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Research article

Assess the Effects of the Ratio of Na_2O Solid Oxide to Electric Arc Furnace Slag as a Binder on the Physical and Mechanical Characteristics of Alkali Activated Mortars

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A B S T R A C T

The purpose of the study is to reduce environmental impacts and advance sustainability through the use of electric arc furnace slag. The experimental results focus on using EAF slag to replace a portion of cement. The percentages of partial replacement are 0%, 5%, 10%, 15%, 30%, 60%, 80%, and 100%. NaOH concentrations of 2M, 4M, 6M, and 8M were employed, along with a ($R=Na_2SiO_3/NaOH$) of 0.5-1.5. Physical characteristics of the pastes, including fresh density and flow test. The effects of alkaline-activated solutions (AAS) on compression and flexural behavior strength have also been investigated after a 28-day drying process in dry air at 30°C. The optimal ratio might be thought of as 15% EAF slag. The results show that a higher Na_2O content results in a higher density, a lower compressive strength, and less workability. Results showed that mixes with NH molarities of 2M, 4M, and EAF slag concentrations of 5, 10%, and 15%, respectively, could attain 28-day compressive strengths of up to about 30MPa. However, higher R led to the development of more solid oxides, which reduced mortar performance. When the molarity reaches 4M, the EAF slag ratio of greater than 15% has no discernible effect on the compressive and flexural strength.

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1. INTRODUCTION

The massive amount of construction of waste materials generated by the world's infrastructure sector's rapid development is an important concern for the coming years because of the ineffective waste to re-utilization processes. Making use of the waste products produced by industry, resulting in sustainable development and an environmentally friendly planet. However, the emerging nations, who are in dire need of essential industries, face the biggest challenges. According to [1], the amount of carbon dioxide in the atmosphere increased

between 1840 and 2000, while the production of portland cement increased globally since its development in 1840.

Since the 1970s, cement output has grown significantly faster than the concentration of carbon dioxide in the atmosphere, or faster than all of the main human-caused carbon dioxide emissions from energy and transportation. a continuation of current industrial and demographic trends without significant technical advancements or other specific limitations [2]. The CO_2 emissions of one ton of OPC range from 0.82 to 1.0 metric tons due to the large amount of embodied energy consumed during manufacture. Researchers have begun to investigate new, more ecologically friendly materials to lower CO_2 emissions because of the amount of OPC consumed annually and the high related embodied energy [3,4]. Accordingly, a number of remedies were used to lessen the issues facing the cement sector. For the international cement and concrete community, finding alternatives for Portland cement has proven challenging [1]. Current studies' findings support the usage of slag, fly ash, silica fume, and other minerals By-products for Portland cement replacement materials. Thus, blending of Portland cement enables the use of low-CO_2 emissions cementitious materials in upcoming industrial processes. [5] contested that a consistent rise in green concrete research over the recent few years. As a result, they said, geopolymer concrete research is moving forward. They demonstrated a few of the precursors that have been employed to increase the maximum compressive strengths of some gypolymers, such as fly ash (45 MPa), basic oxygen furnace slag (20 MPa), coper taillings (50 MPa), and grunlated blast furnace slag (70 MPa). They came to the conclusion that these industrial wastes can yield high-quality geopolymers. Steel slag contains calcium, silicon, and phosphorus (Ca, Si, and P) [6] together with other components that are beneficial to plant growth [7]. Because steel slag contains a lot of CaO-based alkaline metal oxides, it has a lot of potential for sequestering CO_2 [8].

Electric arc furnace slag (EAFS) is one type of steel making slag (SMS). EAFS chemistry, which is rich in aluminosilicate, makes it a potential replacement for cement in concrete. However, due to its high content of calcium oxide (free-CaO) and ferric oxide (FeO), researchers are currently examining the possibility of using EAFS as a cement substitute in further detail. Cement clinker and electric arc furnace slag have more similar chemical compositions. Melting recycled scrap in the Electric Arc Furnace (EAF) is the primary function of the electric cycle. In order to produce extreme heat and melt the steel, it uses an electric arc between the electrodes and the scrap steel [9]. Since EAFS has a lower density than steel, it is believed to float on molten metal when it is liquid [8]. EAF slag is eliminated and usually air-cooled gradually to produce crystal forms. While the molten slag is tapped and taken out, the molten crude steel is tapped into a ladle [10]. The EAF slag contains the metallic oxides that are generated as various components, such as silicon, sulfur, manganese, phosphorus, iron, aluminum, and carbon [11]. In addition, the oxide composition of EAFS is greatly influenced by the type and makeup of the raw material (scrap) utilized in the process, as well as the techniques used to make steel. A considerable concentration of iron oxides, up to 40% by weight, is found in the chemical composition of oxides, according to a number of authors. In order to improve iron recovery for use in later castings, the iron oxide content of the slag is frequently regarded as a gauge of manufacturing progress. These components are often removed from steel during purification processes in electric arc furnaces; the phosphorus is reduced by 20% to 50% in the EAF process. Desulphurization is thus carried out during ladle furnace operations and tapping, which results in the production of calcium aluminate slag. Once that, slag is then poured out of the furnace by the rearward slag door [12]. By removing the slag at this point, phosphorus reversion is completely eliminated. Lee et al. [13] concluded that in the manufacturing process, EAF slags can be acquired independently. By reducing slag process or oxidizing slag process. The carbonation that follows the hydroxylation of free-CaO is what causes the volumetric instability of EAF slag [14]. Its volumetric expansion is linked to the long-term oxidation of Fe_2O_3 to Fe_3O_4, while the high Fe oxide concentration lowers the chemical activity in concrete during the hydration process. Electric arc furnace slag is a coarse, porous, blackish-gray aggregate that contains small particles of metallic iron, and that these problems are the reason it hasn't been employed as a cementing element [14]. However, a number of studies use

EAF powder as a binder material because it is an alkali activator that, when combined with a small amount of cement in alkaline conditions, forms a solid binder. Furthermore, even though EAF slag is produced in significant quantities, its low CaO content and low reactivity and high Fe content, along with metal-Fe and Cr, make it an unattractive choice.

The investigation conducted by Muhoomd et al. [15] revealed that in their study found that 30% clinker–EAFS substitution may produce a compressive strength of 50 MPa, 20% replacement can produce 58 MPa, and 100% cement can produce 58.6 MPa for the reference specimen. Zhao et al. [16] examined the impact of partially substituting EAFS for cement, with particular attention to the particle distribution of EAFS. The results showed that, as compared to the reference blast furnace slag blended cement specimens, concrete specimens with properly ground EAFS exhibited better microstructure, better durability performance, lower porosity, and higher compressive strength.

