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ANALYSIS OF MECHANICAL PROPERTIES OF CEMENT TREATED INTERMEDIATE PLASTICITY GRAVEL SOILS BY VARIOUS CURING METHODS

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Abstract

This research examines wheter the Intermediate plasticity-graded gravel soils (GM-GC) treated with cement are suitable for the construction of the road base and sub-base layers.According to IS 2720 Part: IV-1985,depending upon the sizes the IP gravel soils are seperated into categories of various gradations i.e., G25-75 and G25-75, G50-50 and G50-50*, G35-65 and G35-65*, respectively are to be investigated how gradation affects their durability and strength. The CBR and the UCS tests were used to determine the improved strength values of every grade when admixture of cement was increased through the use of a curing method that has partial effect (three days in wet gunny bags and four days in water). Wet and dry tests on mixtures of Intermediate plasticity cementitious graded gravel have been done in order to evaluate the durability of the mixture. IP gravel soils with a G50-50 gradation and a maximum addition of 5% cement by way of partial curing improve compaction characteristics and strength, according to CBR and UCS test results, which are more than adequate in accordance with standards; Consequently, it is recommended for road construction's base and sub-base layers. In a wetting and drying experiment, the IP gravel soils with gradation G50-50 lost 6.4 to 2.5 per cent of their weights with 0 to 10% cement addition, which is below the IRC's permitted limit of 14%:SP-89(Part-II)-2018. The IP-graded gravel mixes (IPGG) had a higher Si/Ca ratio thanthe IP graded gravel mixtures, as determined by SEM and EDS. As a result, cement-treated IPgraded gravel soils' strength and durability are directly impacted by the gravel level, plasticity, and curing process. With lower costs, CT-IPGG improves compaction, strength, and durability.

Keywords: Durability, Gradation, Cementitious, Wetting, drying, Partial Curing, Intermediate Plasticity(IP), Energy Dispersive X-Ray Spectroscopy(EDS), CBR-California Bearing Ratio, Scanning Electron Microscope (SEM)

INTRODUCTION

In addition to influencing the development of a region, the soil is an essential component of any construction. Nature is not at all equal, it is diverse and contains up teen number of soil

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types, few of them are suitable for civil constructions, and some may be not .Natural gravel soils can be found in large quantities all over the world. In India, about 30-40% of the gravel soils are in the Western and Eastern Ghats and Central Deccan Plateau. In some areas, it is also known as lateritic and murram soils. The gradation of the gravel soil's aggregates is one of the factors that affect its compaction and strength properties. it essentially relies upon the molecule measures, its extent in the combinations and the holding among the grains. There are many ways to make this graded gravel soil suitable for use in road construction; cement stabilization is one of them. Because they proved to be a long-desired method of stabilizing local soils and providing a strong economy, the use of cement-treated graded gravel soils in road construction represented a significant advancement The California Bearing Ratio (CBR %) test, which compares the improvement ratio of cement-treated and untreated gravel soils, can be used to determine the strength characteristics of graded gravel soils treated with cement.In the current study, a hybrid curing method was introduced as a partial curing method from both moisture and water curing methods (3 days water curing and 4 days moisture curing) to examine the improvements in strength and durability Method of curing plays a crucial role in cement stabilization to achieve its design strength Traditionally, there are two curing methods: moisture curing and water curing. Cement-treated graded gravel soils can have their microstructure examined by FESEM images, and nanoscale Electron Dispersive Spectroscopy (EDS) analysis reveals the components of the composite and its volume. Experts have previously presented their findings regarding the various civil engineering applications of the efficiency of the treated gravel soils. [1] Has evaluated the efficacy of altering the structure of the road surface's ground base with metallurgical production wastes. The primary strength characteristics of stabilized soils were determined through laboratory and field testing. The ideal dampness content for the combination of slag and ground to produce slag with physical properties and also a high mechanical properties is found to be13-16% in case of sandy type of soils and other soils have recorded 16-18%.Alkali-stabilized cinder samples have a strength that is 37-66% higher than cement-based materials.[2] Talks about the studies that used SEM analysis to improve the microstructural properties of clay. Worked with soil samples collected from the Yamuna river bed in Delhi and utilized SEM-EDAX to examine the elements' atomic and weight percentages. The micro-structural behaviours of soil particles and aggregates can provide an explanation for unexplained physical or mechanical behaviour.[3]The study's major findings from the river bed add to our understanding of the complicated elements Si, O, Al, and Nb. All of the samples in the various ranges contained the highest concentrations of Si O. Additionally, the elements' weight percentage is calculated.SEM pictures of soil tests uncovered platy chips and sporadic and fleecy designs of soil particles.[4] has explored the mechanical tougness and other micro structure properties of top CTRA(concrete-treated reused black) bases and sub-base material tha is delivered by shifting virgin total (VA), reused black-top total (RA) and concrete substance. At cement contents (per cent by weight), cylindrical specimens were prepared using a modified version of the Proctor method of compaction. total) of 2.5, 5.0, 7.5, and 10.0% using various VA and RA combinations. These mixtures can be utilized in place of roller-compacted concrete as bases for concrete pavements or as

