Engineering and Technology Journal
Journal homepage: engtechjournal.org

The Effect of the Waste of Materials and Carbon Nanotube on the Concrete Incorporated with Steel Fibers

Mayada H. Saleem [a*] , **Farhad M. Othman** [b] , **Alaa A. Abdul-Hamead** [c]

[a] Materials Engineering Department, University of Technology, Baghdad, Iraq, mae.19.17@grad.uotechnology.edu.iq

[b] Materials Engineering Department, University of Technology, Baghdad, Iraq,130031@uotechnology.edu.iq

[c] Materials Engineering Department, University of Technology, Baghdad, Iraq, 130043@uotechnology.edu.iq

*Corresponding author.

Submitted: 23/02/2021 Accepted: 30/04/2021 Published: 25/06/2021

K E Y W O R D S

Steel fiber, waste material, Carbon Nanotube, concrete, advanced application

A B S T R A C T

The addition of agricultural and industrial solid wastes and nanomaterials to concrete combined with steel fibers to improve the mechanical and electrical properties of concrete was investigated. This approach could be used in advanced applications in electromagnetic shielding and conductive concrete. Steel fibers were used at 2%wt. of sand and (induction furnace slag (EIF), carbon nanotube (CNT), steel wool fibers, prepared corn husks) at 0.5 and 1 wt.%. of cement. Obtained results of using 1% for both carbon nanotube and steel wool with steel fibers in the mixture 4 and 6, respectively, showed the highest rates of compressive strength. A similar result was shown when tested at 3,7 and 28 days of age and compressive strength was 47.4MPa,47.34MPa for the mixture 4 and 6 respectively. The electrical conductivity and electrical resistance of the samples were measured at the age of 7 days. The findings have also shown that adding steel wool as well as(CNT) gave the best results and the sample containing the furnace slag achieved satisfactory results as well.

How to cite this article: M. H. Saleem, F.M. Othman, and A. A. Hamead, “The Effect of the Waste of Materials and Carbon Nanotube on the Concrete Incorporated with Steel Fibers,” Engineering and Technology Journal, Vol. 39, No. 06, pp. 956-964, 2021.
DOI: https://doi.org/10.30684/etj.v39i6.2018

1. Introduction

The study of concrete incorporated with steel fibers has been investigated from the side of physical, mechanical, and electrical properties as well as electromagnetic interference (EMI) in electrical noise. It creates a disturbance or an unwanted response in electrical circuits and devices and this helps in their use in the military protection of some installations from the impulses resulting from the explosions for example.]1[Muhammad Usman et.al, investigated in addition of steel fibers to concrete helped reduce brittleness and increase ductility, but it did not show a significant effect in improving compressive strength.]2[Emmanuel Ejiofor Anike et. al, The effect of adding steel fibers in three different forms with recycled materials in concrete was studied, and the results showed an increase in water absorption.]3[Ali Toghroli et.al, The use of steel fibers helped improve the compressive and bending strength of the concrete.]4[Ketan Ragalwar et. al, The addition of steel fibers and steel wool to ultra-high performance concrete was investigated, and the steel wool significantly increased the concrete resistance.[5] Doo-Yeol Yoo et. al, The presence of steel fibers in a certain percentage affects the electrical resistance and conductivity of concrete, as well as the effectiveness of electromagnetic shielding.]6[Fakhri Javahershenas et.al Steel fibers were used at a ratio of 0.4,0.7,1%It helped improve the properties of the concrete in general.[7] Jingjun Li et. al, The steel fibers in the self-cementing concrete helped improve the mechanical properties. [8] Akeem A. Raheem and Bolanle D. Ikotun, agricultural waste was used as a partial substitute for cement by 5-15% after treatments were carried out to reduce the cost and benefit from the waste and the results of the compressive strength showed the strength of up to 25MPa.[9] Seon Yeol Lee et. al, The presence of steel fibers along with the slag helps reduce electrical resistance and increase compressive stress.[10] Nitendra Palankar et. al, The use of iron and steel industry waste represented by slag in concrete, which affects cost reduction and waste disposal.[11] D. Micheli et. al, Adding carbon nanotubes to concrete helped improve electrical conductivity and electromagnetic shielding.[12] Myungjun Junga et.al, The presence of carbon nanotubes helps to improve mechanical properties by filling in pores, and by synthesizing the denser C-S-H structure.[13] Liaqat Ali Qureshi et.al, Agricultural and industrial waste with steel fibers helped improve the mechanical properties and durability of concrete.[14] Xijun Shi et. al, The steel fiber has improved the stress properties and compressive strength of concrete.

