STABILIZED AND SOLIDIFIED CALCIUM HYDROXIDE CONCRETE

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Abstract- Compressive test have been done in different mix ratio of Calcium Hydroxide which has been prepared to replace the river sand in the concrete in form of cubes and cylinders to analyze the strength of the concrete. The size of the cubes that has been used is 100mm x 100mm x 100mm. The cylinders size is 300 mm length and 150 mm diameter as it recommended by the Eurocode. 12 cylinders and 52 cubes have been produced, in each samples the percentage of calcium hydroxide increased. Results obtained that the strength of concrete increased by replacing the calcium hydroxide. The work evaluates four partitions of the calcium hydroxide replacement in sand, started with 0% CH, 20% CH, 30% CH and 40% CH. The result obtained that the best mix ratio and best strength when the CH replaced sand at 20%. Besides that, crushed block leaching test have been used to determine how much calcium hydroxide has been leached out from the crushed block concrete. The results obtained that the stabilization and solidification has been achieved as the optimum percentage of using CH in concrete found and the crushed block leaching elements have not exceed the standard leaching limit values for hazardous wastes.

Keywords- Cement, Calcium Hydroxide, Compressive Strength, Stabilization and Solidification.

I. INTRODUCTION

Throughout the time many researches have been conducted to stabilized and solidified suitable waste material that could be a good replacement in concrete. Previous studies found that the stabilized copper slag has almost the same behaviors as the medium sand in the concrete, that lead to the utilization of this waste material in place of sand in concrete or as an addition admixture with sand. Another partial replacement in concrete is bottom ash, which has high possibility to evolve to be perfect pozzolanic material. There was investigation on the usage of fly ash class F as a partially fine aggregate replaced by weight in concrete [3]. Previous results indicated that cement is an excellent stabilization and solidification binder for hazardous waste.

Stabilization is the converting of chemical wastes from risky pollutes into more chemically stable form that do not harm the environment or any living organisms while solidification is concerning about stealing the waste from solid materials that do not contain chemical interactions between the polluted material and solidifying additives [4].

Calcium Hydroxide is a fine white powder which is an inorganic compound with the chemical formula Ca(OH)2. It is a colorless crystal or white powder and is obtained when calcium oxide is mixed with water. Table 1 represents the common chemical properties of Calcium Hydroxide.

Table 1: Chemical properties of Calcium Hydroxide

Appearance	White powder
CaO (Calcium Oxide)	72.0 % min
Ca(OH)2 (Calcium hydroxide)	95.0 % min
Moisture	0.75 % max
MgO (Magnesium Oxide)	0.5 % max
CaSO4 (calcium sulphate)	0.05 % max
Fe2O3 (Iron Oxide)	0.08 % max
Al2O3 (Aluminum Oxide)	0.15 % max
SiO2 (Silica)	0.7 % max
Mn	130 ppm max

Categorized as scheduled waste SW427 by Malaysia's Environmental Quality Act 2005 [5], Calcium Hydroxide is a by-product material which is considered as a waste that could be hazardous to human life. It can cause severe skin irritation, chemical burns, blindness, or lung damage when exposed. The huge release of this material in the manufacturing processes caused massive increase of the amount of this waste on the earth.

Table 2 summarized the worldwide production of Calcium Hydroxide.

Table 2: Production of Calcium Hydroxide [6]

World	348 million tonnes
United States	19 million tonnes
Europe	27 million tonnes
China	220 million tonnes
Rest of Asia	32 million tonnes

The main objectives of this study were to investigate the effect of using stabilization and solidification method to treat Calcium Hydroxide and utilize the S/S product in concrete. The study consisted of the following tasks:

1. Investigate the effect of Calcium Hydroxide replacement as fine aggregates on the compressive strength of concrete at different curing period.
2. Evaluate the effect of Calcium Hydroxide replacement on the workability and density of concrete.
3. Conduct crushed block leaching testing on the concrete.

II. MATERIALS

A. Cement

The cement used in this study was ordinary Portland cement (OPC) produced by Lafarge Cement Malaysia. This cement is the most widely used in the construction industry in Malaysia.

