DEVELOPMENT OF WLP IN GEOPOLYMER

By

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Department of Civil Engineering
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Approved:

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Project Supervisor

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TRONOH, PERAK

December 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Khaled Mohamed Naji Alrowaishan

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ABSTRACT

The production of hazardous waste materials from industrial processes has cause major concern on the environment due to their intractable, harmful and costly disposal methods. Waste products from mining could be listed among the harmful ones including WLP, Water Leach Purification. WLP is a waste produced from rare earth material from mining activities. In Malaysia it is produced by the mining company Lynas. WLP can be a radioactive element. Hence, ways to use it in construction materials can be a good solution for the environment.

Geopolymers are the alternatives of the Portland cement. Using geopolymers can save and reduce carbon footprint. A new type of geopolymer composites are to be synthesized waste products namely water leach purification (WLP) with fly-ash as a based material as one of the alternative solution for the issues. The strength development of the geopolymer concretes produced at different mixing ratios of raw materials (0%, 5% and 10% of WLP) was studied in this research. With different percentage in the mix design, WLP is tested to know its influence in the strength of the concrete.

Within the above variety of WLP inclusions in geopolymer, the samples produced from the trial and error mix design are tested by both destructive and nondestructive tests. Tests include compression test, Ultrasonic Pulse Velocity and Rebound Hammer.

The study of the development of WLP in the fly ash based geopolymer results are optimizing. Although base Fly ash (0%WLP) geopolymer resulted in higher strength values, WLP 5% shows better results as compared to the 10%WLP. This means, for the tests performed for the samples in his research, the 5% WLP is to be a better geopolymer than 10%WLP.

CHAPTER 1: INTRODUCTION

1.1 Background of Study

In the last decade, geopolymer binders have emerged as one of the alternatives to cement binders for application in concrete industry. Geopolymers can be produced by polymerization of alumino-silicate oxides with alkali polysilicates yielding Si-O-Al bonds [1]. The method of producing geopolymer is known as geopolymerisation whereby many small molecules were combined into a covalently bonded network. While geopolymer concrete was produced as a replacement for the existing conventional concrete, it was actually manufactured by reusing and recycling of industrial solid wastes and by-products. Not only it is acknowledged as a type of sustainable concrete, it is also cost-effective.

In this modern world, numbers of devices and appliances were utilizing the rare earth elements in their production. Mobile phones, plasma and Liquid Crystal Display (LCD) televisions, disk drives and hybrid vehicles are some of the equipments that incorporating rare earth elements for instance [2]. Based on 2009 USGS report and report from the Ministry of Industry and Information Technology of China, there are about six countries that can provide the world with rare earth products namely China, Russia, India, USA, Brazil and Malaysia. Even though there are plenty of rare earth reserves in Australia, however, no processing plant could be built for environmental problems. Hence, Lynas had moved its separation and smelting factories to Malaysia [3].

The refinery processes of rare earth by Lynas generated few different kind of waste products namely water leach purification residue (WLP), flue gas sulphurisation residue (FGD) and neutralization underflow residue (NUF) which consist of thorium, uranium and their decay product at concentrations of about 1,6000 ppm (Th) and 30 ppm (U). Those wastes will be disposed of in at least three separate waste ponds which are referred to as residue storage facilities [4].

On the other hand, Flyash is a by-product of coal-fired electric generating plants which is popular in Malaysia and huge amounts can be used.

1.2 Problem of Statement

Geopolymers are materials that were used in various applications such as fire-resistant and heat-resistant coatings and adhesives, medicinal applications, high-temperature ceramics, new binders for fire-resistant fiber composites, toxic and radioactive waste encapsulation and new cements for concrete. In construction industry, geopolymers were first introduced in the 1957 by Viktor Glukhovsky, Kiev, Ukraine, in the former Soviet Union which had developed concrete materials originally known under the names "soil silicate concretes" and "soil cements", derived from the low basic calcium or calcium-free aluminosilicate (clays) and alkali metal solution used in the cement production [5]. Although, geopolymerisation is not a new concept, however, the application of this technology in incorporating waste materials from industrial processes is relatively recent. Fly-ash based geopolymer concrete that was considered as one of the earliest waste incorporated geopolymer concrete were still lack in popularity compared than the conventional concrete produced by utilizing ordinary Portland cement (OPC). This is probably due to the lack of awareness on the significant benefits of geopolymer concrete among the users as well as the short number of geopolymer binder manufacturers.

Conversely, Water Leach Purification residue (WLP) is a major waste materials produced by the water leaching and purification process of the lanthanide concentrate in the rare earth industry. This process utilizes Magnesium Oxide and water which produces WLP as the most toxic waste materials in the rare earth refinery process. According to a report done by the National Toxic Network (NTN), WLP generated from Malaysia's Lynas Waste Advanced Materials Plant (LAMP) is expected to be about 478,800 m^3 after 10 years of operation which make it the most abundant wastes out of the total solid waste generated by the whole processes [6]. At present, due to the unfeasible total disposal of the waste; the storage of the WLP itself has become a major concern along with the potential threats it might pose to the environment and public health. Therefore, new trustworthy and environmentally friendly disposal methods are crucial.

In order to solve the tricky disposal issues as well as the health and environmental issues posed by these waste materials, making a geopolymer from Flyash has become one of the possible alternative environmental and commercial approach to treat the problems. Thus, by utilizing these waste materials, WLP and Fly ash, into concrete mixture will consume a significant amount of this by-product and also it can save the hassle of waste disposal and storage problems. Indirectly, environmental pollution posed by OPC which has reportedly causes the increase of carbon footprint and the depletion of raw materials due to its manufacturing activity could be lessen. It is believed that this resolution could produce a new type of sustainable construction material which not only economic, but also a good catalyst to the preservation of environment quality in the future.

1.3 Objective

The main objective for this research is to establish effects of WLP inclusion in geopolymer concrete containing Fly ah as source material. The inclusion of the WLP in the source material ranges between 5% and 10% WLP.

1.4 Scope of Study

The development of the WLP inclusion in the base material Fly ash in this study will include 0% WLP (pure Fly ash or Base mix), 5% and 10% WLP. There are 3 successful mixes for the study with 12 samples in every mix. The size of the samples for testing are the mold size of 100x100x100mm.mThe material used is the WLP that is the mining waste from Lynas, the high calcium Fly ash, Sodium Hydroxide with molarity of 8 moles, Sodium Silicate and aggregates (fine and coarse).

