Journal of ICT, Design, Engineering and Technological Science (JITDETS)
VOL. 7, NO. 2, pp. 28-35, 2023
DOI: https://doi.org/10.33150/JITDETS-7.2.4

ORIGINAL CONTRIBUTION

Optimum Utilization of Volcanic Rock as Pozzolana for the Maximum Compressive Strength of Mortar

Zeeshan Ahmad [1*], Muhammad Suleman [2], Masooma Sabtain [3], Muhammad Abdur Rehman Hamid [4], Waqas ur Rahman [5], Hamid Bilal [6]

[1]Lanzhou University of Technology, Gansu, China

[2,3]Swedish College of Engineering and Technology, Rahim Yar Khan, Pakistan

[4]Xi'an University of Architecture and Technology, Xian, China

[5]Jiangsu University of Science and Technology, Jiangsu, China

[6] Iqra National University, Peshawar, Pakistan

Abstract*— This research describes the Dir-Utror volcanics in terms of geochemical analysis and compressive strength results to determine their Pozzolanic properties. Adding pozzolana to cement mortar enhances compressive strength by providing a supplementary binding material that reacts with calcium hydroxide to form additional cementitious compounds. This not only improves the overall durability of the mortar but also reduces the risk of cracks, making it an economically viable solution for constructing robust and long-lasting structures. For this purpose, this research concentrates on exploring the Pozzolanic characteristics using the X-ray Florescence technique, to illustrate chemical composition, and compressive strength test using 2 inch or 50 mm mortar cube. According to chemical composition and compressive strength results and by comparing it with the standard cube compression results with Ordinary Portland Cement (OPC), these materials are suitable to use as an additive or substitute for cement replacement. Four different samples were collected from the same region three of them, at 28 days of age, gave satisfactory results, while a single sample (sample 2) had less compression result than the standard cubes, cured for 28 days, according to the graphs' trend lines. A total of 78 (2-inch) cubes were made, 6 considered to be standard (OPC) and 72 for 4 different samples. Three cubes for each ratio, such as by 15%, 25 and 35%, have been prepared and have taken the average value for each Pozzolan-ratio sample. The 1st series, 36 Pozzolan cubes', compressive strength results were conducted after 14 days of age which was not as satisfactory as the 2nd series cured for 28 days of age.

***Index Terms*— Concrete, Mortar, Volcanic rock, Dir-utror Compressive strength, Pozzolana, X-ray fluorescence**

Received: 19 July 2023; **Accepted:** 25 September 2023; **Published:** 30 December 2023

I. INTRODUCTION

Pozzolan can be defined as, a material that has less or no cementing properties but can develop a reaction with the calcium hydroxide in the presence of water [1]. Pozzolan is used as a cheap alternative to cement mortar having a major composition of silica and is divided into two main types such as natural Pozzolan and artificial [2]. Workability and durability can be increased when Pozzolan lowers the mortar's heat of hydration, the heat produced during cement reaction; on the other hand it also resists and controls the alkali-silica reaction and sulfate attacks [3]. To conserve energy, strenuous research has been done for the production of less energy-intensive materials in the form of fly ash, slag, and natural Pozzolan and suggested that the natural Pozzolan could be in the form of fly ash which is considered the original Pozzolan (ASTM C618), diatomaceous earth, burnt clays, opaline chert and shale [4]. Pozzolan could be collected from the five preeminent sources in which the naturally occurring Pozzolan is present in the form of volcanic ash resulting from a volcanic phenomenon and can be allocated in Europe and the Middle East [5]. This volcanic ash's Pozzolan is famous for use in concrete during wet conditions. Pozzolan can also be obtained from burnt and crushed clays, like bricks and this has proved to be more efficient than volcanic ash [6]. Another type is furnace slag which is produced as a by-product of industrial materials, such as the by-product of manufacturing steel [7]. The last variety can be collected from burnt organic coal or lime, but it has been shown that it is not suitable for mortar cement. The last and final type of Pozzolan is in the form of crushed rock and sand [8]. Besides workability and durability, Pozzolan is important to bring down the amount of carbon dioxide, emitted to the atmosphere during cement manufacturing, which is estimated as 7 percent of the total greenhouse gas, contributing to global warming. Minimize the energy consumption in manufacturing cement can indirectly decrease by using such kind of