repalcements in place of the granular bases or any sub-bases in the felxible pavements of roads.[5] It has been summed up that soils that are stabilized by the cement addition are widely utilised in the pavement construction application due to the high potential for time and cost saving efficiency. The UCS and soaked CBR test were used to investigate the impact that the cement had with respect to the samples that are stabilized by the cement. Evidently, the result demonstrated that the increase in the content of cement proportion to result of 28-dayscompressive strength test, CBR, and modulus of rupture test.[6] investigated the chemical, mechanical, and paramater of microstructures of the soil in conjunction with effects of magnesium slag & cement. By increasing the amount of the cement and the magnesium slag there is an increase in pH was observed, indicating improved conditions of soil for better hydration and pozzolanic reaction execution.[7] The durability of RAP was examined when it was stabilized with Portland cement and mixed with crushed rock (CR).Stabilized RAP/CR material's compatibility and durability were found to be enhanced by CR replacement. For a specific RAP: Cement-stabilized RAP/CR composite compression curves are virtually identical for all cement contents, whereas unstabilized composite compression curves differ; That is, when compared tothe unstabilized RAP/CR composites dry unit weight ,the composites stabilized by cement have a higher maximum dry unit weight.[8] An extensive research these are the subjects involved they are, The strength characteristics and compaction strength of well-graded cement-stabilized aggregates. At a cement-to-dry-weight-of-soil ratio of 6%, 10%, and 14%, well-graded aggregate remains stable. After 7 days and 28 days of curing, the practical result with respect to the strength of cement-stabilized, well-graded aggregate soil was evaluated.M-10-like results were obtained from well-graded gravel stabilized with 10% cement.

1.1. Research Significance

Cement stabilization will soon be shown to be more suitable for pavement design due to its strength and durability. Although there is a general understanding of how gravelly soils stabilize, the effect of aggregate gradation on cement-treated gravel soils and the various curing methods associated with them have not yet been discussed. As a result, the present study examines durability and microstructure in addition to gradation with various curing methods on gravel soils with cement additions of 0, 1, 2, and up to 10 per cent.

2. MATERIALS

2.1. Gravel Soils

The gravel soils that were accessible locally were collected for this investigation from the city of Vishakhapatnam in Andhra Pradesh. Their latitude and longitude are 17.729830 and 83.321495, respectively. In accordance with IS2720 Part-IV, 1985, Before the analysis of the gravel soils for particle size, they are dried and sieved.The gravel soils are categorized as G50-50, in whichfifty per cent of the particles sizes range from 26.5 -12.5 mm (two-thirds), 12.5 to 4.75 mm (thirds), and 0.075 to 4.75 mm (fifty per cent).50% of particles with sizes between 26.5 and 12.5 mm (third), 12.5 to 4.75 mm (third), and 0.075 to 4.75 mm (G50-50*).G35-65

are the sizes of 35% of particles between 26.5 and 12.5 mm, 13% of particles between 12.5 and 4.75 mm, and 65% of particles between 4.75 and 0.075 mm.35% of particles between 26.5 and 12.5 millimetres, 23% between 12.5 and 4.75 millimetres, and 65% between 4.75 and 0.075 millimetres (G35-65*).G25-75 indicates that 25% of particles are between 26.5 and 12.5 mm (one third), 12.5 to 4.75 mm (one third), and 75% are between 4.75 and 0.075 mm.G25-75* indicates that 25% of particles are between 26.5 and 12.5 mm (one third), 12.5 to 4.75 mm (two thirds), and 75% are between 4.75 and 0.075 mm.

