Effect of molar content on GGBS based geopolymer pervious concrete

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Abstract : GGBS based Geopolymer pervious concrete (G-GPC) with different molar ratio M8, M10 and M12 studied in this research work. Geopolymer concrete normal fly ash used but in this study GGBS is used, for maintaining the previous property in G-GPC without fine aggregate, 12mm size coarse aggregate utilized in this work, Alkaline solution (sodium silicate Na2SiO3, Alkaline liquid to solid ratio 0.45).Ratio between Sodium silicate and sodium hydroxide is 2.5. The casted concrete kept in ambient curing. The specimens are attending compression test, Split tension test, Water absorption test, density tests are conducted in the specimen. The Experimental results are analyzed by ANNOVA analysis Method and compare the results of compression test split tension test water absorption test. Based on the above study M12R2.5 G-GPC is perform well when compared to other two molar ratio.

1. INTRODUCTION

The Global generation of Portland cement (PC) increment consistently and has given no indication of hindering huge measure of normal assets, for example, limestone non-renewable energy sources power and petroleum gas are required in (PC) creation high temperature record in the generation of PC and this has brought about a lot of carbon dioxide CO2 emission into environment in Thailand roughly 33 million tons of Portland cement where delivered in 2012[1]. In an effort to decrease the development of PC utilization optional pozzolanic materials, for example, slag Palm oil fuel debris, fly Ash and rice husk Ash are utilized as option cementitious materials to supplant some portion of Portland cement these materials are by items from modern process and subsequently require less vitality to create contrasted with PC generation[2-4].The absence of water porousness and air penetrability after regular solid asphalt the water isn’t sifed underground without steady supply of water to the soil plants are hard to develop normally.[5] Research has demonstrated that the central point that influence pervious solid quality incorporate the solid porosity, water-to-cement material proportion (w/cm), glue trademark, and size and volume substance of coarse totals [6-10].The mechanical properties of pervious cement can be significantly improved by utilizing appropriate solid materials and blend extents[11-12]

Ground granulated blast furnace slag (GGBS) is a result from the impact heaters used to make iron. These work at a composed of around 1500 degree centigrade and are sustained with a deliberately controlled blend of iron ore, coke and limestone. GGBS is utilized limited quantity only [13]
Its high void substance makes it feasible for use in different applications, for example, thermally protecting, acoustic assimilation, solid bed for vegetation or again living being, and water refinement\cite{14-18}. In this way, pervious cement is condition benevolent. The pervious solid blend is typically made out of cover material, coarse total, practically no fine totals, water, and some admixture if necessary. For the most part, Portland cement is utilized as a binding material in pervious cement and there is as yet an absence of concentrate on the utilization of other restricting materials, for example, geopolymer fasteners in pervious concrete. Fly ash is now a day’s maximum utilized for making Portland Pozzolanic cement.

Therefore, this study focuses on the use of a geopolymer binder for making pervious concrete which comprises GGBS, sodium silicate and sodium hydroxide solution, and coarse aggregate. The mechanical and aquatic properties of the G-GPC M8, G-GPC M10, G-GPC M12 were tested. The acquired information will without a doubt be valuable for the future use of G-GPC in the construction of pervious concrete which will prompt the decrease of cement utilization and ecological issues. The results are analysis by ANNOVA software.

2. MATERIALS

Ground granulated blast furnace slag is used for making geopolymer pervious concrete in this study. The chemical composition of GGBS have been show in table 1\cite{19}

| Component  | GGBS  |
|------------|-------|
| SiO$_2$    | 32.40 |
| Al$_2$O$_3$| 14.96 |
| Fe$_2$O$_3$| 0.83  |
| CaO        | 40.70 |
| MgO        | 5.99  |
| K$_2$O     | 0.29  |
| Na$_2$O    | 0.42  |
| TiO$_2$    | 0.84  |
| P$_2$O$_5$ | 0.38  |
| Mn$_2$O$_3$| 0.40  |
| SO$_3$     | 2.74  |
| LO$_1$     | NA    |

12mm coarse aggregate used in this study. Sodium silicate solution assorted with sodium hydroxide as an alkaline activated. Sodium hydroxide (NaOH) was dissolved in portable water to construct sodium hydroxide solution with different molar concentrations. Sodium silicate solution (Na$_2$SiO$_3$) dry density was 1.53 g/cm$^3$, chemical concentration includes 14.7% sodium oxide, 29.4% silicate and 44.1% solids.

3 MIXING FRACTION, MIXING AND CASTING

The weight of GGBS 450 Kg/m$^3$ is constant used in this experimental works, Sodium silicate to sodium hydroxide ratio of 2.5 and Liquid to solid ratio 0.45 were the ratio of Geopolymer Pervious concrete. Coarse of 12mm size, Sodium hydroxide molar weight basis solution concentration prepared, here three different molar are used G-GPC M8, G-GPC M10 and G-GPC M12 in this experimental work. The preparation of alkali solution by adding sodium hydroxide required molar with sodium silicate as per mention ratio prepared 24 hours before casting of specimen. Mixing was done in pan mixing machine dry GGBS, Coarse aggregates and further alkali solution is added and if need water reducer used to improve workability. The specimen is kept for 24 hours after remove molding have to do. The specimen kept for ambient curing on room temperature required age of
testing. The specimen’s sizes 150X150X150mm cubical shape were casted in steel moulds.

