Chapter 10

Alternative Stabilizer for Mud Concrete

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Additional information is available at the end of the chapter

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Abstract

Cement is one of the key stabilizers for earth constructions since Roman civilization. The invention of cement was one step in the human civilization. However, cement has many issues especially when it comes to the environmental conservation. The production of cement creates a lot of carbon dioxide and destroys the natural setting to some extent due to the high consumption of clay and lime. Therefore, this study was conducted to alter the cement in mud concrete block. The study started with an inventory of alternative stabilizers that can be found in nature as well as in the human production. And then, the chemical patterns of those stabilizers were carefully identified to alter the typical Portland cement. Several mix proportions were tested and developed to alter the cement and found that the following materials can be developed to alter cement. A natural stabilizer such as tree resins, latex rubber stabilizer, waste ash, rice husk ash and many other ashes can be developed to chemically stabilize the earth blocks. However, out of the invented stabilizers, fly ash and rice husk ash have the high potential to replace cement.

Keywords: mud, cement, alternative stabilizers, natural polymers, industrial waste

1. Introduction

Cement as stabilizer had a vital role in the human civilization. The earliest civilizations such as Egyptians habituated calcined gypsum; Greeks and Romans used heated limestone powders made by volcanic explosions to make mortar. Finally, Romans built continental scale civilizations by using cement to build bonds. It was Romans who found and named cement 'pozzolanic' cement after the village Pozzuoli near Vesuvius, a giant volcano found in Italy.

However, not all civilization had the fortune of using volcanic ash. Britain learnt the technology from Romans and developed the technology to produce cement by crushing clay tile and systematically burned with lime to produce cement. It was Joseph Aspdin from the UK who got the first patent for the Portland cement in 1824. Since then, Portland cement was developed into many variations to optimize and customize the stabilizing capacity (see **Table 1**).

The idea of stabilizing is to create a bond between two particles. Cement is such a stabilizer used widely on earth due to the availability of raw materials and production method. However, the cement as a stabilizer has much weakness including a high carbon footprint.

1.1. Mud concrete block

Mud concrete block is a building material invented by the University of Moratuwa, Department of Civil Engineering. The concept is to use available soil and mix them with 6% of cement and used alternative to the brick and cement blocks, mostly available in the market [1–5]. The concept is to aggregate 'Concrete' made using earth/soil. Concrete is a typical composite construction material made out of cement, sand, metal and water. Here, metal (coarse aggregate) controls the enduringness, cement acts as the binder and sand (fine aggregate) reduces the porosity and water acts as the reactor to cement. In mud concrete, the designated parts of sand and metal of concrete are replaced by a fraction of the soil. The precise gravel percentage governs the strength of mud concrete. The production method of mud concrete block is shown in **Figure 1**.

Description	**SLS 107**	**SLS 1247**	**SLS 1257**
Chemical composition			
Magnesium oxide (MgO) %	2	2.5	2.5
Sulfur trioxide (SO_3) %	2.25	2.3	2.3
		0.01	0.01
Chloride (Cl) %	0.01	1.5	1.5
Lime saturation factor (LSF) %	0.94		
Tri calcium aluminate (C_3A) %	7.5	275	275
Loss on ignition %	1.4	320	320
Insoluble residue %	1.4		
Physical properties		3350	3350
Fines (blaine) cm^2g	3200	1	1
Expansion soundness mm	0.9	0.04	0.04
Autoclave %	0.04	130	130
Time of setting	140	19	19
Compressive strength (N/mm^2)	45.5	50.5	50.5
2 Days	22.5	0.005	0.005
28 Days	55.6	0.046	0.046

Table 1. Chemical and physical properties of cement.

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The cement in this concrete is also used as a stabilizer in very low quantities. The quality of the cement is shown in **Table 1**. In this research, a fraction of soil has been classified as follows [5]:
Gravel—sieve size 4.25 mm ≤ gravel≤20 mm
Sand—sieve size 0.425 mm ≤ sand ≤4.25 mm
Fine (silt and clay)— ≤ sieve size 4.25 mm

In achieving the concept of sustainability, green buildings are which provide environmentally suitable and friendly aspects of the building construction. In relation to material conservation, Mud Concrete Block (MCB) invented by the University of Moratuwa is a novel experience today in combining ancient technology with the modern [6]. Issues related to modern technology that needed to predict towards MCB were non-sustainability and higher cost [7–9]. Therefore, the invention of MCB has become a major companion in answering these two issues due to the facts that it is sustainable in the sense that it gains no harm to the environment and it is abundantly available [10]. Apart from that, MCB has 92% of reusability and concrete has only 70% [7]. This supports to reduce even waste generation due to the demolition of buildings. However, mud concrete has a weakness of having little higher carbon footprint due to the use of cement as a soil stabilizer. The use of cement as soil stabilizer creates other practical issues including the initial cost of the production of mud concrete blocks. Therefore, this research was conducted to alter the cement and explore possible alternative stabilizer for cement.

1.2. Soil stabilization

Soil stabilization is the alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load-bearing capacity of a sub-grade to support construction technology.