Tab-1: Different Engineering properties of the soil

S No	Property of the soil	Factor value	Value
1	**Analysis of the Grain size**		
	• Gravel size (%)	50	37.9
	• Sand size (%)	30	44.0
	• Fines (%)	20	17.9
2	**Characteristics of Plasticity**		
	• LiquidityLimit of soil (LL) (%)	28	36
	• PlasticityLimit of soil (PL) (%)	17	23
	• Plasticity Index of soil (PI)(%)	11	13
3	**Characteristics of Compaction**		
	• OMC(%)	8.6	8.7
	• Max. Dry Density (g/cc)	1.99	2.05
4	**California Bearing Ratio**(%)	26	25
	UCS (MPa)	2.4	2.3

2.2. Cement

Through various laboratory tests using the OPC-53 grade different physical properties of the cement were enumerated.All results of these tests are tabulated in the table-2.

Tab 2:- Physical Properties of Cement

	Cement	Numerical value
A	Settling Time- Initial (min)	90
B	Settling Time- Final (min)	225
C	Strength- Compressive (N/mm^2)	
	3days	24.8
	7days	36.2
D	Specific Gravity	3.09

3. METHODOLOGY & EXPERIMENTAL STUDY

In order to determine various characteristics of the IP gravel-cement mix including CBR and UCS the soils are graded in the following types Soils are graded into(G 25-75 and G 25-75*),(G50-50 and G50-50*),(G 35-65 and G 35-65*)and These soils are then added with cement in varying quantities, ranging from 1% to 10%. The samples of the CBR and UCS were then prepared by the OMC and MDD values by the modified proctor test. After the curing process for seven days the samples were then tested for the values of their CBR and UCS in accordance IS-2720(Part:16) and IS:2720(Part-10), 1991. Additionally, these samples underwent a wetting and drying method in order to obtain the durability results of the sample, in accordance with IRC: SP:89-2018(part 2), as well as microstructural analysis using EDS and FESEM.

3.1. California Bearing Ratio Test

The opted OPC-43 grade cement is mixed with gravel soils that are graded in proportions ranging from 0% to 10% of the total mix. For the purpose of determining the ideal cement dosage for the partial curing method of three days in moisture and four days in water for 7 days, and the outputs of the tests done on the samples are tabulated in Tab 3 and Fig 1 and 2

Improvement ratio =CBR-treated/CBR-untreated
Percentage Increase= {(CBR- T)-(CBR-UT)/(CBR-UT)}

Tab-3: Values of CBR of IPGG soils (three days of moisture and four days wat

CBR values of Intermediate Plasticity Soils-Partial Curing													
		Gradation (%)											
	%	G 50-50				G 35-65				G 25-75			
	Cement	G 50-50		G 50-50*		G 35-65		G 35-65*		G 25-75		G 25-75*	
S. No	Addition	CBR%	Improvement Ratio	CBR%	Improvement Ratio	CBR%	Improvement Ratio	CBR%	Improvement Ratio	CBR%	Improvement Ratio	CBR%	Improvement Ratio
1	0	26		25		23		22		20		18	
2	1	36	1.38	33	1.32	29	1.26	28	1.27	23	1.15	22	1.22
3	2	47	1.80	44	1.76	35	1.52	32	1.45	27	1.35	26	1.44
4	3	61	2.34	57	2.28	44	1.91	41	1.86	33	1.65	32	1.77
5	4	78	3	72	2.88	57	2.47	52	2.36	42	2.1	40	2.22
6	5	94	3.61	87	3.48	72	3.13	68	3.09	52	2.6	50	2.77
7	6	110	4.23	103	4.12	85	3.69	78	3.54	64	3.2	62	3.44
8	7	128	4.92	120	4.8	100	4.34	92	4.18	76	3.8	73	4.05
9	8	145	5.57	135	5.4	114	4.95	106	4.81	88	4.4	83	4.61
10	9	162	6.23	154	6.16	128	5.56	115	5.22	100	5	90	5
11	10	175	6.73	167	6.68	140	6.08	130	5.90	110	5.5	96	5.33