The research will carry out mechanical test measuring the maximum amount of compressive load a material can bear before fracturing. The test piece in the form of a cube is compressed between the platens of a compression-testing machine by a gradually applied load. Other tests are also being followed which are non distructive tests; One is the Ultrasonic Pulse Velocity (UPV) test which can give the velocity the waves cross the samples to show the quality. The other not destructive test is the round hummer test for strength of samples.

1.5 The Relevancy of the Project

Since the world has been facing a number of environmental issues related to the construction activities like the greenhouse gases emission by the manufacturing of Portland cement and land dereliction problem due to the disposal of industrial waste, the world is in need of a green and sustainable engineering solution for the affair. Study on incorporating the most abundant waste materials produced by the industrial and agricultural process into concrete is crucial in resolving the disposal problem. Adding to that is the waste material that comes from mining of Lynas Company in Malaysia. This project is also related to Lynas issue, given that UTP has carried out similar research on this topic with rice husk ash as the focal point and had proven succeed. With the preceding experience, research on WLP as a raw material in geopolymer concrete has become straightforward. Additionally, UTP has all the necessary equipment for the experimental lab.

CHAPTER 2: LITERATURE REVIEW

2.1 Implication to Environment

Environmental issues due to the manufacturing of OPC have led to the finding of substitute materials by the researchers. Production of 1.5 billion ton of cement generates 1.5 billion ton of CO_2 which are responsible for 5% CO_2 production in the world [7]. This has contributes to global warming and thus climate changes all over the world particularly the developed and developing country.

2.2 Geopolymerization

The geopolymer technology has recently attracted increasing attention as a viable solution to reusing and recycling industrial solid wastes and by-products, which provides a sustainable and cost-effective development for many problems where hazardous residues have to be treated and stored under critical environmental conditions [8]. Therefore, countless studies and researches on geopolymer have been going on for few decades with various waste materials, hazardous or not, utilized to replace Ordinary Portland Cement (OPC) in the conventional cement concrete.

2.2.1 Source Materials

Throughout the year, a number of waste materials have been successfully utilized in replacing OPC such as Pulverized Fly Ash (PFA), Ground Granulated Blast Furnace Slag (GGBS) and Microwave Incinerated Rice Husk Ash (MIRHA). In respect to hazardous waste materials, few researches have been conducted on geopolymerization of these materials in construction industry. Among them are the geopolymerization of lead smelting slag (LSS), bauxite residue and red mud (RM).

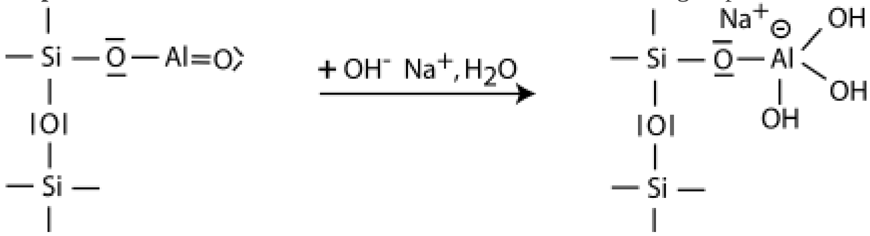
2.2.2 Alkalinity

The alkalinity or Na/Si ratio was also altered by changing the concentration of NaOH solutions [9]. This geopolymer which posses the compressive strengths of up to 20.5 Mpa, which is comparable to most Portland cements.

2.2.3 Condensation of Geopolymer due to Alkalinity

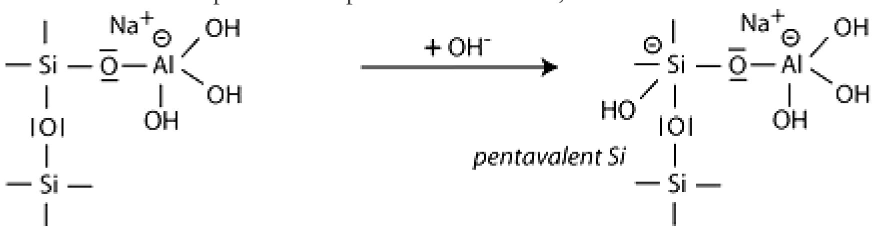
The chemical mechanism can be interpreted in the following way, with NaOH

Step 1: alkalination and formation of tetravalent Al in the side group sialate $-Si-O-Al-(OH)_3-Na^+$,



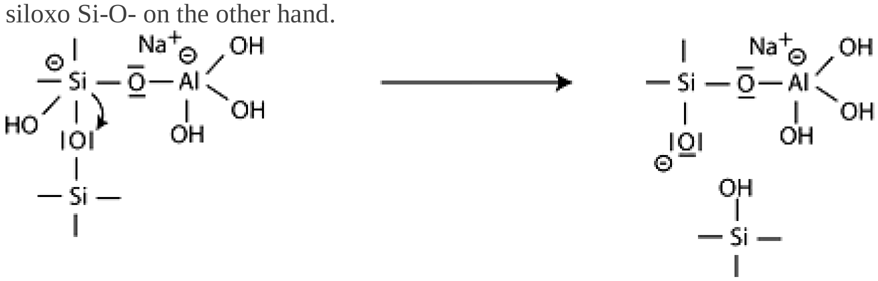
(1)

Step 2: alkaline dissolution starts with the attachment of the base OH- to the silicon atom, which is thus able to extend its valence sphere to the penta-covalent state,



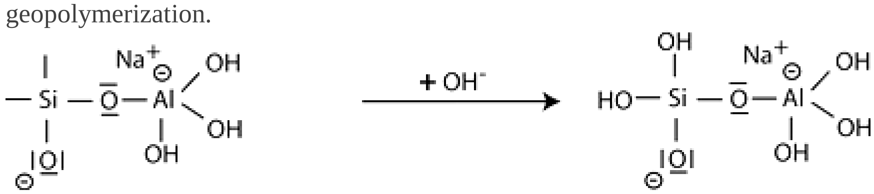
(2)

Step 3: the subsequent course of the reaction can be explained by the cleavage of the siloxane oxygen in Si-O-Si through transfer of the electron from Si to O, formation of intermediate silanol Si-OH on the one hand, and basic siloxo Si-O- on the other hand.



