Journal of Research Administration
Society of Research Administrators International

A DETAILED REVIEW ON DIFFERENT GEOPOLYMER BASED DOSAGES IN SOIL STABILIZATION

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Abstract. In the stabilization of soft and weak soils, Ordinary Portland cement plus lime are often utilized. According to several researches, the manufacture of cement creates a large quantity of Carbon dioxide gas, which would be the primary cause of global warming. Geopolymers (Geo-P), that are cheap as compared to other, have great UCS and durability's, and create less Carbon dioxide than Ordinary-PC and Activator, offer an alternative to many building materials. Geopolymers are sustainable composites materials made from alkali- treated alum inosilicate wastes including such fly ash, rice husk. Different uses of geopolymers binders, such as the creation of Eco-friendly concretes, coated elements, brick, and as a means of stabilization of the soil, have been investigated during the past 30 years. Furthermore, the manufacturing of geopolymers uses less energy. This review article focuses on research into the application of various geopolymers as soil stabilizers. The implications of several geopolymer factors such as percentage mixes (percent), curing time (days), Alkaline Activator type, and Unconfined Compressive Strength (UCS) determinations for various geopolymers have been reviewed in this paper. Soil stabilization, sub - base and base course of paving constructions might all benefit from geopolymer-stabilized soils. Additionally, this soil stabilization method is still not much more cost-effective and ecologically friendly, but also produces good usage commercial waste material.

1. INTRODUCTION

Because of their low shear strength and excessive compressibility, constructing buildings and infrastructure on thin or weak soils is very dangerous. Differential settlements are a risk as a result of this. As a result, it's critical to improve soil qualities by using stabilizing procedures that can adapt to changing conditions. Chemical stabilization of soft soils is now a typical strategy for improving particle interfacial bonding by adding binding material like Portland Cement (OPC) and limestone into the soil [1][2]. Because of its appropriate mechanical qualities, availability, and affordability, OPC is the preferred material in geotechnical engineering projects. As a result, it's employed in a variety of stabilizing methods such deep concrete mixing and drilling [3]. However, over reliance on cement has resulted in high CO2 emissions, natural resource depletion, and dust creation, all of which are environmental problems. OPC manufacture is a high-energy process (5000 MJ/t PC) that emits 0.7–1.1 tons of CO2 every tons of OPC. Apart from the negative effects on the environment, OPC often exhibits higher plastic shrinkage as well as decrease in strengths considering Mechanics prospect as a result of water loss also insufficient moisture from start [4][5]. This is a significant disadvantage for geotechnical uses, particularly in arid areas, since large-scale wet curing is not possible. OPC is partly substituted with materials including fly ash (FA) [6], GGBS, red gypsum [7], rice husk, and recycled glass powder [8] in order to lessen environmental consequences and improve mechanical performance. In terms of moisture resistant and shrinking, the partly replaced OPC specimens had improved mechanical characteristics and durability [8, 9]. However, the substitution is often confined to small amounts, and OPC's environmental effect remains a problem.

Geo-P has developed as a feasible option for OPC by recycling aluminosilicate-rich contaminants into a value- added binding materials [9]. Apart from environmental considerations, geopolymers stabilized soils have shown better qualities in terms of compact microstructures, increased mechanical properties, and volume stability in order to satisfy the criteria of engineered clayey soil [10-12]. Mechanical characteristics of geopolymers stabilized clayey soils was evaluated using various mixing designations. The shrinking strain of geopolymer stabilized soils was shown to be significantly less than that of non-stabilized or Portland Cement- incorporated soils. The sluggish evaporating pore fluids from the stabilized soil’s structure were related to the low shrinkage [13]. Stabilization of soil refers to the altering of soil molecular characteristics outside of their normal state to improve stability and durability, allowing the structural load to be sustained and transferred without failure during its service life. Chemicals or mechanical procedures have traditionally been used to remediate expansive soil [14]. In the chemical treatment procedure, soil stabilizers such as limestone, concrete, bitumen’s, and fly ash are applied. Various commercial wastes, by-products, or natural resources, on the other hand, are used in soil treatment to limit the faults of those substances. Not all of these treatments, however, are applicable to all soil types. Each kind of treatment was advised in general, based on the state of the soil, its structure, and its qualities. Chemical treatment procedures can endure harsh environmental conditions such as acid rain when compared to mechanical stabilizing methods, however they are not regarded eco-friendly [15]. As a result, a virtually ecologically acceptable chemical treatment procedure known as "Geopolymer" is needed to reinforce expansive soil for use in the building industry [16]. Figure 1 illustrates the fundamental geopolymerization technique for soil stabilization where untreated soil and alkali activator like sodium hydroxide (NaOH), Sodium Silicate (Na2SiO3) or liquid activator are mixed with Fly-Ash or slag to get stabilized soil with or without Soil with gel formation.