*Corresponding author:Zeeshan Ahmad
†Email: zeeshan.mkd04@gmail.com

materials as an additive stuff as silica fume, slag, and natural Pozzolan. As a result, inexpensive environment-friendly cement can be obtained. Pozzolan produces calcium silicate hydrate bond in response to containing amorphous silica which reacts with calcium and make an additional cementation bond calcium-silicate hydrate (CSH). This resultant compound is more resistive than ordinary binder matrix [9, 10]. Ancient and gigantic structures in different parts of the world such as Greece, Egypt, and Rome, stood by materials having Pozzolan. It has also been concluded that these people had used crushed pottery during the period of Minoan (3000-5000 B.C) [11]. Recent research has illustrated that a water storage tank made in the ancient city of "Camiros" which was manufactured around 400-500 B.C, contains volcanic earth of about 20% of the mass of the concrete [12]. Romans made use of Pozzolan by adding it into some proportion of lime and rubble introduced the amount of water needed and then obtained a compacted mass by ramming the mixture. They also used grounded purple or red tuff present in the vicinity of Naples (Pozzuoli) and mixed it with lime and sand [13]. They also used pottery or tiles when it was hard to find Pozzolanic earth. Many Structures were made by Romans and have been shown the combination of Pozzolanic materials and lime in concrete samples, these structures have survived about 2000 years having a 42m-span dome in the location of Pantheon, Rome which can be considered a good example among the several [14]. Lime-Surkhi (crushed clay bricks) is also one of the Pozzolan types that were used from the 19th century for canals and dam works because of certain important properties like low shrinkage value, impermeable structure, and the capacity to accommodate internal stresses, due to these characteristics it is still in use. The demand for Pozzolan was and still is going in an upward direction in Europe [15]. An aqueduct was made in loss Angeles in the United State in 1912, in which 1×108 kg of Pozzolan cement were used which was composed of 50% of OPC (Ordinary Portland Cement) and 50% of deeply altered rhyolite [16]. Some structures have been made under the control of the U.S Bureau of Reclamation for example Arrowrock Dam; which Pozzolan had used but it has proven poor due to surface weathering and being repaired in 1976, although a report was made which showed this concrete has no problem from inner side [17].

Prior, the US investigation of American Pozzolan suggested that adding Pozzolan to the concrete mixture makes the type of concrete more durable in terms of permeability and more resistant to the action of enough aggressive water. This property Pozzolan was used in the Bonneville Dam and Friant Dam by 1935 and 1942 respectively [18]. The first real Pozzolan used in the Friant Dam which is composed of pumacite and calcined opaline shale was used in the Davis Dam in 1950. This used amount of Pozzolan saved approximately $301,000. The contemporary use of Pozzolan in Asia, Europe, and America and being used in ancient civilized structures proved Pozzolan to be a beneficial material in construction management [19, 20]. The solid portion of the earth's crust consists of 5% extrusive igneous rocks, and these rocks are distributed within all six continents and have covered a large portion of the developing countries in South and Central America, Africa, Asia, and Australia [21]. Natural Pozzolan can occur in two forms; a consolidated form, usually in a solid mass, or an unconsolidated, fragmental form. Some fragmental deposits are present in 'Tosca' and 'Tetin'. Both are volcanic ash deposits and also present on a huge scale in Japan and New Zealand [22].

Laboratory study on the strength development of concrete containing fly ash and optimum use of fly ash in concrete was done. Fly ash was added according to the partial replacement method in mixtures. A total of 28 mixtures with different mix designs were prepared. 4 of them were prepared as control mixtures with 250, 300, 350, and 400 kg/m3 cement content in order to calculate the Bolomey and Feret coefficients (KB, KF). Four groups of mixtures were prepared, each group containing six mix designs and using the cement content of one of the control mixtures as the base for the mix design. In each group 20% of the cement content of the control mixture was removed, resulting in starting mixtures with 200, 240, 280, and 320 kg/m3 cement content. Fly ash in the amount of approximately 15%, 25%, 33%, 42%, 50%, and 58% of the rest of the cement content was added as partial cement replacement. All specimens were moist cured for 28 and 180 days before compressive strength testing. The efficiency and the maximum content of fly ash that gives the maximum compressive strength were obtained by using Bolomey and Feret strength equations. Hence, the maximum amount of usable fly ash amount with the optimum efficiency was determined [23].

This study showed that strength increases with increasing amount of fly ash up to an optimum value, beyond which strength starts to decrease with further addition of fly ash. The optimum value of fly ash for the four test groups is about 40% of cement. Fly ash/cement ratio is an important factor determining the efficiency of fly ash.

The main aim of the present research work is to evaluate the volcanic rocks of the Dir Group northwestern KIA for its Pozzolan potential. This aim can be obtained with the following objectives.

- To find out the major oxides of the volcanic rocks X-ray Fluorescence technique is required.
- To find out the compressive strength of the concrete made up of the Pozzolanic materials/volcanic by using ASTM standard procedure.
- To compare the obtained results with some standard known Pozzolans around the world.

II. MATERIALS AND METHOD

Different methods have been applied on pozzolana usage in the preparation of cement mortar by many scientists. One of the researchers worked in such a way that the series of mortar specimens first was created with replacement levels of 0%, 10%, 20%, 30%, and 40% of natural pozzolana. These specimens were then continuously cured at 20, 40, and 60% Celsius with saturated humidity. The second set, which included just 20% natural pozzolan, was heated to high levels for one, three, and seven days before being cured in a saturated atmosphere at 20 °C [24]. Also, local ordinary Portland cement with a fineness of 350 m2/kg was used for all the mixes. The natural pozzolana used in this work was from Beni–Saf quarry in the west of Algeria. The limestone and pozzolana were ground in a laboratory mill to a specific surface of 370 m2/kg and 420 m2/kg−1 respectively [25, 26].

This section of our research mainly focuses on the tests conducted on the collected samples including both analytical and Strength tests. The analytical test conducted on the samples is mainly XRF. This test is done to find out the details of the major oxides present in the samples. The strength tests include only the compressive strength test, which is conducted on the cubes made up of concrete having different proportions of pozzolanic materials and cement. The details of the tests, procedures, and values are presented in the following sections.

The methodology for this research is comprised of Fieldwork and Laboratory work.

