Effects of Molority on Bond Strength of Brick Masonry with Alkali Activated Composite Mud Mortar - Modelling by Ansys.

Palanisamy, P [1] and Kumar, P.S [2]

[1] Research Scholar, Department of Civil Engineering, Anna University, Chennai- 600025, Tamil Nadu, India.

[2] Professor, University College of Engineering, Ariyalur, Tamil Nadu, India.

[*]Corresponding Author: Palanisamy, P. Email: mpspps3@gmail.com

Abstract

This study identifies new Alkali Activated Composite Mud Mortar to alternate Cement Mortar used for laying masonry works. This study handles both experimental and numerical analysis of strength and durability for mortar, especially bond strength along mortar and brick joints have studied detail and compared with ANSYS. The bond strength has estimated through the triplet brick prism of shear behavior. The strength and deformation characteristics of masonry constituents obtained from these tests depend on the actual composite conduct of masonry. There is always a good reception for environmentally friendly, low energy, new construction materials, and used in preparing mortar/brick unit combinations all around the world. Also, this study fulfills those requirements. Especially, masonry laid with the mud mortar meets all. Fly Ash, Ground Granulated Blast furnace Slag, and Quarry Dust have utilized the new composites' preparation with 8Molority, 10Molority developed excellent strength. The composite specimens are having compression and bond strength, ranging from 4.84-5.14 and 0.12-0.18N/mm2. The mixed ratio of materials has taken (0.5 parts of Fly Ash, 0.5 parts of Steel Slag, 1.75 parts of Soil, and 0.25 parts of Quarry Dust). The samples tested resistance against acidic, sulfate, and alkalinity indicated PH values less than 7 and 9 simultaneously. Compression strength varied from 10-20% and gained more and fit composite used for mortar in masonry works.

Keywords: Alkali Activated Composite Mud Mortar; Alternate to Cement Mortar; Numerical Analysis; ANSYS; Bond strength; Shear crack behaviour;

1. INTRODUCTION

Mortar is an essential material for making the bond between brick units. The strength of brickwork is varied with bricks' quality, quality of mortar, mortar ratio, and bonding. Bond strength is affected by the quality of cannon, water absorption, porous material, mortar ratio, and water available in the mortar, temperature, shape, workers involved, and supervision. The new alternative mix plays a vital role in resource conservation and Recycling, Sustainable building construction bio-material, and Environment science and technology. It is an original binding and plastering material used in Brick Masonry units (Kunasegaram Sajanthan et al. 2019)

The surface absorption of brick defined as the rate of water sucks by the brick units from the mortar. Masonry strength depends on the quantity of water available at the mortar interface and brick strength. Brick strength desires masonry strength and design requirements. Surface characteristics and absorption are two essential properties in other durability indices have also been developed based on the relationship between porosity and water absorption. The water absorption properties of bricks vary depending on the nature of the raw materials involved (Ibrahim A. S AL-Jumailya et al. 2015). The block's choice varies with the character. Excessive water absorption can cause cracks in the bricks and damage the construction structures. Too little absorption results in reducing the mortar joints' durability because of more water move from the block to the bones. More industrial wastes instead of cement and natural sand for this research used because when a ton of cement produced, It releases approximately a ton of carbon dioxide and pollutes the environment (Najabat Ali et al. 2015). To reduce CO2 expels from the cement plants by more ideas are recommended (Robbie M. Andrew 2018).

Waste materials from thermal plants and steel industries contained pozzolanic and cementitious properties around ten percentages (Oswal T, Manojkumar VC, 2014). Highly alkaline liquids are reacted with the waste materials and formed the best binder (Boskovic Ivana, and Zejak Radomir 2013). Geo-polymer mortar is a substitute for the commonly used cement mortar and environmentally sustainable (Konstantinos A. Komnitsas 2011). More studies are conducted on geopolymer concrete and proved it is used instead of cement concrete (Pradip Nath, 2015) and (Abdul Aleem MI, Arumairaj PD, 2012).