The current work aims to make use of industrial and agricultural waste by preparing slag powder and corn husk ash and using it as a partial substitute for cement, as well as studying its effect on concrete incorporated with steel fibers by studying the physical and mechanical properties, resistance and electrical conductivity properties.

2. EXPERIMENTAL PROGRAM

I. Materials

Induction furnace slag was used from the State Company for Steel Industries in Baghdad. Visible impurities were removed, crushed, and grinding to obtain a fine slag powder to be used as a partial substitute for cement in this study Figure1. Cornhusk was used in this study by immersing it in water for 3 days and then drying it for two days After that, it was burned at a temperature of 500 °C]15[, then milled for 15 minutes Figure 2 and used as a partial substitute for cement. SEM for slag and prepared corn husk as shown in Figure 3. Ordinary Portland cement (OPC) (kubasuh cement plant in Iraq) was used. The sand was passed from a 0.085 sieve to remove all impurities that might reduce the quality of the concrete. The maximum size of coarse aggregate is 14 mm. Steel fiber from SAPEN INTERNATIONAL CO., LTD was used as a partial substitute for sand. Table I shows the physical properties of these fibers. Carbon nanotube (CNT) from Sky Spring Nanomaterials, Inc. used as a partial substitute for cement in this study Table Π shows the physical properties of Multiwall nanotube. Steel wool or shredded steel fibers are used in brake linings, cleaning, automobile exhaust pipes, metal separating, etc., Table Ш shows the properties of steel wool.

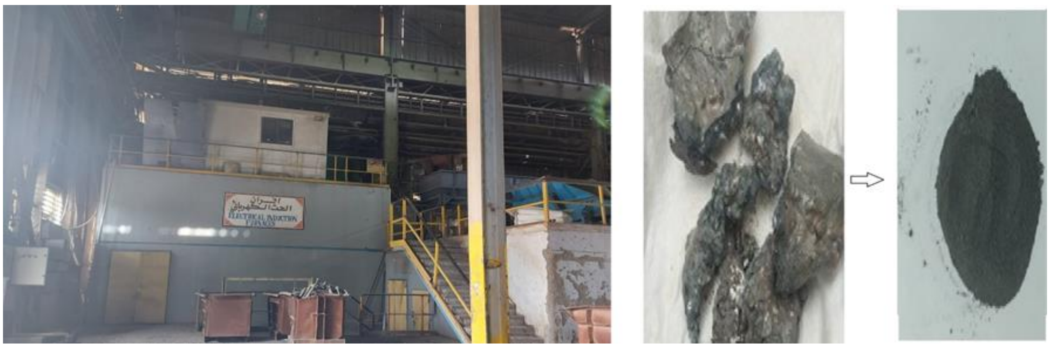
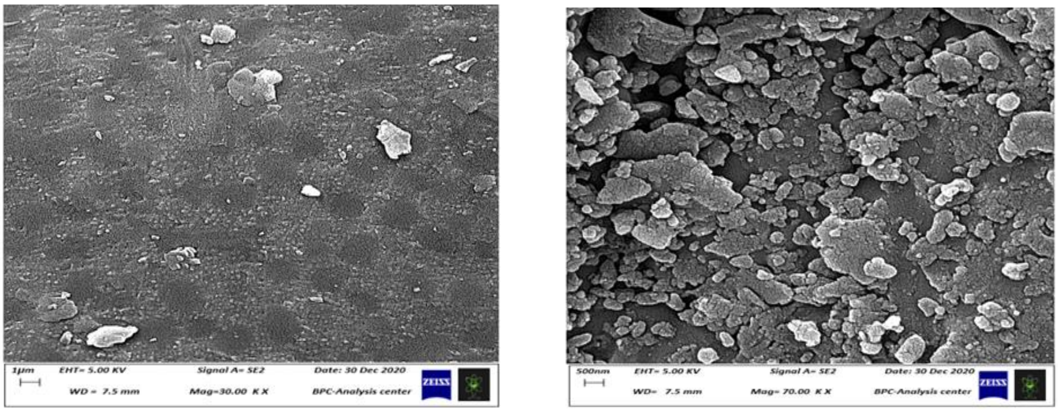


