Hindawi
Advances in Civil Engineering
Volume 2023, Article ID 5532027, 11 pages
https://doi.org/10.1155/2023/5532027

Research Article

Potential Use of Scoria as a Cementitious Material for Green Concrete Production

Habtamu Ayene, Anteneh Geremew, and Teklu Amenu

Jimma University, Faculty of Civil and Environmental Engineering, Jimma, Ethiopia

Correspondence should be addressed to Habtamu Ayene; habtamu.ayene@ju.edu.et

Received 14 December 2022; Revised 27 February 2023; Accepted 4 April 2023; Published 13 April 2023

Academic Editor: Masoomeh Mirrashid

The demand for cement, which is one of the key components of concrete, is high in Ethiopia, but it is the most expensive and environmentally unfriendly construction material. Due to the increasing concerns about the environment worldwide, researchers have started looking for other resources that can be used to reduce the pollution caused by the cement industry. One of the most effective ways to reduce the pollution caused by the cement industry is by using volcanic scoria powder as a partial replacement for cement in concrete production. Scoria is a locally available natural volcanic material in Ethiopia, especially around the rift valley regions. This natural resource can also be used to reduce energy consumption and the cost of production of cement. To investigate this study, nonprobability sampling techniques were adopted to collect samples from the study area. A differing proportion of scoria powder was considered as a partial replacement of cement after analyzing its characteristics, and its effect on the fresh and mechanical properties of hardened concrete was examined. The test results on the characteristics of scoria revealed that the material is suitable to be used as a supplementary cementitious material in concrete production; hence, its main constituents $SiO_2 + Al_2O_3 + Fe_2O_3$ are higher than 70% as per ASTM C618. As the content of scoria powder replacement in cement is increased, it reduces the slump of freshly mixed concrete properties. The hardened concrete specimens made with 10%, 20%, and 30% partial replacement of cement with scoria achieved the specified minimum strength after 28 days of curing time. But concrete specimens made with 40% scoria content do not satisfy the minimum specified concrete strength even after 90 days. The significant strength achievement in scoria blended concrete specimens occurred when moving from 56 to 90 days of curing with 10% replacements. However, in reference specimens, this was observed during 28 days of curing times. The findings of this investigation revealed that scoria powder could replace cement by 30% for the production of normal concrete and it also has the potential to protect the environment from carbon dioxide emissions. These findings satisfy the basic strategy of green concrete production in worldwide.

1. Introduction

The ever-increasing populations, living standards, and economic development in developing countries like Ethiopia lead to an increasing demand for constructing infrastructure by using concrete materials. The demand for cement, which is one of the key components for concrete production, is high in such countries; cement is the most expensive and environmentally unfriendly material used in construction industry to build complex apartments, bridges, and concrete pavements [1]. Therefore, requirements for economical and more environmental-friendly cementing materials have extended interest in other cementing materials that can be used as alternatives to Portland cement which is available around constructing infrastructure. Historically, numerous kinds of volcanic scoria have been effectively utilized in dams and aqueducts, where the strength demand is not high but the durability and thermal cracking control are of major concern [2, 3].

The study by [4] reported that the compressive strength of concrete incorporating powdered scoria is affected by both the scoria rocks source and its replacement level. Because of the different volcanic lava fields, powdered scoria rock samples exhibit clear variations in morphology and mineralogical compositions. According to [5], the final setting time of the blended cement containing 15%, 25%, or

35% natural pozzolans (volcanic scoria) increased substantially when compared with the reference Portland cement. The binders of 30% micro-volcanic scoria showed higher durability, particularly after 28 days of curing, when compared with the ones of zero volcanic scoria content. As per this study, the optimum content of micro-volcanic scoria is recommended not to be more than 30% [6]. According to Celik et al. [7], the use of 30% natural pozzolans, 15% limestone, and 55% OPC mix produces a low-cost and ecofriendly concrete that does not bear calcining of natural pozzolans or limestone with OPC and would reduce CO_2 emissions 48% compared with the 100% OPC control mix while providing higher ultimate strength and resistance to chloride penetration. Scoria can be used up to 12% as a partial substitute for Portland cement in the production of blended cement; this additional ratio could provide economic and environmental benefits due to reduced clinker consumption and lowered CO_2 emissions from cement production [8]. In all, the incorporation of natural pozzolanic material in concrete has insignificant effects on the properties of fresh concrete, namely initial slump, setting times, and slump loss [9].

One of the strategies in green concrete production is the utilization of locally available and environmentally friendly materials [2, 10]. Ground granulated blast furnace slag, fly ash, silica fume, pumice, scoria, and other materials containing pozzolanic characteristics have been effectively utilized to reduce the negative environmental consequences of the cement industry [3, 11–13]. Currently, the critical view of global warming efforts is to reduce the emission of CO_2 to the environment. Cement industry was the major contributor to the emission of carbon dioxides to the environment as well as using up high levels of energy resources in the production of the cement industry. Therefore, by replacing cement with a material of pozzolanic characteristics, such as coal ash (fly ash), volcanic scoria, eggshell, marble dust, coconut shell, saw dust ash, rice husk ash, and sugar cane bagasse ash, the cement and the concrete industry together can meet the growing demand in the construction industry as well as help in reducing the environmental pollution investigated by researchers [14–17]. There was a huge availability of volcanic scoria in lots of countries, but its low value and the pressure towards greater sustainable construction have ended in renewed interest in volcanic scoria as natural pozzolan for concrete. The use of locally available cementing alternatives to produce green concrete has the advantage of the cost of concrete production in construction [17–23]. Natural volcanic scoria materials have been investigated in some parts of the world for their potential use as binding alternatives, fine aggregates, and coarse aggregates, and had been found to enhance some of the engineering properties of paste, mortar, and concrete. As reported by many authors, supplementary cementing material such as volcanic scoria has a beneficial influence on the compressive strength of concrete [24, 25]. In the case of environmental pollution, the incremental cost of cement, high amount of energy, and raw materials consumption, some researchers tried to find alternative resources which are available in the local environment to reduce the problem. The use of binders containing volcanic scoria and other pozzolans as cement substitutes can lead to the effective use of natural resources, saving energy consumption, and reduction in CO_2 emissions [8, 26, 27]. So, to reduce environmental pollution, high amount of energy consumption, raw material consumption during the production of cement, and to reduce the incremental cost of cement, natural volcanic scoria would be a good alternative material as a partial replacement for cement [17].