Within limits, while increasing the alkaline solution's molarity ratio, the more compressive strength of concrete is achieved (Reddy BSK , 2010). The binder system used either river sand or any suitable material. Alternative material used instead of the river sand to prevent environmental issues. Due to this, a sandy fraction of (4.75mm to 0.075mm) soil has collected for fine-aggregate and used (FAO, 2010). It is modified and used (Bahoria B.V., Parbat D.K., and Nagannaik P.B, 2013), (Madheswaran.CK, Gnanasundar G, 2013) and (Park jin-soo, Kim. Myung, 2013). The Geo-polymer binder is resisted enough by the acid and alkalinity in the environment. The mortar does not allow the concrete to weaken and shorten the life of the concrete. Such environmental impacts evaluated by absorption tests and anti-acid tests (Thokchom, S., Dr. Partha Ghosh, P., and Ghosh, S , 2009) and (Michele Angiolillo and Amedeo Gregori, 2020). The triplet Brick prism test delivers bond strength, mortar's shear crack behaviors of the masonry. Usually mortar and the brick units bonded either chemically, or friction, or both. The tensile force has occurred at the periphery of brick and mortar due to electrostatic force.

The electrostatic force acts inversely proportional to the rate of brick absorption. Bricks should be immersed well in water 24 hours before laid to increase the electrostatic force between brick and mortar joints. More techniques introduced for investigating the performance of the triplet Brick prism (Sergey Churilov, Elena Dumova- Jovanoska, 2013). Finite Element Analysis (FEA) supports in outlining the masonry failure mechanisms. Modeling techniques, especially masonry performance under loading conditions in Finite Element Analysis using analytical software of ANSYS for Complex structures has been accepting by scientists (Shahid Nazir, Manicka Dhanasekar, 2013),(David A. Weed, 2020) and (Haach, V.G. Vasconcelos, G, Loureno PB, 2011).

2. SCOPE

The scope of the experiment is to identify the optimized mortar mix among various mixes.3 constituents, influences on Alkali Activated Composite Mud Mortar (AACMM). The types of sample mixes are (1) 0% to100% of GGBS and 100% to 0% FA, 0% to100% FA and 100% to 0% GGBS interval at 25% (Binder ratio). (2) 0% to100% of soil and 100% to 0% QD, 0% to100% of QD and 100% to 0% Soil at the Interval of every 25% (Fine aggregate ratio) (3) Binder: Fine aggregate ratio from 1:1, 1:2, 1:3 and 1:4. (4) Fluid-to-Binder Ratio (F/B): 0.1, 0.2, 0.3 and 0.4. (5) The mortar mixes with molarities like 4M, 6M, 8M, and 10M. (6) To study which composite mortar gives the best bond strength by conducting a triplet brick prism test with BM unit combinations and compared with numerical analysis results.

3. EXPERIMENTAL INVESTIGATIONS

3.1 GPEB

Composites like blocks and mixer build the brick wall. Hence, it has heterogeneous in properties. The performance of masonry depends on the individual features of brick and mortar. Standard blocks or GPEB of size 19cm× 9cm×9cm are used in this research

(Palanisamy.P, Kumar.P.S, 2018, 2020). As per requirements, blocks of better quality selected from the stack.

3.2 Alkali Activated Composite Mud Mortar (AACMM)

AACMM prepared by fly-ash waste from thermal plants, steel slag from steel manufacturing industries, locally available Soil, Dust collected from quarries, Na2SiO3, and NaOH with different molarities (Palanisamy.P, Kumar.P.S, 2020).

3.3 Fly Ash

The 'C' category FA generally collected from local possesses both pozzolanic and cementitious properties around ten percentages. Both physical and chemical properties of FA confirmed to grade 1 of (IS-3812) and (ASTM C 618- 1993.Class C)..

3.4 GGBS

It obtained from the local steel industry, and their physical and chemical properties also confirmed to (IS- 12089) and (Bennet JS, Sudakar M, Natarajan C, 2013).

3. 5 Excavated earth

Soil available either at local or construction sites used for this test. External inspections carried out before testing the soil in the lab. Soil directory characterization based on the foreign check. There should be no contaminants in the soil tested. Therefore, it is imperative to avoid dirt available on the ground level. Good soil available at depths of 450 mm from ground level. The land used for the test should first be sieved.

The stagnant soil should be used in a 75-micron sieve to enter a 4.75mm sieve and confirm (IS: 2720 Part 5). Soils should be substituted for naturally available sand and stabilize with a geo-polymer (Manjunath G.S. et al. 2011).

Soil particles in the soil classified according to their size and quantity. Soil particles are well graded if all dimensions are present and listed in Tab. 1. The size of soil particles between 4.75mm and 75 microns has taken 90%, and finer than75micron used 10% for smooth finishing and less absorption of water.