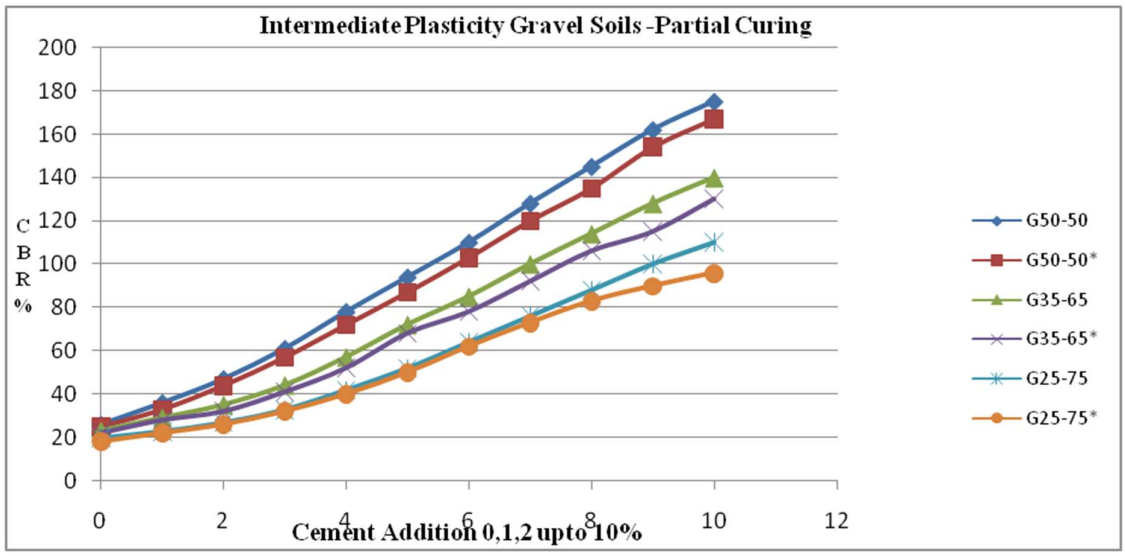


Figure-1: CBR Valuesof IPGG soils (three days of moisture and four days water)

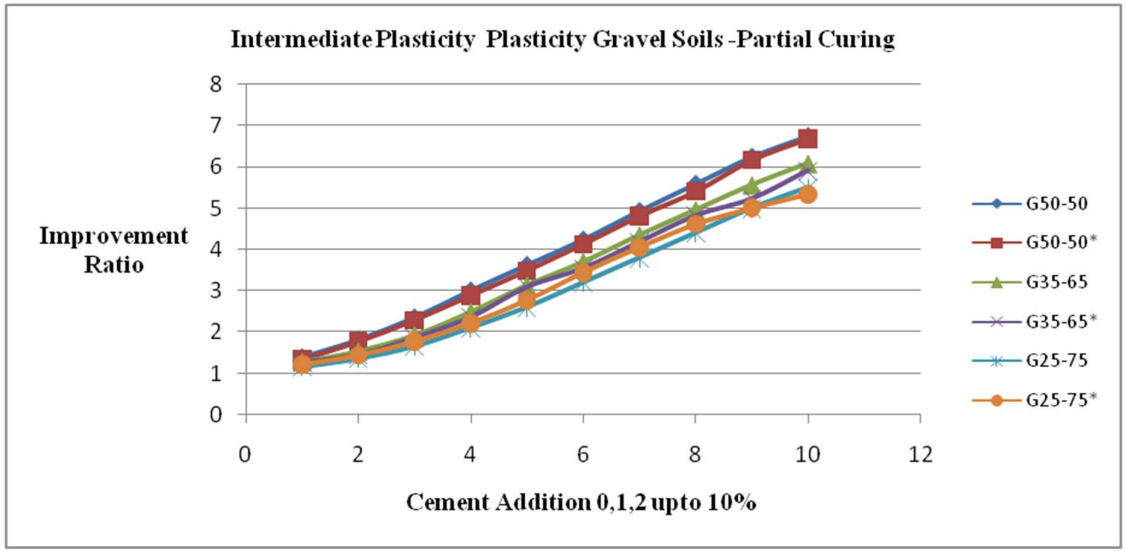


Figure-2: CBR Values of IPGG soils (three days of moisture and four days water)

3.2. Unconfined Compression Strength Test

The graded gravel soils are mixed with the selected OPC-43 grade cement in proportions ranging from 0%, 1%, 2%, and 3% to 10% of the total mix. The test results are presented in Table 4 and Figures 3 and 4 in order to determine the relative compressive properties using the UCS-Test values, its improvement ratio, and the optimal dosage of cement using the partial curing method (3M+4W) in accordance with IS:2720 Part-10, 1991.