Figure 1: Electrical induction furnaces slag

Figure 2: Steps of prepare cornhusks



a- b-

Figure 3: SEM a-(EIF) slag, b-corn husk prepared.

TABLE I: Steel fiber properties.

Product-code	L(mm)	D(mm)	Tensile strength(MPa)	Aspect ratio
SAP 6560 GHW	60	0.9	≥1150	67

TABLE II: Steel wool properties.

Purity	Outside	Inside	Length	SSA	Ash	Electrical	Bulk
>95wt% 2.1g/cm³	<8nm	2-5nm	5-20µm	>500m²/g	<1.5wt%	>100s/cm	0.27g/cm³

TABLE III: Steel wool properties.

Length (mm)	*Diameter(µm)*	*Density (g/cm³)*	*Tensile Strength (MPa)*
2-6	20-60	7.85	200-400

II. Concrete Mixture Proportioning

A concrete mixing ratio of 1:1.5:3 was used and 9mixtures were designed in this study, as shown in Table IV, the percentage of steel fiber is 2% of the weight of sand, the ratio of EIF slag, CNT, steel wool, and corn husk was 0.5 and 1% of the weight of cement. The concrete was poured into molds of 10×10×10 cm dimensions]2[According to British specifications BS EN 12390 – 3 [16], and the concrete components were manually weighed and then mixed in the electric concrete mixer. The concrete cubes were removed after 24 h from the molds, kept underwater for curing, and tested After 3,7,28 days.

TABLE IV: Concrete mixture experimental design in Kg/m³.

Concrete Mix	Cement	Sand	Gravel	steel fiber	EIF. Slag	CNT	Steel wool	Corn husk
Mix0	403	609	1260	-	-	-	-	-
Mix1	400.98	596.82	1260	12.18	2.015	-	-	-
Mix2	398.9	596.82	1260	12.18	4.03	-	-	-
Mix3	400.98	596.82	1260	12.18	-	2.015	-	-
Mix4	398.97	596.82	1260	12.18	-	4.03	-	-
Mix5	400.98	596.82	1260	12.18	-	-	2.015	-
Mix6	398.9	596.82	1260	12.18	-	-	4.03	-
Mix7	400.98	596.82	1260	12.18	-	-	-	2.015
Mix8	398.97	596.82	1260	12.18	-	-	-	4.03

III. Inspection and Test

1.) The compressive strength test with device specifications, capacity: 3000KN, was performed for 3, 7, and 28 days.

2.) The electrical conductivity was measured by a precision impedance analyzer (brand Agilent, model 4294A made in USA), OSC level was (500 mv). Samples were prepared in the form of discs with dimensions of diameter (3.5cm) and thickness (0.5 cm) with the same replacement ratios for steel fiber 2% of the weight of sand and for each of the EIF slag and CNT, corn husks and steel wool 1% of the cement weight. The DC conductivity(σ) was calculated using the Eq.(1) [12]

$$\sigma = 1/\rho = L/RA \tag{1}$$

Where

ρ is the electrical resistivity, R is electrical resistance, L is the distance between the two electrodes, A is the cross-sectional area of the electrical contact.

3.) Scanning Electron Microscope (SEM), This test analyzes the microstructure and morphology of the prepared samples examined at the Nanotechnology Research Center at the University of Technology using TESCAN Vega II.

4.) The density of samples was tested at an age of 3, 7, 28 days, samples were in the form of a circular disk with a diameter of 1 cm and a thickness of 0.5 cm, It is possible to calculate the density through the following Eq.(2)]17-21[

$$\rho = W1/(W2 - W3) \times \rho w \tag{2}$$

Where

w1: Dry weight of sample in gm, W2: Average weight of wet sample in gm. W3: submerge weight of the sample in gm ρw: The density of water which is equivalent to 1 g/cm3.