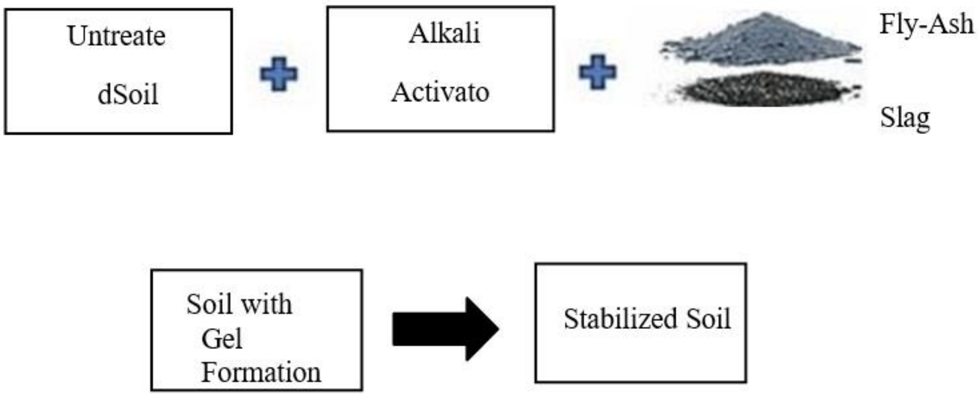

Fig-1 Shows the basic procedure of Geopolymerization for Soil Stabilization

2. GEOPOLYMER AND GEOPOLYMERIZATION MECHANISM

Various activating material like Alkali-silicate or hydroxyl is infused in powdered forms with binders to make a solid alumino - silicate components[17]-[20]. Various researchers have divided the term "geopolymer" into four categories: alkali bonded ceramic, aqueous ceramic materials, earthy cemented, and biopolymers. The reaction process of Geo-P was first studied in 1978, with the goal of expanding the use of Geo-P as a synthetic polymer composite in a range of manufacturing purposes. Geo-P molecular unit is often described as shown in figure-2 where a series of interconnecting networks and strings of naturally occurring materials linked by covalent bonds[21]]22]. The interconnecting material are Poly Silicone, Poly-Silixo, Poly Sialate, Poly-Silalate- Siloxo Poly- Phospho- Sialate , Poly- Phospho- Siloxo , Poly-Phosphate and Poly- Sialate-Disiloxo linked by covalent bonds as shown in figure-2.