4. TESTS AND RESULTS

4.1 Compressive Strength test
GGBS based Geopolymer pervious concrete (G-GPC) is casted various molar ratios, compression strength is increase based on the two parameter which is molar concentration, compression strength is directly proportional shown in Table 2. Due to the molar concentration bond strength increases up to certain limit, increase in molar concentration liquid to solid ratio decreases by more concentration of sodium hydroxide reduce the liquid quantity by heat emission. Workability decreases if increase of molar concentration. For this constrain the molar value limited up to 12. Compression strength is high in G-GPC12 when compare to other two. Based on the result in tabulation compression value gradually increase strength compare to G-GPC M8, G-GPC M10 and G-GPC M12 shown in Figure 1. Molar concentration limited which stated in previous study Workability inversely proportional to molar concentration (2). Compression value increases due to bond in alkaline solution and aggregate binding based on duration (7, 9)

| Specimen   | Compression Strength kN/mm² | 7 days | 14 days | 28 days |
|------------|-----------------------------|--------|---------|---------|
| G-GPC M8   |                             | 1.89   | 2.30    | 3.22    |
| G-GPC M10  |                             | 3.18   | 3.44    | 4.97    |
| G-GPC M12  |                             | 4.44   | 4.81    | 5.48    |

![Figure 1. Compression Strength of Geopolymer Pervious Concrete](image1)

4.2 Split Tension and Density
GGBS based Geopolymer pervious concrete (G-GPC) pavement is highly concentrate on tension strength which is low but minimum requirement is needed to maintain the pavement properties. Same like compression strength the value relatively proportional to molar concentration and tensile strength shown in Table 3 and Figure 2. Based on duration also strength increases (7, 12, 13). Density varies gradually, which states molar also plays a role in density of geopolymer pervious concrete shown in Table 3 and Figure 3. Normally pervious concrete density is not more than 1850 kg/m³ which is limited as per the requirement (11, 13)

| Specimen   | Split Tension Strength kN/mm² | Density kg/m³ |
|------------|-------------------------------|---------------|
|            | 7 days | 14 days | 28 days |
| G-GPC M8   | 0.567 | 0.69    | 0.966   | 1707    |
| G-GPC M10  | 0.954 | 1.032   | 1.491   | 1787    |
| G-GPC M12  | 1.332 | 1.443   | 1.644   | 1831    |
4.3 Water Absorption

GGBS based Geopolymer pervious concrete (G-GPC) water absorption decreases due to molar concentration increases, water absorption is variation minimum with respect to time Shown in table 4. Pervious concrete water absorption limited to 20 percentages which follow all sample of geopolymer concrete (5,6,7). Compression strength directly proportional to split tension strength and inversely proportional to water absorption which shown in graph Shown in Figure 4.

Table 4 Water Absorption of Geopolymer Pervious Concrete

| SAMPLE       | W1  | W2  | Water Absorption (%) |
|--------------|-----|-----|-----------------------|
| G-GPC M8     | 2.487 | 2.814 | 13                   |
| G-GPC M10    | 2.517 | 2.812 | 11                   |
| G-GPC M12    | 2.174 | 2.405 | 10                   |

Figure 2. Split Tension Strength of Geopolymer Pervious Concrete

Figure 3. Density of Geopolymer Pervious Concrete

Figure 4. Combination of Compression strength, Split Tension Strength and Water Absorption of Geopolymer Pervious Concrete
4.4 ANOVA Analysis

GGBS based Geopolymer pervious concrete (G-GPC) properties are compression strength, split tension and water absorption analyzed by one way ANOVA software, mean value shown as average and standard deviation increases in compression strength. Standard deviation in split tension decreases but higher standard deviation in water absorption 1.52 which shown in Table 5. Statistical value between the three properties which F value 60.32521 and p value 0.00011 Shown in Table 6 and Figure 5.

| Table 5. ANOVA Analysis Summary data of Geopolymer Pervious Concrete |
|----------------------------------------------------------|
| Group          | N | Mean   | Std.Dev. | Std.Error |
|----------------|---|--------|----------|-----------|
| Compression Strength | 3 | 4.5567 | 1.1853   | 0.6844    |
| Split Tension  | 3 | 1.367  | 0.3556   | 0.2053    |
| Water Absorption | 3 | 11.3333 | 1.5275  | 0.8819    |