A. Fieldwork

A one-day detailed field was arranged in the proposed research area. The research area lies within the village of Ayagy Sharqi, which is located in the northeast of Dir City and to the West of the Shaheed Benazir Bhutto University Sheringal, at a distance of about 13 km from Sheringal bazaar. During fieldwork, four samples were collected from three different locations within Hayagy village. And the sample is denoted by S1, S2, S3 and S4.

Fig. 1. Shows locations of collected samples at the village of Ayagai

B. Laboratory work

The laboratory work is composed of two techniques.

- Analytical Tests for the major oxides and
- Physical Test for the compressive strength of the cubes

For analytical tests, the samples were brought to the Central Resource Laboratory (CRL) of the University of Peshawar. Major oxides were determined using X-ray fluorescence (XRF) techniques. However, for the strength tests the required powders for concrete were made in the Geochemistry laboratory of the National Center for Excellence in Geology (NCEG), UOP. The required cubes (1×1 inch) for the compressive strength were prepared in the Civil Engineering Lab of UET Peshawar. The compressive strength of cubes both for 14 and 28 days was then determined in the Civil Engineering Lab of UET Peshawar.

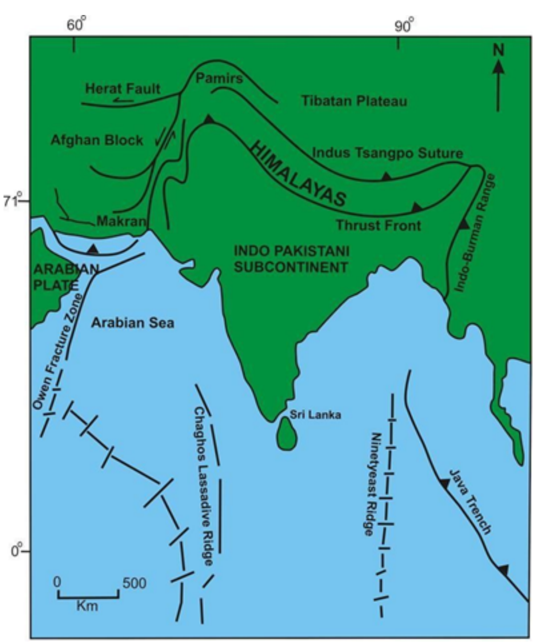


Fig. 2. Shows Tectonic map of the India-Eurasia collisional zone

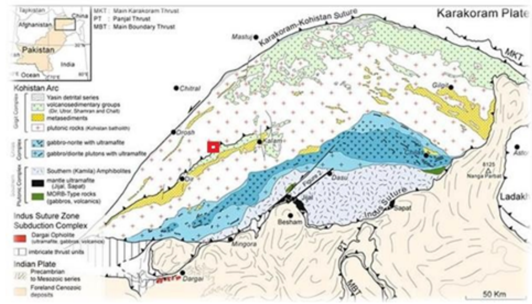


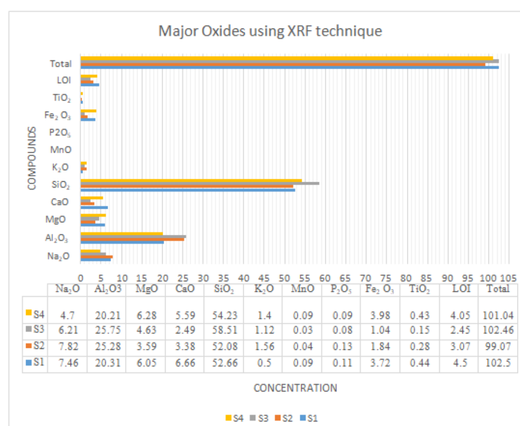
Fig. 3. The geological map of the Kohistan Island Arc

C. X-Ray florescence method

The selected Rock samples are volcanic. These samples were subjected to analysis geochemistry. The following are the main objectives.

- To evaluate different major oxides
- To find out the concentration of these oxides

XRF techniques were used to find out the geochemical composition of the collected samples. The XRF analyses were carried out on fused disks called glass beads. Each bead was analyzed for (T_iO_2), (Al_2O_3),(Fe_2O_3), M_nO,(M_gO), (C_aO), (Na_2O), K_2O and (P_2O_5). The analyses were performed through a PANalytical PW4400/24 spectrometer equipped with a rhodium anode X-ray tube. International standards, namely WROXI-1, WROXI-2, WROXI-3, DT-N, SDC-1, PG-1, and G-2 were alternately run with each batch of five samples to monitor the precision and accuracy of the machine. The minimum detection limits for major elements are as follows: T_iO_2 (0.003%), Al_2O_3 (0.0039%), Fe_2O_3(0.0085%), M_nO (0.016%), M_gO (0.0055%), C_aO (0.0042%), Na_2O (0.0039%), K_2O(0.0038%) and P_2O_5 (0.0013%). Four samples were collected from 4 different locations and then ground by the Loss Angles machine to make them easy to carry. The samples were then processed in the laboratory of the National Center of Excellence in Geology, University of Peshawar.