Tab-4: UCS Values of IPGG soils (three days of moisture and four days water)

UCS Values of Intermediate Plasticity Graded Gravel Soils -Partial Curing Method													
		Gradation (%)											
		G 50-50				G 35-65				G 25-75			
	%	G 50-50		G 50-50*		G 35-65		G 35-65*		G 25-75		G 25-75*	
S. No	Cement Addition	UCS (Mpa)	Improvement Ratio	UCS (Mpa)	Improvement Ratio	UCS (Mpa)	Improvement Ratio	UCS (Mpa)	Improvement Ratio	UCS (Mpa)	Improvement Ratio	UCS (Mpa)	Improvement Ratio
1	0	3		2.8		2.7		2.5		2.2		2	
2	1	3.3	1.1	2.9	1.03	2.9	1.07	2.6	1.04	2.4	1.09	2.2	1.1
3	2	3.5	1.16	3.1	1.10	3.2	1.18	2.8	1.12	2.5	1.13	2.4	1.2
4	3	3.8	1.26	3.4	1.21	3.3	1.22	3.1	1.24	2.8	1.27	2.6	1.3
5	4	4	1.33	3.6	1.28	3.5	1.29	3.3	1.32	3.1	1.40	2.8	1.4
6	5	4.2	1.4	3.8	1.35	3.8	1.40	3.5	1.4	3.3	1.5	3.2	1.6
7	6	4.7	1.56	4.3	1.53	4.3	1.59	3.9	1.56	3.6	1.63	3.3	1.65
8	7	5.5	1.83	4.5	1.60	4.6	1.70	4.1	1.64	3.7	1.68	3.6	1.8
9	8	6.7	2.23	5.7	2.03	5.2	1.92	4.6	1.84	3.9	1.77	4.1	2.05
10	9	7.3	2.43	6.8	2.42	6.4	2.37	5.6	2.24	4.5	2.04	4.6	2.3
11	10	8.2	2.73	7.6	2.71	7.1	2.62	6.8	2.72	5.6	2.54	5.4	2.7

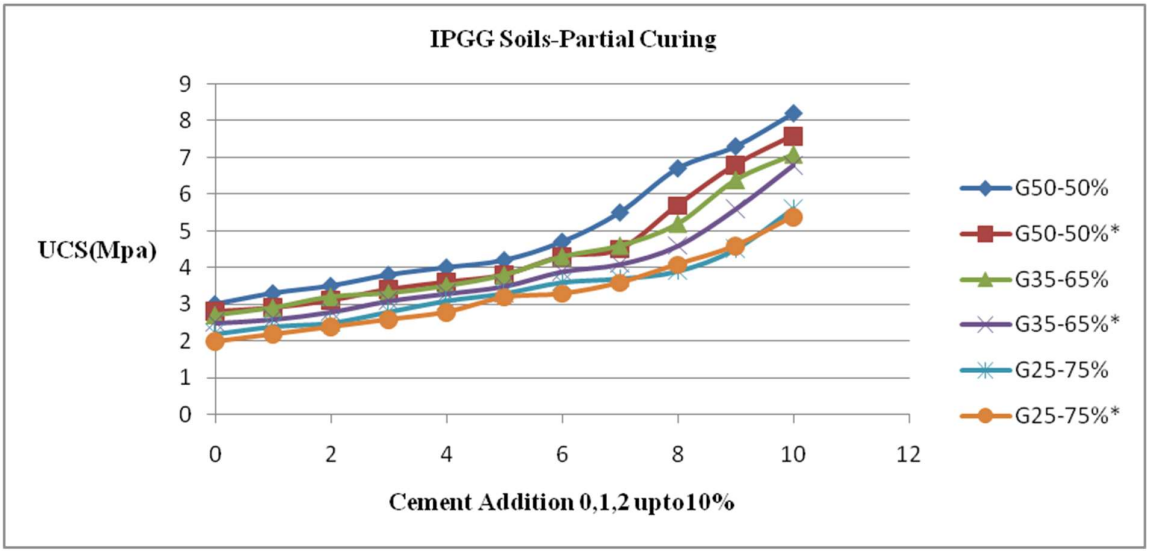


Figure-3: UCS Values of IPGG soils (three days of moisture and four days water)