Table 6. ANOVA Analysis F-Stat and p-Value of Geopolymer Pervious Concrete

| ANNOVA SUMMARY |
|----------------|
| Source          | Degrees of Freedom (DF) | Sum of Squares (SS) | Mean Square (MS) | F-Stat | p-Value |
| Between Groups  | 2                     | 155.4236             | 77.7118          | 60.3252 | 0.0001 |
| Within Groups   | 6                     | 7.7293               | 1.2882           |        |        |
| Total           | 8                     | 163.1529             |                  |        |        |

Figure 5. One-Way ANOVA of Compression strength, Split Tension Strength and Water Absorption of Geopolymer Pervious Concrete

5. CONCLUSION:

As per the Result and Discussion, conclusions are listed below
- Compression strength increases with respect to molar content increases but molar content increases workability decreases due to that molar ratio limited up to M12
- Compression strength directly proportion to Split tension value and density value increases by increase in molar content M12
- Water absorption decreases with increase in molar content up to M12
- Geopolymer pervious concrete properties of three values. ANOVA Analysis F-Stat 60.3252, P-Value 0.0001 which will shows the difference is nearly close value
- When compare all the parameter the molar of M12 which show higher compression strength and split tension strength and lower water absorption. From this study suggested go for G-GPC12. Other parameters are also have to study in further
REFERENCES

[1] Reston VA. “US geological survey, mineral commodity summaries” US Geological survey. 2013, pp 38.

[2] Chindaprasirat P, Chareerat T, and Sirivivatnanon V. “workability and strength of course high calcium fly ash based geopolymer” cem. Concr. Bulid. Mater. 2007, Vol. 29(3), pp 224-229.

[3] Sata V, Jaturapitakul C, and Kiattikomol K. “Influence of pozzolan from various by-product on mechanical properties of high strength concrete” Construction and Building Materials. 2007, Vol. 21(7), pp 1589-1598.

[4] Tangcharapat W, Jaturapitakkul C, and Chindaprasirit P. “Use of palm oil fuel ash as a supplementary cementitious material for producing high strength concrete” Construction and Building Materials. 2009, Vol. 23(7), pp 2641-2646.

[5] Jing yang, Guoliang jiang. “Experimental study on properties of pervious concrete payment materials” Cement and Concrete Research. 2003, Vol. 33, pp 381-386.

[6] Chindaprasirat P, Hatanaka S, Chareerat T, Mishima N, Yuasa Y. “Cement past characteristics and porous concrete properties” Construction and Building Materials. 2008, Vol. 22(5), pp 894-901.

[7] AnandhBabu Malayali, Ramesh Babu Chokkalingam, Vinay Singh M. “Experimental Study on the Compressive Strength and Permeable Properties of GGBS Based Geopolymer Pervious Concrete” IOP Conference Series: Materials Science and Engineering(MSE). 2019, Vol.561(1), Article number 012004.

[8] Ghafoori N. “Development of No-fines concrete pavement applications” J Transp Eng.1995, Vol. 121(3), pp 283-8.

[9] Deo O, Neithalath N. “Compressive behavior of pervious concretes and a quantification of the influence of random pore structure features” Mat Sci Eng A -Struct. 2010, Vol 528(1), pp 402–12.

[10] Crouch LK, Pitt J, Hewitt R. “Aggregate effects on pervious Portland cement concrete static modulus of elasticity” J Mater Civil Eng. 2007, Vol. 19(7), pp 561–8.

[11] Sumanasooriya MS, Neithalath N. “Pore structure features of pervious concretes proportioned for desired porosities and their performance prediction”. Cem Concr Compos. 2011, Vol. 33(8), pp 778–87.

[12] Huang B, Wu H, Shu X, Dong Q, Burdette EG. “Laboratory evaluation of permeability and strength of polymer-modified pervious concrete”. Construction and Building Materials. 2010, Vol. 24(5), pp 818–23.

[13] Anandh Babu Malayali and Ramesh Babu Chokkalingam. “Mechanical Properties Of Geopolymer Pervious Concrete” International Journal of Civil Engineering & Technology. 2018,Vol.9, pp 2394–2400.

[14] Yang J, Jiang G. “Experimental study on properties of pervious concrete pavement materials” Cem Concr Res. 2003, Vol. 33, pp 381–386.

[15] Park AB, Tia M. “An experimental study on the water-purification properties of porous concrete” Cem Concr Res. 2004, Vol. 34, pp 177–184.

[16] Tennis DP, Leming ML, Akers DJ. “Pervious concrete pavement” Portland cement association. National ready mixed concrete association. 2004, pp 27.

[17] Luck JD, Workman SR, Coyne MS, Higgins SF. “Consequences of manure filtration though pervious concrete during simulate rainfall events” Biosyst Eng. 2009, Vol. 102, pp 417-423.

[18] Kim HK, Lee HK. “Acoustic absorption modeling of porous concrete considering the gradation and shape of aggregate and void ratio” J Sound Vib. 2010, Vol. 329(7), pp 866–879.

[19] Australasian slag association, Wollongong, NSW 2500, accessed on January 2016, http://www.asa-inc.org.au/ground-graunlated-blast-furnace-slag.php,2016.