	Na_2O	Al_2O_3	MgO	CaO	SiO_2	K_2O	MnO	P_2O_5	Fe_2O_3	TiO_2	LOI	Total
S4	4.7	20.21	6.28	5.59	54.23	1.4	0.09	0.09	3.98	0.43	4.05	101.04
S3	6.21	25.75	4.63	2.49	58.51	1.12	0.03	0.08	1.04	0.15	2.45	102.46
S2	7.82	25.28	3.59	3.38	52.08	1.56	0.04	0.13	1.84	0.28	3.07	99.07
S1	7.46	20.31	6.05	6.66	52.66	0.5	0.09	0.11	3.72	0.44	4.5	102.5

Fig. 4. Shows the concentration of oxide in each sample using X-ray fluorescence techniques

The above figure illustrates the number of major oxides such as Sodium oxide (Na_2O), Aluminum oxide (Al_2O_3), Magnesium oxide (M_gO), Calcium oxide (C_aO), Silicon dioxide (S_iO_2), Potassium oxide K_2O, manganese oxide (M_nO), phosphorous oxide (P_2O_5), Iron oxide (Fe_2O_3), Titanium oxide (T_iO_2) and loss on ignition (LOI) during the XRF analysis. For the sake of ready reference, the results are also shown in a graphical display above the table. In the given graph silicon dioxide (S_iO_2) has the highest percentage reaching from 50% to 60% in the selected 4 samples. The second highest value is for alumina (Al_2O_3) which is 20% to 25%. This trend is followed by calcium oxide, magnesium oxide, and sodium oxide which are between 5 to 10 percent. Iron oxide is just under 5% while the rest is less than the iron oxide. Pozzolanicity increases with an increase in the number of oxides, particularly Silicon dioxides and Aluminum trioxides, which produce extra cementitious bonds with calcium.

D. Compressive strength

The sample for the compression test was designed under the specification of ASTM C109, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars. Overall, in this research, four different types of Pozzolan samples were selected and denoted by sample numbers like S1, S2, S3, and S4.

The finer the Pozzolan, the more effective it will be. So, for this purpose, the Pozzolan was ground further and made its powder, and approximately the size was reduced to an upper size limit of 45 microns. Furthermore, a 200# sieve was set to screen out the larger particles.

The powder was then carried to make concrete batches in which each Pozzolan presented three different mixtures with a ratio of 15%, 25%, and 35%. In this way, 24 distinct mixtures were needed for 14 and the same number is taken out for 28 days of age. We were able to make three mortar cubes, as a sufficient quantity of Pozzolan was available, for each of the mixtures from the same percent-admixture. So, the obtained total number jumped to 72 cubes, from which we received an average value for each of the percent-admixtures. The cubes were then cured for 14 and 28 days under the ASTM specifications.

Each cube mixture was designed with the sand/cementitious ratio of 3.25/1.25 respectively. Note that the addition of Pozzolan only replaced a certain portion of cement; meanwhile, the sand and water proportion remained constant throughout the mixing process, as mentioned in Table 1.

TABLE I
SHOWS MIXED PROPORTION OF MORTAR FOR COMPRESSIVE STRENGTH TEST

Set No.	Series	Sand/cementations Ratio	Pozzolan (%)	Cement (%)	Water/cement ratio
1	S1,S2,S3,S4	3.25/1.25	15	85	0.5
2	S1,S2,S3,S4	3.25/1.25	25	75	0.5
3	S1,S2,S3,S4	3.25/1.25	35	65	0.5

After making the paste for each type and percent, the paste is cast into 2 2-inch or 150mm cubes as required by ASTM C109. Each cube has rigid sides and open tops, filled partially and tamped 25 times. After 24 hours the mortar cubes were then removed from the molds and kept wet, wounded in a wet towel, till one day before the compressive test. This whole process was done at the University of Engineering and Technology Peshawar (UET) and was tested for compressive strength at the Civil Works (C&W) laboratory in Balambat Timergara. Besides these admixture cubes, two standard batches were also prepared, in which no Pozzolan has been mixed, to compare their results with the Pozzolan cubes. A total of six cubes were made for standard in which an average value has been taken out of any three, three for 14, and three for 28 days. The obtained results have been shown in the following graphical form.

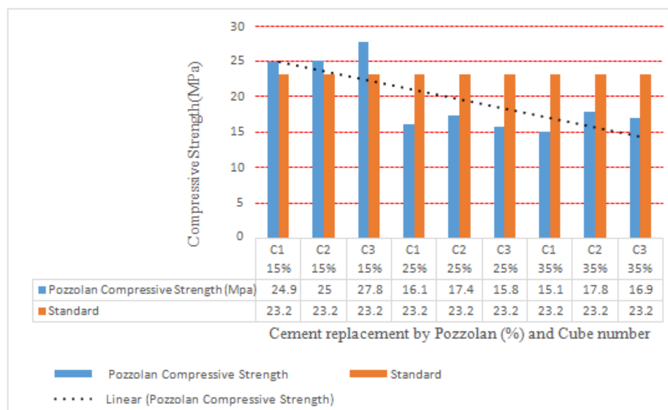


Fig. 5. Shows the compressive strength of each cube, cured for 14 days

III. PREPARATION OF SPECIMEN MOLD

For the preparation of mortar cubes, ASTM C109 was followed. The first three cubes were made for each type and ratio of Pozzolan sample, such as adding Pozzolan by 15%, 25%, and 35% for 14 days. So, the cement ratio went downward as an increase made in the Pozzolan percent. Throughout the preparation of cubes, the sand and water ratio remained constant, though the cement ratio decreased when increased formed in Pozzolan percent and vice versa. The same method has been followed for making 28 28-day samples. The values in the mentioned table are for six mortar cubes three cubes for 14 and three for 28 days of age, in each percent Pozzolan.

