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Effect of Fineness of Homra (Clay Brick Dust) on the Properties of Geopolymer Bricks Produced from Slaked Lime

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Abstract

Waste ground clay brick (Homra) was substituted for costly calcined kaolin in the preparation of geopolymer bricks. Also, as little NaOH as possible was used as alkaline component. Instead spent slaked lime from an acetylene production unit was used. Homra was treated with 8% alkaline solution at about 45°C in four different particle sizes ranging from 0.075 mm to 0.425 mm. The mix was molded in 2” cubical steel molds and left for curing in moist atmosphere for 28 days. The effect of particle size on cold and boiling water absorption as well as compressive strength was investigated. Results showed that standard requirements were achieved on using 0.075 mm homra and 0.5% NaOH as addition to milk of lime.

Key words: Geopolymer – Homra – Particle size – Milk of lime

Introduction

The standard method for producing geopolymer bricks is to add a strong alkaline solution to calcined kaolin [Davidovits, 1991; Kim et al., 2006; Provis et al., 2014].

Polymerization takes place resulting in a strong matrix the mechanism of which has been investigated in several works [Khale et al., 2007; Al–Bakri et al., 2011]. However the increasing cost of sodium hydroxide as well as the expenses associated with calcining kaolin has decreased the attractiveness of this method. Several attempts have been made to increase the strength of these bricks while using as little NaOH as possible. One common trend has been adding fly ash to the mix. The mechanism of the effect of fly ash addition has been recently elucidated by Catanescu et al. [2012] and Xeng [2014]. On the other hand, the effect of fly ash and alkali content on the properties of the formed bricks was studied by Izquierdo et al. [2009] and Thokchom et al. [2009]. Another approach was to use cheap price low quality kaolin instead of purer types [Hatani et al., 2010] or using a lime containing pozzolanic material [Billong et al., 2009]. Little work was, however, devoted to substituting costly NaOH by less expensive alkaline materials. The use of slaked lime (Calcium hydroxide) was only recently tackled by Jeyasehar et al. [2013] in conjunction with using fly ash as additive.

In the present work, cheap clay brick waste (Homra) and waste slaked lime from an acetylene production unit were substituted for the much more costly calcined kaolin and NaOH. The effect of using different particle sizes of homra was investigated. The properties of prepared bricks were tested for compatibility with normal duty building bricks as specified by ASTM C 62 [2013].

Materials and methods

The main two raw materials used are ground waste clay bricks (homra) and spent slaked lime.

The particle size distribution of as received homra is shown in Fig (1). It shows that the minimum particle of delivered homra was about 0.075 mm while the coarsest size reached 3.2 mm.

On the other hand, the XRD pattern shown in Fig (2). It shows that homra mainly consists of quartz and hematite (with minor lines of albite). The reason why only such phases have appeared has to do with the origin of Homra. Since it is the product of firing green clay bricks up to 900^{o}C, then it is expected that only amorphous m–kaolinite and quartz should be present [Bergaya et al., 1995]. Hematite appears owing to its presence as impurity.

Chemical analysis of homra revealed that it consist mainly of SiO_2 (65.83%), Al_2O_3 (16.55%) and Fe_2O_3 (7.97%) with the balance consisting of alkali oxides (3.5%) and alkaline earth oxides (4.27%).

Spent slaked lime was delivered in the form of a fine powder as residue from the preparation of acetylene. XRF analysis showed it to contain 97.9% CaO. On the other hand XRD revealed the main peaks of CaO and few peaks of $CaCO_3$. This was confirmed by thermal analysis performed in air at a heating rate of 10^{o}C/min. The result is shown in Fig (3) where two peaks appear: The first peak starts at 395^{o}C. The second small peak starts at about 600^{o}C and ends at 740^{o}C corresponding to calcination of calcium carbonate presumably owing to partial carbonation of calcium hydroxide [Mikhail et al., 1966].