The utilization of volcanic scoria and other alternative cementitious materials is gaining huge interest from various researchers, due to the promising results. The significance of this study is to encourage countries like Ethiopia having sample sources of volcanic scoria to investigate their implicit use as cement replacement and therefore make ecofriendly concrete. Still, studies on the potential utilization of volcanic scoria as a cementitious material for green concrete production have not been exorbitantly reported. Moreover, specialized information on the Ethiopian volcanic scoria as a cement replacement is scarce, and this paper might be particularly interesting for the regions where volcanic scoria is abundant. Thus, this study focuses on evaluating the fresh and mechanical properties of concrete made with volcanic scoria powder as a partial replacement for cement.

2. Materials and Methods

2.1. Materials. The raw materials that were utilized in this study include cement, river sand, coarse aggregate (crushed stone), volcanic scoria, and potable water. The cement utilized is ordinary Portland cement (OPC42.5R) fulfilling the requirements of ASTM C 150 [28] standard specifications. The crushed stone with a nominal maximum size of 20 mm was used in the study. The experimental test shows that the coarse aggregate has a water absorption capacity of 0.54% and a specific gravity of 2.73. Table1 shows the summarized physical properties of coarse aggregate used in this study. The particle size distribution curve for coarse aggregate and the limits as per ASTM C33 [29] is shown in Figure 1. The fine aggregate used was natural river sand which was obtained from the Gambella region (Dima source), Ethiopia. The sand used had a specific gravity of 2.62, a fineness modulus of 2.50, and a water absorption rate of 1.03%. The particle size distribution curve for the sand and the limits set in ASTM C 33 are also shown in Figure 1. The chemical, physical, and mechanical properties of the cement used are given in Table 2. The potable tape water was used for the preparation of all concrete specimens. Scoria used in this investigation was obtained from the quarry site around Adama town, which is located in the eastern part of Ethiopia at a distance of approximately 100 km from the Capital Addis Ababa. The grain size distribution of scoria obtained consists of various sizes mostly ranging from 0.15 mm to 38 mm.

2.1.1. Preparation of Scoria Powder. Hence, as shown in Figure 2(a), the aim of this study is to use scoria as a supplementary cementitious material; it was ground by an

Table 1: Summary of physical properties of aggregates used.

It. no.	Description		Fine aggregate	Coarse aggregate
1	Specific gravity, (SSD)		2.62	2.73
2	Fineness modulus		2.50	7.04
3	Unit weight, (kg/m^3)	Loose	1490	1506
		Rodded	1640	1670
4	Silt content, (%)		1.25	—
5	Water absorption capacity, (%)		1.03	0.54
6	Moisture content, (%)		1.40	0.48
7	Nominal maximum size of aggregate, (mm)		4.75	20

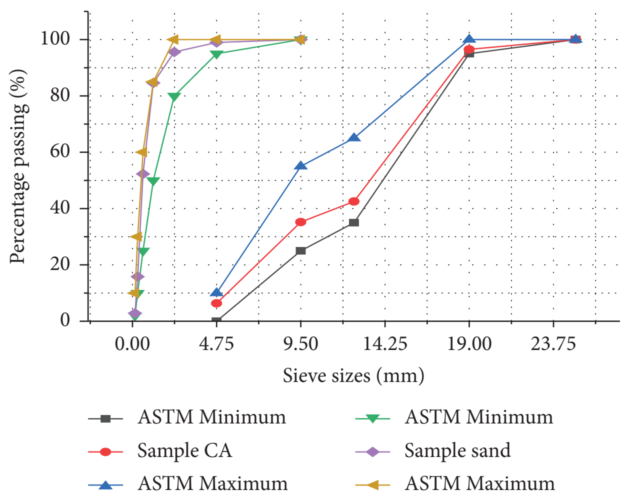


Figure 1: Particle size distribution curve of sand and coarse aggregate (CA).

abrasion machine to have approximately 90% of particles passing through a 75-μm sieve, as shown in Figure 2(b). In order to make sure that a fineness level comparable to Portland cement is obtained, a trial procedure was conducted to reach a satisfactory level of fineness. After each trial, with a specified revolution, the specific surface area of the sample was determined using the air permeability method, specifically by using the Blain test apparatus.

2.2. Mixture Proportioning. In this study, the ACI 211.1 method of concrete mix design was used as a design guideline to prepare concrete mixtures [30]. A reference mixture was designed to achieve a minimum compressive strength of 25 MPa at 28 days. Scoria-based concrete mixtures were prepared with scoria contents of 10, 20, 30, and 40% by weight of cement. The water-to-cement ratio for all mixtures was kept constant (w/cm = 0.52) to see the effect of using scoria as a supplementary cementitious material on the properties of concrete. The proportions of concrete constituents used per cubic meter are presented in Table 3.

2.3. Sample Preparation. Concrete mixing procedures were prepared following the ASTM C 192 specification steps [31]. Five groups of concrete mixtures were prepared based on the partial replacement of scoria powder for cement. The specimens prepared include a total of 60 cubes of 150 mm dimensions. Twelve specimens were cast for each mix, and the mean compressive strength of three specimens was reported for each test age. Batching of cement, aggregates, and water became accomplished through the weighing method. A pan-kind mixer with the most output potential of 125 L was used to supply the concrete mixtures. The concrete mixtures were cast in cubic molds in three layers, and each layer was consolidated manually 25 times by means of a tamping rod of 16 mm in diameter and 600 mm long. The concrete specimens were removed from their moulds 24 hours after casting, and they were immersed in water until the moment of testing [31].