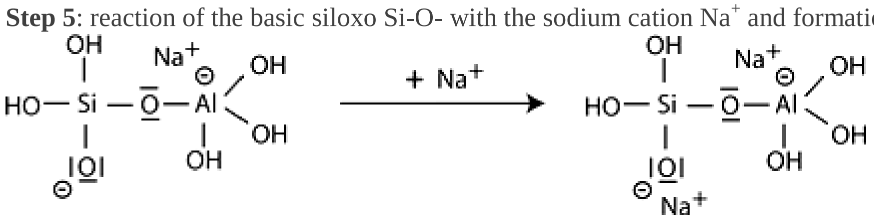
(3)

Step 4: further formation of silanol Si-OH groups and isolation of the ortho-sialate molecule, the primary unit in geopolymerization.



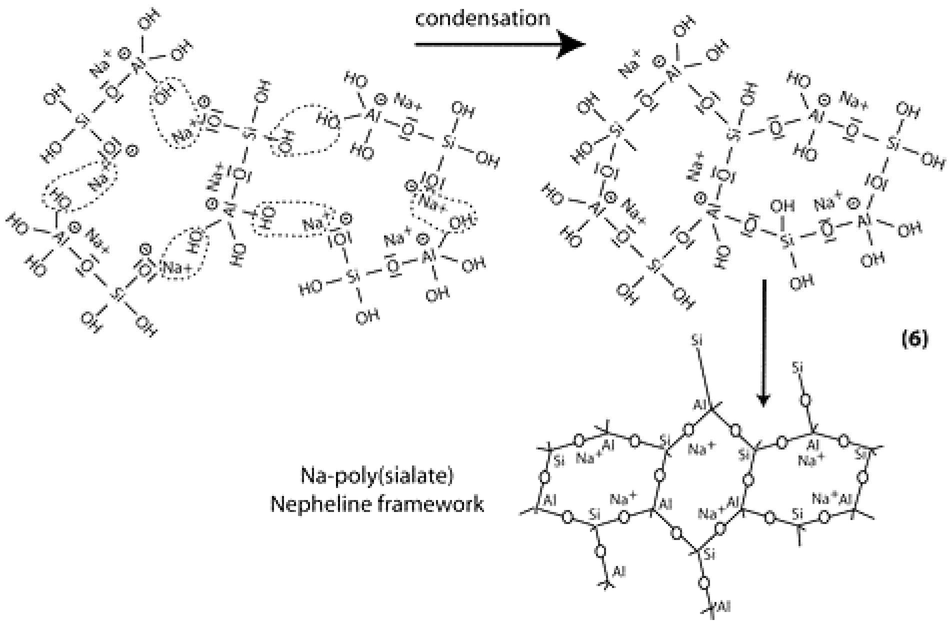
(4)

Step 5: reaction of the basic siloxo Si-O- with the sodium cation Na^+ and formation of Si-O-Na terminal bond.



(5)

Step 6a: condensation between ortho-sialate molecules, reactive groups Si-ONa and aluminum hydroxyl OH-Al, with production of NaOH, creation of cyclo-tri-sialate structure, whereby the alkali NaOH is liberated and reacts again and further polycondensation into Na-poly(sialate) nepheline framework.



2.3 Development of Geopolymer

J. He, 2012 has developed geopolymer composites from two types of waste materials namely red mud (RM) and rice husk ash (RHA). For this research. J. He prepared 4 specimens to study different parameters on the geopolymer. He studies the characteristics of the geopolymer with different curing durations. The geopolymer was cured in a laboratory ambient environment for 14 days after casting. The specimens where then demoulded, followed by prolonged curing in exposed condition and at elevated temperatures [10]. It is to study the effect of curing time on geopolymer. From this experiment, J. He et al. [11] concluded that the complete curing time for RM-RHA was about 35 days and with curing progressing, there is an obvious transition from a more ductile to a brittle failure. [12]. Therefore, J. He et al. [13] concluded that much longer reaction or curing time is required for this type of RM-RHA based geopolymers to develop its maximum strength and stiffness and that a great amount of impurities in the final geopolymeric products from the two raw materials may cause negative impact on the geopolymerization rate. The effect of RHA particle size was also studied by J. He et al. [14].

2.3.1 Curing of Geopolymer

It is to study the effect of curing time on geopolymer. From this experiment, J. He et al. [11] concluded that the complete curing time for RM-RHA was about 35 days and with curing progressing, there is an obvious transition from a more ductile to a brittle failure. [12]. Therefore, J. He et al. [13] concluded that much longer reaction or curing time is required for this type of RM-RHA based geopolymers to develop its maximum strength and stiffness and that a great amount of impurities in the final geopolymeric products from the two raw materials may cause negative impact on the geopolymerization rate. The effect of RHA particle size was also studied by J. He et al. [14].

Another study on Immobilization of Lead Smelting Slag within Spent Aluminate – Fly Ash Based Geopolymers shows that hazardous waste material such as lead smelting slags (LSS) generated from the production of lead have a potential to be turned into useful building materials under controlled conditions in specific situations [15]. The experimental result of this LSS geopolymers was plotted as compressive strength versus curing time graph. The plot shows that the higher the value of LSS incorporated into the geopolymer the higher the compressive strength of the geopolymer at 28 days of curing (M.B. Ogundiran et al., 2013). Research on Synthesis and Heavy Metal Immobilization Behaviours of Slag Based Geopolymer was a work done for the synthesis of slag based geopolymer with four different slag content (10%, 30%, 50%, and 70%) and three types of curing regimes (standard curing, steam curing and autoclave curing) to obtain the optimum synthesis condition based on the compressive and flexural strength. In this research, the slag based geopolymer achieved 75.2 MPa compressive strength and 10.1 Mpa flexural strength [16]. Consequently, these methods should be considered in the study of WLP geopolymer development.

2.4 WLP

The question of what to do with Water Leach Purification residue (WLP) in Malaysia arose with the operation of the rare earth refinery industry by the Lynas Advanced Materials Plant (LAMP) in Gebeng, Pahang towards the end of the year 2012. According to the research done by the National Toxic Network (NTN), Lynas assumed that the waste materials will be utilized in other industries such as construction industry due to its storage and environmental issues [17]. The waste water treatment plant will generate up to 2000tpa of bio sludge which will be disposed of to the WLP tailing pond [18]. The bio sludge is likely to contain residual uranium, thorium and other hazardous materials as a result of the concentration of contaminants in the water filtration process [19]. Red mud which possess the similar qualities to the LAMP tailing but with a lower concentration of radioactive uranium and thorium and their decay products [20] was reviewed as it is the closest example which incorporating radioactive waste materials in construction materials.