Table 1.characteristics of soil samples

Serial Number	Properties	Values	Unit
1	Specific Gravity	2.40	-
2	soil density (free)	1.580	KN/m³
3	soil density (dense)	1.690	KN/m³
4	Sand fraction(4.75mm to 75µm) (Wet sieve analysis)	65	%
5	Fineness Modulus	2.71	-
6	Plastic Llimit	35	%
7	Liquid Limit	32	%

3.6 Quarry Dust waste

The waste material sieved from the stone aggregate manufacturing industry has been used in this research to alternate for the sand of minimum quantity and had fineness modulus of 3.3, and specific gravity as 2.0. The bulk of QD free and dense had 1.5KN /m³ and 1.751KN/m³.

3.7 Alkali Activator

Sodium hydroxide pellets of 97- 98 percentage clarity and Na_2SiO_3 liquid purchased from local chemical suppliers of the required quantity. Solids of NaOH flakes concentration were measured and dissolved in water in terms of Molarity 4M, 6M, 8M, and 10M, as indicated in Tab. 2. Na_2SiO_3 and NaOH added as per the requirements of an alkali activator for the polymerization process.

Table 2. Molarities of NaOH

Molarities	Molecular weight	NaOH in grams
4M	40	160
6M	40	240
8M	40	320
10M	40	400

4. METHODS

4.1 Mortar cube samples

NaOH and $NaSiO_3$ solutions were mixed as per the requirements at least 24 hours well before mixing dry materials for cube making.

4.2 Dry Mix

Trial mixes choose the combinations of material from past research experience in GPEB production. Among trial mixes, finally selected

Fluid/Binder = 0.3, NaOH: $NaSiO_3$ = 1:2, and the abstract of (1/2:1/2::1 3/4: 1/4), (Fly Ash: Steel slag:: Excavated earth (90% of sandy soil + 10% of soil passing through 75 microns): QD) with 4M, 6M, 8M, 10M of alkaline solution. Dry materials were measured in predetermined proportions in the mixer and mixed for 180 seconds when even color appears.

4.3 Wet Mix:

The alkaline activator prepared as per the F/B ratio after the dry mix process completed. Wet mix mixed like preparing CM when uniform color appears. Prepared wet mix placed in the steel mold of 762 mm^3 size for making specimens. Demolded specimens were (IS-3495-

1976) until tested without curing. The ambient cured samples tested under the compression test.

5. RESULTS AND DISCUSSION

5 .1 General

Generally, tests on mortar include strength and durability features.

5.2 Compression strength of AACMM

Mortar plays an essential role in filling material to construct a masonry wall. Mortar has influenced more on the strength of masonry. It is complying with standards of IS-2250 (2000) Both mortar type and mortar thickness affect the strength of masonry. For this research, increases in compressive strength of AACMM cube cured at room temperature at various highlighted points have discussed. Besides that, test results have sorted out in the tables about to discuss. The presented data has shown that increment in compressive strength due to age and the higher molarity. Twenty-five samples in each category tested after the next day **of** a week and four weeks, and the average results obtained were listed in Tab. 3.

Table 3.Compression strength of AACMM cube

Specimen Id.	Molar ratio	Average strength	
		In Compression After 7days	In Compression After 28days
AACMMT1	4M(160)	< 0.1 N/mm^2	< 0.1 N/mm^2
AACMMT2	6M(240)	0.35 N/mm^2	0.47 N/mm^2
AACMMT3	8M(320)	3.78 N/mm^2	4.84 N/mm^2

AACMMT4	10M(400)	4.91 N/mm^2	5.14 N/mm^2

The test results listed in the table showed that the compressive strength was directly proportional to the age of the cube, and after 7 days, the force listed as 4.8 N/mm2 and after 28 days gained as 5.1N/mm2. Besides that, only 0.3 N/mm2 had increased after 21 days. This increment evidenced that the mortar cube attained more strength at an earlier stage and showed in Fig. 1, which higher than regular conventional cement mortar cubes of ratio 1:4 and 1:5. It comes under the grade of MM5. So AACMM is considered where Cement Mortar used.

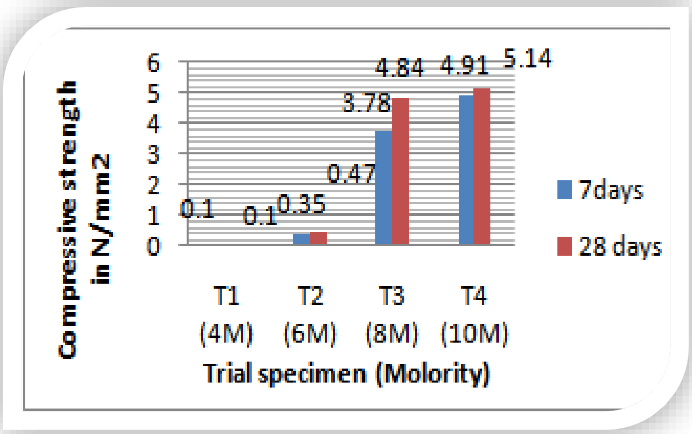

Figure 1 Compression test results on AACMM cube

5.3 Acid attack test

The acid attack test conducted after 28 days of ambient cured AACMM cube of size 7.62mm immersed in water containing 5% H2SO4. The specimen's acidic attack was evaluated by measuring changes in dimension and determining the decrease in strength and weighing the loss in weight. As shown in Fig 2, acid resistance measured in terms of PH value after 28 days and less than 7 found useful.