TABLE II
PRESENTS THE MATERIAL NAME AND AMOUNT FOR SIX CEMENT MORTAR CUBES ACCORDING TO ASTM C109

Serial No.	Material name	Amount
1	Sand	1375 gram
2	Cement	500 gram
3	Water	240 ml

The above figure is designed to determine the compressive strength of sample1 at three different percentages of Pozzolan, which at 15%, shows an abrupt increase in the compressive strength, and ranges from 25 MPa to 27.8 MPa and almost 3 to 5 MPa greater than the standard line (23.2 MPa). The remaining cubes, at 25% and 35% enough less than the standard value. Overall, the graph shows a continuous decline as pozzolan increases from 15-35%.

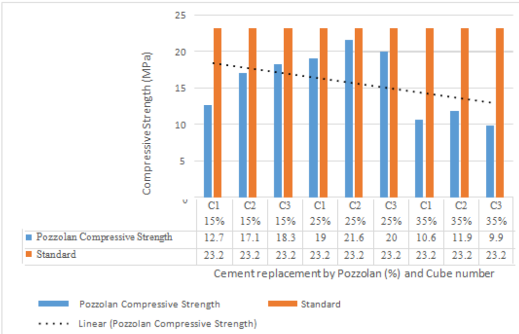


Fig. 6. Illustrates the compressive strength for three cubes in each percent Pozzolan for 14 days

The figure describes the information about the compressive strength of sample 2 cured for 14 days. Although Pozzolan by 25% shows a significant rise, comparatively with 15 and 35% Pozzolan, but did not cross the standard compressive strength value (23.2) which is almost 3 MPa greater than mixing Pozzolan by 25%. Overall, here also the compressive strength trend line shows a negative trend.

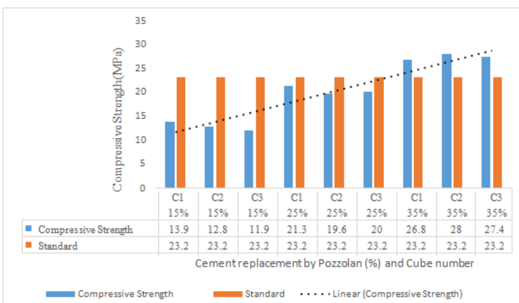


Fig. 7. Illustrates the compressive strength for three cubes in each percent Pozzolan for 14 days

The figure shows an upward trend by mixing pozzolan at 35% and crossing the standard line value (23.2MPa). The lowest value is recorded when Pozzolan is mixed by 15% where the difference to the standard line is about 10 MPa. This value is followed by mixing the Pozzolan by 25%, about 20 MPa, which is greater than mixing it by 15%. Overall, the figure shows a continuous surge as the percentage of the pozzolan increases. The highest value for Pozzolanic compressive strength is recorded as 28 (MPa) by mixing Pozzolan 35%.

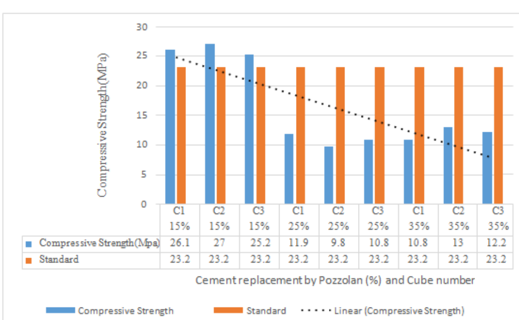


Fig. 8. Shows the Compressive Strength for each cube in Sample 4, cured for 14 days

In the given graph the Pozzolanic compressive strength, at 15%, shows a significant rise, ranging from 25.2 MPa to 27 MPa, and rocketed over the standard line (23.2). The remaining cubes, at 25% and 35% Pozzolan from sample 4, stayed behind the standard line, ranging from 9.8 to 13 percent, randomly. Overall, when cement is replaced by 15% it shows a dramatic rise but the Pozzolanic strength decreases as the Pozzolan percent increases.

A. Discussion

In conclusion, in the above 4 graphs, based on 14 days of age, three different percent Pozzolan in 4 samples, showed a takeover on the standard line by mixing Pozzolan by 15%, 35%, and 15% at S1, S2 3, and S4, respectively, obtained more strength than the standard compression value (23.2).

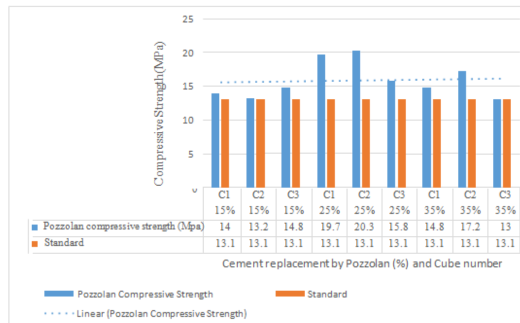


Fig. 9. Based on 28 days compressive strength for each cube in sample1 at 3 different percent of Pozzolana

In brief, the graph shows a positive trend compared to the standard value (13.1). The highest compressive strength value is gained by adding Pozzolan by 25%, which is higher than the standard line (13.1 MPa). The least compressive strength value is recorded when adding Pozzolan by 15%, although, still greater than the standard line.