2.4. Test Methods

2.4.1. XRD and SEM Analysis. The chemical analysis of the volcanic scoria used in this investigation was studied in the Geological Survey of Ethiopia and is summarized in Table 4 based on the analytical method. The mineralogy and microstructure of scoria were analyzed using X-ray diffraction (XRD) equipment with C_u-radiation of (wavelength = 1.54 Å) at 40 K.V., 35 m.A., and a scanning speed of 0.02°/sec. The reflection peaks between $2\theta = 2°$ and 60°, and corresponding spacing (dÅ) and relative intensities (peak areas) were obtained. In XRD analysis, around the sample scoria powder, the detector position is recorded as the angle 2theta (2θ)-. The detector records the number of X-rays observed at each angle 2θ. The X-ray intensity is usually recorded as "counts" or as "counts per second." Scanning electron microscope (SEM) images of scoria were analyzed at two magnification levels: at low magnification (Figure3(a)) and at high magnification (Figure 3(b)).

2.4.2. Workability. The slump cone test method was adopted for the determination of the workability of fresh concrete as per ASTM C143 [32]. As specified in ASTM C 143, the cone was filled in three layers of approximately equal volume, and each layer was consolidated by rodding 25 times with a smooth, straight steel tamping rod of diameter 16 mm. After the top layer has been rodded, the surface of the concrete was struck off by means of screeding and rolling motion of the tamping rod. The cone was immediately removed from the concrete by raising it carefully in a vertical direction. Then, the slump was measured by determining the vertical difference between the top of the cone and the displaced original center of the top surface of the specimen [32]. The slump values for each scoria replacement are indicated in Table 5.

2.4.3. Density (Unit Weight). The unit weight of fresh concrete with various scoria replacement levels was determined according to ASTM C138 [33]. For the determination of the fresh density of concrete, the mass and

Table 2: Chemical and physical properties of cement used.

Chemical composition of oxides		Physical properties		
Oxides	Mean value	Description		Mean value
SiO_2 (%)	20.65	Residue (%) on 45 μm		10.50
Al_2O_3 (%)	4.96	Standard consistency		28.5
Fe_2O_3 (%)	3.02	Setting time (minutes)	I.S.T	155
CaO (%)	63.08		F.S.T	230
MgO (%)	1.42	Compressive strength (MPa)	1 day	11.02
SO_3 (%)	2.11		3 days	17.40
LOI	0.82		28 days	42.63

Figure 2: Scoria: (a) before grinding; (b) scoria powder.

Table 3: Proportions of concrete ingredients per cubic meter (kg/m^3).

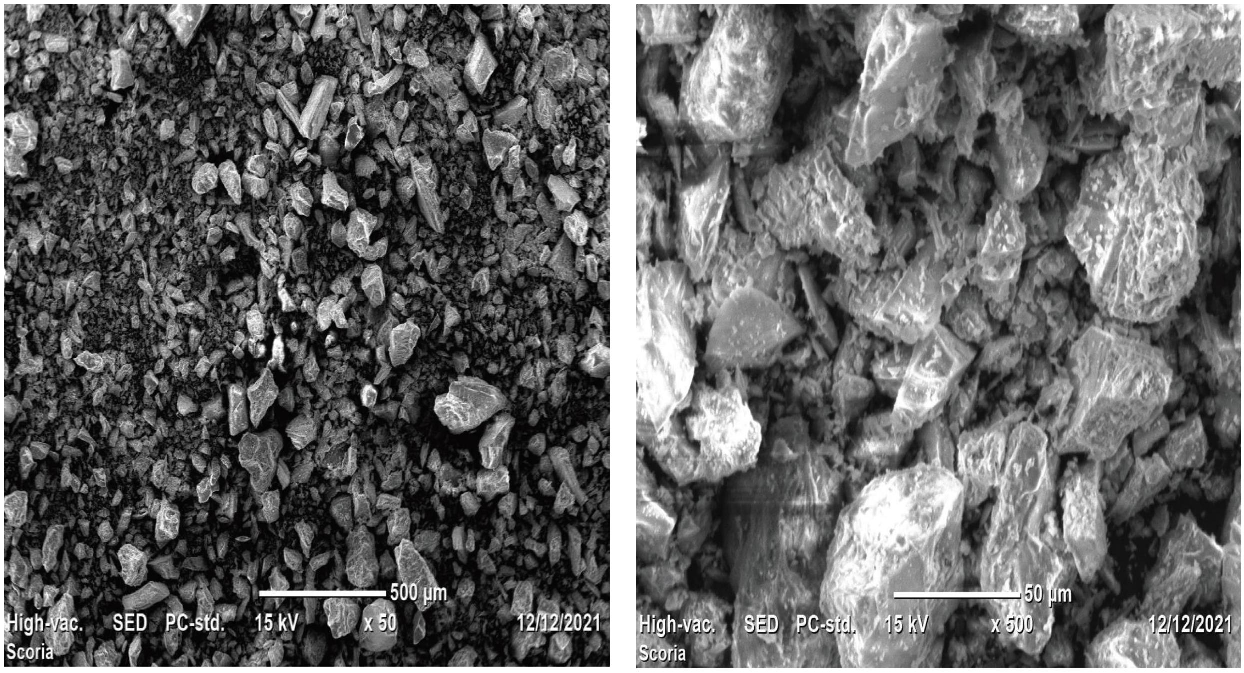
Constituents	Cement	Water	Sand	Coarse aggregate
Amount (kg/m^3)	370	192.4	733	1095

Table 4: The chemical composition of scoria used.

Chemical composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	MnO	P_2O_5	TiO_2	H_2O	LOI
Content (%)	53.84	15.02	10.89	11.25	4.08	2.61	0.17	0.16	0.86	0.62	0.84

volume of the measure have first been measured. Then, the mass of the measure with the specimen is measured. The net mass of the concrete was calculated by subtracting the mass of the measure from the mass of the measure filled with concrete. The density of concrete is calculated by dividing the net mass of concrete by the volume of the measure [33]. The results of the density of fresh concrete for each scoria replacement rate are presented in Table 5.

2.4.4. Compressive Strength. The compressive strength of specimens was carried out in accordance with ASTM C39. The compression machine used in this study was an automatic compression testing machine which has a loading capacity of 2000 kN. Loading of specimens was applied at a constant loading rate between 0.2 and 0.4 MPa/sec until the failure. The specimens were tested after the ages of 7, 28, 56, and 90 days.