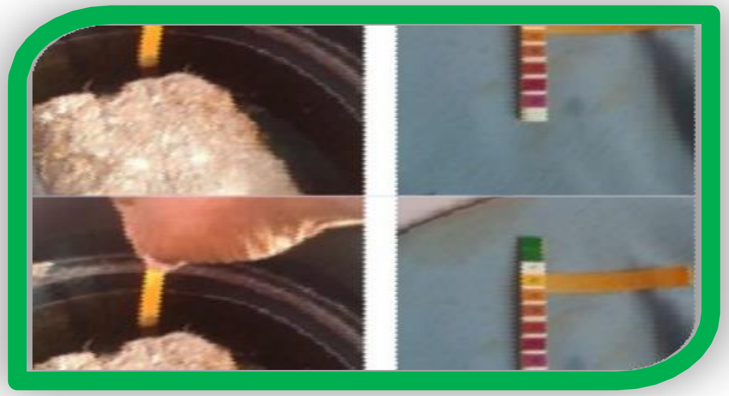

Figure 2 Acid attack test of AACMM cube

The weight loss calculated as% of weight lost = (W2 – W1) / W1; W1 = weight of specimen before the attack; W2 = attack after a weight sample. Test results of the acid attack listed in Tab. 4.

Table 4 Acid and Sulphate attack test of AACMM cube

Trial Mix	Average Dim. / weight loss	Average compressive strength (gain)			
		Acid		Sulphate	
	mm/grams in %	Gain in N/mm^2	%	Gain in N/mm^2	%
AACMM	No				

CUBE	significant	6.17	20	5.65	10

Based on the (IS 1077 –2007) weight loss not exceed 1.5% for class I bricks and 4% for grade II bricks. Also, the minimum compressive strength for class I brick is 7MPa and 5MPa for type II. So this study comes under class I. Geo-polymer is one of the inorganic polymer composites. It manufactured and strengthened well at room temperature and even aggressive environmental conditions, in the presence of NaOH and Na2SiO3 solutions. During the polymerization process, alumino-silicates are quickly reacted and dissolved and left SiO4 and AlO4 tetrahedral units in solution. The units are interchanged into new while dividing atoms of oxygen. Therefore unshaped geo-polymers created.

The positive ions of sodium and iron are availed at specimen cube pores, stabilize the negative ions. This chemical reaction strengthened the materials when subjected to aggressive environments.

5.4 Sulphate attack test

The sulfate resistance conducted after 28 days of ambient cured AACMM cube of size 7.62mm sunk into water containing 5% Na2SO4. The alkaline compound has to be changed while the value of PH is more than 9.5, but in this case, it is less than 9.0, as shown in Fig 3.

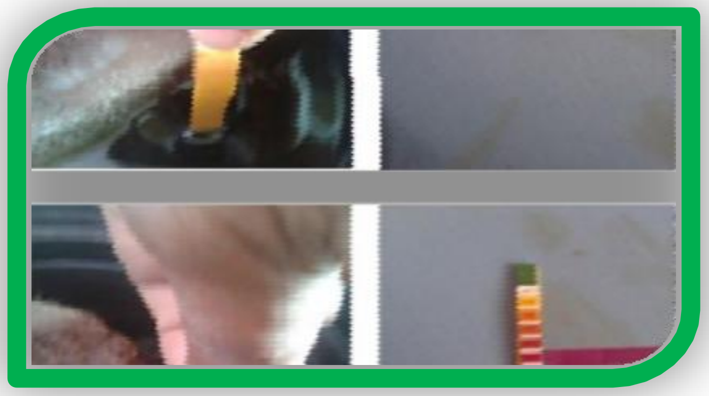

Figure 3 Sulphate attack test of AACMM cube

The sulfate attack of the specimen was evaluated by measuring changes in dimension and determining the decrease in strength and weighing the loss in weight. There are no significant dimensional changes along the surface edges. Test results of the Sulphate attack also listed in the same Tab. 4.