- **Mechanical**—This involves physically changing the property of the soil somehow, in order to affect its gradation, solidity and other characteristics. Dynamic compaction is one of the major types of mechanical stabilization; in this procedure, a heavyweight/force is dropped repeatedly onto the walling block at regular intervals and create the block, for example, cement-stabilized earth blocks (CSEB).
- **Chemical**—Chemical solutions are another of the major types of soil stabilization. All of these techniques rely on adding an additional material to the soil that will physically interact with it and change its properties. There are a number of different types of soil stabilization that rely on chemical additives of one sort or another; you will frequently encounter compounds that utilize cement, lime, fly ash (FA) or kiln dust. Most of the reactions sought are either cementitious or pozzolanic in nature, depending on the nature of the soil present at the particular site you are investigating.
- **Polymer/Alternative**—Both of the previous types of soil stabilization have been around for hundreds of years, if not more; only in the past several decades have technology opened up new types of soil stabilization. Most of the newer discoveries and techniques developed thus far are polymer based in nature, such as rubber. These new polymers and substances have a number of significant advantages over traditional mechanical and chemical

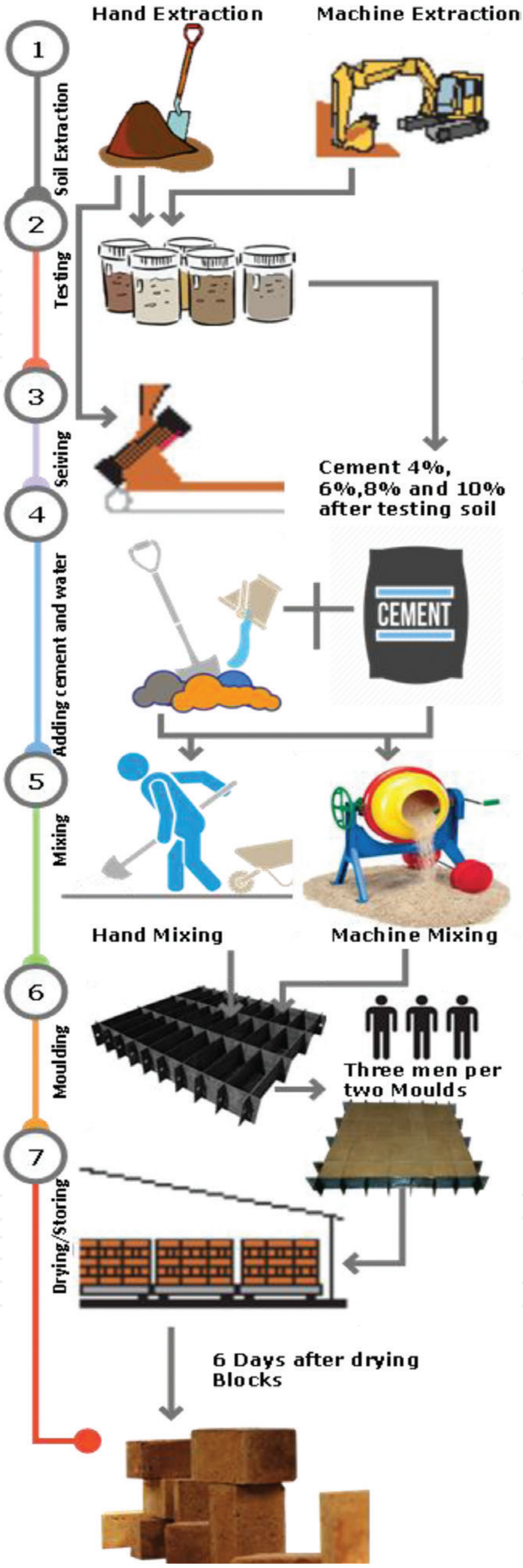

Figure 1. Manufacturing framework mud concrete block.

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solutions; they are cheaper and more effective in general than mechanical solutions and significantly less dangerous for the environment than many chemical solutions tend to be.

1.3. Compares and alternatives for cement

The objective of this study is to alter cement in mud concrete technology. And the study was started with an inventory of alternative stabilizers found in nature. Nature is a grand material engineer. First, the study came up with an inventory natural polymer shown in **Table 2**. And then, the study was conducted to understand other waste from the human world. Therefore, the inventory was based on two types of stabilizers such as natural and artificial, polymers and non-polymers.

1.4. Polymeric substance-based stabilizers

Meanwhile, many types of research have been conducted on avoiding the use of cement or concrete in walling materials as its effect on the thermal comfort of the occupants due to the gypsum content [20]. The inclusion of polymeric substances has been one of the prominent recommendations for enhancing the general performance of concrete, especially cement and asphalt concretes [21]. Therefore, many effective polymeric latex substances have attracted the focus in order to develop and use them in respect of cement concrete in the construction industry [11]. There has been an active research development in polymer-modified mortar and concrete in various countries around the world for the past 70 years. As a result of these research and developments, polymer mortar and concrete became the dominant materials in the construction industry in the 1970s in Japan and in the 1980s in the United States. Now, they are competitively employed as popular construction materials [22]. The inclusion of polymeric substances into hydraulic cement concrete has made a tremendous effect on improving its performance properties. However, it should be included in concrete and should not cause damage to its mechanical capacities or to its durability characteristics [23]. Results have shown that the performance of latex-modified concrete is depending largely upon the techniques involved in the mixing procedure, water/cement ratio, latex content and curing regime [24]. Various bio-polymeric construction materials for soil treatment or enhancement have been introduced in several studies, to replace the use of conventional materials that have high environmental impacts, as efforts to develop environmentally friendly construction engineering approach [25].