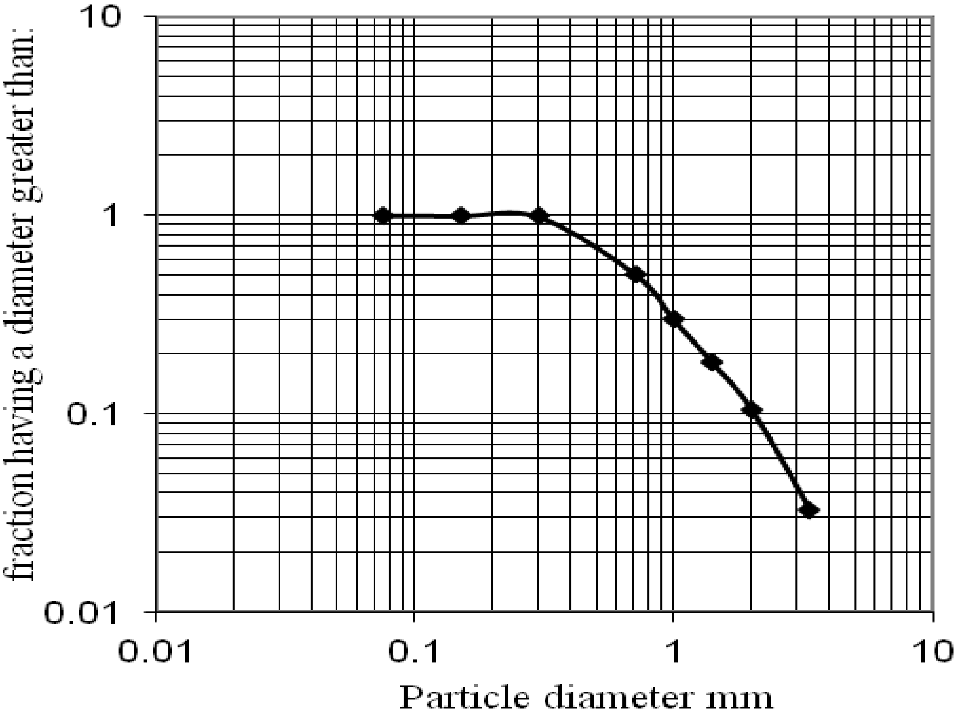

Fig. (1): Screen analysis of the as–received homra

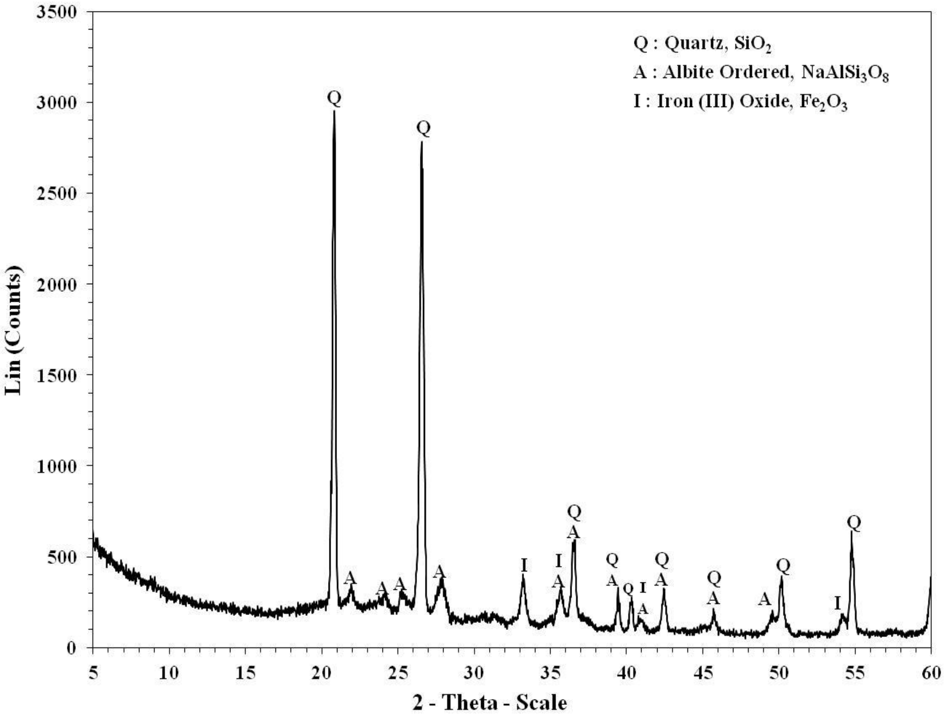

Fig. (2): XRD analysis of the as–received homra

Finally sodium hydroxide was used as powder (Merck) and stated to contain 99.9% NaOH.