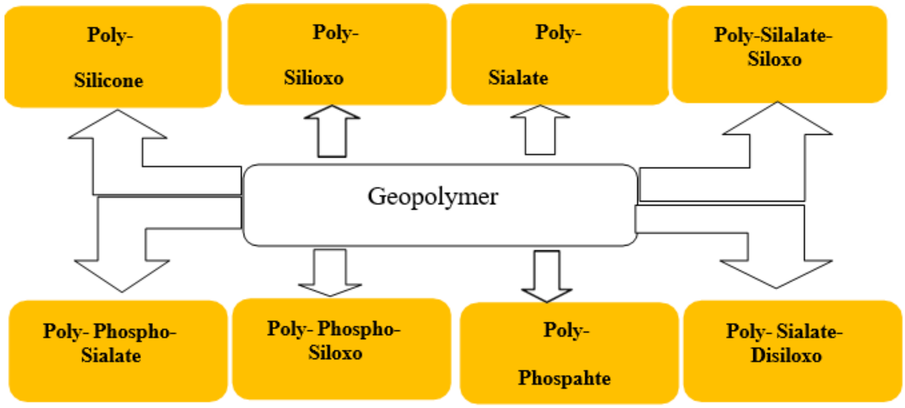

Fig-2 Geopolymer molecular unit

Duxson et al. [23] presented a polymerization method that involves numerous phases that are described in the conceptual framework. Figure 3 depicts the unified framework of geopolymerization. The framework assumes that geopolymerization begins with the alkaline solutions dissolving the source materials, causing the alumino - silicate bond to rupture and the liberation of silica and alumina, mostly in the primary sources [24-25]. Alkali potassium ions such as potassium, sodium, or limestone neutralize the negatively charged of the aluminosilicate chain. As a result, the amount of silica and alumina in the source material influences geopolymer effectiveness. Additionally, when the alkalinity of the solution rises, so does the amount of dissolved material. This rate determines how long it takes to achieve saturation, after which the aluminosilicate solution becomes supersaturated [26-27]. The major condensation process then starts, and the aluminosilicate gel precipitates as oligomers, resulting in bigger and more stable networks. When the solution includes a greater concentration of Si and Al, the first polymers (Gel 1) is generated. As the reaction, progresses, more Si penetrates the solutions, leading to greater Si concentrations in the gels (Gel 2). When the aluminosilicate species' condensation rate exceeds the dissolution rate, the initial setting is activated. Eventually, polycondensation and rearranging activities generate increasingly linked 3D networks, resulting in the final geopolymer matrix.

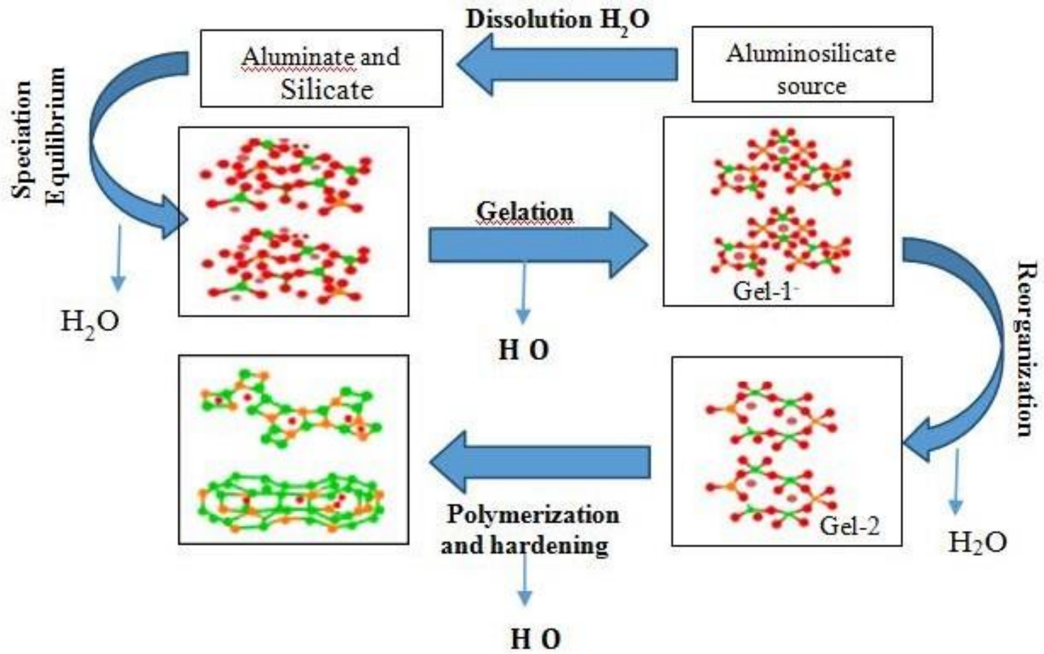

Fig-3 Geopolymerization Process

Geopolymer concrete is more corrosion and fire resistant, has higher compressive and tensile strengths, and can reach maximum strength quicker (cures fully faster). Additionally, it shrinks less than traditional concrete. Uses of Met kaolin-based Geopolymer are as follows:

1. Construction of pavements, Construction of retaining walls,
2. Commercially available geopolymers might be utilized in fire- and heat-resistant coatings and adhesives, medical applications, high-temperature ceramics, novel binders for fire-resistant fiber composites, encapsulation of hazardous and radioactive waste, and new concrete cements.
3. Construction of water tanks, precast bridge decks.

3. LITERATURE REVIEW

Geopolymers, that are used to start making composite material, earth concrete blocks, cement paste, and pavers, were the subject of numerous studies. The use of geopolymer binders to stabilize soil is a relatively new phenomenon. To stabilize clayey soil, researchers used GGBS, RGP, Rice husk and fly-ash-based geopolymers [28-29]. This section focuses on UCS strength test, Activator, Curing time, and previous studies on soil stabilization with fly ash, GGBFS-based geopolymer, Rice Husk, and recycled Glass Powder.

Fly-Ash Based Geopolymer Soil Stabilization:

In latest days, a fly ash-based Geo-P has been widely used to replace cement in soil reinforcement, with the additional benefits of more efficient energy use and less hazardous emissions [30,31, 32].

The purpose of this paper [33] is to employ a high-unburned-carbon fly ash, which has a lower market demand since it could not be used in PCO, as per ASTM C618. The ca sources for alkali-activated cementitions based on this commercial by-product. The AACs were employed to enhance soils of the A-4 kind. The soil treated was tested for compression strength, flexural modulus, and durability. The UCS improved by 119.40 percent after seven cured days and 78.60 percent after 28 Cured Days under wet circumstances, according to the findings. Furthermore, after 11-12 rainy and dried cycles, the mass loss percentages were lower than Colombian standards for stabilized soil. As a result, the suggested solutions are comparable to existing chemical stabilizing procedures.

This study [34] looks at the strengths improvement and carbon footprint of Fly ash based GP-stabilized marine clay based on Ca-Carbide Residual (CCR). A combination of sodium silicate solution (Na2SiO3) and NaOH was utilized as a liquid alkaline activator (NaOH). At a silicate solution /Sodium Hydroxide = 7/3 ratios as well as Activator/Fly-Ash = 1.0 for clayed hydro-concentration, the FA geopolymer (without CCR) stabilized CIS reached its maximum strength (LL). CCR has three different effects on the strength of Fly Ash- GP stabilized. In practice, the active zone is defined as the range of CCR concentration between 7% and 12%. The addition of 12 percent CCR may increase the strength of the FA cementitious materials by up to 1.5 times. GP stabilized soils had carbon footprints that were around 22-43% lower than either cement based sample at equal strengths with range in between of 400-800 kPa. Fly Ash based GP's efficiency as an eco-friendly soil stabilizer alternative to normal OPC is shown by its lower ecological impact at high strength.

In [35] proposed a Recycled Concrete Aggregate strength test on fly Ash based Geo-P mixed with to improve the compressive as a lightweight stabilizing pavement base composed is the subject of this study [35]. A combination of solution was used as an aqueous alkaline activating element (L). Curing days range between 7- 60days, strength tests were evaluated. The findings show that when the Rice Husk with fly ash and Sodium Hydroxide/Sodium Silicate ratios fall and the cured duration rises, the UCS of proposed GP stabilized RCA rises with a lower unit weight of 21.10-kiloNewton/cubic meter. The feasibility of FA-RHA-GP stabilized RCA as an alternate stabilized road foundation material is confirmed by this research. The fly ash level of the samples was varied from 5-20%, and the testers were treated with a lesser quantity of 5M Sodium Hydroxide solution. The UCS tests, CBR tests, and elastic modulus values of the stable specimens were determined in the laboratory. Micro structural investigation was also carried out utilizing EXD, scanning electron microscopy, and Fourier transformed based IR spectroscopy to get insight into to the mechanical properties. The current research concludes that a GP-based on fly ash might be utilized to stabilize black cotton soil for roadway preparations [36].