Polymers are being increasingly used in civil engineering applications as concrete materials modifiers, especially for the purpose of improving workability, drying shrinkage, strength properties and durability characteristic [26]. Apparently, among several polymeric substances used in practice, elastomeric latexes are the most frequently applied [24]. Currently, elastomeric latexes, which mainly consist of hydrocarbon substances, are being used increasingly in civil engineering applications as modifiers for the purpose of performance improvement of hydraulic cement concrete [24].

	Name of stabilizer	Chemical formula	Available sources	Uses and properties	Production method
Natural Polymers	Rubber Latex [11]	Polyisoprene	Can be collected from rubber plants	Used in many applications and products in combination with other materials	Can be used with sulfur to stable and create longer bonds between the rubber materials
	Pines Gum	Pinene	Obtained from pines	Used as stabilized in many civilizations	Pines resins are generally produced as stem secretions
	Lignin	Carboxymethyl lignin	Sugarcane bagasse	Stabilizing agent in aqueous ceramic suspensions	Using ethanol-water as the solvent and sulfuric acid with 70c for 30 min
	Molasses	$C_6H_{12}NNaO_3S$	Sugarcane bagasse	Soil stabilization	Molasses made from sugar beets differ from sugarcane molasses. Only the syrup left from the final crystallization stage is called molasses
	Hydrophilic polymer		*Aegle marmelos*	(a complex mixture of vitamins, polyphenols, esters, aldehydes, sugars, mineral salts, organic acids and amino acids)	Concentrations used in the formulation were 2, 4, 6 and 8% w/w of cordial fruit gum
Industrial Waste	Fly ash [12–14]	Pulverized fuel ash	Any coal combustion plant	Land fill, dump	Coal combustion process produces tons of fly ash per day even in Sri Lanka
	Bottom ash [15, 16]	SiO_2 Al_2O_3 Fe_2O_3 CaO K_2O TiO_2 MgO SO_3-Na_2O P_2O_5 BaO	Ash that falls in the bottom of the boiler is called bottom ash. In modern coal-fired power plants	Bottom ash is part of the non-combustible residue of combustion in a furnace or an incinerator	Stuck in the furnace and taken out more than four lorries per day in Lakvijaya power plant
	Rice husk ash [17–19]	Crystalline silica		Increases the electrochemical stability of the film	
	Lime			stabilizer	

The inventory has produced to develop the experimental criteria. The most suitable stabilizers experimented with soil in order to test the strength development. The whole idea of developing alternative stabilizer to stable soil and mortar. Therefore, the main experiment is to develop the strength development.

Table 2. Inventory of alternative stabilizers for cement.

If this technology can be used in relation to soil, the product will be a sustainable one since that avoids the cement usage and lessens the energy usage. As soil is an environmentally friendly source and it provides a sufficient forum for energy conservation, the inclusion of soil into the newest technology of polymeric stabilizing will be an attractive turning point in civil engineering constructions.

1.5. Waste ash substance stabilizers

There are so many wastes generated and abundant in the natural setting without proper methods. The study shows that ashes like fly ash, bottom ash and rice husk ash have the similar cementitious properties such as color, particle size distribution, and so on. In addition, there have been many studies to develop those ashes into cementitious materials and stabilized earth. Geopolymerization is a similar concept where the ashes are activated by using alkaline solution to improve the bonding capacity of the ashes. First, ashes were combined with an alkaline solution and then make with soil and build earth blocks. This was invented in 2007 by Professor Joseph Davidovits. He has developed a series of geopolymerization techniques to develop the cementitious properties of the ashes to alter cement in the earth construction. Since after his innovation, there have been many attempts to develop the idea of geopolymerization. But for the first time, this study was conducted to geopolymerize mud concrete.

2. Effect of alternative natural and industrial waste for mud concrete construction

2.1. Latex (rubber)

Latex (rubber) got the attention due to many reasons. It is the best natural polymer in Sri Lanka. It is mass-produced and can be found in large scale if in case of a mass production of earth blocks. On the other hand, earth blocks have the compressive strength but not the tensile strength. Latex (rubber) has this capacity to bend if in case of a force and absorb tensile force. Hence, the idea of experimenting with rubber was optimized by various mix proportions as shown in **Figure 2**; it was to identify the best mix proportion for mud concrete block shown in **Table 3**. The ammonium hydroxide and sulfur were used as add mixtures to develop the workability and the strength of the mixture.

Since cement and rubber do not show any strength improvement, the study was extended to improve the quality of rubber soil mixture with altering cement with sulfur (see **Table 4**). The experimental programme is shown in **Table 4**. In this experiment, only the rubber was used in

Figure 2. Mix preparation for testing.

Soil (%)	Latex (%)	Dry rubber (%)	Cement	Admixture NH_4OH (%)
96	6.90	4	3.36	5
94	10.30	6	3.36	10
92	13.80	8	3.36	15
90	17.20	10	3.36	20
95	6.90	4	3.36	1
92	10.30	6	3.36	2
89	13.80	8	3.36	3
86	17.20	10	3.36	4
95	6.90	4	3.36	5
92	10.30	6	3.36	10
89	13.80	8	3.36	15
86	17.20	10	3.36	20

Table 3. Experimental compositions of rubber and soil mixes.