For WLP to be utilised in the construction industry as one of the cement replacement materials, a study and experimental research on the geopolymer development are eventually will become the focus of this paper. One of the most distinctive ways adopted by researchers in geopolymer concrete study is by observing the compressive strength development of the geopolymer versus the curing time of the geopolymer (A. Kusbiantoro et al., 2012) [21]. The geopolymer comprises of varying mixing ratios of the raw materials will be studied by observing their respective compressive strength development over the days.

It is proven that hazardous materials can be utilized into construction product by incorporating its optimum amount into the concrete to produce acceptable concrete with high compressive strength. This optimum amount needs to be studied by carrying out development study of the material which comprises of a range of experiments. WLP waste may contain some useful and valuable elements but these are frequently bound up with toxic or radioactive elements that make other uses hazardous to workers and consumers of the final product or the environment [22].

CHAPTER 3: METHODOLOGY

3.1 Materials

The materials that are used for the experiment range between source material, WLP and other basics for a concrete mix including fine and coarse aggregates and not to forget the chemical additives, alkaline.

3.1.1 Fly Ash and WLP

Materials like coarse aggregates and fine aggregates will be prepared as according to the appropriate standard set in the guidelines. For the waste materials comprises of fly ash (FA) and water leach purification residue (WLP), all will be obtained from the respective industries related to the generation of those wastes. Since, the main constituents of geopolymer are source materials and alkaline liquid, therefore, alkaline liquid consists of the combination of sodium hydroxide or potassium hydroxide with sodium silicate or potassium silicate will be needed [23].

3.1.3 Other Materials

This part includes the aggregates in the mix. The coarse aggregates used are those passing 20mm in the sieve test. Moreover, the fine aggregates used in the experiment is the portion passing 5mm in sieve analysis.

Figure 1: Sieve Analysis Tools

The additives that are used in the mix include the NaOH with portion as shown in the mix proportion table and molarity of 8. Sodium Silicate also is added together with water according to the mix proportion as well.

3.2 Experimental Details

The experiment goes in to many steps to search for the results and to analyze them. There were 27 samples for the 3 different mix proportions of WLP inclusion. The 9 samples would then be divided in to the 3 different ages (7, 14 and 28 days). The experiment in detail is shown in the table below.

<table>
<tr><th></th><th>Tests</th><th>WLP Inclusion</th><th>Age of Tests</th><th>Size of Samples</th><th>Curing Method</th><th>No. of Samples</th><th>Standard Used</th><th>Units</th></tr>
<tr><td>NDT</td><td>UPV</td><td rowspan="3">0%,5%,10%</td><td rowspan="3">7,14,28 Days</td><td rowspan="3">100x100x100 mm</td><td rowspan="3">Instant (Oven) + External Exposure</td><td rowspan="3">27</td><td>BS 12504-4: Part 4 2004</td><td>Km/s</td></tr>
<tr><td></td><td>RH</td><td>BS: 1881</td><td>Mpa</td></tr>
<tr><td>DT</td><td>Compression</td><td>BS: 1881</td><td>Mpa</td></tr>
</table>

Table 1: Experimental Details

3.3 Mix Proportion

For this study, fly ash-based geopolymer will be replacing the function of ordinary Portland cement as the binder for the concrete. The manufacturing of WLP geopolymer concrete will apply the trial and error concrete technology methods with a number of varying mixtures to be tested. Those sample mixtures will be tested with necessary tests such as the mechanical tests to study the strength and durability of the concrete.

DETAILS OF MIX PROPORTIONS (g/m3)

Code	**Coarse Aggregates**	**Fine Aggregates**	**Fly Ash**	**WLP**	**Water**	**NaOH**	**Na_2SiO_3**
0%WLP	1200	645	350	0.0	35	41	103
5%WLP	1200	645	332.5	17.5	35	41	103
10%WLP	1200	645	315.0	35.0	35	41	103

Table 2: Mix Design per Mold

DETAILS OF MIX PROPORTIONS (All in kg/m3) for **12 Samples (1 mix)**

Code	Coarse Aggregates	Fine Aggregates	Fly Ash	WLP	Water	NaOH	Na_2SiO_3
0%WLP	14.4	7.8	4.2	0.0	0.42	0.492	1.263
5%WLP	14.4	7.8	3.99	0.21	0.42	0.492	1.263
10%WLP	14.4	7.8	3.78	0.42	0.42	0.493	1.263

Table 3: Mix Design per 12 Molds (9 molds are taken for testing samples)

Before mixing process, all the essential materials will be prepared in advance due to certain reasons. Alkaline solutions for instance were prepared 1 hour before mixing process started to prevent precipitation of NaOH in the solution [24].

Figure 2: Mixing Machine

Mixing process will also be decided either to use wet mix or dry mix or both to ensure the mixture homogeneity so as to prevent problems like concrete bleeding or segregation afterwards.

3.4 Curing of Samples

After casting the specimens, they will be kept in rest for some times before being demoulded. The curing process of a concrete is extremely crucial since this is the time where concrete will achieve their best strength. Thus, the method adopted for curing will determine the best method to achieve the optimum concrete compressive strength.

Figure 3: Samples in Oven at 80 degrees Celsius

Few available curing methods are ambient curing, oven curing, external exposure curing and hot gunny curing where the specimens will be kept under different controlled temperature and environment according to the varying methods.

3.5 Nondestructive Tests

This type of testing of samples does not destroy the sample. There are many ways to test the samples without destroying them. In this experiment, Ultrasonic Pulse Vleocity and Rebound Hammar are both used to check for quality of samples and strength respectively.

3.5.1 Ultrasonic Pulse Velocity

This test is to check on the quality of the sample. The device has an emitter of waves and a receiver. When both emitter and receiver are put on sample sides, the device calculates the time through which the waves traveled through the sample. The time will then be transferred to velocity in Km/sec to check on the quality of the samples. The larger the value of the velocity shows a better quality.

Figure 4: Ultrasonic Device

3.5.2 Rebound Hammar

The Rebound hammer at the concrete lab helps in getting the surface hardness and strength of the samples. The procedure is to get 9 readings for 3 sides of every sample. Then with the average of reading and using the conversion curves, we get the approximate hardness and strength. This is repeated to all the samples.