B. Fine aggregates

River sand has been utilized in the mixture of concrete. It appears in brownish color and has the size of aggregates ranging from 0.029mm to 0.0787mm.

C. Coarse aggregates

The size of coarse aggregates that have been used in this work is range between 10-20 mm.

D. Calcium Hydroxide

20 kg of dewatered calcium hydroxide was taken from a gas manufacturing company in Malaysia for this research purpose.

III. RESEARCH METHODOLOGY

The calcium hydroxide waste was mixed with the concrete as a replacement over sand in different percentage started with 0%, 20%, 30% and 40% of sand. The mix ratio followed in this research is 1:1:2 which is cement: sand: coarse aggregate and water to cement ratio of 0.5 according to the consistency, coarse aggregate used in this research was in range between 10-20mm. 12 cylinders of 300 mm length and 150 mm diameter were made each 3 has a different percentage of Calcium hydroxide in order to take the average of them to find the optimum percentage. 4 set of mixes were made with calcium hydroxide with size of 100 mm x 100 mm x 100 mm. In accordance to the BS 8500 the compressive strength of 150 mm and 100 mm cubes are considered equivalent. The cubes were made to be tested in the universal testing machine in different days started from day 1, day 3, day 7, day 14 and day 28 to record the improvement of the concrete strength till it become hardened which is after 28 days [8]. The total numbers of the cubes used for compressive test are 40 cubes. Another 12 cubes have been made in order to test the water absorption [9] and moisture content [10] to make them in total 52 cubes. After the compressive test is done the crushed cubes has been collected to be used in the leaching test to test the chemical stability of the concrete.

Crushed block leaching test were conducted by collecting crushed block of the concrete cubes and have been tested by using ICP-OES. Purpose of the crushed block leaching test to determine chemical reaction of the crushed concrete with the acetic acid and to study whether the crushed concrete has leached or not. The samples that were tested using this technique is 0% and the 20% calcium hydroxide which has the highest compressive strength to ensure its leaching stability is within the acceptable leaching limit [11].

IV. RESULTS AND DISCUSSION

A. Moisture content of concrete

The moisture content of Calcium Hydroxide concrete shown in Table 3 has been concluded from 3 samples for each percentage of calcium hydroxide stabilization which are 0%, 20%, 30% and 40%.

Table 3: Moisture content of Calcium Hydroxide concrete

Moisture content percentage			
0%	20%	30%	40%
4.04%	3.83%	3.48%	2.22%
4.29%	3.44%	3.36%	2.54%
3.88%	3.42%	3.58%	1.83%

It can be seen that the moisture content in 0% calcium hydroxide has the highest moisture content. The percentage of moisture content reduced in 20%, 30% and 40% by an average of 0.5%, 0.6% and 1.87% respectively. This explains that when the amount of calcium hydroxide is higher the moisture content of concrete is lower which can be due to the good components of calcium hydroxide which help to bind the materials together. The moisture content experiment results conclude that calcium hydroxide has low moisture content.

B. Water Absorption of Calcium Hydroxide Concrete

The obtained result in Table 4 shows that the water absorption percentage increased gradually with the increased amount of calcium hydroxide.

Table 4: Water Absorption of Ca(OH)2 Concrete

Water absorption percentage			
0%	20%	30%	40%
5.59%	6.49%	7.03%	9.84%
5.53%	5.83%	6.68%	9.12%
5.96%	6.64%	8.18%	8.75%

The percentage of water absorption considered the highest in concrete cubes which have 40% of calcium hydroxide. The control cubes of 0% have the lowest water absorption. Water absorption increased in concrete cubes which contain more calcium hydroxide. It start increased in cube 20% as the absorbed water is 6.49% and have increased more and more in concrete cubes of 30% and 40%. This is due to the huge percentage of waste of porous calcium hydroxide replacing the content of sand in the cubes which decreased the density of the cubes that help to absorb more water compared to the control cubes.