(a) (b)

Figure 3: SEM images of the scoria sample at different magnification sizes.

Table 5: Unit weight and slump value of fresh concrete.

Mix ID	Scoria content (%)	Density (kg/m^3)	Density reduction (%)	Slump value (mm)	Slump reduction (%)
SP-0	0	2420	—	34	—
SP-10	10	2375	1.9	32	6
SP-20	20	2358	2.6	26	24
SP-30	30	2334	3.6	18	47
SP-40	40	2317	4.3	14	59

2.5. Mix Designations. The following are the details of descriptions and designations of the concrete mixtures studied as shown in Table 6.

3. Results and Discussion

3.1. Chemical Composition of Scoria. The chemical composition carried out on scoria is shown in Table 4 and Figure 4. The results of the chemical analysis indicate that SiO_2, Al_2O_3, CaO, and Fe_2O_3 constitute their major components. As it can be seen from Table 4, the major constituents of scoria are $SiO_2 + Al_2O_3 + Fe_2O_3 = 79.75\% > 70\%$. Scoria can be considered as a suitable pozzolanic material for use as supplementary cementitious materials in green concrete production. Hence, it fulfilled the specification requirements for natural pozzolanic materials. According to ASTM C 618 specifications, the scoria powder is fulfilling the requirements of pozzolanic materials. In addition, the physical and mechanical properties of scoria are also fulfilling the requirements of ASTM C618 [34].

The XRD pattern of scoria is given in Figure 4. As expected, scoria is an amorphous rock. As indicated in XRD data (Figure 4), scoria consists mainly of volcanic materials of amorphous structure, with the basic composition of relatively high quartz (SiO_2) and low Fe_2O_3 contents. The main oxide content of Portland cement is CaO (63.08%); however, scoria also has CaO (11.25%).

3.2. SEM Images of Scoria. The result obtained from SEM views of the used raw material in this investigation is shown in Figure 3. The scoria particles, as when observed with an SEM image, look like a square and diamond in nature and it is also similar to the particles of ordinary Portland cement (OPC). The OPC appears to have a box and stone-shaped particles as observed by the SEM instrument [20]. The scoria particles shown by SEM are close to spherical particles with a minor number of pedospheres and an irregular morphology or shaped porous a cellular-structure (amorphous structure). After grinding scoria, the porous structures were crushed and broken down into smaller fractions leading to an increase in surface area and it improved the fineness of the particles.

Table 6: Mix designations.

Designation	Description
SP-0	Portland cement concrete produced with 0% replacement of scoria powder
SP-10	Portland cement concrete was produced with 10% replacement of scoria powder
SP-20	Portland cement concrete was produced with 20% replacement of scoria powder
SP-30	Portland cement concrete was produced with 30% replacement of scoria powder
SP-40	Portland cement concrete was produced with 40% replacement of scoria powder

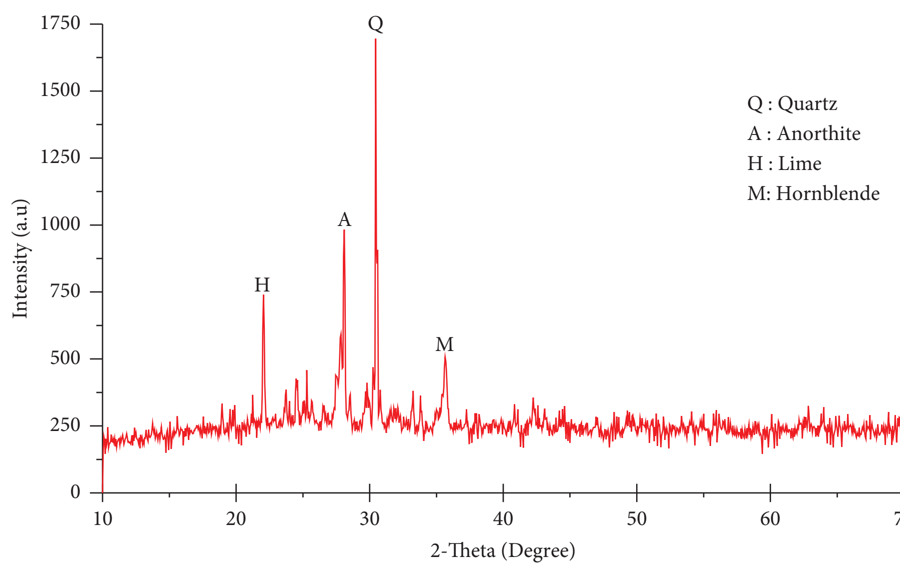


Figure 4: XRD patterns of scoria powder.

3.3. Setting Times of the Blended Paste. The setting time test was conducted on blended pastes containing scoria replacements of 0%, 10%, 20%, 30%, and 40% by weight of cement. The setting times of blended paste containing different replacements of scoria powder are shown in Table 7 and Figure 5. It can be seen from the table that the setting time of the blended paste increases as the percentage of scoria powder increases due to the slow hydration reaction of the scoria-based binder system. The results of this study indicated that the setting time of blended paste was delayed due to the partial replacement of cement with scoria; however, this retardation was within the limits specified by the Ethiopian standard, ASTM standard, and other related standards.

3.4. Density of Fresh Concrete. As it can be seen in Table 5, the unit weight of fresh concrete shows a slight reduction as the percentage of scoria increases. The unit weight of fresh concrete up to 3.6% reduction was observed when 30% of cement was replaced by scoria powder. Furthermore, 40% replacement of cement by scoria reduces the unit weight of fresh concrete by 4.3%. The slight reduction in the unit weight of fresh concrete is due to the lightweight nature of the scoria material.

Table 7: Setting times of blended pastes at various scoria powder content.