Alkali-activated alumino-silicates are new inorganic cementitious compositions that are activated by alkali activators. According to a study on alkaline activators, NaOH (NH) and Na_2SiO_3 (NS) are more effective than other activators at releasing Si and Al polymerization during a process [17]. While using NS alone produced mostly amorphous products with traces of crystalline phases, using NH alone or in combination with NS produced crystalline hydrated gels that coexisted with amorphous products [18]. Slag that has been alkali activated with dissolved silica exhibits increased initial reactivity, which leads to an early loss of workability [19]. In an alkaline solution, the concentration of silica delays the slag's primary reaction, resulting in a delayed set [20]. Compare to the CaO/SiO_2 ratios of the C-S-H gel, which vary between 1.5 and 2.2, but with smaller amounts of CaO/SiO_2, which typically range between 0.9 and 1.2. The response product is produced along with byproducts [21]. When NaOH is used as an activator, the resultant product has a higher CaO/SiO_2 ratio and a more organized structure than the kind of C-A-S-H gel produced by sodium silicate hydrate-based activators [21]. In alkali-activated slag, calcium silicate hydrate with aluminum absorption, or C-(A)-S-H, is the main reaction product. Higher compressive strength and more incorporation of silica in the C-(A)-S-H are the results of adding it to the activating solution. The final strength of the activating solution is unaffected by its sodium concentration. Sodium is present in the alkali-activated slag as an amorphous, water-soluble material. Furthermore, even though one would expect to have improved performance from the interaction of Ca from EAFS with SiO_2 from the activator to produce C-S-H gels, it is possible that the Ca-bearing mineralogical phases were stable at high pH levels, thereby minimizing the dissolution of $Ca2^+$ ions to the solution. The dissolution of $Ca2^+$ ions in the solution was reduced because mineralogical phases remained stable at high pH values [20]. While sodium silicate (NS) solutions at comparable alkali concentrations have a lower pH than NaOH activating solutions, equivalent amounts. When each kind of activator is present, the slag reacts, giving the silicate a higher mechanical strength than in systems activated with NaOH. As a result of the systems' extra silicate supply combining with the dissolved slag's Ca^{2+} cations, dense reaction products (C-S-H gel) is produced. [22]. As a result of the systems' extra silicate supply combining with the dissolved slag's Ca^{2+} cations, dense reaction products (C-S-H gel) are produced. Malkawi et al. [23] they looked into how the alkali solution affected the mechanical and physical properties of the geopolymer mortars made from high calcium fly ash (HCFA). They concluded that The workability and setting time of the geopolymer mixes are influenced similarly by the concentration of NaOH and the ratio of Na_2SiO_3/NaOH; higher ratios led to longer setting periods and less workability. Conversely, the concentration of NaOH has the greatest impact on workability and setting time, whereas the content of Na_2SiO_3 has a greater impact on the characteristics of later strength. Ms of sodium hydroxide and sodium silicate combined with binary alkaline activators [24].

The strength, microstructure, material, and bond characterizations of alkali activated GSS/ultrafine palm oil fuel ash (AAGU) concrete made with NaOHaq and Na_2SiO_3aq activators were examined in relation to the impacts of silica moduli (SiO_2/Na_2O) [25] Silica modulus (0.915 and 1.635) has no discernible impact on early 3 days compressive strength. Within the given Ms range, strength of 65–69.13 MPa can be attained. Consequently, the ideal choice of Ms will be determined by cost effectiveness and durability

considerations, particularly for concrete made with a workable ratio of total activators to pozzolanic material. They clarified further that in comparison to concrete made with low silica modulus (LSM), AAGU concrete produced with high silica modulus (HSM) favors Si-Al substitution, resulting in less homogeneous and more amorphous products. Whereas the LSM system promotes the development of C-S-H and more crystalline or less amorphous products, HSM encourages greater polymerization, which results in the formation of more Ca/Na-aluminosilicate products (C/N–A–S–H). Therefore, cost-effectiveness and durability factors will define the best Ms choice, especially for concrete built with a practical ratio of total activators to binder material. Eventually, Yusuf et al. [25] concluded that their findings, high silica modulus (Ms) and alkali dosage produce high-quality binder by speeding up the rate of polymerization between precursors and activators and increasing the replacement of Si and Al. Thunuguntla et al. [26] were studied the impact of low sodium hydroxide (NaOH) concentrations and the alkaline ratio (weight of alkali hydroxide/alkali silicate) on the mechanical and physical characteristics of alkali-activated GGBFS. Activator concentration (1-9M) and alkaline ratio (1-3) are the parameters taken into consideration. The results showed that the uniformity, initial setting time, and compressive strength of alkali-activated GGBFS are significantly impacted by changes in the concentration of NaOH. They maintained that up to a certain point, a rise in NH concentration permits more C-S-H and C/N-A-S-H to develop, as well as more crystalline compounds. The Na ions, or Na_2O/SiO_2, increase as the activator ratio rises. Larger SiO_2/Na_2O ratios; Ca^{2+} of EAFS ions is caused by the rapid reaction of the with the solution's silicate ions, which results in the precipitation of an initial C-S-H, which is responsible to the setting [20]. They have been suggested by [27] that the delayed strength enhancement of Portland slag cement be clarified; The NH molarity, which in turn influences workability, is determined by the concentration of silica monomers and (OH^-) hydroxyl ions. It is more effective to use NH molarity (1–8M) when mixing mortar; the ratio (R = NS/NH) of (1-3) is based on several previous experiments [26]. An important factor influencing the slag's activation, flow, and workability with the alkaline solution is the size and form of its particles.

The EAF Slag's fineness has a major influence on mortar strength. It seems that grinding Portland cement is less difficult than grinding water-granulated slag. It is believed that slag particles smaller than 10 μm contribute to the early strength development for up to 28 days. After 28 days, gels with particles ranging in size from 10-45 μm have stronger structures and are more hydrated. The strength of mortar is significantly affected by particles larger than 45 μm [28]. Particles greater than 45 μm are often restricted under most standard standards. For concrete to develop its strength sufficiently, the Blaine surface area of the slag granulates must be between 4000-6000 cm^2/g. Increasing the slag fineness up to 4000 cm^2/g after 28 days did not significantly affect compressive strength, according to Caijun et al. [29]. However, significant improvements were noted after 3 and 7 days when the size reached approximately 6000 cm^2/g. The ideal slag fineness, according to Talling [30], was 4000 cm^2/g since a finer slag resulted in false setting and a higher water need. According to Wang [31], the ideal range for slag fineness is 4000–5500 cm^2/g. According to other research conducted in other settings, strength improved as slag fineness increased up to 6000 cm^2/g [32], and even 10,000cm^2/g [33]. The risk of decreased mechanical properties is reduced though, as cementitious activity rises with longer grinding times and higher concentrations of fin steel slag particles [34]. Concrete's mechanical qualities can be improved by using steel slag with a finer particle size since it can better fill the pores and increase compactness. The kind of hydration products is not affected by changes in the size of the steel slag particles; however, the smaller the steel slag particle size, the better the mechanical characteristics, the denser the structure, the larger the hydration products, and the better the forming activity [34]. Salman, et al, [35] reached the conclusion that adding steel slag decreased the workability of mortar mixes. The surface area of the slag applied as a cementitious material will be greater due to its extreme fineness. As a result, it is less feasible. Consequently, the amount of water needed rises. Use of a superplasticizer can achieve the necessary workability without causing the mixture's resistance to drop as a result of the increased water content.