The feasibility of employing PVA and high calcium FA-GP to increase the UCS of SC in deep soil uses is investigated in this study. Sodium silicate+ NaOH were used to make the aqueous activator.

The best component for FA GP stabilized SC in terms of workability and cost was determined to be 1.0LL, Sodium silicate+ NaOH = 1, Fly Ash around 40%, and Activator/Fly Ash around 0.6, results in a strength of 1026 kPa with 28 cured days. PVA enhanced the 7-day and 28- day UCS values by 40% and 42%, respectively, when contrasted with those of the specimen lacking PVA. This study's findings will encourage the use of PVA-FA GP as sustainable soil stabilization alternate to OPC. The mechanical characteristics of hazardous Clays stabilized utilizing an FA-GP and BFSS substitution are investigated in this work [38]. 20:10 was shown to be the optimal FA: BFS proportion. Increased sintering temperature expedited the proposed process, leading in better strengths at extremely high temperatures. The usage of waste elements from furnaces and FA to stabilize unsettled soil in construction purpose will result in huge financial saving and long-term life cycle of the project efficiency.

Experiments on the stabilization of BCS utilizing FA-RHA based GPs are carried out in this work. The alkaline activator solution is made up of sodium silicate (SS) and NaOH (SH) at a ratio of 1.5. The results of the trials show that Geopolymerization significantly enhances the strength of BCS while also making it less susceptible to swelling and shrinking. As a result, stabilized soil with blending GP-Ash may be utilized as a long-term replacement for traditional stabilizers. All GP-stabilized BCS has a UCS of 1500 kPa at the conclusion with cured days around seven. [39]

Table-1 Shows the comparison of different Fly Ash Based GP recent studies

Refere-nces	GP	Activator	Other findings	UCS Findings	Curing Days
[33]	fly ash	liquid alkaline activator	-	UCS=119.4% increased, 78.6%	7 28
[34]	CaC Residual+FA	sodium hydroxide (NaOH) silicate solution (Na2SiO3)	UCS improves 1.5%	400,600 and 800 Kilo Pascal	7 14 28
[35]	FA and RHA	NaOH and Na_2SiO_3	-	UCS of FA-RHA-GP stabilized with lower unit weight of 21.1 kN/m3	7, 28 and 60
[37]	polyvinyl alcohol(PVA) and FA	NaOH and Na_2SiO_3	UCS increased upto percent	1026 kPa	28

[39]	FA based Geo-P	NaOH	-	1500 kPa	7

Ground granulated blast furnace slag Based Geopolymer Soil Stabilization

The best additional component for reinforcing poor-quality soil was GP made with GGBS. BFS comes in three different forms: granule- fine, and non-crystalline. As contrasted to the treated soil within the usual cementitious approach, the unprocessed soil reactivated with the GGBS derived alkaline medium had the highest UCS value.

This study looked at the sulphate attacks resilience of a LAS stabilized clay made up of GGBS, sodium silicate, and CCR soil [41]. Stabilized specimen is soaked in a sodium sulphate solution for 3-120 days. The suggested sample has greater sulphate attacking resistance in relation to water absorbing and strengths, as per the results. The sample suggested is crack free for almost 120 days of observation in the Sulphate solution. The soil remains unaltered for 90 and 120 days of soaking, it develops extensive lateral and longitudinal fissures. The LAS stabilized soil's pressure steadily declines from 750 to 800 kilo Pascal to 540– 700 kilo Pascal as soaking duration increases.