3. RESULTS AND DISCUSSION

I. Compressive strength

The presence of steel fibers enhanced the strength and compressive strength of concrete]20[, and the rates of improvement varied according to the additives used in this research (slag, CNT, steel wool, corn husks). Figure 4 shows the results of the compressive strength of the prepared concrete samples, the results were much better compared to Ali Toghroli et. al]3[and Tareq S. Al-Attar et. al]18[. The figure shows the improvement of all mixtures compared to the control sample at all ages 3, 7, 28 days, And the additives with the highest percentage, which is 1% of the weight of cement, showed a greater improvement than using it by 0.5% Concrete mixture M4 and M6 showed the best results when tested at 28 days of age, and the rate of improvement compared to the control sample was 41.6% for mixture No. 4 containing 1% CNT and 41, 4% for mixture 6 containing 1% steel wool. Also, compressive strength improved, With a percentage of 20, 9% when slag add by 1% in mixture 2 and for mixture 8 contain 1% corn husk at 18%.

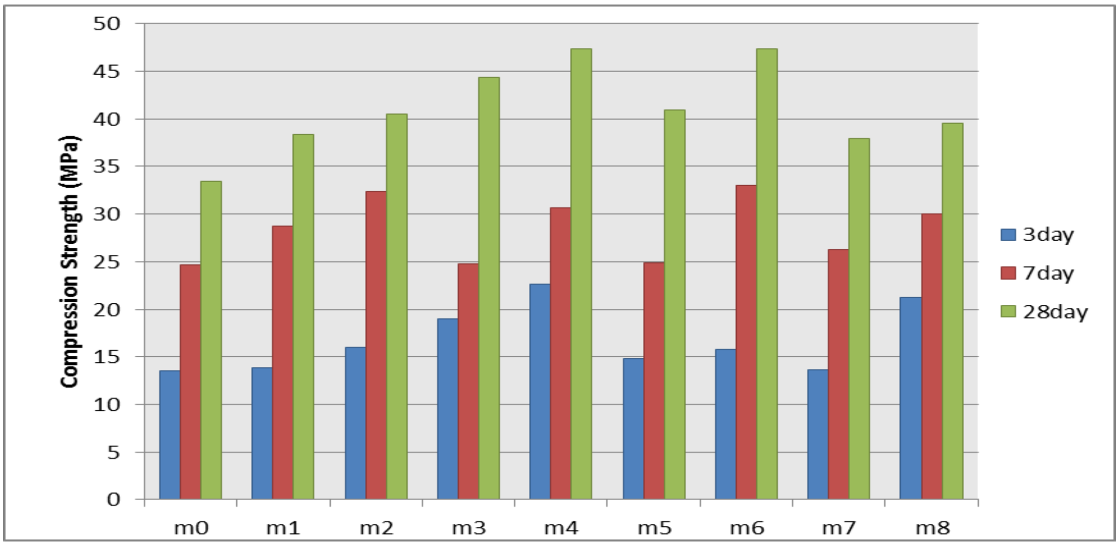
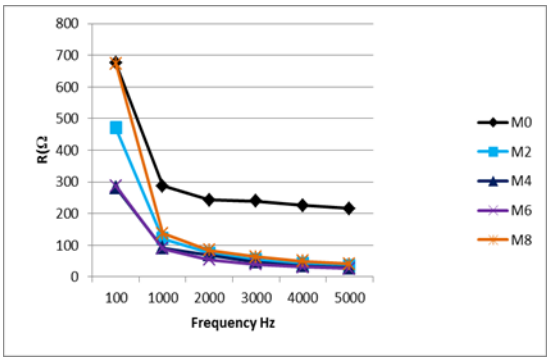


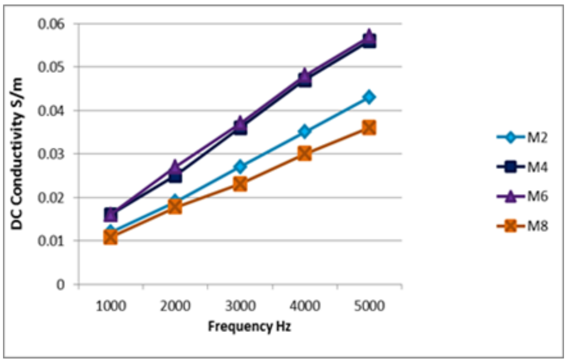
Figure 4: Results of compression strength.