The shape of particles is frequently analyzed using scanning electron microscopy (SEM). Numerous studies in the literature have found that slag

particles can have irregular, angular, or even spherical shapes, with occasional smooth surfaces. Research has discovered particles that resemble diamonds and are square in shape [36]. It has been shown that increasing the fineness of the slag shortens the setting time and improves the strength of the concrete mixes. When the SiO_2 and Na_2O concentrations are included, the activator dosage definitely increases with the setting time. The effect of SiO_2 on the setting time was also found to be more pronounced than that of Na_2O. While increasing amounts of Na_2O enhance the activator's pH value, higher concentrations of SiO_2 decrease it. [37].

The findings demonstrated a clear proportionality between strength improvement and the SiO_2/Na_2O ratio. Following an initial 24-hour thermal curing process at 80°C, the highest containing 4% (Na_2O/binder) and silica modulus (SiO_2/Na_2O) of 2.5 was 9.1 MPa. Furthermore, they demonstrated that treatment methods can be maximize the compressive strength (i.e., 31 MPa as opposed to 3.9 MPa in uncarbonated mixes) was achieved in mixes containing 12% (Na_2O/binder) and silica modulus (SiO_2/Na_2O) of 1.0, respectively. They supposed that after a further 28 days of increased carbonation, a shift in the optimal alkaline activator composition. Concrete formation therefore is affected by the impacts of SiO_2 and Na_2O concentrations as well as the effective application of alkaline activators.

A silica modulus (Ms= SiO_2/Na_2O) of 0.6 to 1.5 could indicate an exceptionally high strength. [38]. In order to investigate additives that delay the setting time, further studies found that phosphoric or silicic acid is frequently added to the alkaline activator. This suggests a close relationship between pH and setting time, which may be explained by a drop in the alkaline activator's pH. AAS pastes using varying amounts of SiO_2 and Na_2O. The alkali modulus (SiO_2/Na_2O) and pH are related, according to the findings. Smaller SiO_2 and Na_2O dosages in particular produced observably initial and final setting times. This resulted in a higher alkali modulus and a greater setting time [39]. Silica modulus (Ms) of a mixed with Na_2O of alkaline activators, as well as the heat release, workability, and setting time of AAS slag pastes, are all taken into consideration when calculating the compressive strength of AAS mortars [24]. Despite the fact that the pastes with a Ms of 1.0 and a Na_2O concentration of roughly 6% had a sharp fall in flowability and quick setting, the test results demonstrated that the AAS mortars had a high strength of 25 MPa at 24 hours, even at ambient temperature. [24]. However, strength is not much increased by higher Na_2O content. Slag, activator, and curing conditions are just a few of the variables that affect it. It may even enhance undesirable traits like efflorescence and brittleness. These days, strength is just one consideration when figuring out the ideal alkali concentration; other considerations and cost are also taken into account [40]. Recent studies [41] shown that strength was not significantly affected by varying the NaOH level between 3–11% and 1-8%. Therefore, trying to enhance strength by increasing the alkali concentration is not advised from an economic and property standpoint. Considering all of this, the optimal amount is most likely 3.0-5.5 percent Na_2O by slag weight.

The purpose of this study is to use Misurata City's electric arc furnace slag (EAFS) as a partial cement substitute in alkaline activated mortar (AAM), at varying weight percentages (0%, 5%, 10%, 15%, 30%, 60%, 80%, and 100%).
NaOH (NH) molarities concentrations (2M, 4M, 6M, and 8M), Na_2SiO_3 (NS) solution, R ratio (NS/NH) of 0.5, AAS/B ratio is 0.4, were employed. To ensure that all mixtures had the same temperature, the alkaline solutions were made 24 hours before mixing.

Using R = NS/NH, which varied from 0.5 to 1.5, the effect of the Na_2O to EAFS ratio was investigated. Following a 28-day hydration period at 30°C± 5 in ambient curing conditions, in plastic sac, the workability and compressive and flexural strength of AAEAFS mortar were assessed by comparing its fresh and hardened properties with its Na_2O to EAFS ratio. Investigated were comparable outcomes to reference mortar (C_{0S}). The findings show that the ideal compressive strength of 29.94 MPa is attained at 5% EAFS replacement, molarity ratio (R) of 1.5, and NH molarity of 2M; with 5% EAFS replacement, R of 1, and NH molarity of 4M, the optimal compressive strength is 25.09 MPa. The workability of alkali-activated EAFS mortar was also shown to be dependent on R and Ms (SiO_2/Na_2O) and to diminish with NH concentration. An increase in SiO_2/Na_2O ratios can cause workability to significantly diminish, because the viscosity of the alkaline solution increased.

2. MATERIALS

EAF slag massive aggregates of a grayish black color in a solid condition, contains scrap iron 2-4 (%), granular size from 1-300 mm, density of 1.6 ton/m^3 was used as a partial replacement of cement type CEM II-4-1 A-L 42.5 N Zilitan cement, Al-Burj Factory. In the initial mortar mix, the cement is replaced with steel waste, with percentages of 0%, 5%, 10%, 15%, 30%, 60%, 80%, and 100%. The main oxides and mineral compositions are indicated in table 1,2. EAF slag was crushed using a Los Anglese machine with 12 rolled steel during a 2hr period, and it passed through a 0.75μm sieve. Natural river sand from the Gulf of Bomba near of Derna City was brought for use in this research, fineness modulus (FM) of 1.89, and from ASTM C128 was determine the specification coefficient of absorption 1%, Bulk density (2.75 kg/m^3).

Table 1. The Main oxide components (%) of Libyan steel slag,

Zn	Cl	CaO	MgO	Na_2O	SO_3	SiO_2	K_2O	Al_2O_3	MnO	TiO_2	Fe_2O_3
12	0.085	33.0	7.11	0.25	0.35	17.54	0.13	5.45	2.277	0.94	25.9

Table 2. Mineral composition (%) of Libyan steel slag (factory of Misurata).

Element	Chemical composition [%]			
	C_2S	C_3S	C_3A	C_4AF
Cordierite (C)	105.0	72.62	29.32	78.73

The reference mortar (C_{0S}), which has a w/c of 0.44 and is composed of cement, sand, water, and superplasticizer at a weight percentage of 1.0%, yielded NaOH molarities of 2M, 4M, 6M, and 8M 24 hours before casting. One molar of NH was added, and a heat temperature from the dissolution of particles in alkaline solutions was observed. It was thirty minutes before mixing when sodium silicate (Na_2SiO_3) was added. According to [25], the molarity ratio (R = Na_2SiO_3 /NaOH) for estimating the solid Na_2O content in alkali activators (NH+NS) ranges from 0.5, 1, and 1.5. And mortar mixed prepared according to ASMT C305-06, see table 3.

Table 3. Proportions of the EAF slag alkaline activated mortar mix (kg/m^3).