This research [42] aims to generate a novel, environmental sustainable composite material by blending OPS with GGBS. During 56 curing age, the newly produced adhesives included 35 percent Cement, 35 percent Blast furnace slag, and 30 percent HCFA, with strength and surface electrical performance of 30.80 MPa and 103.5 k/cm across both cases. The shape of the created binding material changed dramatically over time, as evidenced by SEM imaging. The proposed work considering all the factors the UCS might be framed with a determination coefficient, R2, of 0.890. This new binders has the significant effect on the amount of construction materials while simultaneously cutting CO2 emissions.

Another study [43] looked at the problems of degraded (crumbled, split, and decreased strength of the soil) pavement surface structures constructed on clay. The impacts of Furnace + FA on potassium hydroxide activator (aqua) after one and seven curing days are examined. The mass ratio of l employed was adjusted to 2.0 and the molar mass of Hydroxide were adjusted at 10M. With a Geopolymers to KOH activator ratio of 1.5 as well as a Sodium silicate to Hydroxide ratios of 2.0, the greatest strength obtained was 3.15 MPA after different curing periods. These results will contribute to the improvement of knowledge in the field of soil consistency GPs, especially for application in road construction.

This research [44] compares the mechanical characteristics of clay soils stabilization of soil with volcanic ashes (VA) predicted GP and Portland cement. The effects of ambient curing and duration, as well as potassium hydroxide activator/clay, are evaluated. The suggested layer's UCS grew from 0.20 to four MPa and two to twelve MPa. When the soil were partly substituted by 15% weight percent of the bindings. In dried circumstances (DC), GP pretreatment has been proven successful, although OPC works brilliantly in wet situations (OC). The presence of liquid and acidity in the GP and OPC hydration kinetics accounts for the disparity. The UPC of GP-treated soil is improved by increasing the molar mass of activator/clay. Furthermore, as contrasted to OPC, the improved energy absorbing throughout all GP sample reveals the structure's greater ductile.

In this paper [45], the GP source material was GGBC slag, and the alkali activator was na2co3 solution. As according previous research, different parameter which is important parameters for stabilized soil were discussed and, as a result, as I/p parameters for Strength Predictor. The proposed findings of this investigation demonstrated that GMDH and Artificial Neural Network are viable methods for predicting UCS values in GP-stabilized soils. The outputs of the two methodologies for forecasting unlabeled data were good regardless on the coefficients of determination that were 0.9670 and 0.9740. Furthermore, a unique direct formulation based on the GMDH-NN approach is offered, which may be utilized to calculate UCS with simplicity.

This paper [46] discusses the use of anhydrous sodium metasilicate (ASM) powdered as an alkaline fluid binding used in stabilization of soil to improve the strength qualities of soft clay. The effects of elasticity ratio, moisture content, and curing period on the strength development of the GP-stabilized clay samples were determined. This study reveals that anhydrous sodium metasilicate powder may be used instead of KOH to form Geo-P binders that might contribute to even more realistic Geo-P applications in the stabilization of soil.

Pavement development generally advocates all use of cements/chemically prepared foundations and sub base. Therefore, this paper [47] investigates different soil sample replaced with laterite soil as the Stabilized Lateritic Soil replaces a base used for roadway constructions, the aggregate base used. The proposed soil sample uses a mixture of 25percentage GGBFS and alkaline treatments including OH and NaSi concentrations of 4-6%, silicon modulus of 1/2-3/2, and a fixed water binding content (w/b) of 1/4. For just a sample treated having 5 % sodium oxide and 1.0 Ms cured for twenty eight days, UCS of 5452 and 6593 kilo Pascal was reached for the medium and heavy compactions, correspondingly. The development of proposed results in a higher strength throughout the curing phase. Wetting–drying and freezing–thawing experiments were used to assess the samples' durability.