5.5 Alkalinity measurement test

The powdered samples of the cube specimen sieved through a 75-micron size. The particles entered through the sieve collected for testing. Twenty grams of powdered samples dissolved into 100 ml of distilled water and were permitted to allow for three days. The watery solution's quality was measured in terms of PH value after 72 hours was less than 9, as shown in Fig 4.

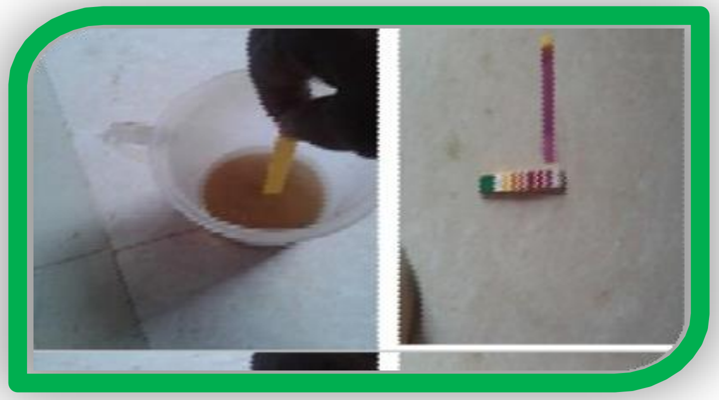

Figure 4 Alkaline test of AACMM cube

5.6 Triplet prism test

Mortar and the masonry hit contacting places are determined only through testing triplet specimens. The specimen made by GPEB of size 19cm×9cm×9cm and 10mm thick AACMM was taken for the testing process and find the mortar bond strength. The mortar used for making prisms is 4M, 6M, 8M, and 10M. The specimen positioned to test in the UTM and recorded the results in Tab. 5.

Table 5.Bond strength of Triplet prism

Mix Id	Molar ratio	Avg. bond strength (28days) N/mm^2
BMPT1	4M(160)	0.05
BMPT2	6M(240)	0.08
BMPT3	8M(320)	0.12
BMPT4	10M(400)	0.18

The maximum shear load at failure recorded. The prism assumed as a low beam subjected and evaluated to average bond stress $\tau b = Pv / 2A$.

Where Pv = shear load (Newton). Where A = peripheral area of mortar contacts (mm^2).

Triplet brick prism placed in the testing machine's platform and failure sorted out the ultimate load-carrying capacity by brick-mortar joint. Bond strength along the bed joint is the function of bond strength between mortar and brick under zero compression loads (Ean L.W et al. 2013). The bond stress is compared with varying molarity of masonry prism, as shown in Fig 5. The observed test results found that AACMM prepared with a molarity of 10 is better to bond strength than lower molarity prepared mortar.

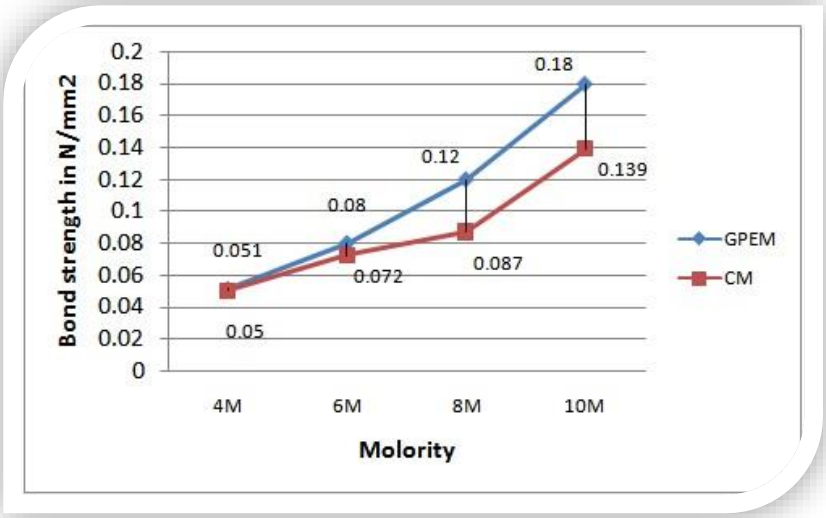

Figure 5 Comparison of bond strength (BM with AACMM) Vs. (BM with CM)

5.7 ANSYS- Numerical study

Triplet brick prism properties are assumed as nonlinear and non-homogeneous here. The triplet brick prism contains 3 numbers of brick 19 cm × 9 cm × 9 cm size, as shown in Fig 6, and AACMM of 10 mm thickness taken for the study.