Mix code	BFS100s	CBFS80s	CBFS60s	CBFS30s	CBFS15s	CBFS10s	CBFS5s	C_{0s}
Cement (kg/m^3)	580	464	348	174	87	58	29	580
NH Molarity	2M,4M,6M, 8M	2M,4M,6M, 8M	2M,4M,6M, 8M	2M,4M,6M, 8M	2M,4M,6M, 8M	2M,4M,6M, 8M	2M,4M,6M, 8M	
EAFS (%)	100	80	60	30	15	10	5	0
Fine sand (g)	1157	1157	1157	1157	1157	1157	1157	1157
SP (%)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Water (kg/m^3)	255.2	255.2	255.2	255.2	255.2	255.2	255.2	255.2
W/B	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44

Based on [25], the amount of each molarity, or Na_2O solid mass, from NH and NS solution was determined. Table 3 lists the quantities needed for producing AAEAFS mortar (kg/m^3). The water/binder (W/B) ratio was fixed at 0.44, and the AAS/binder ratio was also maintained at 0.4.

Table 4. Proportions of R = Na_2SiO_3/NaOH, the Na_2O total in alkaline activated slag mortar mix (kg/m^3).

Mix	AAEAFS Mortars											
Molarity	8M	6M	4M	2M	8M	6M	4M	2M	8M	6M	4M	2M
NS	139.2	139.2	139.2	139.2	116	116	116	116	77.33	77.33	77.33	77.33
NH	92.8	92.8	92.8	92.8	116	116	116	116	154.67	154.67	154.67	154.67
R	1.5	1.5	1.5	1.5	1	1	1	116	0.5	0.5	0.5	0.5
Na_2O (NH)	23.01	17.26	11.51	5.75	28.77	21.58	14.38	7.19	38.36	28.77	19.18	9.59
Na_2O (NS)	12.25	12.25	12.25	12.25	10.21	10.21	10.21	10.21	6.81	6.81	6.81	6.81
Na_2O $_{total}$	35.26	29.51	23.76	18.00	38.98	31.78	24.59	17.40	45.16	35.57	25.98	16.39

3. EFFECT OF R = Na_2SiO_3/NaOH ON PHYSICAL PROPERTIES

3.1 Flow test

The mortar's workability was evaluated by their average flow diameter Df according to the ASTM C230, [42], for Ms = 0.5, speard flow ratio (E) is stabilized with reduced EAFS replacement up to 15% and continuously increases. When sodium hydroxide and sodium silicate's total solid mass (Na2O) decreases (i.e. 2M), the AAEAFS mortar becomes more workable (see figure 1).

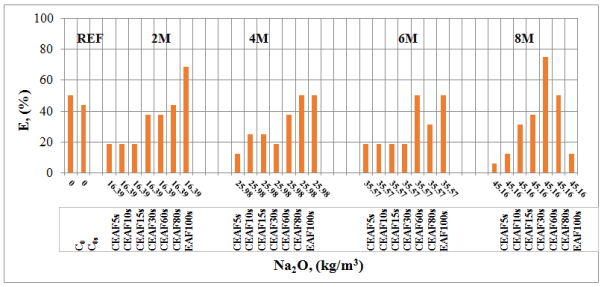


Fig. 1. Workability of AAEAFS mortar, R = 0.5.

As a result, raising the R to 1 seemed to have no discernible effect on the different EAFS ratios, with the exception of EAFS 100% (no cement in mortar), which rose with Na_2O molarity, figure 2. Since every paste takes the shape of a cone, then D_f (the mortar's average diameter) equal to D_i (cone's basic diameter), thus R=1.5 is not present here, therefore E=0. Because Na_2SiO_3 has a higher viscosity, using the aforementioned ratios necessitates using additional water to create a workable combination. It has been shown that when the molarity of NaOH increases, workability diminishes [23]; [43]

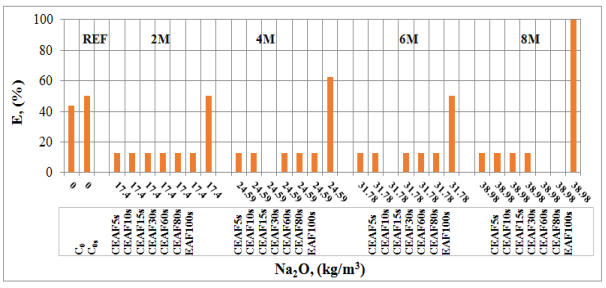


Fig. 1. Workability of AAEAFS mortar of R= 1.0.

3.2 Fresh density

Density measurements were made, as stated in [44]. More fluidity has been obtained from 2M concentration as shown in figure 3. It is clear the fresh density decreases with increasing the percentage of slag in the mortar.

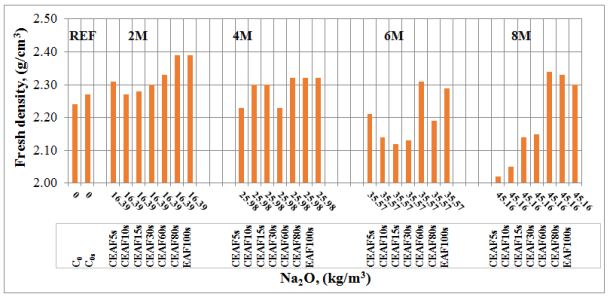


Fig. 2. Fresh density values, R = 0.5.

3.3 Hardened density

Density was calculated by dividing mass by specimen volume [45], after 28 days of curing. The density increases when EAFS increases relative to C_{0S}, and the Na_2O mass solid doesn't significantly affect (figures 3-5).

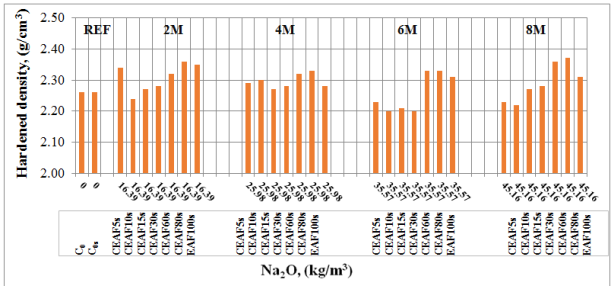


Fig. 3. Bulk density of AAEAFS mortar, R = 0.5.

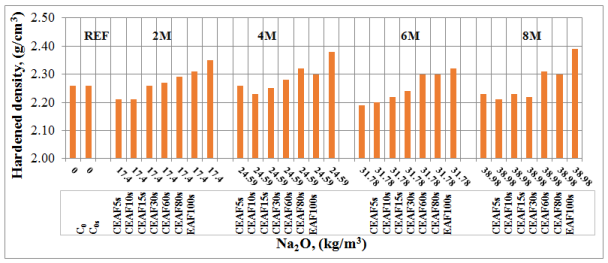


Fig. 4. Bulk density of AAEAFS mortar, R = 1.0.

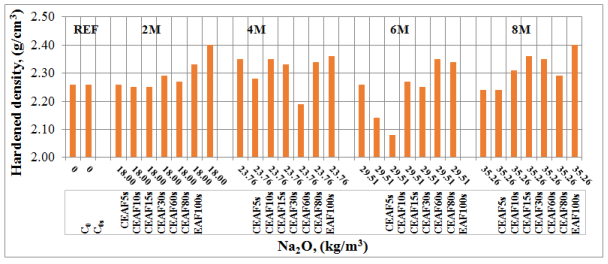


Fig. 5. Bulk density of AAEAFS mortar, R = 1.5.