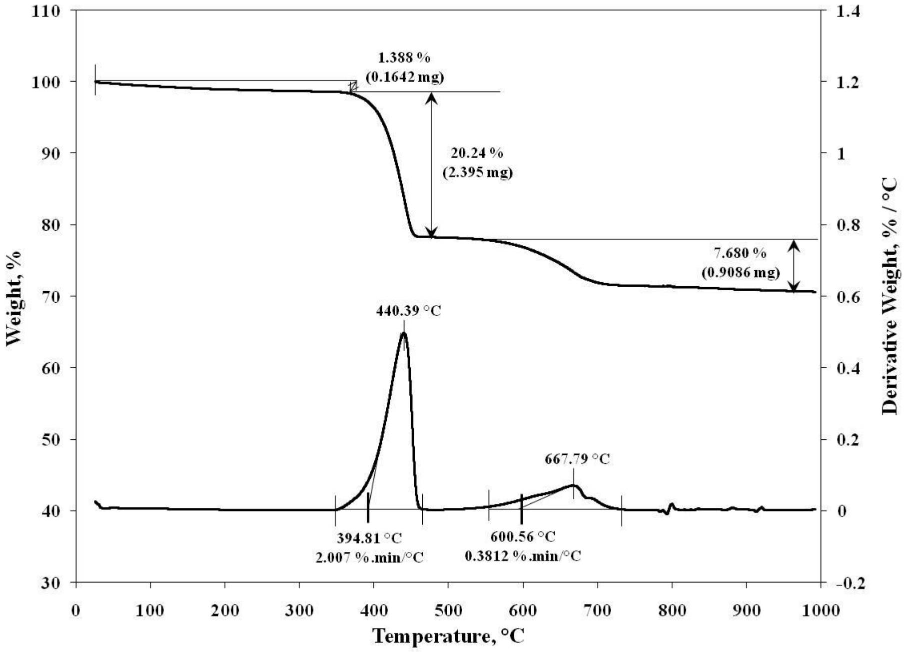

Fig. (3): Thermal analysis curves of slaked lime

Different brick specimens were prepared using different powder fractions of average particle size of 0.425 mm, 0.3 mm, 0.18 mm and 0.075 mm These bricks themselves were prepared by mixing homra with 8% slaked lime powder (and occasionally NaOH powder) and 28 to 30% water for 10 minutes using a mechanical stirrer and pouring in 50×50×50 mm steel molds after which the viscosity starts to increase due to initiation of setting. The mix was then cured for 28 days in moist environment (RH from 70 to 80%). The formed bricks were then subjected to the following tests.

Boiling water absorption was determined according to ASTM C 20 [2010]. Bricks porosity was calculated consequently.

Compressive strength of the prepared bricks was determined according to ASTM C 67 [2014].

In all cases samples consisted of three specimens each time and the average value was taken each time.

Results and discussion

Boiling water absorption

Fig (4) and (5) show the effect of varying particle size on the percent water absorption after 5 hours boiling in case of using 0% and 0.5% NaOH respectively for two different water contents (28 and 30%). These curve show that there is a general increase in water absorption with increasing particle size. This is due to the fact that an increase in particle size corresponds to lower specific surface area leading to lower polymerization. This in turns leaves more pores resulting in higher water absorption. Also higher water content will leave upon evaporation more pores. That is why; higher water levels should be associated with higher boiling water absorption. It is noted however, that at high particle sizes, this effect no more prevails. This is since large particles leave such high porosity that the effect of water level is overshadowed.