Rubber + NH4OH					Rubber +Sulphur				
		Area (mm²)	N/mm²	Average			Area (mm²)	N/mm²	Average
R 4%	A	8556	2.04	2.20	S 2%	A1	8188	0.83	0.82
	B	8556	2.43			B1	8418	0.89	
	C	8742	2.14			C1	8099	0.73	
R 6%	A	8417.5	2.33	2.29	S 4%	A1	8789	0.86	0.87
	B	8554	2.40			B1	9025	0.85	
	C	8742	2.12			C1	8554	0.89	
R 8%	A	8281	2.74	**2.79**	S 6%	A1	8648	0.83	0.80
	B	8281	2.67			B1	8836	0.80	
	C	8326.5	2.97			C1	8930	0.77	
R 10%	A	8418	2.67	2.61	S 8%	A1	8648	1.01	**0.99**
	B	8096	2.65			B1	8740	1.06	
	C	8280	2.49			C1	8930	0.90	

Table 4. Experimental composition with latex and sulfur to improve the dry strength.

order to improve the quality of rubber-stabilized earth block mixture. And the experimental criteria are as follows.

Table 5 shows the experiments done with sulfur and rubber mix design with soil in order to gain the strength. In addition, the upper corner of **Figure 3** shows the sun-drying process of

Mix design	Soil (g)	Cement(g)	Rubber		
			Rubber milk(g)	Water(g)	Sulfur(g)
0.5S2R4C	4675	200	100	50	25
1S2R4C	4650	200	100	50	50
1.5S2R4C	4625	200	100	50	75
2S2R4C	4600	200	100	50	100
4S2R4C	4500	200	100	50	200

Extended experiments with pure rubber-composed soil brick.

Table 5. Extended study with 100% rubber soil mixture altering cement with small amount of sulfur.

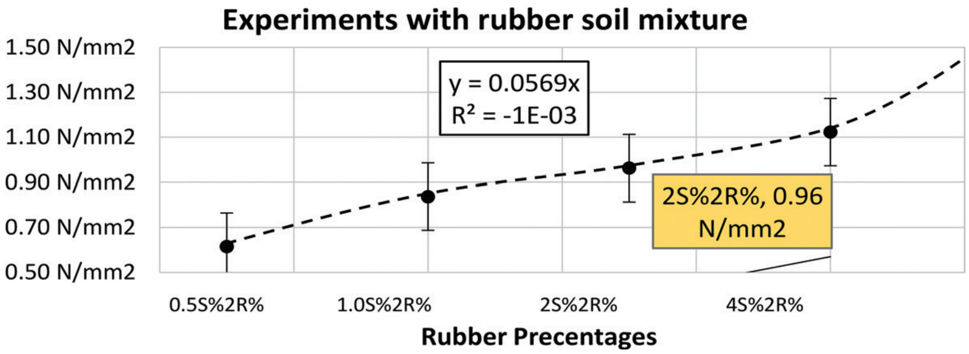

Figure 3. Improving the rubber soil mixture with the addition of sulfur.

the same bricks produced by the rubber and soil mixture. The results are astonishing to alter cement with 100% natural materials to use as a brick. The results are as follows.

2.2. The effect of rubber ratio into the constant sulfur combinations

The next study was conducted to understand the strength development due to an increase of rubber while maintaining the soil and sulfur ratios constant as shown in **Table 6**. This experiment was conducted to understand the optimum rubber content to be used to build rubber-stabilized earth blocks. And the previous experiments were observed where the rubber blocks may cause to shrink during the curing process. Therefore, alternatively, 100 × 100 mm blocks were used to understand the strength of the new mixture. The experimental schedule is shown in **Table 6**.

This study was to understand the optimum rubber content to develop the rubber-stabilized earth block. The optimum sulfur content was recognized as 2%. The sulfur is not natural materials and cannot be found in the natural form. The increase of carbon footprint may occur due to the use of sulfur. However, the sulfur itself helps to improve the compressive quality of the RSEB block. Therefore, the combination of rubber and sulfur may create a better bond between particles of the blocks. In addition, the results are as follows.

Experiments with latex-stabilized mud concrete block gave senior results with a high tensile capacity as shown in **Figure 4**. However, rubber-stabilized mud concrete blocks had many weaknesses including dry shrinkage. The dry shrinkage and the cost of latex rubber motivated

Mix design	Soil	Cement	Rubber		
			Rubber milk	Water	Sulfur
2S2R	92%	4%	2%	1%	2.00%
	4600 g	**200 g**	**100 g**	**50 g**	**100 g**
2S4R	90%	4%	4%	1%	2.00%
	4500 g	**200 g**	**200 g**	**50 g**	**100 g**
2S6R	88%	4%	6%	1%	2.00%
	4400 g	**200 g**	**300 g**	**50 g**	**100 g**
2S10R	84%	4%	10%	1%	2.00%
	4200 g	**200 g**	**500 g**	**50 g**	**100 g**

Table 6. Extended study with admixtures to develop the dry strength.

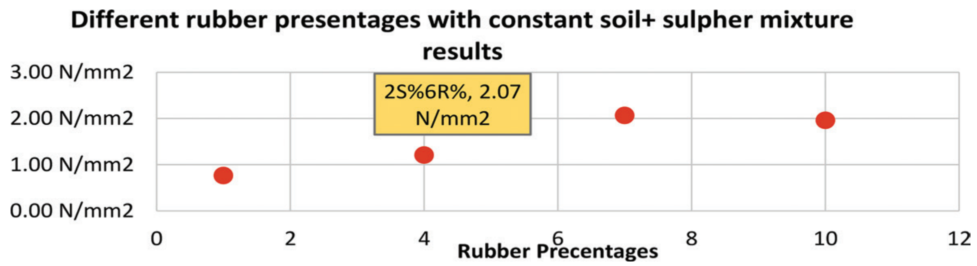

Figure 4. Different rubber percentages with constant soil+ sulfur mixture results.

to perform experiments with other natural polymers, assuming that there will be a better bonding to alter cement in mud concrete. The most common assumption for experimenting with natural polymers is the ability to develop a bond between two or three particles. And the own ancestors have used this for a long time in the past.