4. EFFECT OF R = Na_2SiO_3/NaOH ON MECHANICAL PROPERTIES

4.1 Compressive strength

In this study, 50 x 50 x 50 mm^3 cubes of AAEAFS mortar specimens are tested for compressive strength at a constant loading rate of 0.9 kN/s [46]. For R values of 0.5, 1, and 1.5, a compression test was performed. Figures 6–8 demonstrate that the compressive strength drops by more than 15% when the EAFS ratio increases. In comparison to reference mortar (C_{0S}), higher percentages were recorded: 48.00, 44.62, 34.06 and 26.47% of 2M, 4M, 6M, 8M and EAFS of 5%; 33.60, 41.43%, 27.41 and 29.68 % of 2M, 4M, 6M, 8M and EAFS of 10%; 35.99, 33.23, 26.68 and 29.20% of 2M, 4M, 6M,8M and EAFS of 15% respectively. Thus, a lower percentage of EAFS cement substitute (5%) resulted in a greater improvement in compressive strength.

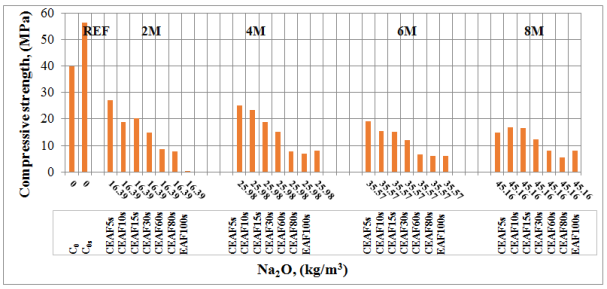


Fig. 6. Compressive strength of AAEAFS mortar, R = 0.5.

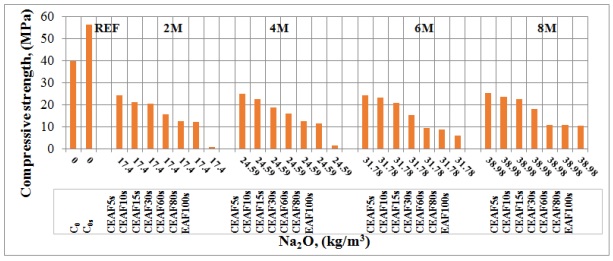


Fig. 7. Compressive strength of AAEAFS mortar, R = 1.0.

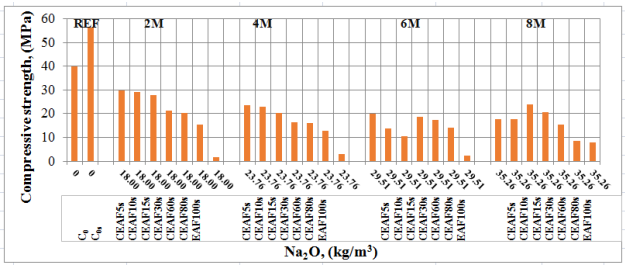


Fig. 8. Compressive strength of AAEAFS mortar, R= 1.5.

4.2 Flexural strength

According to [47] testing of mortar flexural strength is performed on 4x4x16 cm prisms by loading them with a constant rate of 0.05 kN/s. Figure 9 shows that flexural strength rate compared to reference mortar (C_{0S}) were recorded: 53.66, 56.91, 61.79 and 45.53% of 2M, 4M, 6M, 8M and EAFS of 5%; 50.41, 52.03, 53.66 and 50.41% of 2M, 4M, 6M, 8M and EAFS of 10%; and 60.16, 45.53, 50.41 and 56.91 of 2M, 4M, 6M, 8M and EAFS of 15% respectively. Thus, flexural strength exceeded 50% of reference mortar (C_{0S}) when the amount of EAFS cement substitute was attaining up to 15%. Flexural characteristics thereafter start decreasing, with the exception of EAFS30% of 2M, which yielded 63.41 MPa.

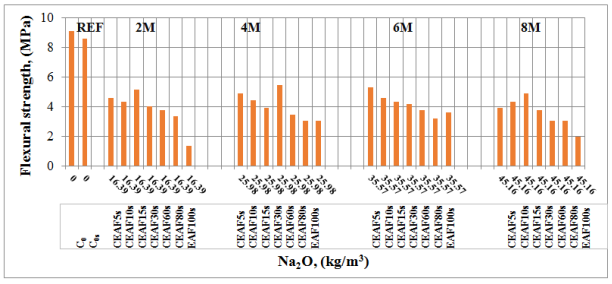
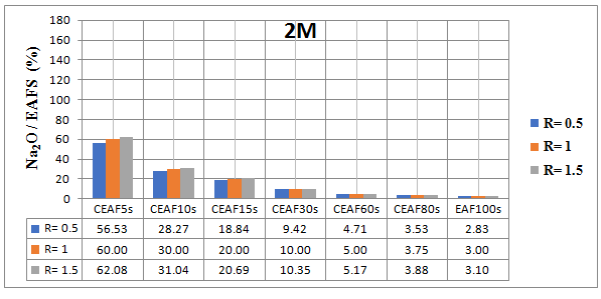


Fig. 9. Flexural strength of AAEAFS mortar, R = 0.5.

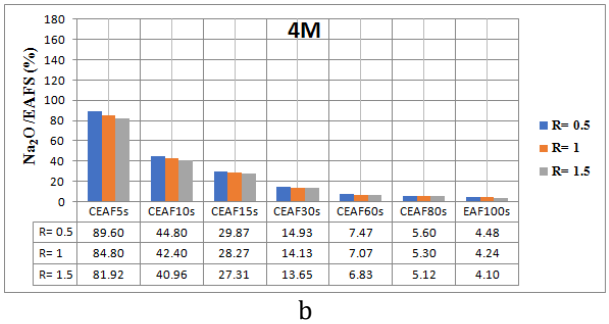
5. EVALUATION THE PERCENTAGE OF Na_2O TO EAFS BINDER OF R = Na_2SiO_3 /NaOH

The percentages of Na_2O mass solid to EAFS binder are shown in the figure 10. The concentration of Na_2O decreases as the EAFS binder increases.