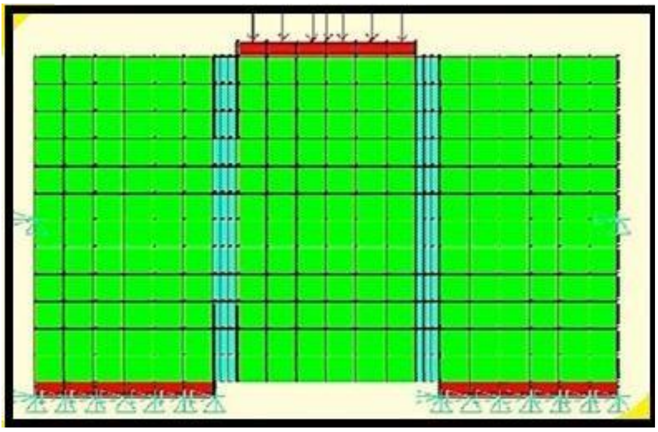

Figure 6 Micro modeling of prism for shear

Considering more deflection and strain capability are modeled using 3D isoperimetric solid 65 elements of linear elastic. Considering 3D solid 45 steel plates is used for load distribution on the brick prism. The end conditions considered as the base is constrained all degrees of freedom and top the load applied over the thin plate under compression load. Shear cracking behaviors assessed by the triplet GPEB prism's performance with AACMM 8 molarities of 8M and 10M. In numerical modeling, triplet brick prism under shear loading observed that the shear stress predominant at the joint using 8M than 10M and more at top and less at the bottom, as shown in Fig 7.

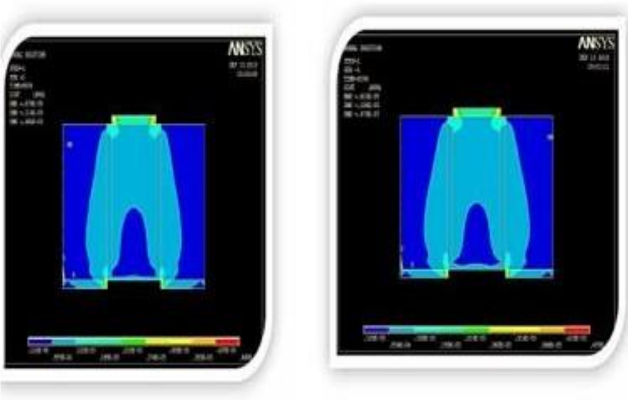

Figure 7 BM (8M & 10M) Triplet shear Prism stress distribution

Shear cracks had been developing in mortar joints towards brick when failure. Fig 8 shows the displacement of specimen prism in detail.

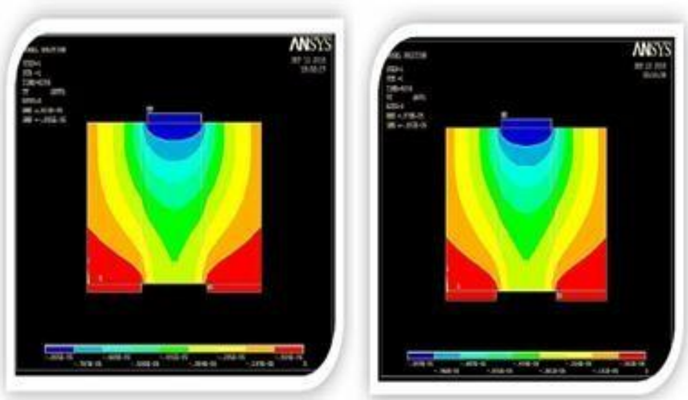

Figure 8 BM (8M &10M) Triplet shear prism displacement

Fig 9 displays the integrity of bond strength of specimen prism between experimental and numerical analysis.