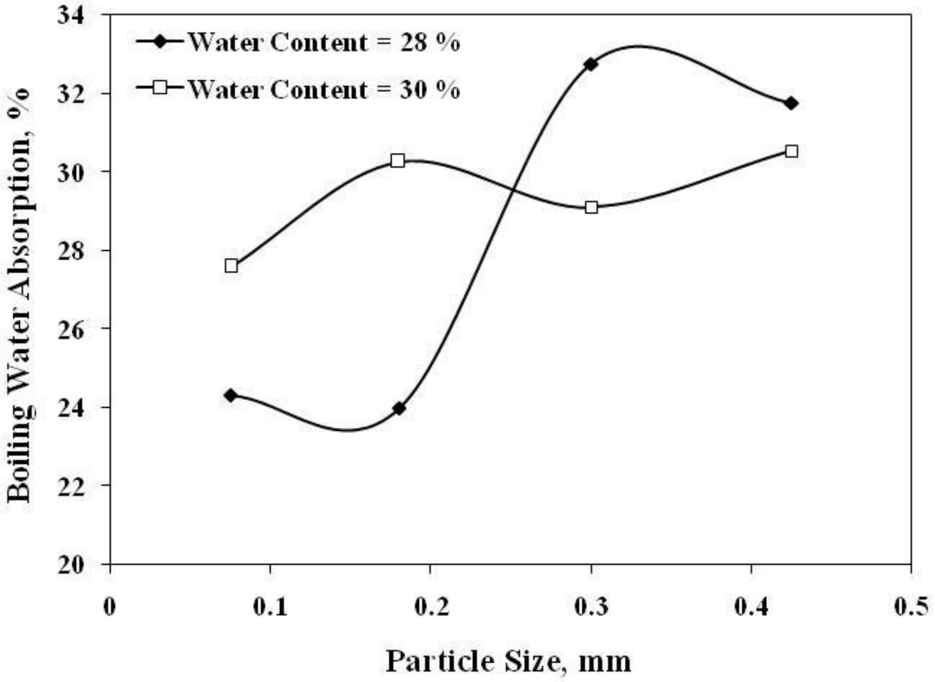

Fig. (4): Effect of particle size on boiling water absorption (0% NaOH)

It is to be noted in case no NaOH is used, the percent boiling water absorption exceeded for most particle sizes use, the maximum permissible value of 25% for medium duty building bricks. On the other hand, the use of NaOH even in amounts as small as 0.5% has a positive effect on the extent of polymerization decreasing absorption values below the maximum permissible value even for the largest particle size investigated.

The corresponding effect of particle size on porosity is illustrated in Fig (6) and (7) for the two levels of NaOH investigated (0 and 0.5%).

At zero NaOH level, the porosity of the bricks first increased, as expected, with increased particle size. However, at particle sizes exceeding about 0.3 mm, the porosity once more decreases. This is probably due to the inclusion of polymerized particles in the large pores left by the coarser particles. Since, on adding 0.5% NaOH, polymerization reaches high extent porosity does not decrease once more and stabilizes at high particle size.