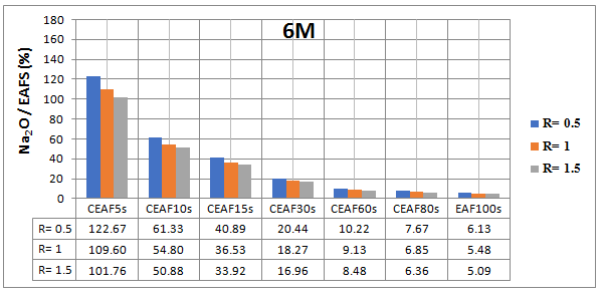
	CEAF5s	CEAF10s	CEAF15s	CEAF30s	CEAF60s	CEAF80s	EAF100s
R= 0.5	56.53	28.27	18.84	9.42	4.71	3.53	2.83
R= 1	60.00	30.00	20.00	10.00	5.00	3.75	3.00
R= 1.5	62.08	31.04	20.69	10.35	5.17	3.88	3.10

a

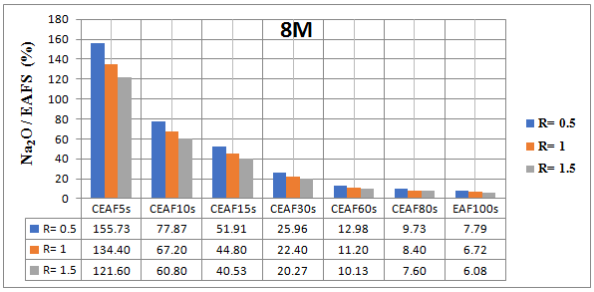


	CEAF5s	CEAF10s	CEAF15s	CEAF30s	CEAF60s	CEAF80s	EAF100s
R= 0.5	89.60	44.80	29.87	14.93	7.47	5.60	4.48
R= 1	84.80	42.40	28.27	14.13	7.07	5.30	4.24
R= 1.5	81.92	40.96	27.31	13.65	6.83	5.12	4.10

b



c



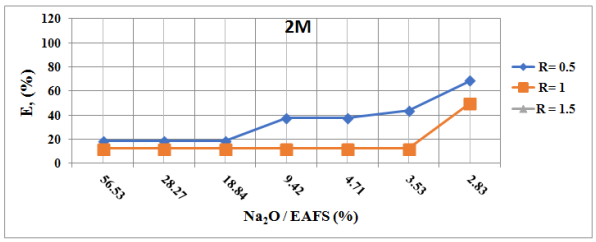
d

Fig. 10. Na_2O/ EAFS ration of difference NH molarity: a) 2M, b) 4M, c) 6M and d) 8M.

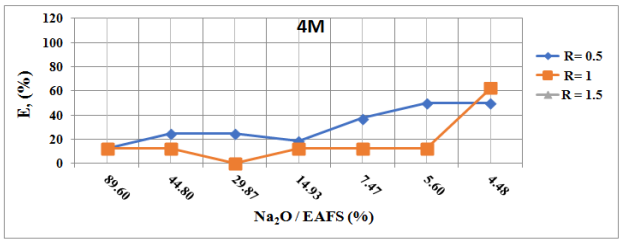
6. INFLUENCE Na_2O TO EAFS BINDER RATIO ON PHYSICAL PROPERTIES

6.1 Workability of AAEAFS mortar

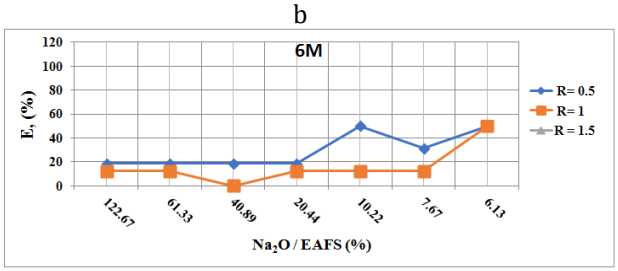
The mass solid of the mixture's Na_2O content is responsible for the AAEAFS mortar's fluidity. The spread flow test adopts the shape of a cone because as the silica modulus rises, the amount of Na_2O in the mortar also rises. The expended ratio, (E), is therefore equal to zero for R = 1.5 (not on the curve). The fluidity of AAEAFS mortar increases as molarity ratio of R = 0.5 is lowered since the mortar is more fluid and an increase in NH allows for greater fluidity in the mixture. As illustrated in figure -, the workability was more closely associated with Na_2O than with the ratio of EAFS cement substitute, as previously mentioned, see figure 11: a, b, c and d. More clarification Workability tends to increase with rising NH molarity concentrations (2–4 M), but it is uncertain at 6–8 M and appears to decrease with EAFS after up to 30%. Particle dispersion was improved by the presence of superplasticizer in the mix mortar, which also displayed distinctive rheological properties. The size and shape of the slag's particles have a major effect on its activation, flow, and workability with the alkaline solution. This resulted from the addition of a solid substance, which increased the alkaline solution's viscosity. Diminish in workability quickly can be attributed to larger SiO_2/Na_2O ratios [20].



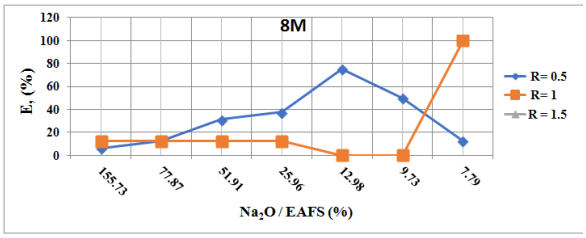
a



b



c

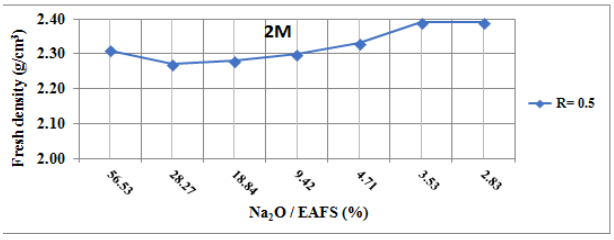


d

Fig. 11. Spread flow AAEAFS mortar vs. Na_2O to EAFS ratio, of difference NH molarity: a) 2M; b) 4M, c) 6M and d) 8M.

6.2 Fresh density

The fresh density of AAEAFS mortar increases with Na_2O/EAFS cement substitute. Furthermore, fresh density tends to decrease with the percentage of EAFS reaches 30%, after which it tends to increase. The effects of NH molarity concentrations (2–8M) are unclear; refer to figure 12: a, b, c and d.