Mixture ID	SP-0	SP-10	SP-20	SP-30	SP-40
Initial setting time, (min)	158	186	205	231	250
Final setting time, (min)	235	283	315	338	354

3.5. Effect of Scoria Content on Workability. The trend of a slump for mixtures having different contents of scoria is presented in Table 5 and Figure 6. As the content of scoria powder increased, the slump values decreased with the w/c ratio kept constant. As indicated in Figure 7, the control mix shows a higher slump when compared with all other scoria-replaced mixes. When the content of scoria powder increases from 0 to 30%, the slump was decreased by 47% (14 mm). At a 30% replacement rate of scoria, there is a significant reduction of a slump by 59% (20 mm) due to the significant increment of water demand at this replacement level. Although the workability of concrete is decreased as the content of scoria is increased, up to the replacement level of 20%, the slump value is within the specified limit, which is 25−−75 mm. In general, an increase in the content of scoria powder reduces the slump of freshly mixed concrete. A similar result was also observed by Chambua et al. [35],

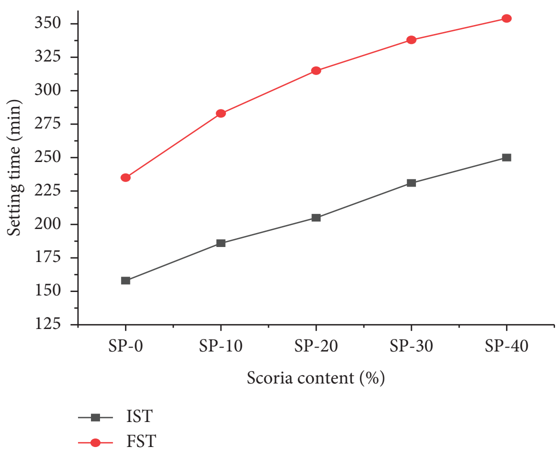


FIGURE 5: Graph of setting time versus scoria content.

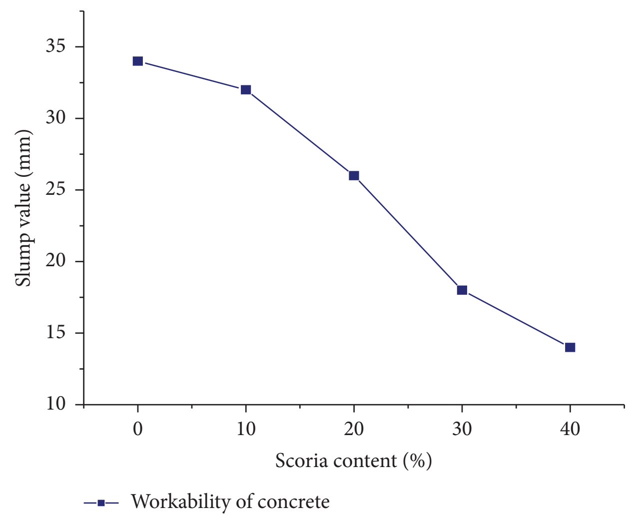


FIGURE 6: Graph of slump versus scoria content.

Mboya et al. [14], and [36]. The reason for this is that there is a high-water demand due to an increase in the contents of scoria powder. The reason behind this may also be the high concentration of SiO_2 (in Scoria $SiO_2 = 53.84\%$ and in cement $SiO_2 = 20.65\%$) in scoria powder increases the water requirement of the mixture. This argument is also revealed by some studies [3, 35, 37].

3.6. Compressive Strength of Concrete. Table 8 shows the compressive strength results after 7-, 28-, 56-, and 90-day curing time. The results of compressive strength development for all concrete mixes containing different amounts of scoria powder are given in Figure 8. As expected, all concrete mixes show an increase in compressive strength with curing time. Concrete specimens containing scoria powder have lower compressive strengths at any curing time compared to reference concrete specimens. However, the compressive strength results of 10% scoria blended concrete exceeded that of control specimens after 56- and 90-day curing. A similar trend was obtained in [35, 38, 39] where strength improved by using 10% of SCMs in concrete. This could be due to the progress of slow pozzolanic reaction with age in scoria-replaced concrete specimens [15]. Also, it is seen that the compressive strength of scoria powder replaced concrete specimens decreases as the scoria powder content increases for all replacements except 10%.

Concrete specimens made with 10%, 20%, and 30% partial replacement of cement with scoria achieved the specified minimum strength (>25 MPa) after 28 days of curing time. But concrete specimens made with 40% scoria content do not satisfy the minimum specified concrete strength even after 90 days (24 MPa < 25 MPa). This ascertainment is due to a continuation of slow pozzolanic reaction and the formation of secondary C-S-H; a greater degree of hydration was achieved resulting in strength improvements after 56 and 90 days [15, 27, 40]. Therefore, volcanic scoria can substitute Portland cement up to

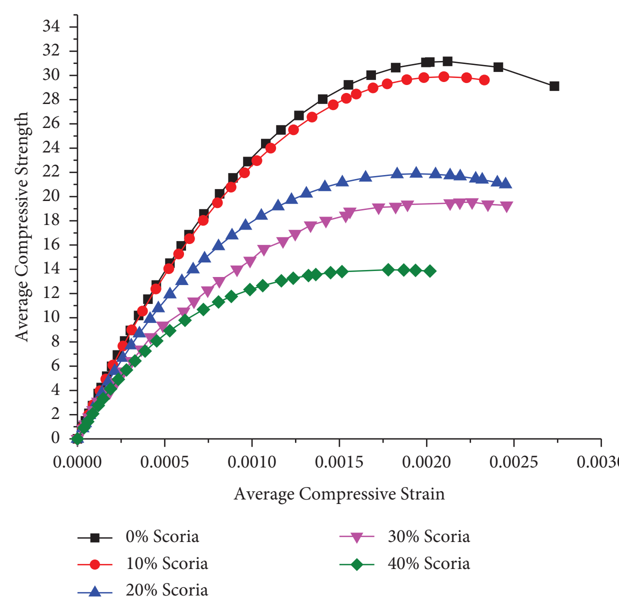


FIGURE 7: Stress-strain curve for 7 days compressive strength results.

replacement levels of 30% by weight basis with a slight effect on workability and compressive strength. The best replacement level for a higher amount of compressive strength is at 10% and other replacement levels such as 20% and 30% are also possible but such contents require more curing time to achieve the specified strength (56 and 90) days. The optimum replacement level of volcanic scoria in the past agrees with the findings of this study for concrete [7]. Moreover, to easily understand the difference, the result is shown graphically in Figure 8.

Table 8: Mean compressive strength results (MPa) with different scoria content.