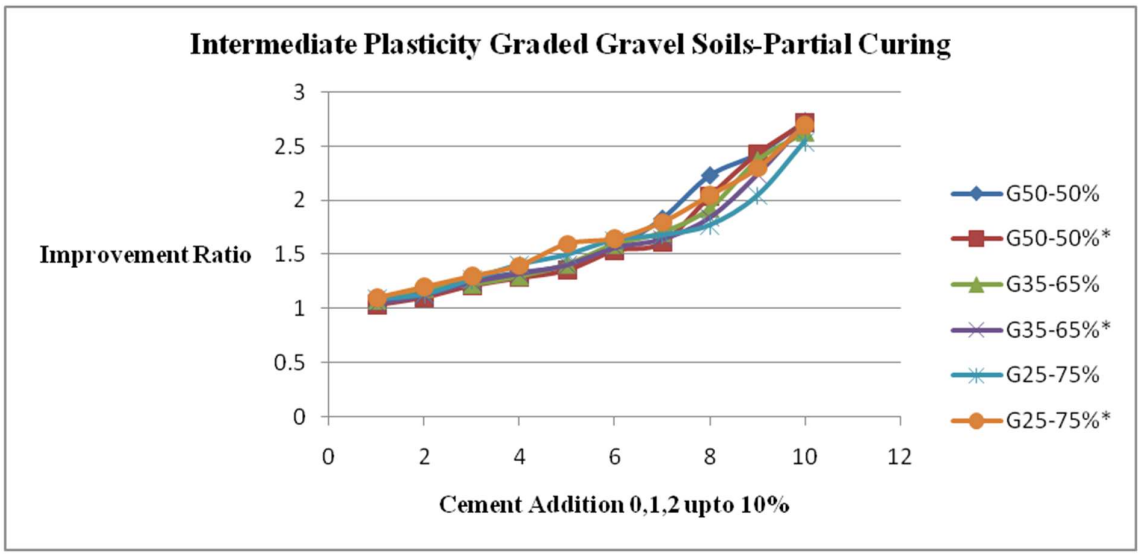


Figure-4: UCS Values of IPGG soils (three days of moisture and four days water)-Improvement Ratio

3.3. Durability test

ASTM D559 used cement graded gravel soils for the drying and wetting tests to see how moisture and dryness affected the mix's performance over time. For a total of twelve cycles, cylindrical samples were subjected to alternate wetting and drying examinations by being brushed on each side. Mixtures with a high porosity absorb more water during the wetting phase, resulting in increased particle disintegration and weight loss. After 12 cycles, graded gravel soil G50-50 and G50-50* with the optimal cement addition percentage experienced a loss of mix of 6.4 to 2.7%, graded gravel soil G35-65 and G35-65* with the optimal cement addition percentage experienced a loss of mix of 6.6 to 2.8%, graded gravel soil G25-75 and G25-75* experienced a loss of mix of 7.7 to 3.4%.

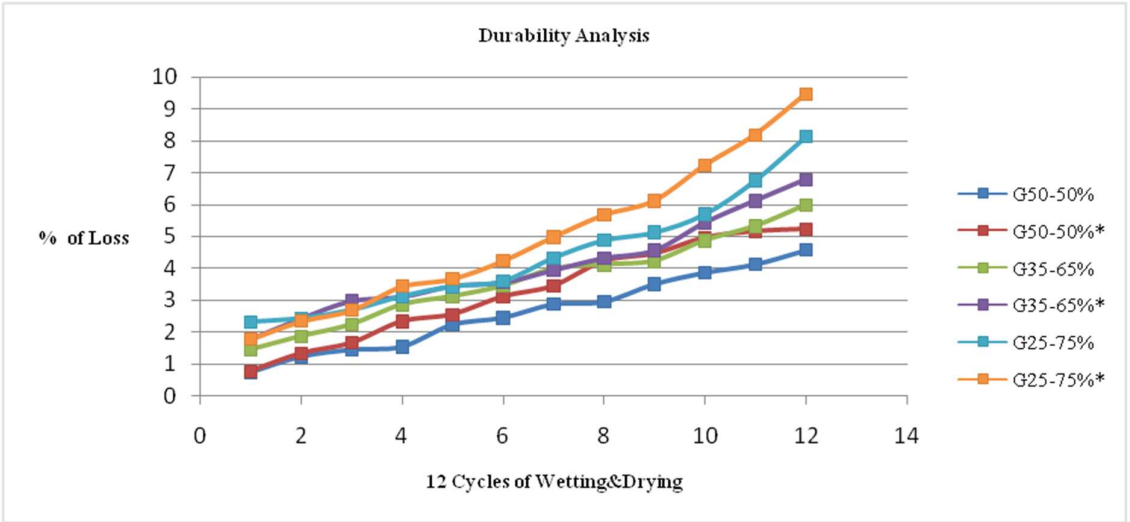
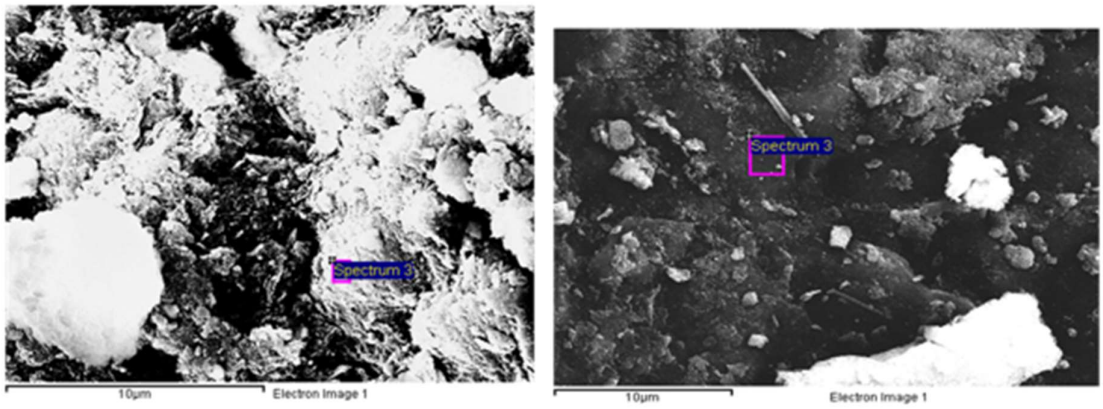