II. Electrical conductivity results

The electrical conductivity is affected by the additions of the conductive materials as well as the presence of the pores in the concrete mixture. The distribution and mixing of the materials in a homogeneous manner has a great effect as well as the conductivity is affected by the temperature and humidity]9[. Figure5 shows the results of the electrical resistance as well as the electrical conductivity of the prepared samples, and it is evident from the figure that the mixture that contains steel fibers with steel wool, he showed improved results in an approach to the mixture containing steel fibers with (CNT), and these were the best results compared to the control mixture, and this corresponds to what was mentioned Doo-Yeol Yoo et. al]5[and Seon Yeol Lee et. al]9[, and the rest of the mixtures showed satisfactory results as well.



(a)

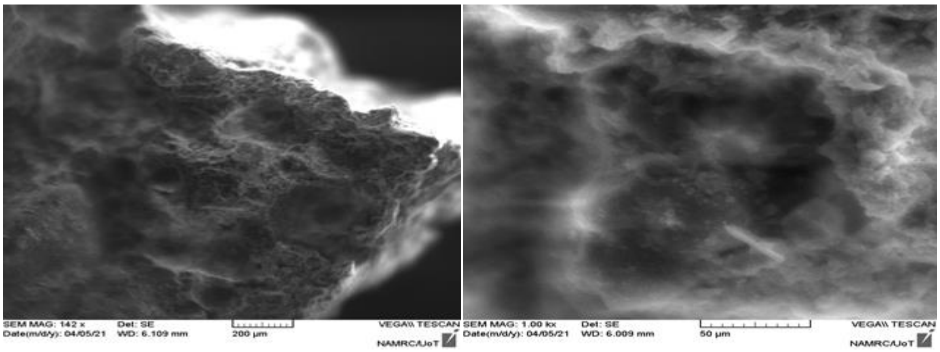


(b)

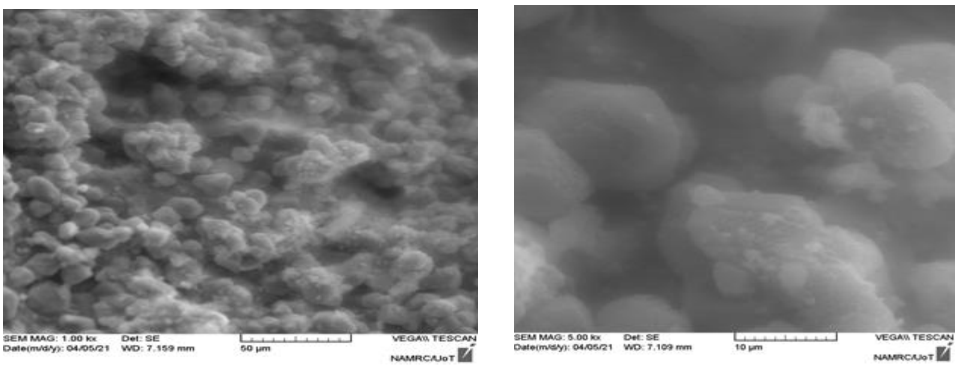
Figure 5: Results of the Mixture incorporated with steel fiber a- electrical resistance , b- electrical conductivity.