Overall, mixing Pozzolan at three different percentages gives more strength than the standard compression value. The Pozzolanic strength fluctuated but did not fall below the standard value.

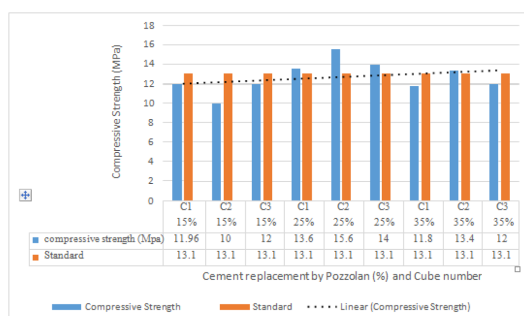


Fig. 10. Demonstrates the compressive of S2 strength for three different percent Pozzolan, based on 28 days of age

In this graph, the Pozzolan strengths trend fluctuates throughout the graph. Pozzolan at 25% received the highest compression value of 15.6MPa, while often Pozzolan at 15% and 35% did not cross the standard line, though Pozzolan at 35% shows a bit less value than the standard line (13.1 MPa). Overall, the Pozzolanic compressive strength's trend line shows a spike. Cement replacement by 25% stayed upon the standard compression value and about 2-4 MPa greater than the standard value.

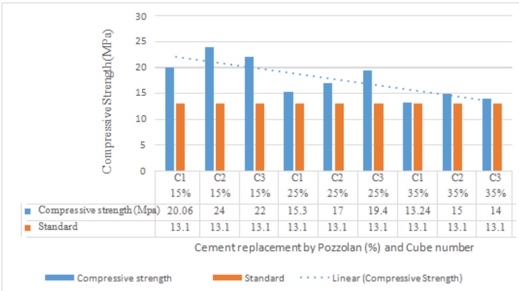


Fig. 11. Presents the data for Pozzolan compressive strength as a mortar cube, cured for 28 days at S3

The graph shows that sample 3 pozzolan mix at 15% gives an average value of 22 MPa which is 7 MPa greater than the standard cube's compression value (13.1). Pozzolanic strength decreases as pozzolan percentage increases, although pozzolanic strength does not fall behind the standard value on each pozzolan percent admixture.

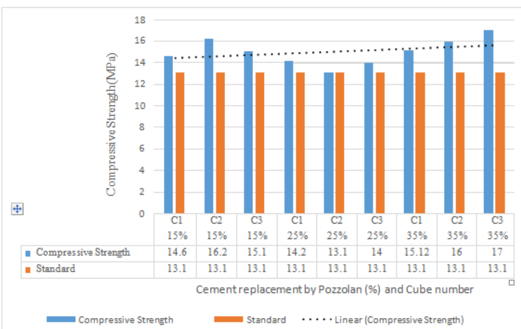


Fig. 12. Describes the compressive strength of each cube with the age of 28 days at S4

It is evident from the graph that the resultant value of the compressive strength ranges from 13.1 MPa to 17 MPa. The lowest value is shown by 25% pozzolan while the highest value of the strength is given by 35% pozzolan. A decrease in Pozzolanic compression value is recorded when the Pozzolan is mixed by 25% but still greater than the standard compression value (13.1). The overall trend of the compressive strength is positive as shown by the dashed line on the graph.

IV. RESULTS AND DISCUSSION

Pozzolan is a complex material to define well, but the need for strength makes it easy to describe. First, chemical composition influences the characteristic of being Pozzolan and secondly, compressive strength testing could reveal the material's Pozzolanicity more clearly, using precise procedures and materials. The points below show a summary for the graphs 3.2-3.9

- Under 14 days of analysis, only Sample 3 shows an increase in the compressive strength as the pozzolan percent increases, while Sample 2, 3, and 4 show a downward trend when the pozzolan percent increases from 15 to 35%. However, sample 2 shows a small increase when pozzolan was mixed by 25% but a decrease from 35% pozzolan.
- Under 28 days of analysis, only sample 4 shows a constant increase in the compressive strength as the pozzolan percentage increases, while samples 1 2, and 3 show a decrease in strength as the pozzolan percentage increases, despite samples 1 and 2 showing an increase when pozzolan mixes by 25%.

Graphs 4.1 and 4.2 illustrate this scenario in detail.

A. Compressive strength

Following are the results of the compressive strength test.

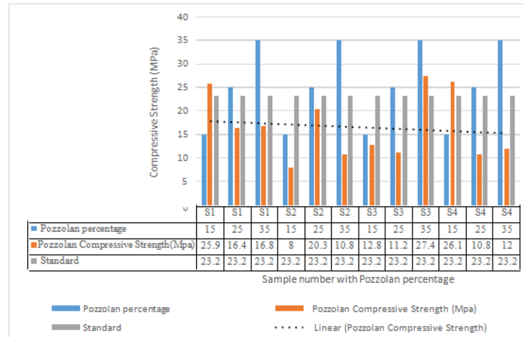


Fig. 13. Shows the compressive strength for the total number of samples at three different percent Pozzolan, having age 14 days

The graph represents the average value for 12 Pozzolan mortar cubes for four samples. All cubes have 15%, 25%, and 35% Pozzolan for cement replacement. Sample number 1, 3, and 4, in which Pozzolan is mixed by 15%, 35%, and 15% respectively, shows an upward trend compared with standard compressive strength value (23.2 MPa). Out of a total of 12 samples, only three samples' strength crosses the standard value. But the overall trend line shows a negative trend as evident from the graph. When the Pozzolan percentage increases from 15% to 35% then the sample 1 compressive strength shows a downward trend/negative trend. Similarly, sample 2 shows a fluctuation in compressive strength at different percentages of Pozzolan at 25% the S2 strength reaches 20.3 mega Pascal. However in sample 3 at 35% Pozzolan crosses the standard line of compressive strength which has been recorded as the highest strength value for 14 days of treatment. In this way, sample 4 at 15% has crossed the standard line and is recorded as 26.1 Mega Pascal and the rest of the samples are under the standard line.