Table-2 Shows the comparison of different GGBS Based GP recent studies

References	GP	Activator	Other findings	UCS Findings	Curing Days
[41]	GGBS	Na2SO4	A gradual and steady drops occurs in LAS stabilized soil	750 to 800 kPa to 540–700 kPa	3-120 Days

[42]	GGBS	NaOH	Coefficient of determination, R^2 of 0.893	30.8 MPa	56 days
[43]	GGBS	Na2SiO3+ NaOH	-	3.15 MPA	7
[44]	GGBS	Na2SiO3+ NaOH	improve the UCS of theGP treated soil	specimens could be increased from 0.2 to 4 MPa and 2 to 12 MPa	7
[46]	GGBS	SiO2/Na2O	more practical applications for GP in soil stabilization	4.2 MPa	28
[47]	GGBS	Na2O	-	5452 and 6593 kPa	28

Recycled Glass Powder Based GP Soil Stabilization

Recycled glass powder [48] is another kind of material utilized in GP. The following are some of the most recent studies in this field. The utilization of bauxite and glass powder processing leftovers as precursors for the manufacture of GPs was investigated in a study [49]. An alkaline NaOH solution with three distinct molarities was utilized as the route. With the introduction of modest volumes of OPC, the compressive strength improved (5 percent). After 28 days, the combination with the greatest performance had a UCS of 11.350 ± 1.23 MPa. The findings of the chemical investigation revealed the creation of the GP's distinctive gel.

The characteristics of fly ash-based GP pastes comprising were examined in this work. At a specific WGP concentration, both the optimal compression and binding strengths were reached (20 percent). The unreacted WGP melted after being exposed to high temperatures (up to 1200°C), filling the porous nanostructures of the matrix material and reducing the number of pores. After adding WGP, the retention ratio of residue strengths increased, demonstrating that an appropriate WGP ratio may improve the fire- resistance of GPs when exposed to high temperatures. [50]

The purpose of this research is to enhance the Clay [51]. The inclusion of 20% IWGP resulted in the greatest improvements. This combination resulted in a 26% decrease in swelled strain at 1kPa maximum equivalent strains. For all pairings of soil and IWGP revealed that, 15% dose was the best amount, offering appropriate strength increase (54.5%) with a significant decrease in capital cost of 19% and a UCS of 110 kPa.

The influence of a GP based on recycled glass powder on the hardness of black cotton soil after 3 and 7 days of curing is examined. The UCS of BCS rises as the fraction of GP increases until it reaches an ideal value of 9%.The UCS of BCS rises as the curing period increases. A GP based on recycled glass powder may be utilized as an efficient soil stabilizer. [52].

The possibility of employing a RGP-GP to enhance the mechanical behavior of clay soils was examined in this study. XRF was used to identify the chemical components of soil and RGP. The mechanical behavior of specimens was investigated using UCS testing. The impacts of several factors such time of cured, temp., concentration of the specimens were studied. The UCS of a GP was higher than those of non- stabilized specimens, according to the findings. The UCS values rose when the curing period of stabilized specimens was increased. The UCS value was maximum at 91 days curing period; nevertheless, the strength gain after 28 days was not substantial. For M4G9 grade specimens, the maximum UCS is roughly 1.5 MPa [52]..

Table-3 Shows the comparison of different Recycled Glass Powder Based GP recent studies

References	GP	Findings	Curing Days
[49]	RPG	11.35 ± 1.23 MPa UCS	28
[51]	RPG	110 kPa with substantial reductionof 19% in capital cost	14
[53]	RPG	1.5 MPa	28

Table-4 Experimental outcomes as per the mixing ratio and composition

References	Type of Geopolymer	Mixing Ratio	UCS	Curing Time
[51]]	Recycles Glass Powder	85:15 Clay to activator ratio	110 kPa	14 days
[37]	Fly Ash Based Geopolymer	Fly Ash around 40%,and Activator/Fly Ash around 60%	1026 kPa	28 cureddays
[42]	Blast Furnace slag	35% Activator: 35 % Cement: 30 % BFS	30.80 MPa	56 curing age
[64]	Fly Ash-based geopolymer	ratio (FAR) variesfrom 0.6 to 2.0 fly ash content varies between 20 and 30%	1606.14 kPA	22.75 DAYS