III. SEM result

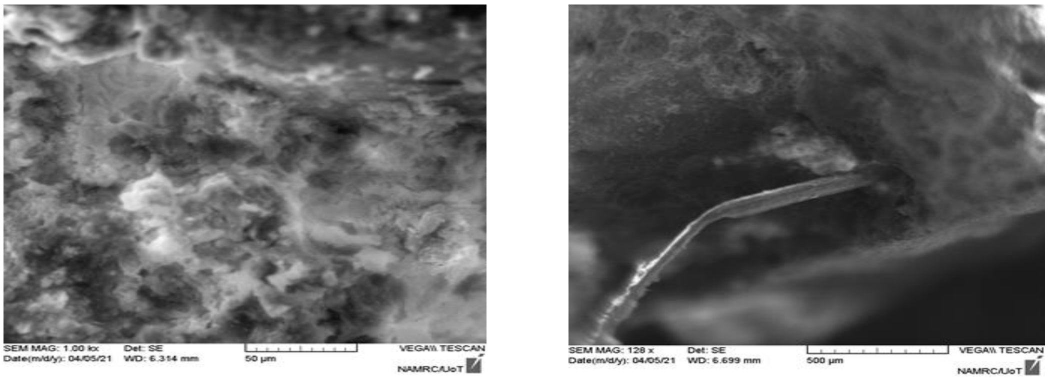
Figure 6 shows SEM images of prepared mixtures, Samples were examined at 7 days old. The results showed that the addition of (slag, carbon nanotube, steel wool, and corn husk ash) led to a change in the concrete's microstructure. The presence of these additives in the mixture gave a relatively thicker consistency. Figure 6-a shows the well and homogeneous distribution of furnace slag in the concrete mixture. Figure 6-b, Several Nano filaments have been distinguished because the nanotube are homogeneous and the concrete mixture is well known and the widespread MWCNT can be distinguished. This may be responsible for the good mechanical and electrical properties of the mixture. Figure 6-c shows that the cut steel wool fibers with steel fibers in the concrete mixture can form fiber groups and thus the conductive channels appear along with them Figure 6-d. Cornhusk ash with steel fibers in the concrete mixture is shown and a clear network helps give good properties to this mixture.



a-



b-



c-

d-

Figure 6: SEM result for concrete mixture incorporated with steel fiber(a-with 1%slag, b-with1%CNT, c-with 1%steel wool, d-with 1%corn ash).

IV. Dry density

Figure7 shows the dry density of the samples prepared at ages 3, 7, and 28 days. The figure shows that the density increases for all mixtures compared to the control sample, but it is higher at the greater substitution rate of cement. mixtures containing 1% by weight for all additives (slag, Carbon nanotube, steel wool, corn husks), but the rates of increase differ because of the difference in the density of the materials used, and it seems that these additives acted as fillers]22[, which improved properties and increased density]17[.

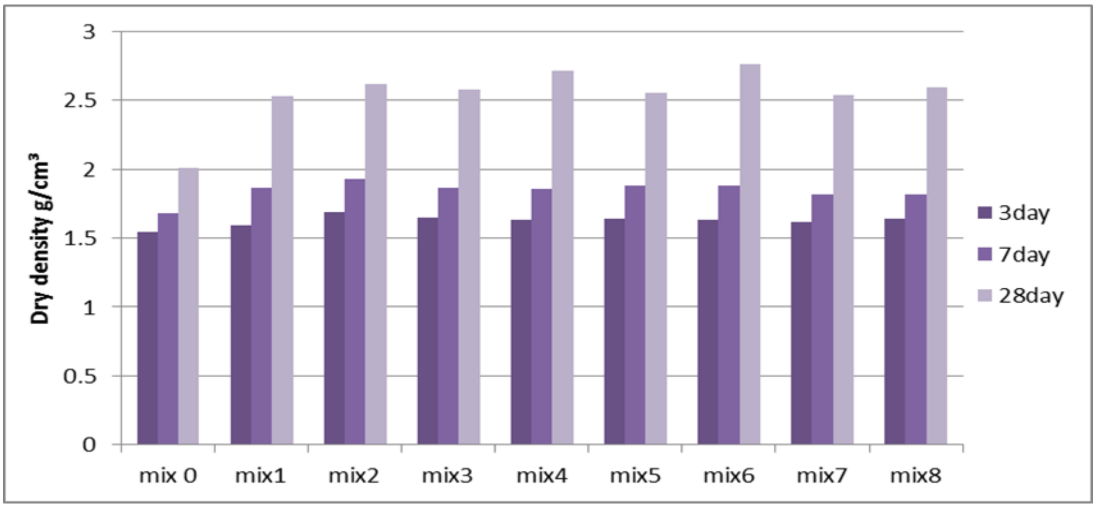


Figure 7: Results of dry density

4. CONCLUSIONS

The concrete reinforced with steel fibers of 6 cm length was studied with the use of agricultural and industrial wastes and carbon nanotube within the prepared mixtures, compression resistance, density, and electrical properties were studied.