Figure 5: Rebound Hammar

In this experiment, the conversion curve in table 4 is used to convert the readings of the Rebound hammEr to values in MPa.

REBOUND HAMMER VALUE VS. COMPRESSIVE STRENGTH R	f'c (psi)	R	f'c (psi)	R	f'c
20.0	1,220	28.5	2,630	37.0	4,360
20.5	1,295	29.0	2,720	37.5	4,460
21.0	1,370	29.5	2,820	38.0	4,560
21.5	1,445	30.0	2,920	38.5	4,570
22.0	1,520	30.5	3,015	39.0	4,780
22.5	1,600	31.0	3,110	39.5	4,890
23.0	1,680	31.5	3,215	40.0	5,000
23.5	1,760	32.0	3,320	40.5	5,115
24.0	1,840	32.5	3,420	41.0	5,230
24.5	1,925	33.0	3,520	41.5	5,340
25.0	2,010	33.5	3,615	42.0	5,450
25.5	2,095	34.0	3,710	42.5	5,560
26.0	2,180	34.5	3,815	43.0	5,670
26.5	2,270	35.0	3,920	43.5	5,785
27.0	2,360	35.5	4,030	44.0	5,900
27.5	2,450	36.0	4,140	44.5	6,015
28.0	2,540	36.5	4,250	45.0	6,130

Table 4: Conversion Table for Rebound Hammar

3.6 Destructive Test

It is a test for samples that will result in destruction? Examples for such tests include compression test and tensile strength test. In this research, compression test is used to determine the strength of the samples.

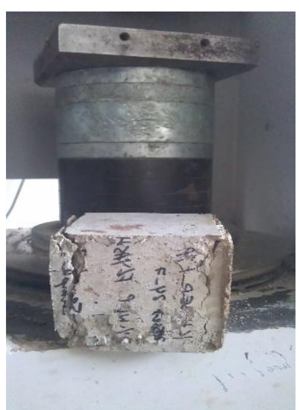


Figure 6: Sample under compression test

3.6.1 Compression Test

This destructive test is used to find the ultimate strength of the samples. All the 27 samples undergone the compression test after the nondestructive tests. The values given from the tests of ages 7, 14 and 28 days are then to be tabled in MPa units.

Figure 7 : Compression Testing

Chapter 4: RESULTS AND DISCUSSION

4.1 Destructive Tests

4.1.1 Compression Test

The results from all the test are out and are divided into different tables. The first is the compression strength test as shown in Table 1 showing the strength in 7,14 and 28 days of the samples of the 3 mixes, base,5%WLP and 10%WLP. The table also shows the difference in % of the strength between Base and the WLP5% results.

As shown in the table, if we take the Base mix, it shows average of 49.32Mpa, 56.9Mpa and 53.38Mpa for the 7,14 and 28 days respectively. The reduction of strength on the 28 day test was also noticed in all the other mixes as shown in the table below.

COMPRESSION STRENGTH TEST (MPa)			
MIX	Avg	Avg	Avg
Base 0%	49.38	56.9	53.38
WLP 5%	43.55	49.84	45.77
Difference %	-11.80%	-12.40%	-14.20%
WLP 10%	40.01	44.36	41.62

Table 5: Results for Compression Test

In the column of WLP 5%, were 5% of the base fly ash was replaced with WLP, the average results for the 7,14 and 28 days are 43.55Mpa, 49.84, and 45.77Mpa. The development of replacing 5% with WLP shows a decrease in the strength with percentage that ranges from 11.8% to 14.2%. The last results for the destructive test, the compression test, show the testing of the replacement of 10% with WLP. The result shows average strengths of 40.01Mpa, 44.36Mpa and 41.62Mpa for the ages of 7, 14, and 28 days respectively. The results for the 10% shows a rapid decrease in strength in the 28 day test too.

Figure 8 below shows a trend of minimum and maximum values for the readings of the compression test. The trend shows the values of the 28 days to be very close to the average between minimum and maximum strength values.

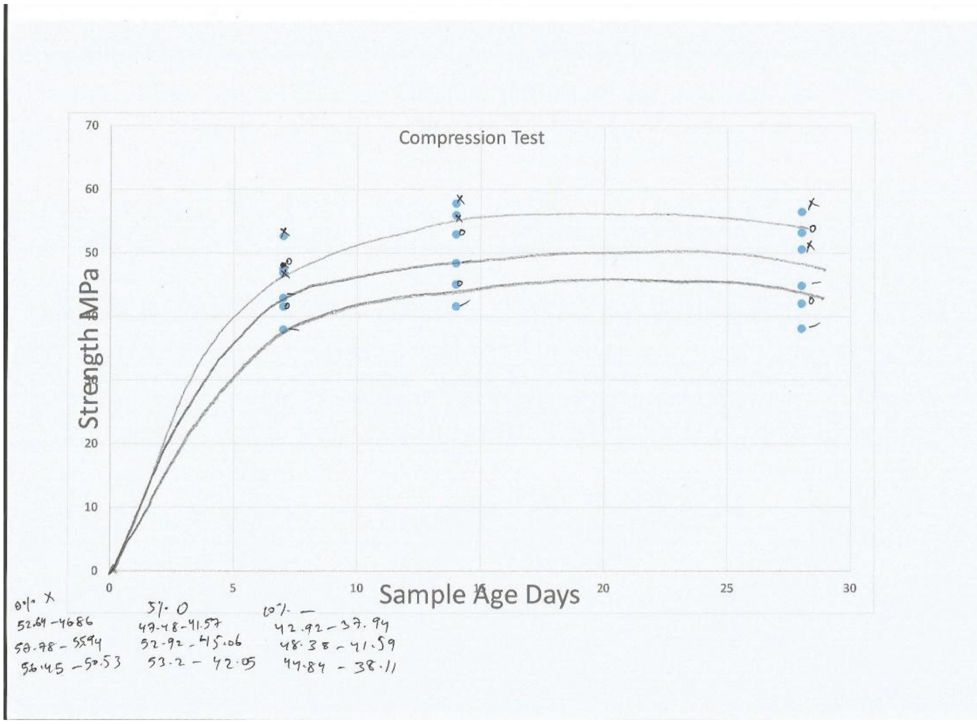


Figure 8 : Min-Max Trend for Compression Test

4.2 Nondestructive Test

4.2.1 Rebound Hammar Test

The results from testing the samples were not as expected. Taking 9 measures from 3 sides of every sample gave results ranging from 24.11 to 33 as average values. The values of the rebound hammar are shown in the tables below.