2.3. Tree resins and natural polymers

This experiment has gone too far corners of the historical methods of stabilizing earth into mortars and blocks. Ancient Sinhalese civilization in the fourth century builds the fortress Sigiriya by using tree resins and lime [27]. The study referred to the same technology and identified that natural polymers can make a bond between two materials and create a cementitious effect. Therefore, following the ancient inscription, cashew juice, Neolitsea cassia juice and pine resins were subjected to this study to alter cement in mud concrete technology (see **Figure 5**). The objective of this study is to study the possibility of developing mineralogy of natural polymers into suitable construction materials. The use of selected natural polymers to stabilize geotechnical properties of soil into engineering property consisting of masonry unit with a load-bearing capacity has been studied. The strength development and suitable mix development for such a masonry unit made out of earth stabilized by using natural polymers has also been studied.

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Figure 5. Experiments with natural polymers as alternative for cement.

The idea is not to use the raw polymers and resins, but to extrapolate the compounds that are developed into the proper mix. The results show that pines resins and cashew juice are vulnerable to make mud concrete blocks shown in **Figures 6–8**. The archived strength is more

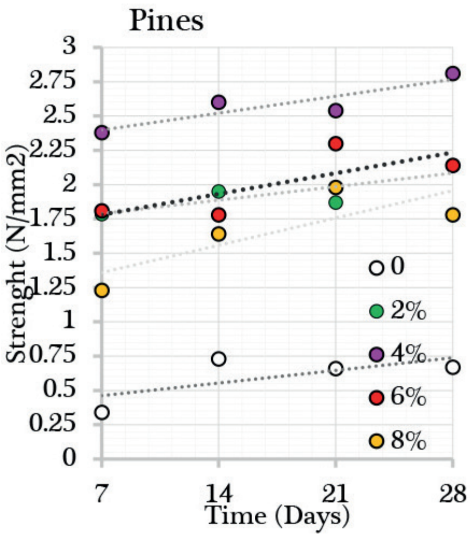

Figure 6. Pines.

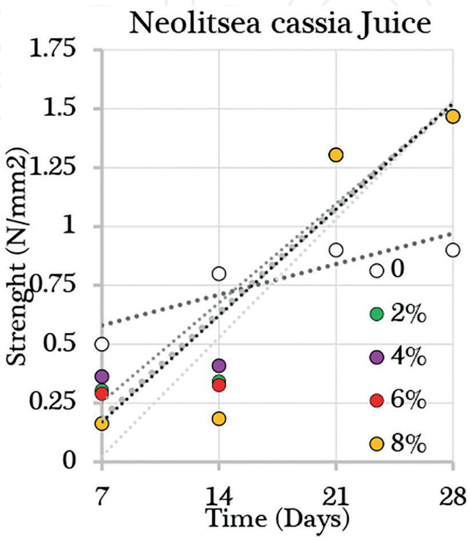

Figure 7. Neolitsea cassia juice.

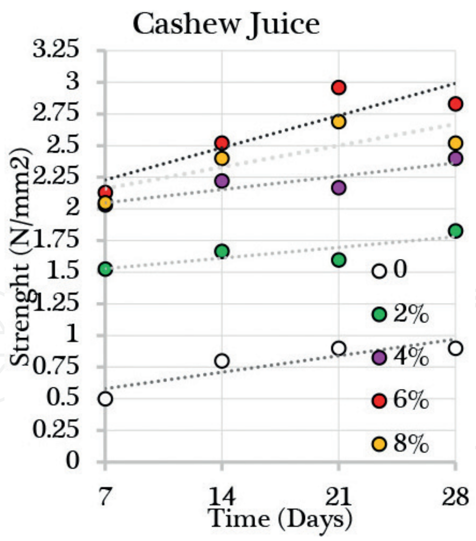

Figure 8. Cashew resin.

than 2 N/mm^2. In addition to the strength, pines-stabilized mud concrete gives a courteous smell and a reddish color. This can lead to developing architectural block. Therefore, these polymers can be developed to make earth blocks. But the issue was the mass production, and there are so many other alternative uses of these polymers and resins.

3. Experiments with industrial waste as stabilizers for mud concrete

The initial experiment was conducted to replace cement with raw fly ash, bottom ash and rice husk ash as shown in **Figure 9** as it is and found that those materials cannot improve the strength. The obtained results show that rather than stabilizing the soil, these materials unbound the clay and reduce the strength lower than 2 N/mm^2 [14, 16, 28].

The initial mix raw ash experiment was a failure without achieving any strength shown in **Figures 10–12**. But then, further study showed that the alkaline activation of ash can build a much better mixture than using it in raw. Therefore, a new experiment was conducted to develop alkaline-activated ash to develop a much stronger mud concrete block. This was invented in 2007 to describe the alumino silicate binders, which is formed by the alkali activation of a source material that is rich in content of aluminum and silicon [29]. These binders have superior properties that promote them as cement replacement materials. Geopolymer can utilize precursors

Figure 9. Fly ash, bottom ash, and rice husk ash.