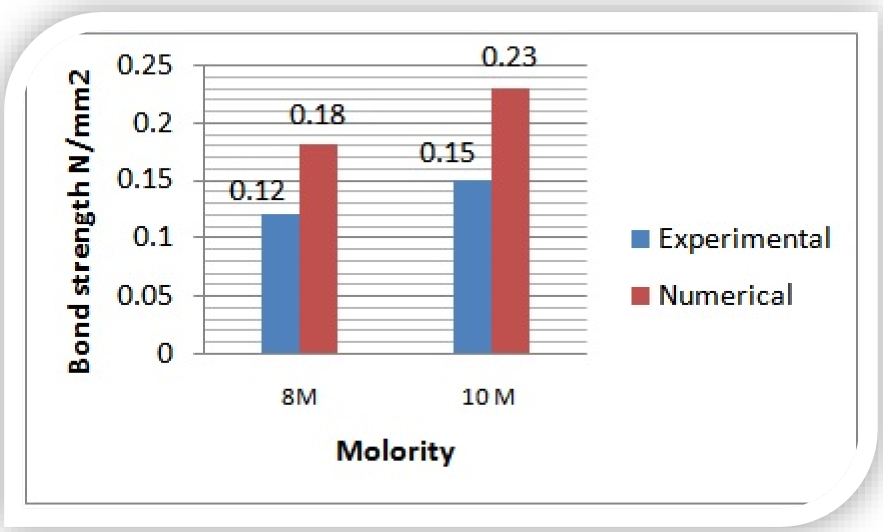

Figure 9 BM-(8M &10M) Bond stress comparison

6. CONCLUSION

From the results of various tests, it concluded that the strength and durability of AACMM are excellent. The power of the new blend is an excellent alternative to cement. Based on the testing of various sample mixtures, the optimum mix ratio (FA: GGBS: Soil: QD), (0.5:0.5:1.75:0.25) with NaOH of 8M and 10M observed.

It is the strength and durability properties of this compound and gives good bond strength for brick masonry. While mortars do not make much of contribution, this is due to poor construction. Therefore it is essential to select the mortar. This research concluded that AACMM used for an alternative to CM and LM. AACMM cube's strength attained a gain of 20% when contacted with 5% sulphuric acid and 10% strength gain with a 5% sodium sulfate solution. AACMM reacts with acid and base solution increasing its strength without losing. Lack of weight loss, it was decided that it was suitable for all situations. Besides that, the numerical results arrived from ANSYS were compared with experimental tests. Numerical results have come merely 25% more than the experimental results. Finally, this research found that AACMM can be successfully proposed for mortar in masonry structures and plastering material to apply masonry structures for external protection. In preparing the AACMM, determined that the use of admixtures would result in better workability.

When the AACMM prepared without GGBS also had an excellent mortar, but it requires curing. In our scope, neglecting water curing, GGBS is placed and added in the mix. It is also possible to produce new mortar through the use of alternative binding materials.

From the results of various tests, it concluded that the strength and durability of AACMM are excellent. The power of the new blend is an excellent alternative to cement. Based on the testing of various sample mixtures, the optimum mix ratio (F.A.: GGBS: Soil: Q.D.), (0.5:0.5:1.75:0.25) with NaOH of 8M and 10M observed. It is the strength and durability properties of this compound and gives good bond strength for brick masonry. While mortars do not make much of contribution, this is due to poor construction.

REFERENCES

Kunasegaram Sajanthan, Balasingam Balagasan, and Navaratnarajah Sathiparan, (2019) Prediction of Compressive Strength of Stabilized Earth Block Masonry, Advances in Civil Engineering, pg.1-13.

Ibrahim A. S AL-Jumailya, Nahla Najib, Qays Kareem, (2015) An overview on the Influence of Pozzolanic Materials on Properties of Concrete, International Journal of Enhanced Research in Science Technology & Engineering, Vol. 4, Issue 3, pp: (81-92).

Najabat Ali; Abbas Jaffar; Muhammad Anwer; Shazada Khurram Khan Alwi; Muhammad Naeem Anjum, Najaf Ali, Muhammad Riaz Raja, Adil Hussain, Xu Mig, (2015) The Greenhouse Gas Emissions Produced by Cement Production and Its Impact on Environment: A Review of Global Cement Processing, International Journal of Research, Volume 2, Issue 2. pp. 488-500.

Robbie M. Andrew, (2018) "Global CO2 emissions from cement production" Earth System Science Data, Vol.10, pp. 195–217.

Oswal T, Manojkumar VC,(2014) Experimental investigations on strength, durability, sustainability, and geo-polymer concrete blocks' economic characteristics. International journal of research in engineering and technology, 3(6):115-22.

Boskovic Ivana, and Zejak Radomir, (2013) The influence of raw mixtures and activators characteristics on red-mud based geo-polymers, JCAE, , Vol. 17, no.1, pp 34-40.

Konstantinos A. Komnitsas. (2011) "Potential of geopolymer technology towards green buildings and sustainable cities", Procedia Engineering, Vol.21, pp. 1023-1032.

Pradip Nath, Prabir KumarSarker, Vijaya B.Rangan, (2015) Early Age Properties of Low-calcium Fly Ash Geopolymer Concrete Suitable for Ambient Curing, Procedia Engineering, Vol. 125, Pg. 601- 607.