[65]	Fly ash-based geopolymer	35:35:5 g for foam, sodium water glassand water	0.51 MPa	-
[66]	Waste ceramic powder-based geopolymer	Alkaline solution tobinder ratio is 0.4–0.7	23.7 MPa 23.3 MPa 27.9 MPa	14 days 7 days 28 days

Rice Husk Based GP Soil Stabilization

The ash created by burning- RH from Industries and manufacturing sites is classified as agricultural wastages and is utilized as a lower cost power combusting supply. It is a coal modification used to generate energy [54] [55]. The organic content is preserved when combusting the rice husk, accounting for almost a quarter of the ash product volume [56]. With a composition of 95 percent amorphous silica, RHA has greater specific surfacing areas. With the establishment of the hard gel phase, the stability rate improves [57].

In a GP stabilizer, Liang et al. [58] found that 30% of the RHA was substituted by metakaolin. The UCS was boosted by 58 percent, and the excess water in the alkaline solution was lowered, which improved the soil's permeability performance.

According to Adeyanju et al. [59], improving the compressive performance of sub-grade soil using a RHA-GP combination containing 10% cement kiln dust enhanced the role of failed subgrades. It provides experimental evidence for soil stabilization using CKD and CKD + RHA- based GPs. For activator reduction, CKD was used as a supplementary material in the RHA- based GP. For CKD stabilization, the stabilizing material used was combined in various quantities varied from nearly 8% to 14.9%. Following that, the ideal proportion was combined with Rice Husk almost four to ten Percent and reactivated with Sodium Hydroxide. The findings suggest that both stabilizers increase mechanical performance. The stabilization proposed however, the most effective.

According to Swamy et al. [60], the RHA-based GP were used as a stabilizer in the treatment of laterite soil at an optimal concentration of 9% and allowed to cure for 0-30 days, and the strength value of the proposed soil enhanced by 5%, proving it a long-term pavement stabilizer.

In [61], In terms of developing a viable materials for construction, the approach of employing RHA as a Geo- P to stabilizing red soil recovered from alloys refinery via the Bayer process is presented. The usage of red soils in subgrade stabilization of soil has shown significant results, according to the research.

Variations in the binding content (10-20%), the eggshell powder to RHA ratios and the chemical activation of the eggshell powder were all investigated in the current study [62]. The 10:90 and

20:80 eggshells to RHA binders are appropriate for block manufacture, according to the examination of several variables and Emissions of carbon dioxide during production. The study's findings also suggest that employing GP technology, the cost, energy needs, and Carbon Dioxide associated with block manufacturing may be significantly decreased.

Rice husk ash (RHA), an agricultural waste, was used as a partial replacement for laterite in the GPs to provide an alternative source of silica. The integration of RHA and quarry dust increased UCS by 15.5 MPa and lowered absorption by 4.10 percent for GPs, according to the results of this study. The RHA added silica to the GP network, resulting in the creation of more GP products and an increase in the efficiency. [63]

4. CONCLUSION

Chemical ground renovation is rapidly gaining popularity in the civil engineering industry as a more environmentally friendly alternative to repairing and openly dumping substandard building ground. Traditional soil stabilizers, such as Paris cementitious material, have a negative environmental impact, so scientists are researching the importance of new gluing agents. Geopolymer The transformation of a soil's physicochemical characteristics for long-term, irreversible strength benefits is known as soil stabilization. By thoroughly analyzing the qualities of raw materials originating from their origin, we investigated different geopolymer paste binder that could be used in the construction industry. It is critical to optimize the process settings in order to achieve this goal. This research looks at the viability of using an RGP, FA, RHA, GGBS- based geotextile as a soil stabilizer. The UCS values of all samples stabilized with a geopolymer should be higher than the non- stabilized specimen. Additionally, raising the calculated fraction to the optimal amount will improve the samples' UCS. Furthermore, the findings show that increasing the curing period of stabilized specimens should result in higher UCS values. Proposed stabilization method is also extremely cost and ecologically friendly, as it enables greater use of manufacturing waste material.

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