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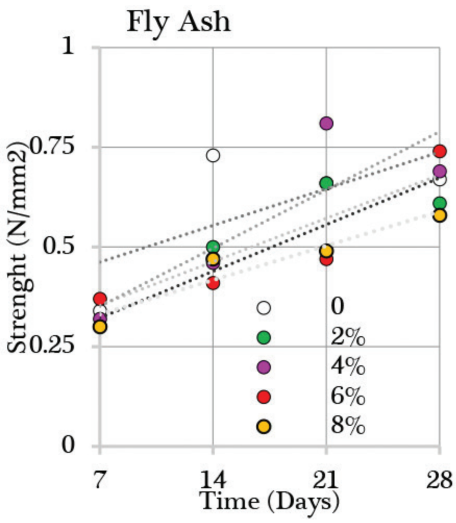

Figure 10. Fly ash.

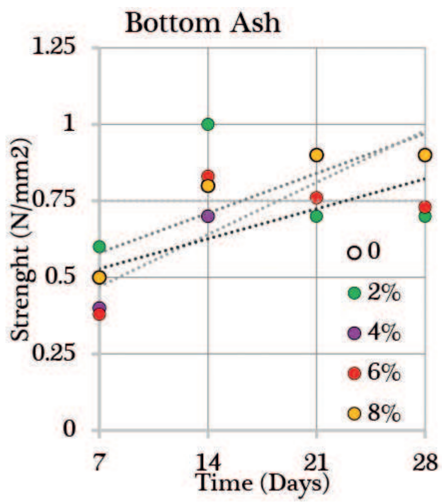

Figure 11. Bottom ash.

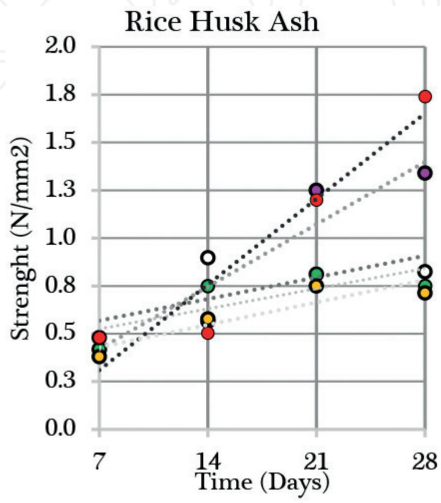

Figure 12. Rice husk ash.

from many industrial by-products fly ash (FA), bottom ash and rice husk ash. These by-products are usually disposed in landfills, which create serious environmental concerns.

4. Alkaline activation of fly ash

The further study about ashes found that they are having similar properties like cement and close brothers of cement (see **Figure 13**). And many studies show that alkaline activation of ashes can make a stronger material to stabilize earth to build the road. By studying the same concept, this experimental programme came up with new experimental criteria to build non-cement but fly ash-stabilized earth blocks. The experimental criteria are as follows.

4.1. The experimental criteria to alkaline activate the fly ash

The study shows that the concept of geopolymer can be applied to replace the cement in the mud concrete technology.

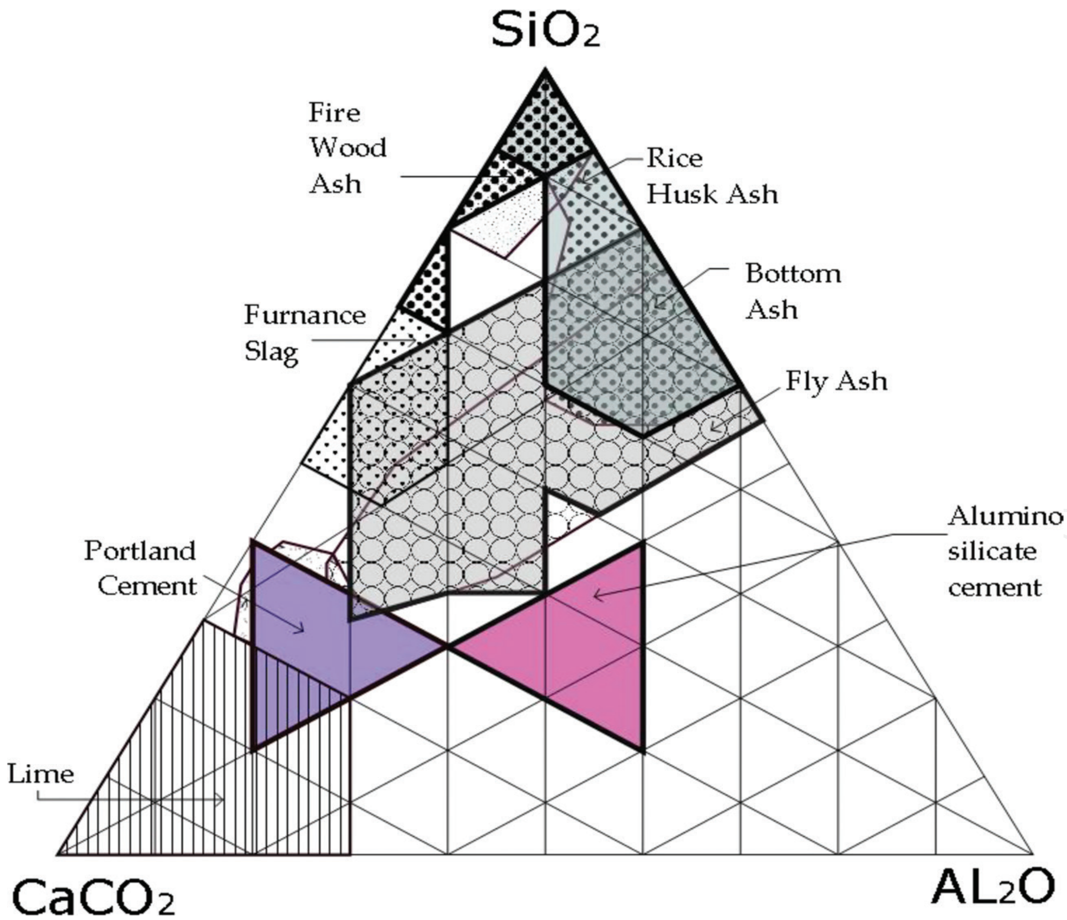

Figure 13. Comrades of cement.