Mix ID	Scoria powder content, (%)	Curing age (days)			
		7	28	56	90
SP-0	0	31.42	42.76	43.28	43.67
SP-10	10	30.80	39.04	44.37	49.00
SP-20	20	22.18	29.60	35.89	37.27
SP-30	30	19.87	27.75	28.55	30.22
SP-40	40	14.25	21.02	23.21	24.00

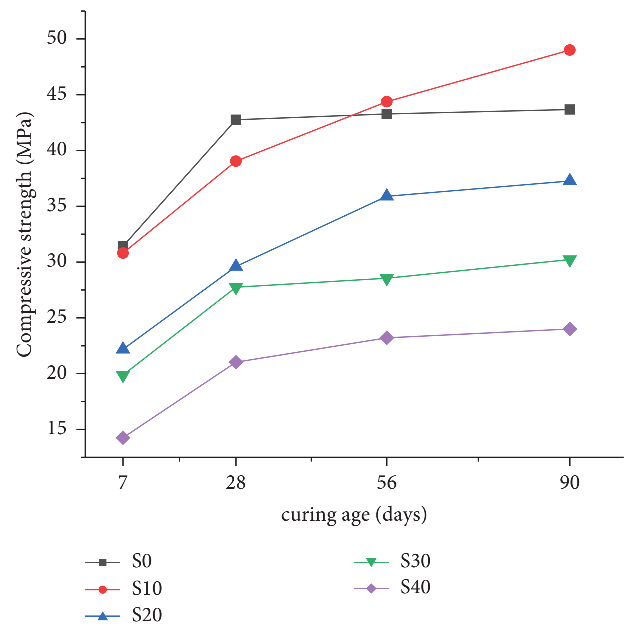


Figure 8: Compressive strength of concrete specimens versus time.

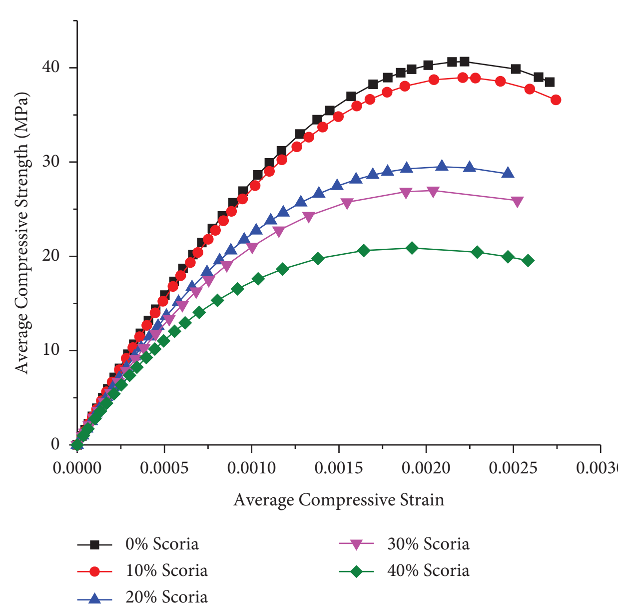


Figure 9: Stress-strain curve for 28 days compressive strength results.

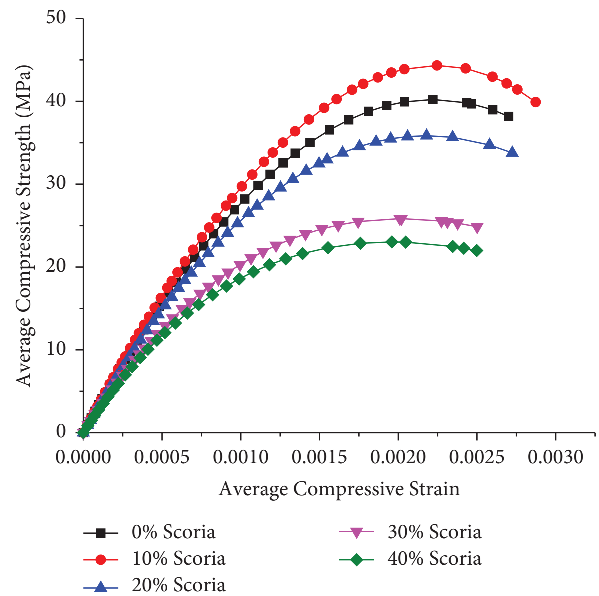


Figure 10: Stress-strain curve for 56 days compressive strength results.

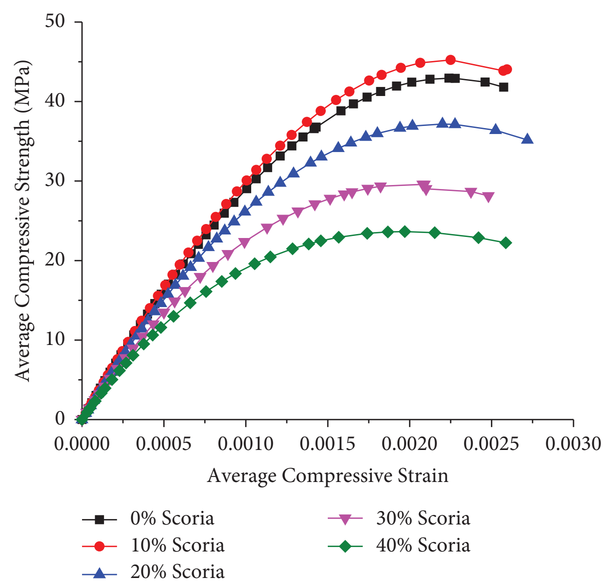


Figure 11: Stress-strain curve for 90 days compressive strength results.