C. Compression Strength for Concrete Cylinders

Compression test has been done for the cylinders and cubes in order to test the strength of calcium hydroxide in concrete and to find the best ratio that could be used in engineering field. Table 5 shows the results of the compression test of the concrete cylinders which contain of 0%, 20%, 30% and 40% of calcium hydroxide as fine aggregate replacement. The average result of cylinders was taken to be analysed.

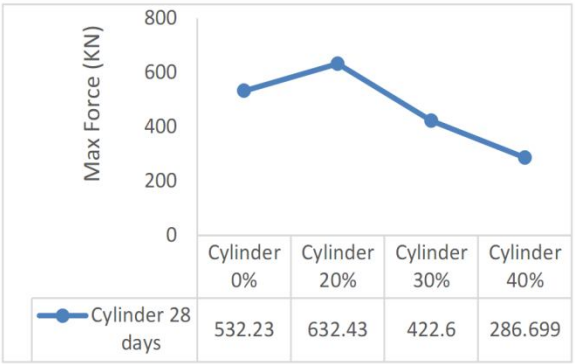


Figure2: Max force vs. Calcium Hydroxide

The maximum force of the calcium hydroxide concrete at 20% design mix is 632.430 kN and it has been reduced in 30% and 40% mix which are 422.6 kN and 286.699 kN respectively. The obtained result of the compressive test shows that the 20% of calcium design mix is at its optimum strength when used as a replacement material for fine aggregate in concrete and it shows that 20% is the maximum percentage that can be used as a replacement material in concrete because the 30%CH and 40%CH proved to be fail to increase the strength of concrete due to the huge percentage of CH that have been used as replacement in sand.

D. Compression Strength for Concrete Cubes

The results obtained in Table 5 proved that cubes of 20% of calcium hydroxide has the highest strength effect on the concrete compared to other cubes which has different percentage of calcium hydroxide as 30% and 40%. The results are approximately equivalent to the cylinders compressive strength which affirmed that 20% of calcium hydroxide is the maximum force and the best mix ratio of calcium hydroxide in concrete as a replacement material. The maximum force of cubes test increased in 20% as it 292 KN and decreased in 40% as the maximum force is 178 KN.

Table 5: Compressive Strength for the concrete cubes

Calcium Hydroxide percentage	Area (mm²)	Compressive Strength (N/mm²)
0 %	100 x 100	25
20 %	100 x 100	29.2
30 %	100 x 100	22.5
40 %	100 x 100	17.8

Figure 3 shows the arrangement of the cubes concrete compressive strength starting from the highest strength which is 20% and ending with the lowest compressive strength in 40%. The difference point between the highest strength and lowest is 10.5. The graph shows the improvement of strength gradually till day 28 and it's clear that concrete cubes of 20%CH has the higher strength over all the cubes. The strength of the concrete cubes in 20% calcium hydroxide has increased progressively as it able to resist load of 113 kN in day 1 and gained the resistance to 292 kN in day 28 which explain the improvement of the cubes strength.

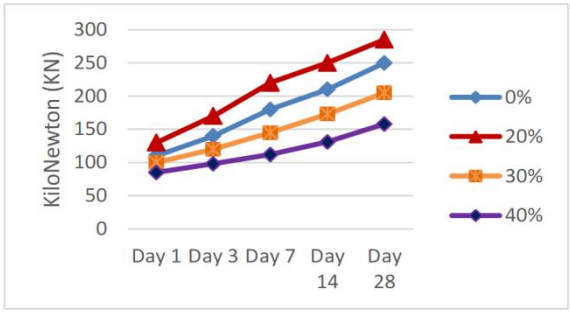


Figure 3: Compressive test for concrete cubes

E. Density of Calcium Hydroxide Concrete

The results of the density of CH concrete in Table 6 shows that the average value of 0% calcium hydroxide has the highest density as it 2238.4 g and the lowest density found in the concrete cubes of 40% of calcium hydroxide as it is expected due to the large amount of calcium hydroxide in the concrete cubes. The average value of the samples of 40% is 2126.9 g. The concrete cubes of 20% which achieved best strength have an average density of 2223.5 g which is the nearest value to the maximum density in 0% as the difference between both samples is only 14.6 g.