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The study shows the use of NaOH, and salt combination can activate the fly ash into the cementitious property. The process of geopolymerization is shown in **Figure 14**. Also known as polycondensation of alumina silicate bonds into jelly particle, they finally create the bond. This is not a novel concept; see Section "Introduction". However, this is the first time geopolymerization is an experiment with mud. The idea of stabilizing mud and developing mud-based mixture is to develop quick flow self-compacting mixture to alter a traditional compressed earth block technology. It was the mother research of this study which has found that utilizing mud can develop self-compacting mixture to alter compressed earth blocks [30].

The experimental programme started with a varying activator to identify the optimum alkaline solution to stable the mud concrete block as shown in **Table 7**. This is due to the different alumina silicate composition in the soil. However, after that, the salt content to dissolve the activator was identified. The results show that the optimum of 2% of the dry weight of the mixture can get the optimum strength for mud concrete block. And then, a profound mix was developed to test the required moisture content to make the mixture. For the mud concrete, the moisture ratio is critical to making a self-compacting mixture. The idea of self-compacting is to reduce the energy consumption of the mixture.

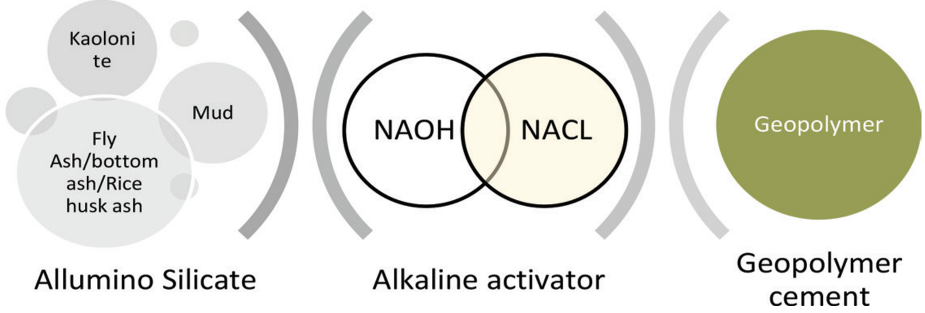

Figure 14. Experimenting with polymerizing mud concrete.

Soil	Fly ash		Activator		Salt		Water	Number of test blocks	
27,300 g	20%	7000 g	0.00%	0 g	2.00%	700 g	20.00%	6sundry	3ovendry
26,950 g	20%	7000 g	1.00%	350 g	2.00%	700 g	20.00%	6sundry	3ovendry
26,600 g	20%	7000 g	2.00%	700 g	2.00%	700 g	20.00%	6sundry	3ovendry
26,250 g	20%	7000 g	3.00%	1050 g	2.00%	700 g	20.00%	6sundry	3ovendry
25,900 g	20%	7000 g	4.00%	1400 g	2.00%	700 g	20.00%	6sundry	3ovendry
25,550 g	20%	7000 g	5.00%	1750 g	2.00%	700 g	20.00%	6sundry	3ovendry

Table 7. Experimental mix design for geopolymerizing fly ash-based mud mixture.

There are more than enough literature as well as the optimum mole content can be calculated. But since this is a practical product, it is better to establish the optimum caustic soda content to build mud concrete blocks out of fly ash and caustic soda [31–34]. The study shows that the required water mole content to produce the reaction is 20%. It is the required moisture content to produce the fly ash block. The moisture content is very important to develop the workability of the block mixture. The quick flow mixture shall help to improve the self-compacting capacity of the mixture. And the water in mud concrete block helps to improve the porosity and porosity helps to improve the thermal property of the block. The next step is the water content analysis, which was to find out the most suitable mix proportions to build fly ash-stabilized earth blocks. As per the results indicated in the previous experiment, the best compressive strength was shown when the moisture content was in between 15 and 20%. The

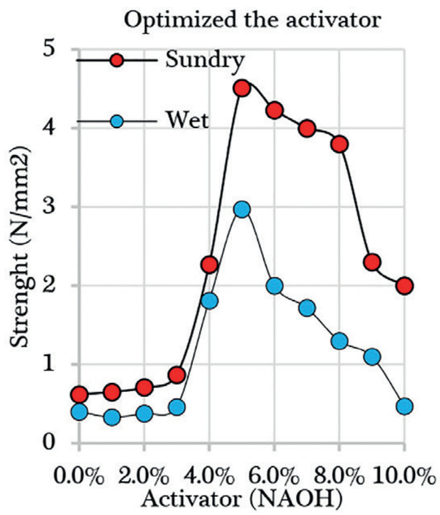

Figure 15. Optimizing NAOH.