Abdul Aleem MI, Arumairaj PD. (2012) Optimum mix for the geopolymer concrete. Indian journal of science and technology, 5(3):2299

Reddy BSK, Varaprasad J, Reddy KNK.(2010) Strength and workability of low lime fly ash-based geopolymer concrete, Indian journal of science and technology, 3(12):1188-89.

FAO Corporate Document Repository, (2010) "Earth as building material", www.fao.org.accessed in 2010.

Bahoria B.V., Parbat D.K., and Nagannaik P.B., (2013) "Replacement of natural sand in concrete by waste products: A state of art J. Environ. Res. Development, 7(4A), 1651-1656.

Madheswaran.CK, Gnanasundar G, (2013) "Utilization of quarry dust and slag for replacement of Sand in concrete", National conference "ENTROIDOS-13" ; P.55-70.

Park jin-soo, Kim. Myung, (2013) recycling of waste sludge of cathode- ray tube manufacturing units as an additive in Asphalt concrete mix, , JERD, 8(1), 82-87.

Thokchom, S., Dr. Partha Ghosh, P., and Ghosh, S, (2009) Acid Resistance of Fly Ash Based Geo-Polymer Mortars, International Journal of Recent Trends in Engineering, 1(6):

Michele Angiolillo and Amedeo Gregori, (2020) 'Triplet Test on Rubble Stone Masonry: Numerical Assessment of the Shear Mechanical Parameters," Buildings MDPI, 10(3), 49.

Sergey Churilov, Elena Dumova- Jovanoska, (2013) "In-plane shear behavior of Unreinforced and jacketed masonry walls," Soil Dynamics and Earthquake Engineering", pp. 85–105.

Shahid Nazir, Manicka Dhanasekar.(2013) "Modelling the failure of thin layered Mortar joint in masonry", Engineering Structures, pp.615– 627.

David A. Weed, Adam G. Tennant, Mohammad Hussein Mohamed, K. Gourav, Craig D. Foster B. V. Venkatarama Reddy(2020) "Finite element model application to flexural behavior of cement stabilized soil block masonry," Materials and Structures, 53, pp.61.

Haach, V.G. Vasconcelos, G, Loureno PB,(2011) "Parametrical study of masonry Walls subjected to In-plane loading Through Numerical modeling, Engineering Structures, 33: pp.1377–1389.

Palanisamy.P, Kumar.P.S, (2018). "Effect of molarity in GPEB reinforced with fibrous coir wastes using sandy soil and quarry dust as fine aggregate" *JCSCM*, 8, 347-358

Palanisamy.P, Kumar.P.S, (2020). "Experimental and Numerical investigation of bond strength of brick masonry using Geo-Polymer Earth Mortar in an aggressive environment." Proceedings of the international conference ICITMSEE 2020, Kongu Nadu College of Engineering and Technology Tiruchy, Tamil Nadu.

Palanisamy.P, Kumar.P.S, (2020). "Technical studies on innovative sustainable and green energy building material of Geo Polymer Earthen Brick Masonry." Proceedings of the international conference NCCE-NITK 2020, National Institute of Technology Karnataka.

Indian Standards -3812 -1," Specification for Fly ash for use as pozzolana".

ASTM C 618- 1993.Class C, "Standard specification for coal fly ash and raw or calcined natural pozzolana for use in concrete".

Indian Standards -12089 (R 2008), "Specification for granulated slag for the manufacture of Portland slag cement".

Bennet JS, Sudakar M, Natarajan c, (2013) Development of coal ash –GGBS based geopolymer bricks, European International Journal of Science and Technology, 2(5):133-39.

IS-2720 Part-5, "Methods of test for soil".

Manjunath G.S. Radhakrishnan.C, Giridhar, Maheshjadhav,(2011) "Compressive strength development in ambient cured Geopolymer mortar", IJESE, Vol.4 &6. Pp.830- 834.

Indian Standards-3495-(1976). "Method of tests on burnt clay blocks (part-I) & (part-II) "Determination of water absorption & Determination of compressive strength".

Indian Standards- 2250 (R 2000), "Code of practice for preparation and use of masonry mortars".

Indian Standards - 1077 (2007), "Common burnt clay building bricks specifications".

Ean L.W, Malek M. A, Mohammed B.S, Chao-Wei Tang, Tamunif M.T, (2019) "Flexural and Shear bond strength of sediment brick masonry "International Journal of Recent Technology and Engineering (IJRTE), Vol.-8 Issue-4