Table 6: Density of the concrete cubes

Label of Samples	Density of Cubes	Average
0 % Calcium Hydroxide	2230.4 g	2238.4 g
	2252.3 g	
	2232.4 g	
20 % Calcium Hydroxide	2221.3 g	2223.5 g
	2228.4 g	
	2220.8 g	
30 % Calcium Hydroxide	2190.6 g	2186.1 g
	2208.9 g	
	2158.9 g	
40 % Calcium Hydroxide	2120.3 g	2126.9 g
	2132.8 g	
	2127.7 g	

F. Crushed Block Leaching

The results obtained from the ICP-MS test for the crushed block leaching test which able to analyze different analyteconcurrently for different days as the standard TCLP 1311 stated which is day 1, day 3, day 7, day 15, and day 31. The samples that were tested is for 0% of Ca(OH)2. The results obtained showed that the concentration for the 0% has a good result against leaching effect among all the analytes except Magnesium (Mg). Aluminum (Al) and Silver (Ag) has leached in all the days recorded started from day 1 till the last day which is 31 as shown in Table 7. The other elements have no reaction and non-leached. The results of 20% calcium hydroxide will be compared with the results obtained from the control percentage 0% to evaluate the effect of leaching on the percentage with the optimum strength.

Table 7. Crushed block leaching test results 0% CH

Analyte	Concentration (Samples) mg/L				
	Day 1	Day 3	Day 7	Day 15	Day 31
Cd 228.802	-0.080	-0.084	-0.085	-0.083	-0.084
Ni 231.604	-0.083	-0.083	-0.084	-0.086	-0.084
Mg 285.213	0.164	-0.026	-0.045	-0.097	-0.104
Cr 267.716	-0.091	-0.104	-0.102	-0.098	-0.101
Mn 257.61	-0.112	-0.112	-0.113	-0.113	-0.113
Fe 238.204	-0.243	-0.243	-0.244	-0.240	-0241
Co 228.616	-0.056	-0.057	-0.057	-0.053	-0.050
Cu 327.393	-0.094	-0.098	-0.105	-0.114	-0.116
Zn 206.200	0.096	-0.098	-0.099	-0.092	-0.094
Al 396.153	0.253	0.305	0.399	1.185	0.728
Ag 328.068	0.209	0.204	0.203	0.202	0.199
Pb 220.353	-0.077	-0.061	-0.059	-0.058	-0.060

The results showed in Figure 4 and Table 8 presenting the improvement that occur in the elements such as the Magnesium (Mg) compared with the result of crushed block leaching for the Mg in 0%. In crushed block leaching test, all the elements should not pass the leaching limit value which is dangerous that could affect the environment and effect the stability of the concrete. In accordance to the results attached, the 20% of calcium hydroxide proved its qualification and ability to be stabled.