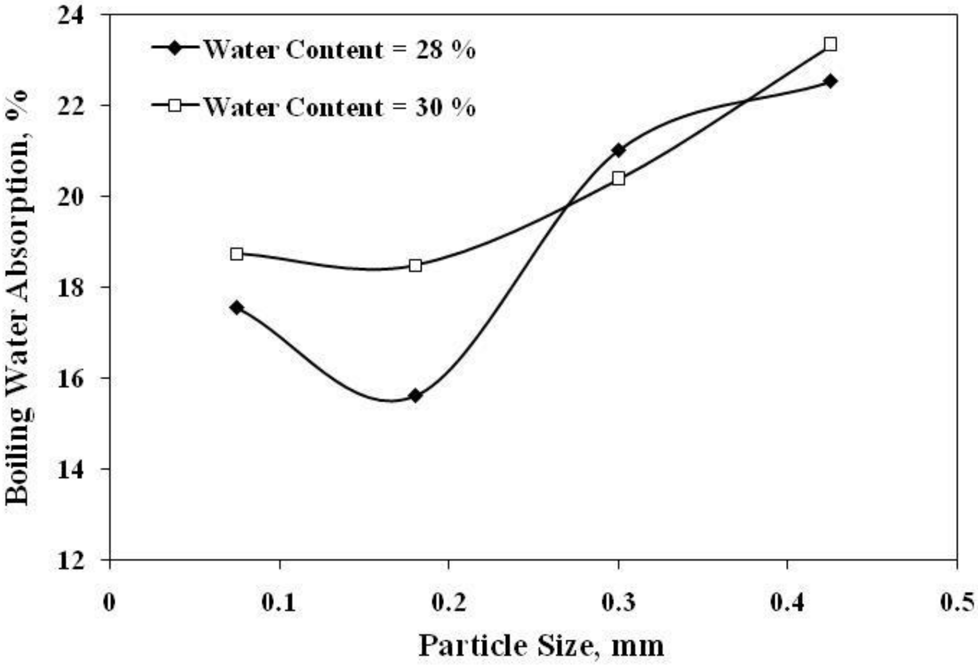

Fig. (5): Effect of particle size on boiling water absorption (5% NaOH)

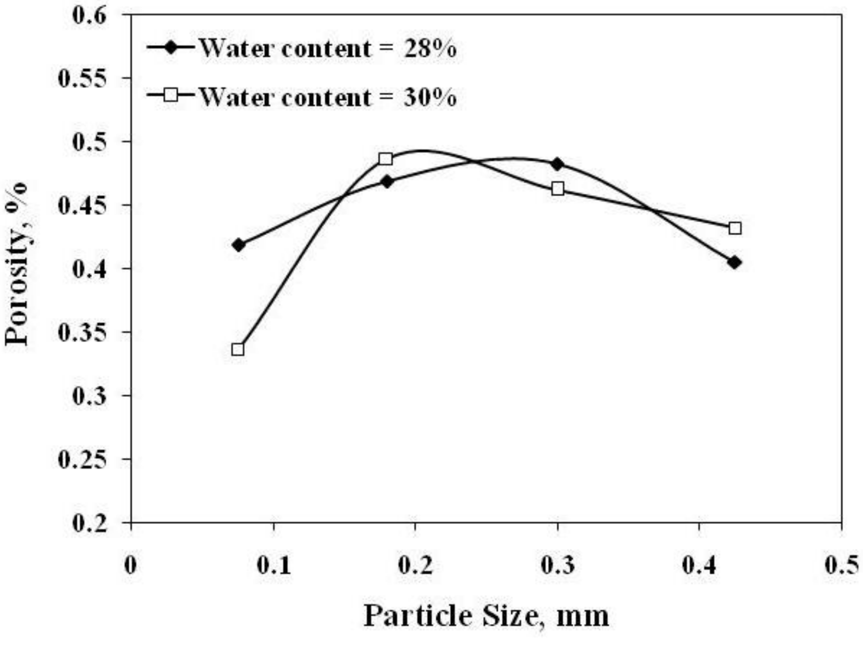

Fig. (6): Effect of homra particle size on porosity (0% NaOH)