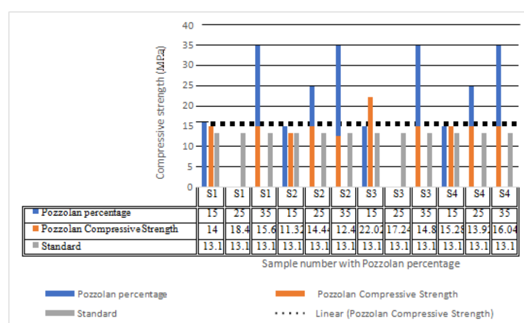


Fig. 14. Shows the resultant data based on 28 days of a cure for each Sample having different percent Pozzolan

The graph and table are designed with the same ratio of sand and water but the cement ratio decreases by increasing Pozzolan. Each sample is divided into three types based on adding 15%, 25%, and 35% Pozzolan. A significant increase is shown by sample 3 when Pozzolan is mixed by 15% and gives a strength value of 9 MPa. This value is followed by sample 1 and sample 2 when mixed by 25% giving compressive strength values of 18.4MPa and 17.2MPa respectively. The rest of the samples give fluctuation in the compressive strength value under the black-dotted standard line of compression.

In this graph, the overall average Pozzolanic strength line value is greater than the standard cubes' compression value. Sample 3 has the highest recorded value, and the value decreases as Pozzolan percent increases. Sample 1 at 25% has also an appreciable strength value over the standard value but no straight relation by increasing or decreasing the Pozzolan percentage. Sample 4 also shows fluctuation by increasing Pozzolan percentage and only produces satisfactory results by 35% of Pozzolan replacement.

V. CONCLUSION

Based on the above results, the studied rock contains Pozzolanic properties. Pozzolanic reactions require silica to form a calcium-silicate-hydrate bond; these materials have more than enough. Most of the time compressive strength is greater than the standard cement value when tested for mortar mixture. Based on 14 days, only three samples are suitable to use as a Pozzolan i.e. S1, S3, and S4 have more compressive strength value than standard value when mixed them as 15%, 35%, and 15% respectively. Based on 28 days of results, almost all samples demonstrate an effective value of compression comparatively to the standard cube compression value. Only sample 3 at 15% and 25% have less value than the standard compressive strength value, while the rest of the sample, by various percent Pozzolan, provided a positive trend according to the standard compression value.

VI. RECOMMENDATIONS

Following are the recommendations for this investigation.

- Investigate the influence of different curing conditions on the performance of pozzolana-enriched mortar, considering variations in time, temperature, and moisture levels to identify the most effective curing regime.
- Explore the impact of varying particle sizes of pozzolana on the engineering properties of mortar, as different sizes can influence the packing density and hydration kinetics.
- Assess the compatibility of pozzolana with common admixtures such as accelerators or retarders, aiming to enhance specific properties like early strength gain or prolonged workability.
- Conduct long-term durability studies, including resistance to freeze-thaw cycles, sulfate attack, and alkali-silica reactions, to evaluate the effectiveness of pozzolana in enhancing the resilience of the mortar.
- Employ advanced imaging and analysis techniques, such as scanning electron microscopy (SEM) and X-ray diffraction (XRD), to investigate the microstructure of pozzolana-modified mortar, providing insights into hydration products and interfacial bonding.

VII. ACKNOWLEDGMENT

All praises to ALLAH, the source of all knowledge, and wisdom within and beyond our comprehension. We cannot repay even a single blessing conferred upon us by ALLAH. So first of all we offer our thanks to Almighty ALLAH for the the courage and interest to complete our project, and without this, it would not be possible for us to finish it. We pay our sincere gratitude to our kind parents and brothers whose love affection and priceless prays helped us to complete our project work with devotion. We are highly privileged to take the opportunity to record a deep sense of gratitude and indebtedness to our project Supervisor Engr. Ali Ahmed Jibran who kindly assigned us with such an interesting project and under whose sincere guidance and scholarly approach; this important piece of work finally achieved its goal. His consistent advice and supervision generated the vigor for excellence in its pursuits, without which this would never have been materialized.

References

[1] M. J. McCarthy and T. D. Dyer, ``Pozzolanas and pozzolanic materials,'' *Lea's Chemistry of Cement and Concrete*, vol. 5, pp. 363-467, 2019.

[2] J. A. Becerra-Duitama and D. Rojas-Avellaneda, ``Pozzolans: A review,'' *Engineering and Applied Science Research*, vol. 49, no. 4, pp. 495-504, 2022.