a

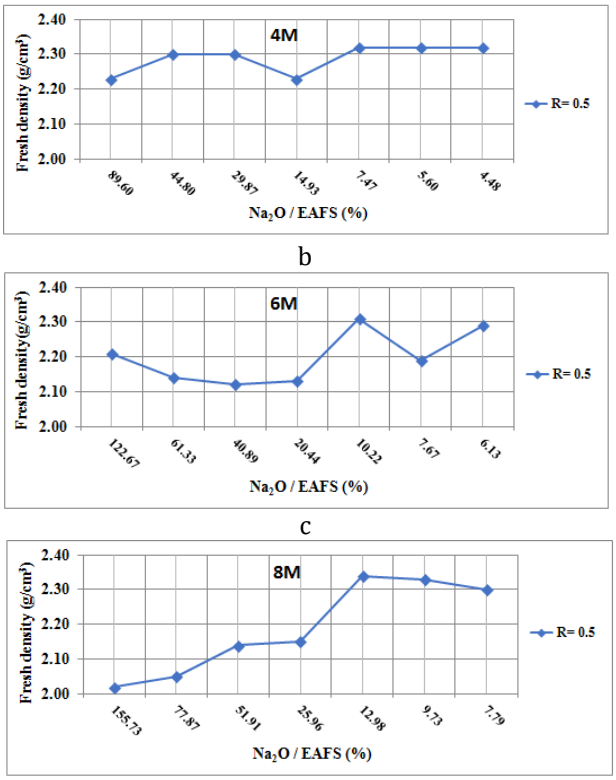
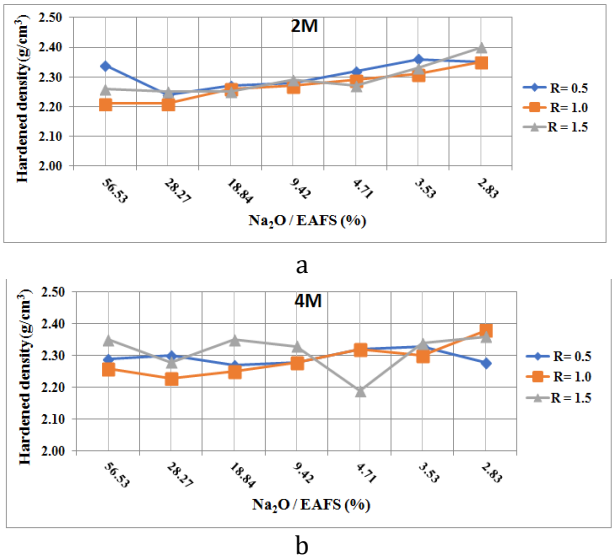


Fig. 12. Fresh density of AAEAFS mortar vs. Na_2O to EAFS ratio, of difference NH molarity: a) 2M; b) 4M, c) 6M and d) 8M.

6.3 Hardened density

With the Na_2O/EAFS substitution of cement, the bulk density of AAEAFS mortar at 28 days rises, figure 13: a, b, c and d. Approach density values were obtained with R values of 0.5 and 1.0 when Na_2O/EAFS increased. Additionally, it seems that density with NH molarity exhibits unstable behavior as the silica modulus increases by 1.5. It can be linked to fluctuating C-N-S-H gel formation and restricted Na_2O levels.



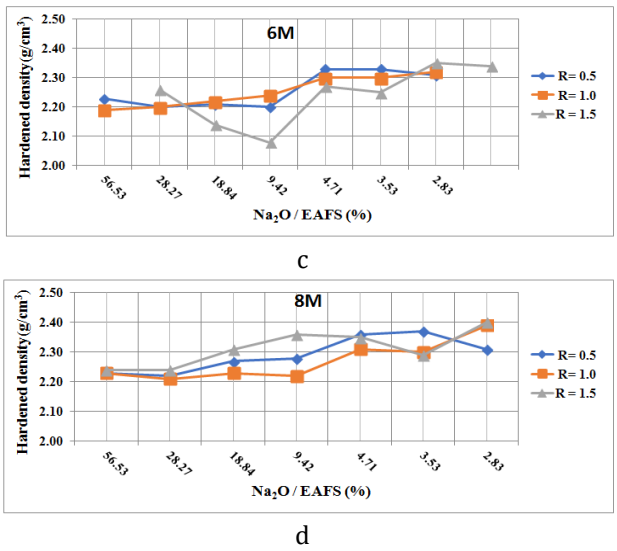


Fig. 13. Hardened density of AAEAFS mortar vs. Na_2O to EAFS ratio, of difference NH molarity: a) 2M; b) 4M, c) 6M and d) 8M.

7. INFLUENCE Na_2O TO EAFS BINDER RATIO ON MECHANICAL PROPERTIES

7.1 Compressive strength

Tables a, b, c, and d in Figure 10 display the results of dividing the solid weight of Na_2O, which was determined from the (NH+NS) solution, by the EAFS binder ratio. Compressive strength reduces when the ratio of Na_2O to EAFS drops. When the mixture's Na_2O content is raised to 6M, the compressive strength decreases by 5–15% of EAFS. Strength values increased when the concentration of Na in the mixtures was increased to a constant proportion. As a result, an undesirable structure was seen when the Na concentration was raised over a fixed value [48].

Figures 14: a and b demonstrate an improvement in resistance with R from 0.5 to 1.5 when EAFS cement is substituted up to 15%, because the paste's density increased for 2M and 4M. Additionally, when R is 1.5 was reached; 6M and 8M showed a decrease in resistance to compression force. Figure 10 showed that the percentage of total Na_2O/EAFS decreases as the amount of slag waste mortar increases. It has been shown that adding additional EAFS to OPC decreases compressive strength and reduces the total heat realized during cement hydration [20].

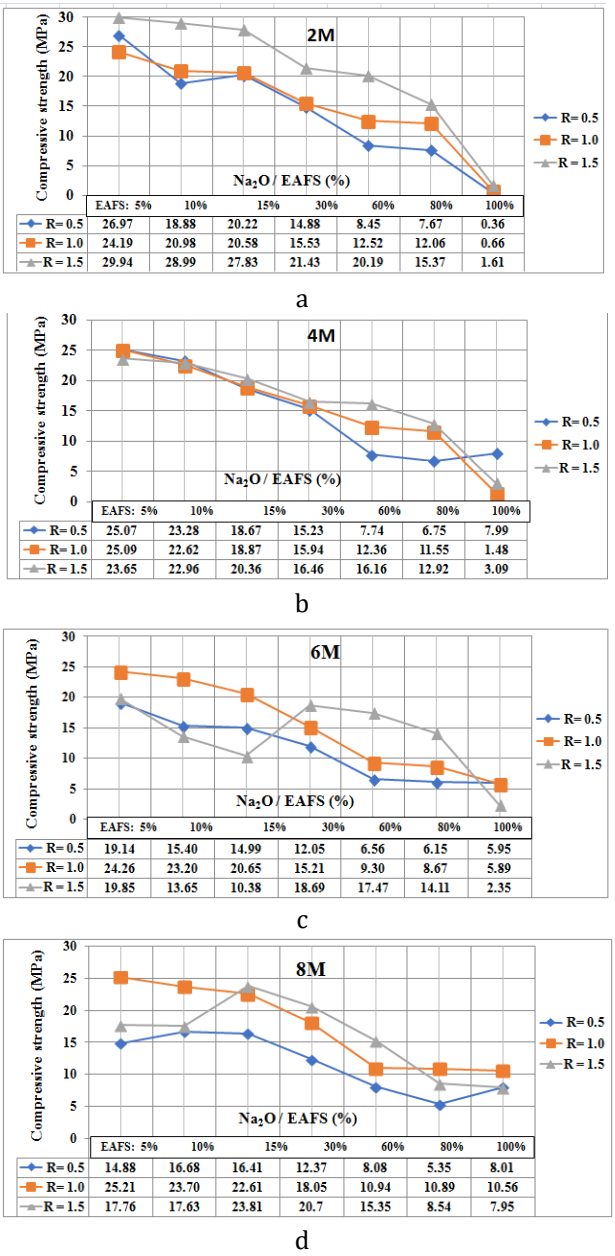


Fig. 14. Compressive strength of AAEAFS mortar vs. Na_2O to EAFS ratio, of difference NH molarity: a) 2M; b) 4M, c) 6M and d) 8M.