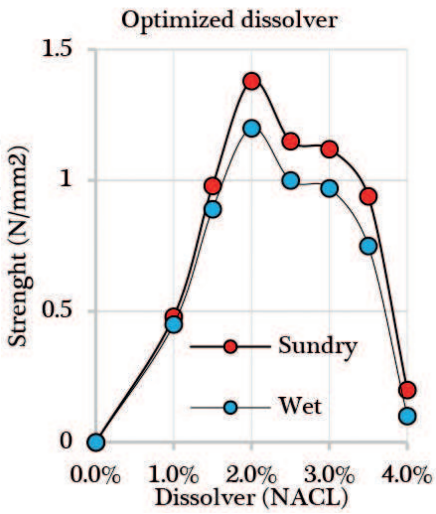

Figure 16. Optimizing NACL.

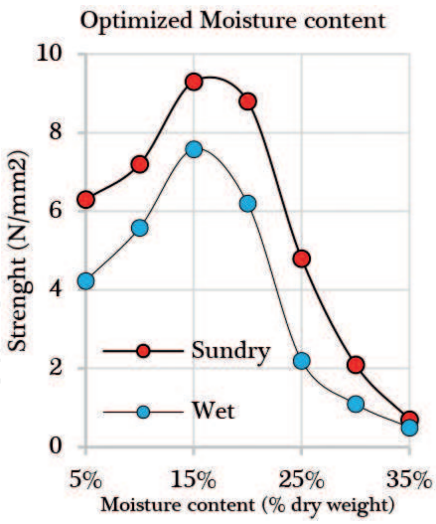

Figure 17. Optimizing moisture content.

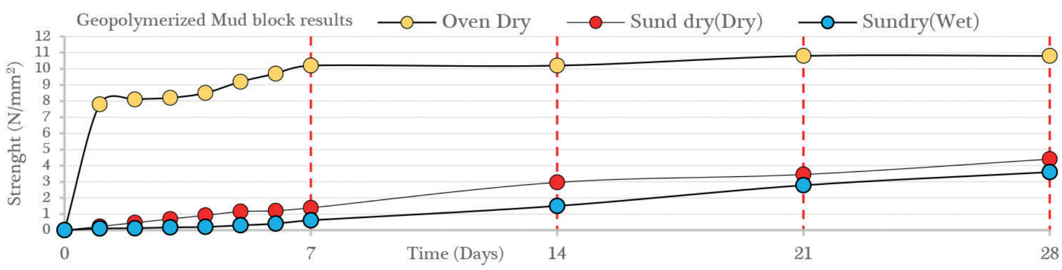

Figure 18. Geopolymerized mud concrete block final results.

results obtained are shown in **Figures 15–17**. After the confirmation of water content, the mix proportion was started varying the sand and gravel combinations as shown in **Figure 18**.

5. Application in construction

The use of invented stabilizers was tested upon different soil combinations to see the strength development. And then, they were employed to build a walling sample width of 1 m and a height of 1 m. Out of the entire study, the most vulnerable and practical stabilizers were selected to develop this walling samples test. A 1-m wide 1-m tall building wall sample was made at the University premises to check the practicality of this new mix as shown in **Figure 19**. The practical use and mass scale production were studied in this process and found that natural rubber should be avoided as alternative stabilizers. Geopolymerization of waste ashes such as fly ash, bottom ash and especially the rice husk ash has the quality of replacing the cement and build a novel walling material.

Figure 19. Fly ash geopolymerized mud concrete masonry unit wall.

6. Conclusion

This study was conducted to alter cement in mud concrete technology. Mud concrete is a novel walling material discovered to alter compressed earth blocks. The concept of mud concrete block is to build concrete by soil. Sand and metal of concrete are replaced by a fraction of the soil. The precise gravel percentage governs the strength of mud concrete. The cement in this concrete is also used as a stabilizer. But the cement has this weakness of initial cost and the heavy carbon footprint. If cement in mud concrete can be replaced with a much greener stabilizer, mud concrete can be recommended as a greener walling material.

The study was conducted after a series of nature studies and literature studies. In addition, the folk knowledge also has been considered prior to the experimenting with stabilizers. Then, the study builds an inventory of possible stabilizer which may replace the cement and act as a stabilizer for soil. At the very beginning, the study was focused to develop natural polymer-based stabilizer because ancient Sri Lankan ancestors used natural polymers to stabilize the earth and build gigantic structures and plastered them with frescos. However, the utilization of natural polymers was an utter failure due to the availability of materials. The experiment with natural latex rubber and mud concrete

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achieved the required strength but there were many practical issues when it comes to the physical use of rubber-stabilized earth blocks. Then, a study was done with a series of natural polymers taken from other plants such as pines, chews, and so on. The results are good enough but practically cannot be applied in the real world where the mass production of earth blocks is required.

Then, the study was focused to utilize industrial waste into cementitious materials for mud concrete block. Fly ash, bottom ash and rice husk ash were subjected to this study and found astonishing results. The initial results with a raw form of waste were failure and they did not produce the required strength. And then, the developed mixture with alkaline solution creates much better strength with mud concrete block. After finalizing the mix and all, a sample wall area of 1 m × 1 m was built to check the practical application of this block to produce affordable walling. And it was noticed that highly alkaline solutions make the mixture somewhat difficult. The expanded study was conducted to rank the alternative stabilizers discovered in this study. The developed stabilizer was ranked according to their workability availability and the initial cost. And then, the extensive study was conducted with life cycle cost and carbon footprint analysis to understand the long-term use and the environmental impact of those stabilizers.

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