Figure-5: Durability Analysis by Wetting& Drying Method

3.4. Microstructure examination

On cement-treated Intermediate plasticity-graded gravel soils, scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS) analysis were performed to comprehend the material's microstructure. The pores and products are identified through the capture of SEM images. Moderate pliancy evaluated rock (IPGG) blends comprise countless voids and slender formed structures contrasted with concrete-treated Middle-of-the-road versatility reviewed rock (CT-IPGG) blends. The elements and their composition in cement-treated Intermediate plasticity-graded gravel mixes were analyzed using the EDS method. The test results show that the cement-treated Intermediate plasticity-graded gravel mixes have a lower Si/Ca ratio (0.66) than the Intermediate plasticity-graded gravel mixes (1.77). The lower the Si/Ca ratio, the weaker the material will be. Table 5 and Figure 6 show the laboratory results, respectively.



a) b)

Fig-6: SEM images a) IPGG mixes b) CT-IPGG mixes

Table-5: The contents of oxides (%) containing K from EDS analysis

Elements	C	O	Mg	Al	Si	K	Ca	Fe
IPGG	12.17	36.87	2.67	3.44	12.33	1.86	18.64	12.02
CT-IPGG	14.67	42.54	3.56	5.78	18.87	2.34	10.65	1.59

4. RESULTS AND DISCUSSIONS

The selected local soils are categorized as IP gravel soils with OMC based on the test results:8.6%, MDD: CBR, 2.06 g/cc:26 percent each.The classified IP gravel soils are divided into three grades: G50-50&G50-50*, G35-65&G35-65*, and G25-75&G25-75*. They are then mixed with varying proportions of regular Portland cement, ranging from 1% to 10%.In the present study, a hybrid method of curing was introduced as a partial curing method from both moisture and water curing (3 days water curing and 4 days moisture curing) to examine the improvements in strength and durability. Traditionally, there are two curing methods: moisture curing and water curing.The test results indicate that the OMC&MDD and cement content of