[3] C. Dedeloudis, M. Zervaki, K. Sideris, M. Juenger, N. Alderete, S. Kamali-Bernard, Y. Villagrán, and R. Snellings, ``Natural pozzolans,'' *Properties of Fresh and Hardened Concrete Containing Supplementary Cementitious Materials: State-of-the-Art Report of the RILEM Technical Committee 238-SCM, Working Group 4*, pp. 181-231, 2018.

[4] R. Firdous, D. Stephan, and J. N. Y. Djobo, ``Natural pozzolan based geopolymers: A review on mechanical, microstructural and durability characteristics,'' *Construction and Building Materials*, vol. 190, pp. 1251-1263, 2018.

[5] L. Contrafatto, ``Volcanic ash,'' in *Sustainable Concrete Made with Ashes and Dust from Different Sources*. Elsevier, 2022, pp. 331-418.

[6] S. Seraj, ``Evaluating natural pozzolans for use as alternative supplementary cementitious materials in concrete,'' Ph.D. dissertation, 2014.

[7] P. T. Teo, S. K. Zakaria, S. Z. Salleh, M. A. A. Taib, N. Mohd Sharif, A. Abu Seman, J. J. Mohamed, M. Yusoff, A. H. Yusoff, M. Mohamad *et al.*, ``Assessment of electric arc furnace (eaf) steel slag waste's recycling options into value added green products: A review,'' *Metals*, vol. 10, no. 10, p. 1347, 2020.

[8] A. Surahyo, Surahyo, and Luby, *Concrete construction*. Springer, 2019.

[9] A. Adesina, ``Recent advances in the concrete industry to reduce its carbon dioxide emissions,'' *Environmental Challenges*, vol. 1, p. 100004, 2020.

[10] D. Mutebi, A. A. Nur, A. D. Haryanto, J. Wiwid, and M. Kazinda, ``Geothermal reservoir prediction using electrical resis-tivity maps: A case study of lili sepporaki indonesia,'' *Journal of Applied and Physical Sciences*, vol. 5, no. 3, pp. 73-80, 2019.

[11] R. Courland, *Concrete planet: the strange and fascinating story of the world's most common man-made material*. Rowman & Littlefield, 2022.

[12] R. L. Day, ``Pozzolans for use in low-cost housing,'' 1990.

[13] J. DeLaine, ``Production, transport and on-site organisation of roman mortars and plasters,'' *Archaeological and Anthropological Sciences*, vol. 13, pp. 1-17, 2021.

[14] M. Mogetta, *The origins of concrete construction in roman architecture: technology and society in Republican Italy*. Cambridge University Press, 2021.

[15] H. Vishwanath, *MATERIALS OF CONSTRUCTION-II*. Sapna Book House (P) Ltd., 2014, vol. 3.

[16] G. Fares, ``Nouveau système cimentaire: cas de la fritte de verre= new cementitious system: the case of glass frit.'' *Library and Archives Canada= Bibliothèque et Archives Canada*, 2010.

[17] R. Wiltshire and G. Scott, ``Us bureau of reclamation dams in the american west,'' *Proceedings of the Institution of Civil Engineers-Engineering History and Heritage*, vol. 162, no. 4, pp. 221-228, 2009.

[18] B. Sangoju, R. G. Pillai, R. Gettu, B. Bharatkumar, and N. R. Iyer, ``Use of portland pozzolana cement to enhance the service life of reinforced concrete exposed to chloride attack,'' *Journal of Materials in Civil Engineering*, vol. 27, no. 11, p. 04015031, 2015.

[19] G. Artioli, M. Secco, and A. Addis, ``The vitruvian legacy: Mortars and binders before and after the roman world,'' 2019.

[20] A. Almssad, A. Almusaed, and R. Z. Homod, ``Masonry in the context of sustainable buildings: A review of the brick role in architecture,'' *Sustainability*, vol. 14, no. 22, p. 14734, 2022.

[21] F. G. H. Blyth and M. De Freitas, *A geology for engineers*. CRC Press, 2017.

[22] I. Cavusoglu, E. Yilmaz, and A. O. Yilmaz, ``Additivity effect on properties of cemented coal fly ash backfill containing water-reducing admixtures,'' *Construction and Building Materials*, vol. 267, p. 121021, 2021.

[23] A. Oner, S. Akyuz, and R. Yildiz, ``An experimental study on strength development of concrete containing fly ash and optimum usage of fly ash in concrete,'' *Cement and Concrete Research*, vol. 35, no. 6, pp. 1165-1171, 2005.

[24] K. Ezziane, A. Bougara, A. Kadri, H. Khelafi, and E. Kadri, ``Compressive strength of mortar containing natural pozzolan under various curing temperature,'' *Cement and Concrete Composites*, vol. 29, no. 8, pp. 587-593, 2007.

[25] M. Ghrici, S. Kenai, and M. Said-Mansour, ``Mechanical properties and durability of mortar and concrete containing natural pozzolana and limestone blended cements,'' *Cement and Concrete Composites*, vol. 29, no. 7, pp. 542-549, 2007.

[26] A. A. Malikyar, Y. Sudoh, N. Nakajima, and S. Date, ``Effect of steam curing condition on the strength gain of mortar containing calcium nitrite based accelerator admixture,'' *Journal of Advances in Technology and Engineering Research*, vol. 3, no. 3, pp. 63-68, 2017.