Using the conversion table, it is possible to get results in Psi which were then changed to Mpa and listed in the tables. The results ranged from 18.4 Mpa to 35.2 Mpa. Those results may not be accurate due to many factors including the angle of the hammer by which the measurement was taken.

Using the conversion table, it is possible to get results in Psi which were then changed to Mpa and listed in the tables. The results ranged from 18.4 Mpa to 35.2 Mpa. Those results may not be accurate due to many factors including the angle of the hammer by which the measurement was taken.

Base0%

		7 Days			AVG Mpa
S1	A	29	31	27	**32** **33.2**
		32	37	40	
		29	29	33	
	B	31	29	18	**31** **31.1**
		33	37	29	
		33	34	39	
	C	20	18	30	**26** **21.8**
		20	22	26	
		30	32	32	
		7 Days			Avg Mpa
S2	A	29	29	26	**30** **29.2**
		37	30	31	
		29	29	33	
	B	20	29	29	**31** **31.1**
		35	36	32	
		33	29	32	
	C	22	23	23	**26** **21.8**
		27	25	31	
		29	28	27	
		7 Days			Avg Mpa
S3	A	20	18	30	**26** **21.8**
		26	26	24	
		30	30	32	
	B	34	28	34	**32** **33.2**
		40	32	44	
		29	24	26	
	C	36	36	33	**33** **35.2**
		29	31	37	
		29	33	29	

		14 Days			AVG Mpa
S1	A	25	27	31	**30.33** **30.15**
		29	31	32	
		29	36	33	
	B	18	32	31	**30.56** **30.15**
		34	29	35	
		35	32	29	
	C	28	28	25	**29.44** **28.2**
		31	29	27	
		33	35	29	
		14 Days			Avg Mpa
S2	A	31	32	32	**29.22** **28.2**
		30	32	21	
		28	31	26	
	B	24	21	29	**27.44** **24.5**
		25	28	27	
		28	31	34	
	C	32	27	28	**27.78** **25.4**
		28	27	24	
		22	31	31	
		14 Days			Avg Mpa
S3	A	26	23	18	**26.78** **23.6**
		31	34	29	
		32	26	22	
	B	26	26	24	**28.89** **27.2**
		27	37	32	
		31	30	27	
	C	36	36	31	**31.22** **32.15**
		28	28	30	
		33	31	28	

		28 Days			AVG Mpa
S1	A	31	26	21	**31.11** **31.1**
		37	34	31	
		34	32	34	
	B	33	28	33	**29.78** **29.2**
		29	29	29	
		23	28	36	
	C	32	36	32	**31.11** **31.1**
		31	27	34	
		29	30	29	
		28 Days			Avg Mpa
S2	A	25	29	27	**29.44** **28.2**
		29	35	26	
		29	33	32	
	B	28	36	32	**32** **33.2**
		36	30	36	
		30	28	32	
	C	26	38	34	**31.89** **33.2**
		28	29	26	
		34	32	40	
		28 Days			Avg Mpa
S3	A	36	33	29	**30.22** **30.15**
		29	29	24	
		31	33	28	
	B	35	26	32	**32.22** **34.2**
		28	34	33	
		35	33	34	
	C	24	26	40	**32** **33.2**
		38	29	34	
		32	33	32	

Table 6: Results For Hammar Test Base Mix 0% WLP

WLP 5%

		7 Days			Avg Mpa			14 Days			Avg Mpa			28 Days			Avg Mpa
		29	26	31				29	28	31				31	26	25	
	A	32	37	40	**31.78** **33.2**		A	30	29	30	**29.78** **29.2**		A	26	32	33	**29.11** **27.2**
		29	29	33				28	31	32				27	29	33	
		31	26	25				32	29	30				33	35	33	
S1	B	26	25	27	**26.22** **22**	S1	B	30	29	31	**30.33** **30.15**	S1	B	30	29	31	**31.44** **32.15**
		26	25	25				33	30	29				29	32	31	
		20	31	24				29	31	31				28	32	29	
	C	29	24	25	**25.44** **21**		C	33	32	33	**31.44** **32.15**		C	26	31	26	**28.33** **26.3**
		26	21	29				29	35	30				31	29	23	
		7 Days			Avg Mpa			14 Days			Avg Mpa			28 Days			Avg Mpa
		24	25	26				25	24	30				27	32	31	
	A	24	21	23	**23.89** **18.4**		A	26	31	24	**27.33** **24.5**		A	28	31	32	**29.67** **29.2**
		25	23	24				33	26	27				33	27	26	
		22	26	26				27	25	26				29	31	31	
S2	B	22	24	24	**24.11** **18.4**	S2	B	33	31	24	**29.56** **28.2**	S2	B	25	32	24	**28.78** **27.2**
		26	22	25				32	33	35				30	27	30	
		25	24	25				29	26	28				27	31	32	
	C	26	31	31	**28.22** **26.3**		C	31	27	28	**29.11** **27.2**		C	29	25	32	**29.78** **29.2**
		29	30	33				33	31	29				30	32	30	
		7 Days			Avg Mpa			14 Days			Avg Mpa			28 Days			Avg Mpa
		23	27	32				31	32	18				28	26	24	
	A	29	30	31	**28.44** **26.3**		A	32	29	28	**27.44** **24.5**		A	26	26	31	**27.33** **24.5**
		30	26	28				29	27	21				27	31	27	
S3		29	32	31				28	21	28				29	30	31	
	B	28	29	26	**28.56** **26.3**	S3	B	26	33	31	**27.33** **24.5**	S3	B	29	26	22	**28.00** **26.3**
		26	27	29				22	29	28				29	30	26	
		31	36	30				32	34	31				28	31	31	
	C	34	31	31	**31.22** **32.15**		C	29	29	29	**30.56** **30.15**		C	28	30	29	**27.56** **24.5**
		26	33	29				31	32	28				28	21	22	