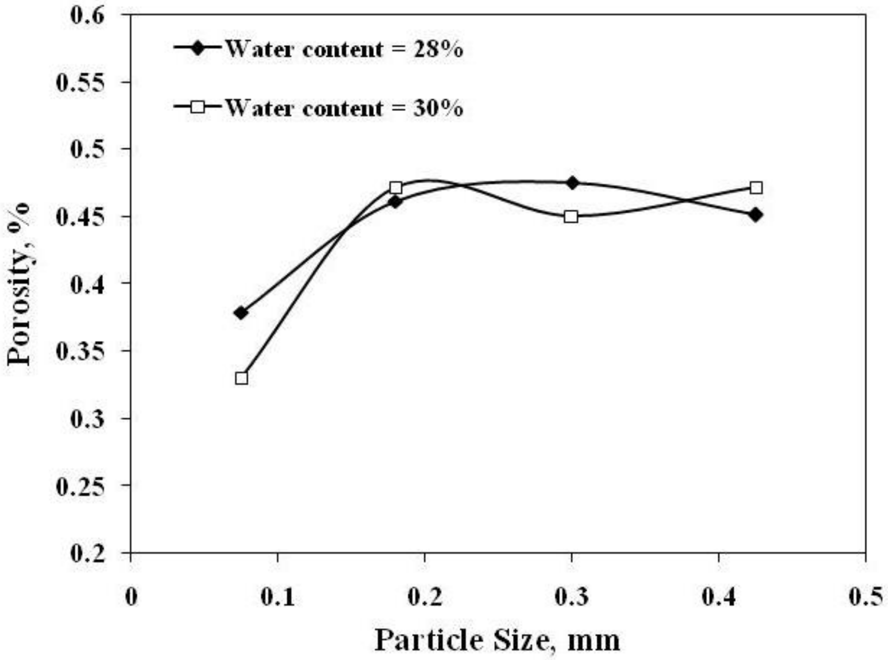

Fig. (7): Effect of homra particle size on porosity (0.5% NaOH)

Compressive strength

After 28 days curing the molded bricks were tested for compressive strength. It should be recalled that the minimum compressive strength stipulated by ASTM C 67 [2014] is 8.6 MPa. Fig (8) and (9) show the results obtained on using 0% and 0.5% NaOH respectively.

In both cases, the increase in particle size leads to a drastic decrease in compressive strength, once the minimum particle size of 0.075 mm is exceeded. However, the value of maximum compressive strength reached when no NaOH is used does not reach the minimum value of 8.6 MPa. This curve also shows that varying the percent of water used does not play any appreciable role in assessing strength. It should also be noted that a slight increase in strength is observed for particle sizes exceeding 0.3 mm. This is probably due to the inclusion of polymerized particles in the large pores left by the coarser particles. Such a decrease in porosity will have for effect to slightly increase the compressive strength.

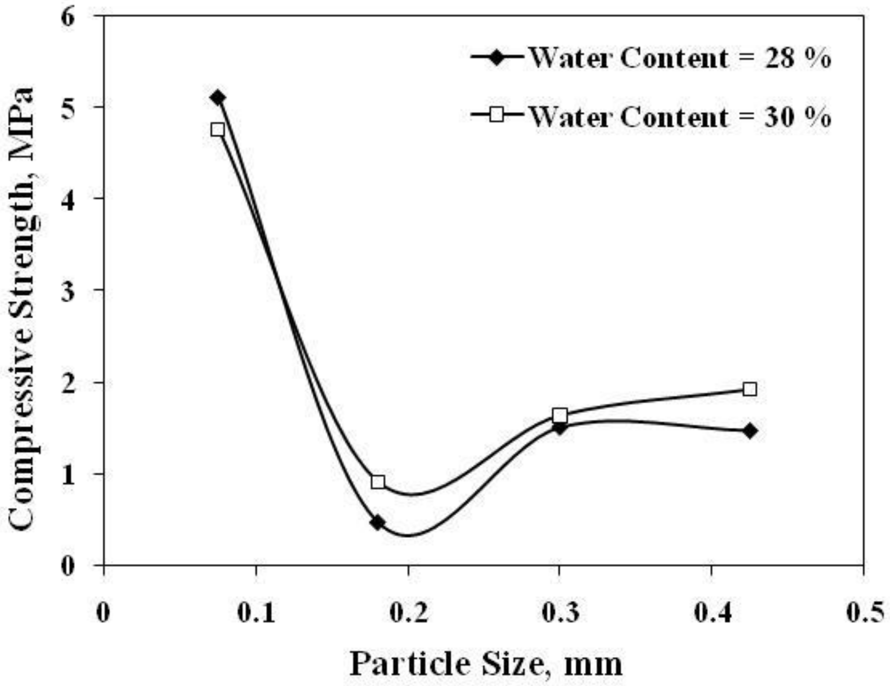

Fig. (8): Effect of homra particle size on compressive strength (0% NaOH)