3.7. Stress-Strain Relationships. The average engineering stress and strains are calculated for all mixes and shown in Figures 7, 9–11. The stress-strain curve is drawn by selecting a better graph from each mix and sample for comparison with the control. It can be seen that the strain values gradually decreased as the percentage of scoria powder increased. In this study, the peak strain of scoria-replaced concrete was found to be lower than that of conventional concrete. Hence, the replacement rate of scoria powder showed an obvious impact on the stress-strain relations of concrete. From the figure of stress-strain results, scoria powder replaced concrete varied due to scoria powder content. From the curve, for all mixes, the compressive stress and the corresponding strain are directly proportional to some extent. This shows the elastic range of concrete. Once the ultimate load is reached, the load-carrying capacity (ductile properties of concrete) is changed for each mix based on the percentage variation of scoria powder. The peak stress and slope of the ascending part of the curve declined with the increase of the replacement rate of scoria powder, which conformed to findings from other researchers [41–43]. Furthermore, as the replacement rate increased, peak stress increased, and both the ascending and descending part of the stress–-strain curves became steeper to some extent. Therefore, it could be concluded that volcanic scoria has a similar behavior to that of Portland cement concrete under compression stress.

4. Conclusions

Based on the current experimental investigation, the findings can be concluded as follows:

(i) The results of the chemical analysis indicate that SiO_2, Al_2O_3, CaO, and Fe_2O_3 constitute their major components. The studied scoria can be used as a partial replacement for cement. Hence, the main oxide contents ($SiO_2 + Al_2O_3 + Fe_2O_3 = 79.75 > 70\%$) are within the range prescribed by ASTM C618.

(ii) The utilization of scoria powder in concrete has a significant effect on the fresh concrete properties such as setting time, slump value, and unit weight. As the content of scoria is increased, the slump values were decreased with the w/c ratio kept constant. At a 30% replacement rate of scoria, there is a significant reduction of a slump by 59% (20 mm) due to the significant increment of water demand at this replacement level.

(iii) Concrete specimens containing scoria powder have lower compressive strengths at any curing time compared to reference concrete specimens. However, the incorporation of 10% scoria significantly increased the compressive strength of concrete specimens after 56 and 90 days (i.e., 44.37 MPa and 49.00 MPa, respectively).

(iv) Based on the investigation, scoria powder is suitable for use in concrete as supplementary cementitious material and the use of this type of material in concrete helps the strategy of green concrete production.

(v) Therefore, based on this investigation scoria is suitable to use to produce concrete as a partial replacement for cement. Its local availability is crucial to be used as an alternative construction material that helps to save cost and energy during production, as well as protects against the emission of carbon dioxides to the environment. Thus, this satisfies the basic strategy of green concrete production in worldwide.

Data Availability

All the data used to support the findings of the study are included in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors wish to thank those who participated in laboratory work and supported during the experimental stage to complete this research study.

References

[1] P. K. Mehta and P. J. M. Monteiro, *Concrete: Microstructure, Properties and Materials*, McGraw-Hill Education, New York, NY, USA, 3rd edition, 2001.

[2] G. K. Warati, M. M. Darwish, F. F. Feyessa, and Ghebrab, "Suitability of scoria as fine aggregate and its effect on the properties of concrete," *Sustainability*, vol. 11, no. 17, p. 4647, 2019.

[3] G. J. Hearn, A. Otto, P. A. K. Greening, A. A. Endale, and D. M. Etefa, "Engineering geology of cinder gravel in Ethiopia: prospecting, testing and application to low-volume roads," *Bulletin of Engineering Geology and the Environment*, vol. 78, no. 5, pp. 3095–3110, 2019.

[4] G. Fares, A. Alhozaimy, O. A. Alawad, and A. Al-Negheimish, "Evaluation of powdered scoria rocks from various volcanic lava fields as cementitious material," *Journal of Materials in Civil Engineering*, vol. 28, no. 3, Article ID 4015139, 2016.

[5] W. H. Juimo Tchamdjou, S. Grigoletto, F. Michel, L. Courard, T. Cherradi, and M. L. Abidi, "Effects of various amounts of natural pozzolans from volcanic scoria on performance of portland cement mortars," *JERA*, vol. 32, pp. 36–52, 2017.

[6] A. M. al-Swaidani, "Use of micro and nano volcanic scoria in the concrete binder: study of compressive strength, porosity and sulfate resistance," *Case Studies in Construction Materials*, vol. 11, Article ID e00294, 2019.

[7] K. Celik, M. Jackson, M. Mancio et al., "High-volume natural volcanic pozzolan and limestone powder as partial replacements for portland cement in self-compacting and sustainable concrete," *Cement and Concrete Composites*, vol. 45, pp. 136–147, 2014.

[8] A. A. Ibrahim A, A.-A. Ahmed M, and E.-A. Mohammed I, "Preliminary assessment of utilization of Al-jaif scoria (NW sana'a, Yemen) for cement production," *SQU Journal for Science*, vol. 23, no. 2, p. 111, 2018.

[9] M. I. Khan and A. M. Alhozaimy, "Properties of natural pozzolan and its potential utilization in environmental friendly concrete," *Canadian Journal of Civil Engineering*, vol. 38, no. 1, pp. 71–78, 2011.

[10] A. D. Gashahun, "Assessment on cement production practice and potential cement replacing materials in Ethiopia," *CER*, vol. 12, no. 1, pp. 22–28, 2020.

[11] N. Kabay, M. M. Tufekci, A. B. Kizilkanat, and D. Oktay, "Properties of concrete with pumice powder and fly ash as cement replacement materials," *Construction and Building Materials*, vol. 85, pp. 1–8, 2015.

[12] M. Seyfe and A. Geremew, "Potential use of cinder gravel as an alternative base course material through blending with crushed stone aggregate and cement treatment," *JCEST*, vol. 10, no. 2, pp. 101–112, 2019.

[13] S. Karthik, R. M. Rao, P. Awoyera et al., "Beneficiated pozzolans as cement replacement in bamboo-reinforced concrete: the intrinsic characteristics," *Innovative Infrastructure Solutions*, vol. 3, no. 1, pp. 50–58, 2018.

[14] H. A. Mboya, C. K. King'ondu, K. N. Njau, and A. L. Mrema, "Measurement of pozzolanic activity index of scoria, pumice, and rice husk ash as potential supplementary cementitious materials for portland cement," *Advances in Civil Engineering*, vol. 2017, Article ID 6952645, 13 pages, 2017.