Table 7: Results For Hammar Test 5% WLP

WLP 10%

		7 Days			Avg Mpa			14 Days			Avg Mpa			28 Days			Avg Mpa
S1	A	25	26	31	**28.44** **26.3**	S1	A	28	27	29	**30.44** **30.15**	S1	A	31	26	21	**31.11** **31.1**
		33	28	26				29	31	32				37	34	31	
		32	27	28				29	36	33				34	32	34	
	B	24	27	23	**25.11** **20.1**		B	18	32	31	**30.56** **30.15**		B	31	27	33	**29.89** **2.2**
		26	27	21				34	29	35				32	29	29	
		25	25	28				35	32	29				27	29	32	
	C	30	31	31	**29.67** **29.2**		C	28	28	25	**29.44** **28.2**		C	27	31	33	**28.78** **27.2**
		29	33	30				31	29	27				28	21	29	
		26	27	30				33	35	29				29	30	31	
		7 Days			Avg Mpa			14 Days			Avg Mpa			28 Days			Avg Mpa
S2	A	27	21	24	**25.78** **21.8**	S2	A	31	32	32	**29.22** **28.2**	S2	A	31	29	26	**29.56** **28.2**
		28	26	24				30	32	21				27	26	33	
		28	29	25				28	31	26				30	33	31	
	B	26	22	24	**30.33** **30.15**		B	24	21	29	**27.44** **24.5**		B	29	33	31	**31.22** **32.15**
		33	35	33				25	28	27				34	27	36	
		32	33	35				28	31	34				35	24	32	
	C	29	29	21	**29.56** **28.2**		C	32	27	28	**29.67** **28.2**		C	34	31	37	**30.33** **30.15**
		29	33	31				24	36	33				29	22	27	
		30	32	32				28	30	29				31	30	32	
		7 Days			Avg Mpa			14 Days			Avg Mpa			28 Days			Avg Mpa
S3	A	21	24	23	**29.56** **28.2**	S3	A	29	32	31	**28.56** **26.3**	S3	A	26	22	24	**28.22** **26.3**
		36	33	36				28	29	26				29	33	31	
		31	30	32				26	27	29				29	28	32	
	B	24	33	32	**30.11** **29.2**		B	28	30	29	**29.11** **27.2**		B	25	24	30	**27.78** **25.4**
		24	36	33				28	30	29				28	26	29	
		29	28	32				31	30	27				32	28	28	
	C	31	32	28	**29.22** **28.2**		C	36	33	36	**31.56** **32.15**		C	33	32	32	**30.89** **31.1**
		28	30	29				28	28	30				28	29	33	
		29	27	29				29	33	31				31	31	29	

Table 8: Results For Hammar Test 10% WLP

For further discussion on the Rebound Hammar test, a table containing the minimum and maximum value resulted from Rebound hammer for every sample to construct a graph.

	7Days	7Days	14 Days	14 Days	28 Days	28 Days

		(MPa)		(MPa)		(MPa)
0% Min	40	59	37	43.6	40	50
0% Max	18	12.2	18	12.2	21	13.7
5% Min	40	50	35	39.2	35	39.2
5% Max	21	13.7	18	12.2	21	13.7
10% Min	36	41.4	36	41.4	37	43.6
10% Max	21	13.7	21	13.7	21	13.7

Table 9 : Min-Max Values of Rebound Hammer

From the above table, a trend as shown in the graph below is obtained. A trend showing the three mixes with results of 7, 14 and 28 days. The curves are marked with x,o and - for 0%WLP , 5% WLP and 10%WLP respectively. From the trend if we compare the 5% and 10%, it can show a slight difference in strength.

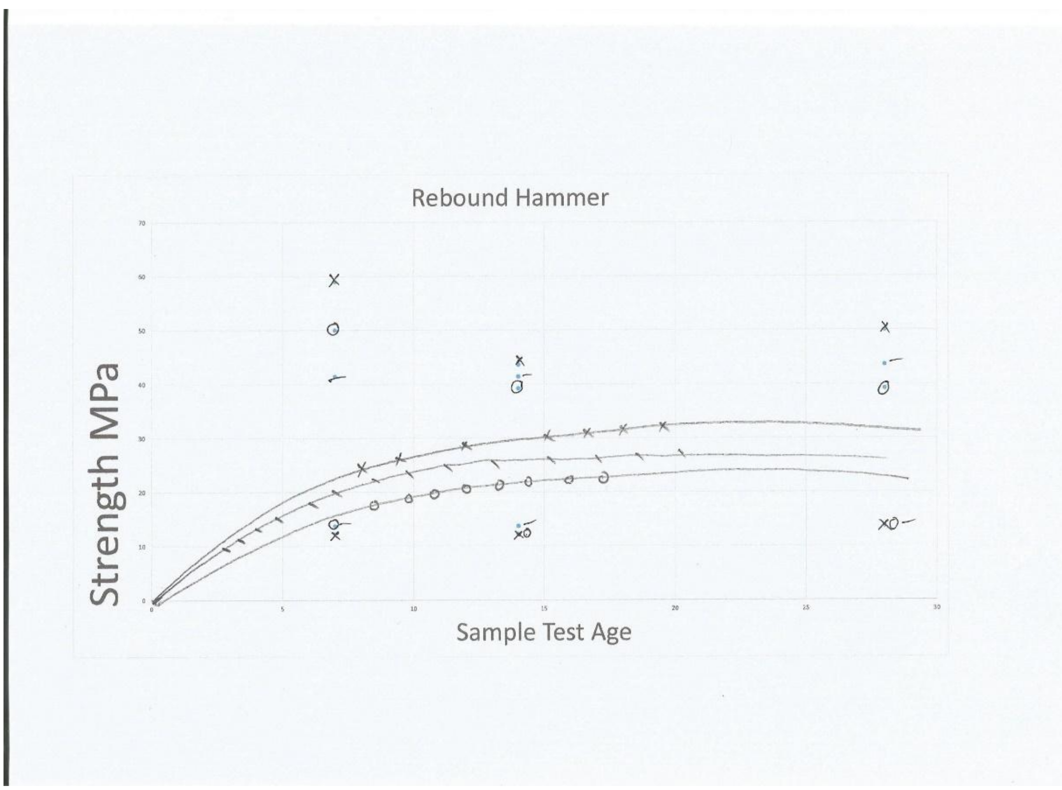


Figure 8: Rebound Trend Results

4.2.2 UPV Tests (Ultrasonic Pulse Velocity)

For the nondestructive test using the ultrasonic pulse velocity , the results shows that the samples are excellent and good. When measuring the time spent for the waves to travel through the 100mm wide sample, the results are shown in the table below. The table show the time spent at 2 sides (Side 1 and Side 2) of every sample (S1, S2 and S3) for the ages of 7,14 and 28 days.