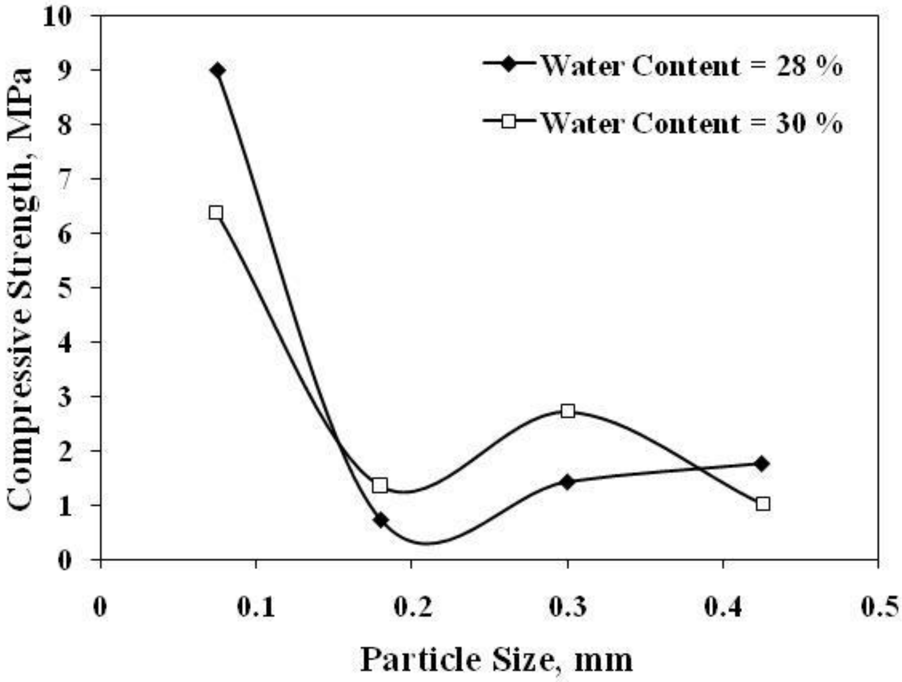

Fig. (9): Effect of homra particle size on compressive strength (0.5% NaOH)

As the percent NaOH is increased to 0.5%, the maximum strength registered at a particle size of 0.075 mm increases above the minimum permissible level on using a water content of 9.1 MPa.

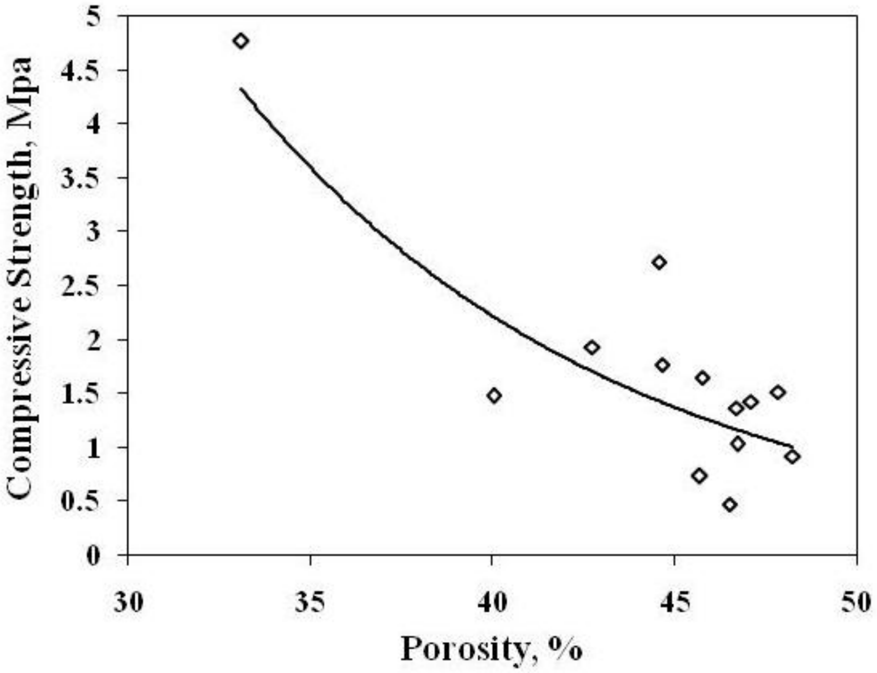

Fig. (10): Relation between strength and porosity

The close correlation between compressive strength and porosity is emphasized in Fig (10) displaying an exponential decrease in strength following an increase in porosity for all samples investigated.