[15] A. M. al-Swaidani, S. D. Aliyan, and N. Adarnaly, "Mechanical strength development of mortars containing volcanic scoria-based binders with different fineness," *Engineering Science*

and Technology, an International Journal, vol. 19, no. 2, pp. 970–979, 2016.
[16] A. Ozvan, M. Tapan, O. Erik, T. Efe, and T. Depci, "Compressive strength of scoria added portland cement concretes," *Gazi University Journal of Science*, vol. 25, no. 3, pp. 769–775, 2012.
[17] G. Tesema and E. Worrell, "Energy efficiency improvement potentials for the cement industry in Ethiopia," *Energy*, vol. 93, pp. 2042–2052, 2015.
[18] B. W. Yifru and B. B. Mitikie, "Partial replacement of sand with marble waste and scoria for normal strength concrete production," *SN Applied Sciences*, vol. 2, no. 12, p. 1938, 2020.
[19] A. Demissew Gashahun, "Production of sustainable concrete by using challenging environmentally friendly materials instead of cement," in *Sustainability of Concrete with Synthetic and Recycled Aggregates*, H. M. Saleh, Ed., IntechOpen, London, UK, 2021.
[20] M. H. Doye, "Green concrete: efficient & eco-friendly construction materials," *Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, vol. 14, no. 3, pp. 33–35, 2017.
[21] R. Jin and Q. Chen, "An investigation of current status of 'green' concrete in the construction industry," in *Proceedings of the presented at the 49th ASC Annual International Conference Proceedings*, San Luis Obispo, CA, USA, April, 2013.
[22] K. L. Scrivener, V. M. John, and E. M. Gartner, "Eco-efficient cements: potential economically viable solutions for a low-CO2 cement-based materials industry," *Cement and Concrete Research*, vol. 114, pp. 2–26, 2018.
[23] H. Marey, G. Kozma, and G. Szabó, "Effects of using green concrete materials on the CO2 emissions of the residential building sector in Egypt," *Sustainability*, vol. 14, no. 6, p. 3592, 2022.
[24] S. K. Adhikary, D. K. Ashish, H. Sharma et al., "Lightweight self-compacting concrete: a review," *Resources, Conservation & Recycling Advances*, vol. 15, Article ID 200107, 2022.
[25] M. Gesoğlu, E. Güneyisi, T. Özturan, H. Ö. Öz, and D. S. Asaad, "Self-consolidating characteristics of concrete composites including rounded fine and coarse fly ash lightweight aggregates," *Composites Part B: Engineering*, vol. 60, pp. 757–763, 2014.
[26] A. M. Al-Swaidani and T. Al-Hajeh, "Effect of adding limestone filler and volcanic scoria on the properties of recycled aggregate," *Concrete*, vol. 14, no. 4, 2019.
[27] A. M. al-Swaidani and W. T. Khwies, "Applicability of artificial neural networks to predict mechanical and permeability properties of volcanic scoria-based concrete," *Advances in Civil Engineering*, vol. 2018, Article ID 5207962, 16 pages, 2018.
[28] Astm C 150, *Standard Specification for Portland Cement*, American Society for Testing Materials, West Conshohocken, PA, USA, 2005.
[29] Astm C 33, *Standard Specification for concrete Aggregate*, American Society for Testing Materials, West Conshohocken, PA, USA, 1993.
[30] Aci Committee 211.1-91, *Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete*, American Concrete Institute, Farmington Hills, MI, USA, 2009.
[31] Astm C192/C192M, *Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory*, ASTM International, West Conshohocken, PA, USA, 2007.
[32] Astmc143/C143M-15a, *Standard Test Method for Slump of Hydraulic-Cement Concrete*, ASTM International, West Conshohocken, PA, USA, 2015.
[33] Astm C 138, *Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete*, ASTM International, West Conshohocken, PA, USA, 2005.
[34] Astm C618, *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete*, ASTM International, West Conshohocken, PA, USA, 2005.
[35] S. T. Chambua, Y. A. C. Jande, and R. L. Machunda, "Strength and durability properties of concrete containing pumice and scoria as supplementary cementitious material," *Advances in Materials Science and Engineering*, vol. 2021, Article ID 5578870, 13 pages, 2021.
[36] D. A. Adesanya and A. A. Raheem, "A study of the workability and compressive strength characteristics of corn cob ash blended cement concrete," *Construction and Building Materials*, vol. 23, no. 1, pp. 311–317, 2009.
[37] W. J. Tchamdjou, T. Cherradi, M. L. Abidi, and L. P. de Oliveira, "Influence of different amounts of natural pozzolan from volcanic scoria on the rheological properties of portland cement pastes," *Energy Procedia*, vol. 139, pp. 696–702, 2017.
[38] F. Hedayatinia, M. Delnavaz, and S. S. Emamzadeh, "Rheological properties, compressive strength and life cycle assessment of self-compacting concrete containing natural pumice pozzolan," *Construction and Building Materials*, vol. 206, pp. 122–129, 2019.
[39] N. Bheel, P. Awoyera, I. A. Shar, S. Sohu, S. A. Abbasi, and A. Krishna Prakash, "Mechanical properties of concrete incorporating rice husk ash and wheat straw ash as ternary cementitious material," *Advances in Civil Engineering*, vol. 2021, Article ID 2977428, 13 pages, 2021.
[40] A. M. Al-Swaidani, "Prediction of compressive strength and some permeabilityrelated properties of concretes containing volcanic scoria as cement replacement," *Romanian Journal of Materials*, vol. 46, no. 4, pp. 505–514, 2016.
[41] A. Shashanka, K. S. Kumar, P. Pravalika, G. K. Kumar, V. Swetha, and G. Samdani, "Study on stress strain behavior of concrete with replacement of cement by natural zeolite," *Journal of Engineering Science*, vol. 13, no. 07, pp. 1679–1685, 2022.
[42] B. Cai, Y. Tao, and F. Fu, "Residual stress-strain relationship of scoria aggregate concrete with the addition of PP fiber after fire exposure," *Fire*, vol. 4, no. 4, p. 91, 2021.
[43] H. Wei, T. Wu, X. Liu, and R. Zhang, "Investigation of stress-strain relationship for Confined Lightweight aggregate concrete," *Construction and Building Materials*, vol. 256, Article ID 119432, 2020.