Conclusions can be drawn from this study:

1.) It is possible to benefit from agricultural and industrial wastes such as corn husks prepared in this research and induction furnaces slag in concrete mixtures and this contributes to preserving the environment through the disposal of these wastes and their reuse, as well as the use of these materials, contributes to reducing the cost.

2.) Concrete containing Nanocarbon and steel fibers showed results of a comparable approach compared to The sample, which contains steel wool and steel fibers, achieved excellent results in the compressive strength test and the conductivity and electrical resistance test for both mixtures, and it scored 47, 4 MPa, and 47.34MPa, respectively, and the electrical conductivity was reached 0.056 S/m and 0.057 S/m.

3.) Concrete can be developed, improved mechanical, electrical, electromagnetic, and physical properties for use in advanced applications in conductive concrete and electromagnetic shielding.

References

[1] M. Usman, S. H. Farooq, M. Umair, A. Hanif, Axial compressive behavior of confined steel fiber reinforced high strength concrete, Constr. Build. Mater., 230 (2020) 117043-117052. https://doi.org/10.1016/j.conbuildmat.2019.117043

[2] E. E. Anike, M. Saidani, A. O. Olubanwo, M. Tyrer, E. Ganjian, Effect of mix design methods on the mechanical properties of steel fiber-reinforced concrete prepared with recycled aggregates from precast waste, Structures, 27 (2020) 664-672. https://doi.org/10.1016/j.istruc.2020.05.038

[3] A. Toghroli, P. Mehrabi, M. Shariati, N.T. Trung, S. Jahandari, H. Rasekh, Evaluating the use of recycled concrete aggregate and pozzolanic additives in fiber-reinforced pervious concrete with industrial and recycled fibers, Constr. Build. Mater., 252 (2020) 118997-119018. https://doi.org/10.1016/j.conbuildmat.2020.118997

[4] K. Ragalwar, W.F. Heard, B. A. Williams, D. kumar, R. Ranade, On enhancing the mechanical behavior of ultra-high performance concrete through multi-scale fiber reinforcement, Cem. Concr. Compos., 105 (2020) 103422-103437. https://doi.org/10.1016/j.cemconcomp.2019.103422

[5] D. Y. Yoo, M. C. Kang, H. J. Choi, W. Shin, S. Kim, Electromagnetic interference shielding of multi-cracked high-performance fiber-reinforced cement composites–Effects of matrix strength and carbon fiber, Constr. Build. Mater., 261 (2020) 119949-119963. https://doi.org/10.1016/j.conbuildmat.2020.119949

[6] F. Javahershenas, M. S. Gilani, M. Hajforoush, Effect of magnetic field exposure time on mechanical and microstructure properties of steel fiber-reinforced concrete (SFRC), J. Build. Eng., 35 (2021) 101975-101988. https://doi.org/10.1016/j.jobe.2020.101975

[7] J. Li, E. Zhao, J. Niu, C. Wan, Study on mixture design method and mechanical properties of steel fiber reinforced self-compacting lightweight aggregate concrete, Constr. Build. Mater., 267 (2021) 121019-121033. https://doi.org/10.1016/j.conbuildmat.2020.121019

[8] A. A. Raheem, B. D. Ikotun, Incorporation of agricultural residues as partial substitution for cement in concrete and mortar–A review, J. Build. Eng., 31 (2020) 101428-101441. https://doi.org/10.1016/j.jobe.2020.101428

[9] S.Y. Lee, H. V. Le, D. J. Kim, Self-stress sensing smart concrete containing fine steel slag aggregates and steel fibers under high compressive stress, Constr. Build. Mater., 220 (2019) 149-160. https://doi.org/10.1016/j.conbuildmat.2019.05.197