Conclusion

Geopolymer bricks were prepared by the action of calcium hydroxide (present in slaked lime) on metakaolin (present in homra). The effect of varying the particle size of Homra on boiling water absorption and compressive strength was investigated for samples containing 0% and 0.5% NaOH. The following results were obtained:

Increasing the particle size was associated with decreased surface area which in turns yields poor polymerization. Thus pores are left that cause an increase in boiling water absorption and observed porosity. The minimum water absorption required by ASTM standards for medium duty building bricks was only fulfilled when 0.5% NaOH was used.

An increase in particle size occasioned an abrupt drop in 28 days compressive strength as the particle size exceeded 0.075 mm. th minimum strength stipulated by ASTM standards (8.6 MPa) was only achieved on using 0.5% NaOH.

A decreasing exponential relation could be obtained between compressive strength and porosity revealing the dependence of the latter on the extent of porosity left after polymerization is completed.

References

1. Al–Bakri A.M., Kamarudin H., Bnhussain M., Nizar I.K and Mastura W.I.W., "Mechanism and chemical reaction of fly ash geoploymer cement", J. Asian Sci. Res., 1 (5), 2011, 247–253.
2. ASTM C 20 / 2000 (reapproved 2010), "Apparent porosity, water absorption, apparent specific gravity and bulk density of burned bricks", Annual book of American Society for Testing of Material (ASTM), U.S.A., 15 (1), March 2014.
3. ASTM C 62 / 2013, "Standard specification for building brick (Solid masonry units made from clay or shale)", Annual book of American Society for Testing of Material (ASTM), U.S.A., 4 (5), June 2014.
4. ASTM C 67 / 2014, "Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile", Annual book of American Society for Testing of Material (ASTM), U.S.A., 4 (5), June 2014.
5. Bergaya F., Dion P., Alcover J.F., Clinard C., Tchoubar D., "TEM study of kaolinite thermal decomposition by controlled–rate thermal analysis", Journal of Material Science, 31 (19), 1995, 5069–5075.
6. Billong N., Melo U.C., Louvet F., Njopwouo D., "Properties of compressed lateritic soil stabilized with a burnt clay–lime binder: Effect of mixture components", Construction and Building Materials, 23 (6), 2009, 2457–2460.
7. Catanescu I., Georgescu M., Melinescu A., "Synthesis and Characterization of geopolymer binders from fly ash", U.P.B. Sci. Bull., Series B, 74 (1), 2012.
8. Davidovits J., "Geopolymers: Inorganic polymeric new materials", J. Thermal Analysis, 37, 1991, 1633–1656.
9. Hatani M., Nasser Y.M., "Investigating the possibility of utilizing low kaolinitic clays in the production of geopolymer bricks", Ceramics – Silikaty, 54 (2), 2010, 160–168.
10. Izquierdo M., Querol X., Davidovits J., Antenucci D., Nugteren H., Perrreira C.F., "Coal fly ash – slag based geopolymers", Journal of Hazardous Materials, 166 (1), 2009, 561–567.
11. Jeyasehar C.A., Saravanan G., Kandasamy S., "Strength and durability of fly ash based geopolymer bricks", Asian J. Civ. Eng., 14 (6), 2013, 797–808.
12. Khale D., Chaudhari R., "Mechanism of geopolymerization and factors influencing its development", Journal of Materials Science, 42 (3), 2007, 729–746.
13. Kim D., Lai H.T., Chilingar G.V., Yen T.F., "Geopolymer formation and its unique properties", Environ. Geol, 51 (1), 2006, 103–111.

14. Mikhail R.Sh., Brunauer S., Copeland L.E., “Kinetics of the decomposition of calcium hydroxide”, Journal of Colloid and Interface Science, 21 (4), 1966, 394–404.
15. Provis J.L., Bernal S.A., “Geopolymers and related alkali activated materials”, Ann. Rev. Mater. Res., 44, 2014, 299–327.
16. Thokchom S., Ghosh S., Ghosh P., “Strength and durability of fly ash geopolymers”, LAP, India, 2007.
17. Xeng S., “Synthesis and characterization of geopolymers using locally available fly ashes”, PhD Dissertation, Civil Engineering Department, Alabama University, 2014.