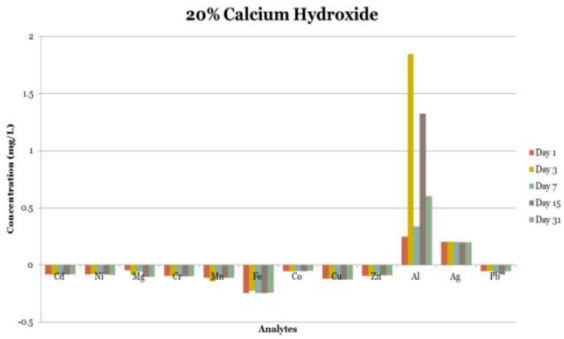


Figure 4: Leaching result of 20%CH

Table 8. Crushed block leaching test results 20% CH

Analyte	Concentration (Samples)				
	Day 1	Day 3	Day 7	Day 15	Day 31
Cd 228.802	-0.085	-0.087	-0.086	-0.084	-0.084
Ni 231.604	-0.084	-0.081	-0.085	-0.084	-0.086
Mg 285.213	-0.045	-0.087	-0.057	-0.102	-0.104
Cr 267.716	-0.096	-0.099	-0.101	-0.100	-0.098
Mn 257.61	-0.113	-0.144	-0.113	-0.113	-0.113
Fe 238.204	-0.246	-0.225	-0.246	-0.245	-0.243
Co 228.616	-0.054	-0.057	-0.056	-0.055	-0.050
Cu 327.393	-0.122	-0.119	-0.123	-0.128	-0.129
Zn 206.200	-0.095	-0.099	-0.097	-0.093	-0.090
Al 396.153	0.249	1.848	0.335	1.326	-0.601
Ag 328.068	0.202	0.204	0.203	0.199	-0.200
Pb 220.353	-0.053	-0.056	-0.068	-0.083	-0.056

G. Scanning Electron Microscope (SEM)

SEM micrographs of the Calcium Hydroxide before and after the stabilization and solidification process are shown in Figure 5 and Figure 6 respectively.

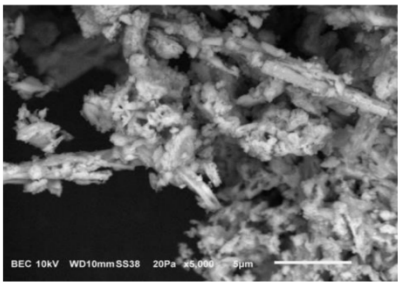


Figure 5: SEM micrograph of Calcium Hydroxide before treatment (5000x magnification)

Figure 5 represents SEM micrograph of Calcium Hydroxide before treated by ordinary Portland cement. The micrographs showed a well definite crystal which can be related to ettringite that can be related to CaO. After 28days of cementitious stabilization and solidification, there are encapsulation seen in Figure 6, which causes the low leachability of the calcium hydroxide concrete cubes.

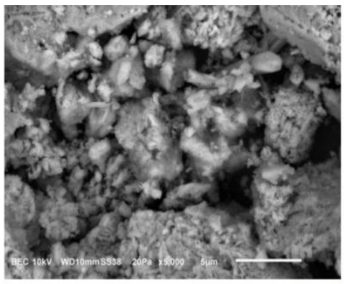


Figure 6: SEM micrograph of Calcium Hydroxide after 28 days of treatment (5000x magnification)

CONCLUSION

Calcium hydroxide can be replaced as a filling material in limited percentage to be used as a concrete admixture. The concrete cube using calcium hydroxide as sand replacement has lower moisture content. As the results shows the maximum compressive strength of concrete in cylinders increased at 20% of calcium hydroxide as river sand replacement and decreased at 30% and 40 % of calcium hydroxide. Compressive strength is increased in 20 % of calcium hydroxide due to the good qualifications of calcium hydroxide which help in the toughness of the concrete. From the crushed block leaching test show that highest strength has no leached and still not exceed the standard leaching limit values which concluded that this waste material non-hazardous and can be used in the construction industry. The method of stabilization and solidification has been successfully achieved as the waste of calcium hydroxide achieved higher strength with concrete compared with normal concrete and low leaching.

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REFERENCES

[1] Kumar N.D., Lavanya C. and Rao S. A Review on Utilization of Copper Slag in Geotechnical Applications. Proceedings of Indian Geotechnical Conference. December 15-17,2011, Kochi (Paper No.H-212)

[2] Y. Bai, F. Darcy, P.A.M. Basheer. Strength and drying shrinkage properties of concrete containing furnace bottom ash as fine aggregate. Constr Build Mater, 19 (2005), pp. 691–697

[3] Siddique, R., Performance characteristics of high volume class F fly ash concrete, Cement and Concrete Research, 34(2004) 487-493.

[4] Shi, C., Fernández-Jiménez, A. 2006, Stabilization/ Solidification of hazardous and radioactive wastes with alkali-activated cements Journal of Hazardous Materials.

[5] The Environmental Quality (Scheduled Wastes) Regulations 2005. Malaysia

[6] US Geological Survey, 2012

[7] BS 8500-1:2002. Concrete. Complementary British Standard to BS EN 206-1. Method of specifying and guidance for the specifier.

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