[10] N. Palankar, A. U. Shankar, B. M. Mithun, Durability studies on eco-friendly concrete mixes incorporating steel slag as coarse aggregates, J. Clean. Prod., 129 (2016) 437-448. https://doi.org/10.1016/j.jclepro.2016.04.033

[11] D. Micheli, A. Vricella, R. Pastore, A. Delfini, R.B. Morles, M. Marchetti, F. Santoni, L. Bastianelli, F. Moglie, V.M. Primiani, V. Corinaldesi, A. Mazzoli, J. Donnini, Electromagnetic properties of carbon nanotube reinforced concrete composites for frequency selective shielding structures, Constr. Build. Mater., 131 (2017) 267-277. https://doi.org/10.1016/j.conbuildmat.2016.11.078

[12] M. Jung, Y.S. Lee, S.G. Hong, J. Moon, Carbon nanotubes (CNTs) in ultra-high performance concrete (UHPC): Dispersion, mechanical properties, and electromagnetic interference (EMI) shielding effectiveness (SE), Cem. Concr. Res., 131 (2020) 106017-106031. https://doi.org/10.1016/j.cemconres.2020.106017

[13] L.A. Qureshi, B. Ali, A. Ali, Combined effects of supplementary cementitious materials (silica fume, GGBS, fly ash and rice husk ash) and steel fiber on the hardened properties of recycled aggregate concrete, Constr. Build. Mater., 263 (2020) 120636-120648. https://doi.org/10.1016/j.conbuildmat.2020.120636

[14] X. Shi, P. Park, Y. Rew, K. Huang, C. Sim, Constitutive behaviors of steel fiber reinforced concrete under uniaxial compression and tension, Constr. Build. Mater., 233 (2020) 117316-117330. https://doi.org/10.1016/j.conbuildmat.2019.117316

[15] M. Shakouri, G. L. Exstrom, S. Ramanathan, P. Suraneni, J. S. Vaux, Pretreatment of corn stover ash to improve its effectiveness as a supplementary cementitious material in concrete, Cem. Concr. Compos., 112 (2020) 103658-103667. https://doi.org/10.1016/j.cemconcomp.2020.103658

[16] Testing hardened concrete- Part3: Compressive strength of test specimens, UK, BSEN 12390-3. 2001.

[17] A.A. Hamead, S. S. Ahmed, S. R. A. Azzat, M. S. Abed, A. B. Al.zubaidi, G. K. Hammod, Employing recycling materials for the fabrication of smart mortar, Mater. Today: Proc., 20 (2020) 397-402. https://doi.org/10.1016/j.matpr.2019.09.154

[18] T. S. Al-Attar, S. S. Abdul-Qader, H. A. Hussain, Torsional Behavior of Solid and Hollow Core Self Compacting Concrete Beams Reinforced with Steel Fibers, Eng. Technol. J., 37 (2019) 248-255. https://doi.org/10.30684/etj.37.7A.5

[19] A. Z. Dahesh, F. M. Othman, A. A. Abdul-hamead, Influence of Microfibers Additive on the Self-healing Performance of Mass Concrete, Eng. Technol. J., 39 (2021) 104-115. https://doi.org/10.30684/etj.v39i1A.1581

[20] S. J. Kadhim, The Effects of Using Steel Fibers on Self-Compacting Concrete Properties: A Review, Eng. Technol. J., 38 (2020) 1666-1675. https://doi.org/10.30684/etj.v38i11A.1678

[21] F. M. Othman, A. A. Abdul Hameed, S. I. Ibrahim, Studying the Effect of Nano Additives and Coating on Some Properties of Cement Mortar Mixes, Eng. Technol. J., 34 (2016) 553-566. https://doi.org/10.30684/etj.34.3A.10

[22] D. M. Abdullah, A. A. Abdullalhameed, F.M. Othman, Preliminary Investigation on G Cement Modified by Nano-Powder, Eng. Technol. J., 38 (2020) 143-151. https://doi.org/10.30684/etj.v38i2A.93