Basic 0%

	7d	14d	28d
S1	4.26	4.08	4.26
S2	4.08	4.08	4.35
S3	4.55	3.92	4.35

WLP 5%

	7d	14d	28d
S1	4.17	4.17	4.26
S2	4.26	4.26	4.17
S3	4.08	4.17	4.26

WLP 5%

	7d	14d	28d
S1	4.17	4.17	4.26
S2	4.17	4.26	4.17
S3	4.26	4.26	4.35

Table 10: Results For UPV Test (Velocity in Km/sec)

The results I found shows many time slots for the waves to travel through the sample ranging from 22.0 micro seconds to 25.5 micro seconds. The shorter the time the better the quality of the sample. To calculate the velocity of the waves, distance divided by the time will give the solution.

Distance= 100mm = 0.0001km

Time= 25.5 microseconds= 0.0000255 seconds

Velocity for 25.5 microseconds= 0.0001/0.0000255 = 3.92 Km/sec Good Quality

Velocity for 22.0 microseconds= 0.0001/0.000022 = 4.55 Km/sec Excellent Quality.

The readings are then changed to velocity as shown in the table above. To understand the meaning of the readings in velocity, a table of conversion in table 11 shows the conversion of velocity to quality of samples.

Sr. No	Pulse velocity be cross probing (direct method)	Concrete Quality Grading
1.	Above 4.5 km/s	Excellent
2.	3.5 km/s to 4.5 km/s	Good
3.	3.0 km/s to 3.5 km/s	Medium
4.	Below 3.0 km/s	Doubtful

Table 11: Velocity VS Quality of Sample

According to the table above, using the least and most time spent to travel through the samples, the pulse velocity showing Excellent and Good quality of all the samples.

A trend curve is then obtained to see the comparison of the mix of samples and the age of testing as shown below in table 12.

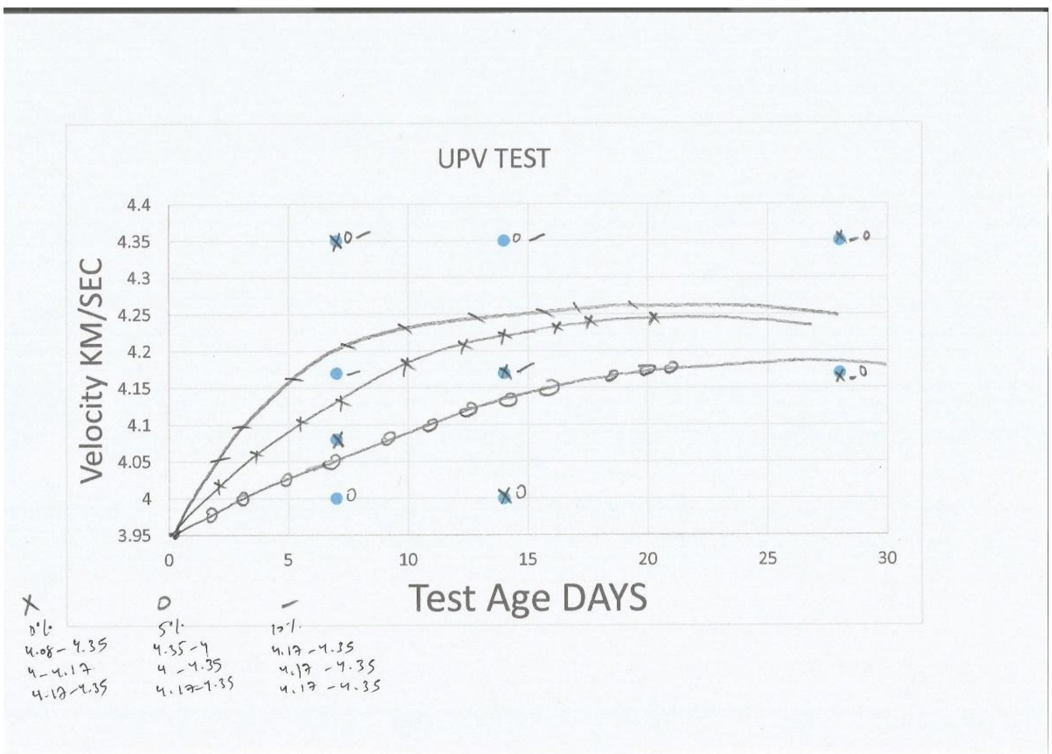


Figure 10: Max-Min UPV Test Trend

Chapter 5 : CONCLUSION AND RECOMMENDATION

At the end of this research, a new type of geopolymer concrete consists of a new type of industrial waste materials will be produced. Additionally, the optimum mix design ratio and curing method to produce the finest geopolymer concrete integrating WLP and fly ash will be still under research for different additives to the WLP to determinethe highest strength of the concrete.. The results showed decrease in the strength of the geopolymer with the increase of the WLP. However, the WLP can still be used and the strength obtained can still be developed with new research methods and additives. With the strength obtained, WLP can be used in concrete industry rather than disposing it costing a lot of money and risk to the environment.

The consumption of WLP in concrete will help with the disposal of this radioactive material that has big impacts on the environment.

My recommendation is to have further research on WLP should be carried out in other area to diverse the utilization of the wastes. For the WLP, more techniques can ome up to totally mix it with all other additives. This will make sure all exposure surfaces of the particles react with the additives like the NAOH and the silicates.

Geopolymer concrete should not be the only focal point for the exploitation of this waste material. A study can be done to observe the suitability of WLP as a subgrade material for the construction of road and highway. Compaction test on the raw material can determine if it can be used as a filling material for the construction work.

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APPENDIX

	COMPRESSION STRENGTH TEST											
	7 days				14DAYS				28 days			
	S 1	S2	S3	Avg	S1	S2	S3	Avg	S1	S2	S3	Avg
Base 0%	52.64	48.65	46.86	49.38	57.87	56.78	55.94	56.9	56.45	50.53	53.17	53.38
WLP 5%	47.48	41.59	41.57	43.55	45.06	51.55	52.92	49.84	42.05	42.3	53.2	45.77
Difference %	-9.80%	-14.50%	-11.30%	-11.80%	-22.10%	-9.20%	-5.40%	-12.40%	-25.50%	-16.30%	0%	-14.20%
WLP 10%	37.94	39.77	42.92	40.01	43.11	48.38	41.59	44.36	42.31	44.84	38.11	41.62