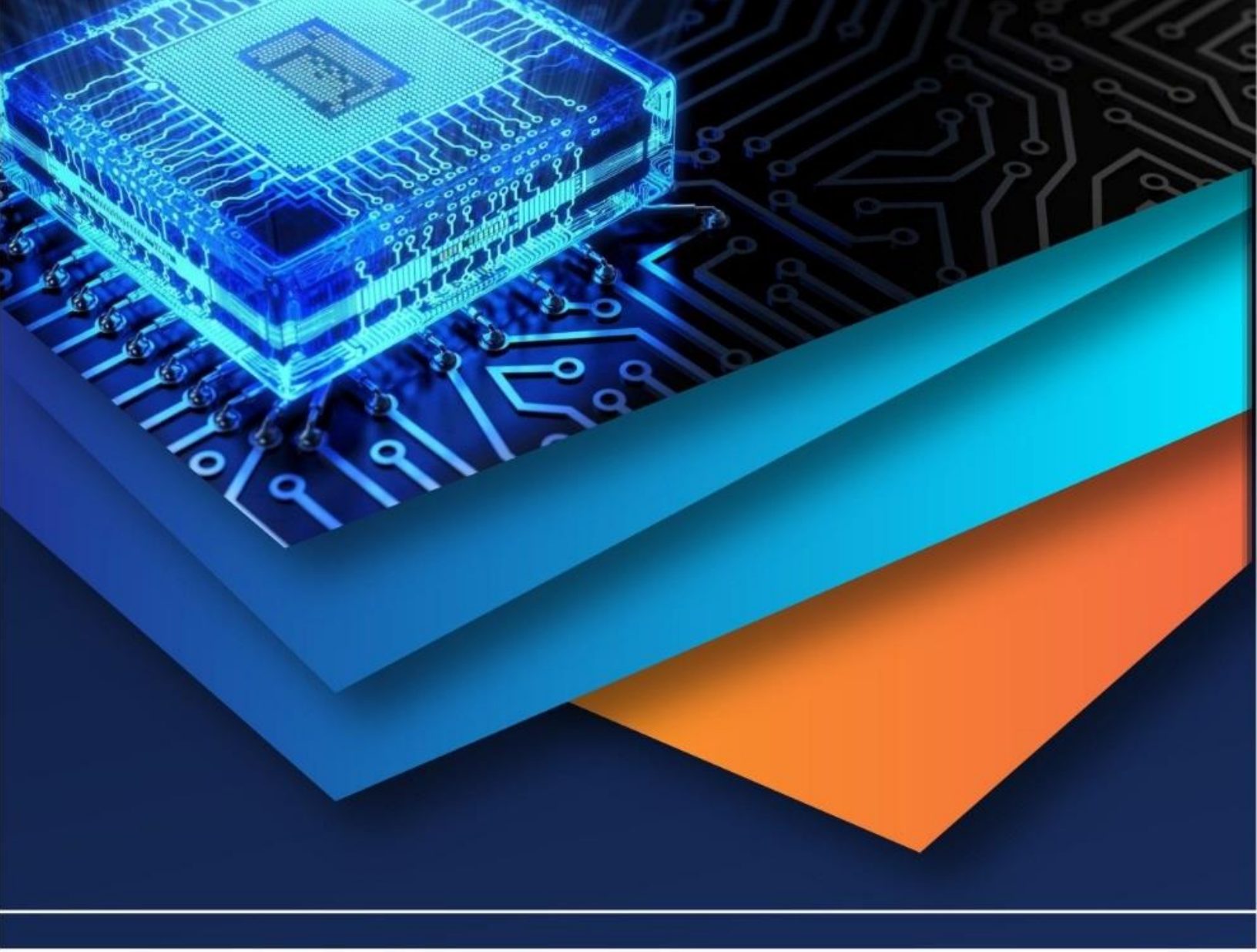
Graph 5.6 XRD graph for Bitumen + Cement + Soil for 28-days

VI. CONCLUSIONS

In this study, an expansive soil is stabilized with different amounts of bitumen, primarily consisting of cement. The objective of this research is to assess the effect of bitumen and cement mix on the unconfined compressive strength and CBR of the soil. Based on the results the following conclusions are made. Addition of bitumen and cement in varying percentages resulted in the increase of optimum moisture content (OMC) and an increase in the maximum dry density (MDD) up to 4% of bitumen + 2% of cement. Later on, with the increase in the admixture content beyond 4% of Bitumen + 2% cement the optimum moisture content is decreased. When higher contents of bitumen and cement are added, the amount of water adsorbed by the stabilizer in the mixing stage may get expelled under the compactive effort thus contributing to the decreased in MDD at higher stabilizer content and reduces after the addition of 6% of stabilizer. Similarly, The maximum value of UCS was obtained as 665 Kpa at 4% of bitumen and 2% of cement content which is 7 times than that of virgin soil.The samples attain significant strength and the gain depends on amount of binder and curing period.Similarly ,The maximum value of CBR was obtained as 25 % at 4% of bitumen and 2% of cement content which is 6 times than that of virgin soil.SEM and XRD studies confirm the formation of reaction products such as C–S–H and calcium hydroxide, which contributed to strength development in the stabilized soil.

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