IPGG soils rise from 0% to 1% to 2% to 10%.According to MoRTH specifications, CBR% for base and sub-base layers are 80 and 30 respectively, so it is more than adequate. IP gravel soils with grades G35-65 and G35-65* have CBR % values of 85 to 100 and 92 to 106, respectively, with 6-7&7-8% of cement addition by partial curing method i.e., three days of moisture and four days water. According to MoRTH specifications, the CBR percentages for the base and sub-base layers are 80 and 30 respectively, so it is more than adequate. Intermediate plasticity soils with gradations of G25-75 and G25-75* have CBR percentage values of 88 to 100 and 83 to 90, respectively, with 8 to 9 percent of cement addition under the partial curing method i.e., three days of moisture and four days water. The halfway pliancy rock soils (GM-GC) with degree G50-50&G50-50*, have UCS(Mpa) upsides of 4.7 to 5.5&4.5 to 5.7 with 6-7% and 7-8% of concrete expansion under the fractional restoring strategy i.e., three days of moisture and four days water ,according to IRC:IRC and 37-2012:The required UCS(Mpa) values for the cement-treated layer in the SP-89(Part-II)-2018 code of provisions are 4.5Mpa, which is more than sufficient.According to IRC, G35-65 and G35-65* have UCS(Mpa) values of 4.6 to 5.2 and 4.6 to 5.6, respectively, with 7-8% and 8-9% cement additions using the partial curing method i.e., three days of moisture and four days water:IRC and 37-2012:The required UCS(Mpa) values for the cement-treated layer in the SP-89(Part-II)-2018 code of provisions are 4.5Mpa, which is more than sufficient.According to IRC, G25-75 and G25-75* have UCS(Mpa) values of 4.5 to 5.6 and 4.6 to 5.4 when using the partial curing method i.e., three days of moisture and four days water, IRC and 37-2012:The required UCS(Mpa) values for the cement-treated layer in the SP-89(Part-II)-2018 code of provisions are 4.5Mpa, which is more than sufficient.The improvement ratio also shows that the improvement ratio goes up when more cement is added to the IPGG mix. At the initial cement dose, which ranged from one to five per cent, a moderate rate of growth was observed; however, after five to ten percent cement addition, a rapid rate of growth was observed.In a wetting and drying experiment using IPGG soils, the percentage of mix lost after 12 cycles for graded gravel soils G50-50 and G50-50* with a cement addition of 6% to 2% and 6.6 to 2.8 percent respectively; graded gravel soils G35-65 and G35-65* with an optimal cement addition of 3% to 3% and gradation gravel soils G25-75 and G25-75* with an optimal cement addition of 7% to SP:89 to 2018 (Part II).The Images from the FEMSEM clearly showed that whencontent of cement increased the voids present in mixes have gradually shown a decline.As porosity in the blend diminishes the thickness of the blend increments which further works on the CBR and UCS separately.TO find out the elements existing in the composites the EDS analysis was also done. The test results shows that Si/Ca ratio is declining when cement quantity is increased in the mixes.The cement-treated IPGG mixes have a lower Si/Ca ratio (CT-IPGG:0.66) than the graded gravel mixes with Intermediate Plasticity (IPGG:1.77), the strength will be lower the higher the Si/Ca ratio.

5. CONCLUSIONS

The following conclusions are drawn from a critical analysis of the study's findings and extensive laboratory experimentation on cement stabilization of gravel soils.

- The gravel soils that have been chosen are gravel soils with intermediate plasticity (GM-GC).
- It has been demonstrated that optimal moisture content (OMC)& also the maximum dry density rises as cement content of IPGG soils (GM-GC) increases from 0% to 1% to 2% to 10%.
- Among the selected three curing methods, partial curing, moisture curing, and water curing, partial curing demonstrated superior strength and durability characteristics.
- Among the various grades, Gradation G50-50 has demonstrated superior strength and durability.
- The results of the CBR and UCS tests show that intermediate plasticity gravel soils with a G50-50 gradation and a maximum of 5% cement addition can improve their strength and compaction characteristics by using the partial curing method i.e., three days of moisture and four days water). According to standards, it is more than adequate; consequently, it is recommended for road construction's base and sub-base layers.
- In an experiment of wetting and drying, the IP gravel soils (GM-GC) with gradation G50-50 lost 6.4 to 2.5 per cent of their weights with 0 to 10% cement addition, which is below the IRC-approved limit of 14%:IRC and 37-2012:SP-89(Part-II)-2018.
- Images from FESEM clearly showed that as there is an increase in cement content, voids in the mixes gradually decreased. The UCS & CBR%, respectively, rise as the mix's porosity decreases, resulting in an increase in density. To find out the elements existing in the composite the EDS analysi was also performed. The results of the tests show that, as there is an increase in the quantity of the cement gradually theSi/Ca ratio goes down. The cement-treated IPGG mixes have a lower Si/Ca ratio (CT-IPGG:0.66) than the graded gravel mixes with Intermediate Plasticity (IPGG:1.77), the Si/Ca ratio is inversely proportional to the strength.
- With a lower Si/Ca ratio, the tested gradation G50-50 of Intermediate plasticity gravel soils improves compaction, strength, and durability with maximum of 5% addition of cement under partial curing i.e., three days of moisture and four days water. For the construction of the road's base and sub-base layers, it can be recommended.

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