Decrease the compressive strength in NH concentration at 6M, 8M enables lower formation of C-S-H and decrease the formation of crystalline compounds as alite and belite [49]. Increase in the strength of AAEAFS mortar when used NH molarity of 2M, and Na_2O to EAFS was increased from R= 0.5 to R=1.0. Increase in the strength of the AAS could be attributed to lower content of Na_2O and increasing EAF slag in the mixture, which also affects the alkali content of the slag mortar. Slag cement improves the percentage of strength gain relative to C_{0S}. Since EAFS are poorly soluble in water, they are known to solidify extremely slowly. Figure 14 shows a minor addition of EAFS, up to 15 weight percent, was found to improve compressive strength, while a higher addition was lead to reduce compressive strength. EAFS of Misurata City has higher contained of Fe_2O_3 (25.9%). While the high Fe oxide Fe_2O_3 concentration lowers the chemical activity in concrete during the hydration process [13]. In addition, the primary oxides as SiO_2 (17.54%), Al_2O_3(5.45%) will consumed faster with increasing R and the primary reaction product of the alkali activation of slag is calcium (alumino) silicate hydrate C-(A)-S-H gel still insufficient in the mixture [19]. Oxide CaO present 33% of slag, this value able to produce $Ca(OH)_2$ is first released when clinker minerals are hydrated to create C–S–H gel and ettringite [50]. The reactions between Ca^{2+} ions of EAFS and OH^- ions of alkali activator might be produce of $Ca(OH)_2$. As explained by [51] the reaction of Portlandite and the formation of $CaCO_3$ may be the reason for strength gaining because the produced $CaCO_3$ could fill the micro voids in the AAEAFS structure [48]. In slag mortar, the gel formation is primarily composed of C-N-S-H gels, which can produce $Na(OH)_2$, however raising R is really attributed to decrease Na_2O oxide and increase SiO_2. It's crucial to remember that Na_2O, an oxide component, makes up around 0.25% of EAFS Misurata City. As the R = Na_2SiO_3/NaOH increases, the pore volume of the pastes decreases and more solid oxides are formed, which reduces the workability of AAEFS mortar. The increase in compressive strength is not attributed to this cause. Reducing R = Na_2SiO_3/NaOH and raising Na_2O from NH solution molarity concentration, i.e., 2M, 4M, is the main factor in achieving maximal strength. As explained by [20] Si^{4+} and Al^{3+} ions from EAFS dissolved more easily in a fluid with a high OH^-concentration. A surplus of OH^- in the combination, however, decreased the Ca^{2+} and Na^+ ions in the EAFS, which would have led to inadequate C-S-H or C-N-S-H gels. This impact significantly affects the mortars' structure and strength. An alternative explanation is that the cement particles' size and the EAFS's inability to blend to 45 µm prevented the alkali from becoming more concentrated and the development of a denser interfacial transition zone, both of which would have reduced strength.

7.2 Flexural strength

Flexural strength values of AAEAFS mortars were recorded using simply R = Na_2SiO_3 / NaOH of 0.5. The chemical rheology and growing size of EAFS beyond 45 µm result in decreased heat hydration and a reduced flexural strength. The flexural strength seems to decrease as a result of the influence of Na_2O to the EAFS percentage. Maximum resistance was seen when 15% and 30% of the cement was replaced with EAFS, figure 15: a,b,c and d.

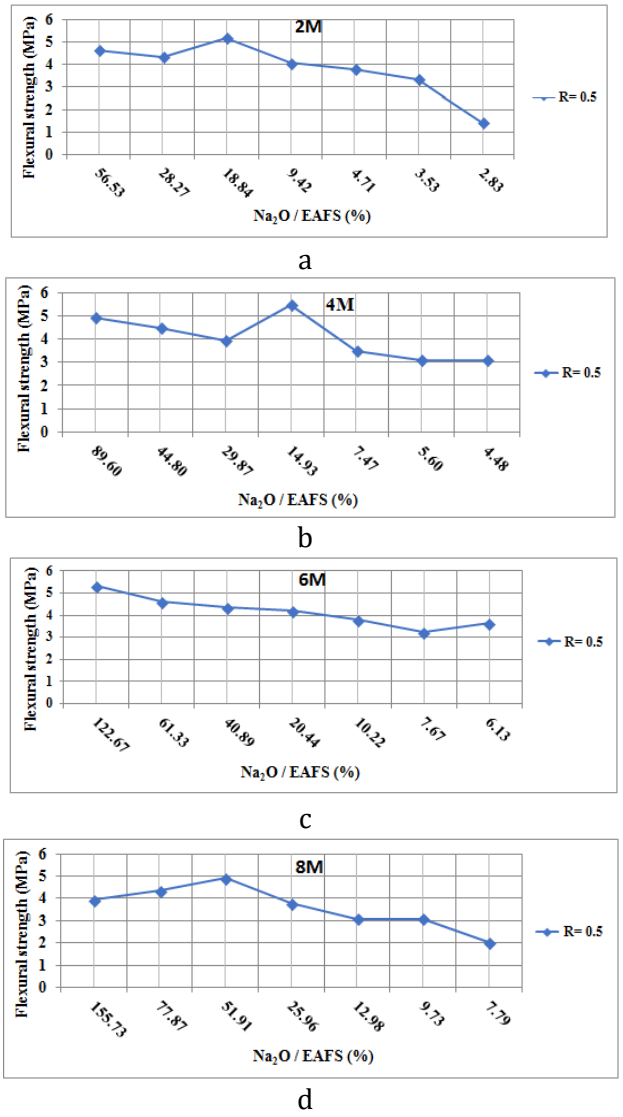


Fig. 15. Flexural strength of AAEAFS mortar vs. Na_2O to EAFS ratio, of difference NH molarity: a) 2M; b) 4M, c) 6M and d) 8M.

8. CONCLUSION

This study examined the possibility of using electric arc furnace slag (EAFS) in place of cement partially or entirely when producing alkali-activated mortars. The findings of this study allowed the conclusion that, depending on a number of variables, mixes using electric arc furnace slag as partial or entire cement replacement (EAF100%) will have comparatively higher performance. The fresh mortar findings indicate that slag mortar's fluidity reduced, density increased, the reduced NH molarity concentration is most likely the cause of this. The low performance in the case of EAFS may be due to the low amount of amorphous phases present in the binder, which did not react with the alkaline activator.

Results from hardened mortar showed that the maximum recorded compressive strength was highly dependent on the size of the slag particles, which should be less than 45µm, NH isn't up to 6M and R less than 1.5. The ideal EAF slag ratio for blinder materials is no more than 15%. With an increase in the EAFS ratio, the compressive strength decreases by over 15%. Complete substitution of alkali-activated electric arc furnace waste for cement could result in substantial cost savings and negligible environmental effects. It can also be utilized in lightweight applications, such as precast masonry hollow blocks.

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