Tiles Manufacturing Using Silica Fume Cement and Tire Ash for Enhanced Durability in Construction

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Abstract. In this study, the possibility of adding tire ash (TA) and silica fume cement (SFC) to construction tiles to increase their structural integrity, wear resistance, and durability is examined. Waste tires used to form tire ash provides good potential in terms of carbon content and reinforcement qualities with good additive. Synthesis of tiles with different compositions was done; SFC content at 85, 80 and 70%; TA at 0, 5 and 15% and tungsten carbide as a fixed amount of 15%. Mechanical and durability characteristics such as surface hardness and resistance to corrosion were checked. Findings showed significant improvement in performance as TA content increased with a 15% TA reinforcement showing the best performance. The hardness increased by 21.2 per cent relative to control specimens and the rate of corrosion decreased by 94.4% after 72 hours exposure. Recycling of tire ash also helps in managing waste sustainably because it will decrease the environmental effect of wasted tires besides enhancing the performance of structural elements. This emission of waste reduction and material improvement fits the idea of the green building and a circular economy, and therefore, tire ash uses in producing sustainable tiles in the context of civil engineering should be adopted.

1 Introduction

The growing volume of waste tires is an important environmental issue because it is not easily decomposed and may be hazardous, like land contamination and emission of toxic agents during its disposal. To work out these issues, scientists are working on finding new means of recycling tire waste into value resources. The use of tire ash (TA) as a silicon-based compound reinforcer is one of the potential solutions. Carbon and other maintaining components are abundant in tire ash, which is a byproduct of the controlled burning of waste tires, thus it is an excellent prospect to improve the mechanical qualities of silicon-based materials. This paper involves the addition of tire ash into silicon-based compounds using the powder slurry technique and with different compositions, to determine the effect of tire ash on the hardness, corrosion resistance, and the overall performance of the material. Incorporating tire ash and tungsten carbide, the study will enhance its durability and

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workability to facilitate environmental-friendly sustainable approach towards industrial materials growth. The paper does not only add to the solid waste management, but also highlights the potential of tire ash as a high-performance reinforcement, which is in line with the global trends of a circular economy and resource-efficient production.

The application of waste materials of tires in silicon-based compounds fabrication and building has been extensively studied and showed a strong enhancement in mechanical characteristics, strength, and life cycle. In the article [1], the study conducted by researchers investigated the synergistic nature of fly ash and waste tires in fiber-reinforced silicon-based compounds in the context of strengthening and durability in cleaner production applications. In a similar fashion, [2] examined how waste rubber tires and waste wood ash can be mitigated in silicon-reinforced concrete with a focus on the ability of waste rubber fiber to enhance the setting properties as well as the mechanical behavior.

Studies on the use of fly ash in thermoplastic vulcanizates based on waste tire powder have also been done as evidenced by [3] whereby better reinforcement properties were recorded. Also, [4] investigated the production of silica powder using the ash of rice husk as an alternative to commercial precipitated silica in tire treads made of rubber which supports the idea that agricultural and industrial waste has some potential in improving material.

Concerning the field of soil reinforcement, [5] researched the topic of waste tire textile fiber reuse in enhancing soil stability and presenting it as efficient. Further discussion of how recycled tire fibers and glass fibers can be used to reinforce clay was also done by [6] that pointed out their advantage in geotechnical applications. Similarly, [7] compared pozzolanic binders in cementitious compounds strengthened with waste tire fibers and opined that they play significant roles in enhancing strength and durability.

The mechanical properties of the waste tire cord-reinforced silicon-based compounds were studied by [8], and they proved to be better in structural use. On the same note, [9] investigated compaction and strength characteristics of tire crumble fly ash-clay compounds, and they proved to be efficient in infrastructure applications. A detailed review by [10] has given the developments of geotechnical reinforcement with end-of-life tires with the highlight on sustainable uses of these tires.

The more recent experiments, including [11], addressed the soil reinforcement using waste tire textile fibers, which brought about some insights concerning small scale experimental tests that prove their usefulness. The bottom ash mortar with recycled tire steel fiber was also discussed by [12], which exhibited an increase in workability, mechanical strength, and microstructural integrity. Finally, [13] determined the stability of silicon-based compounds reinforced with scrap tire wastes and found out that these materials have greater resistant to degradation with time.

1.1 Objectives of the Study

The main purpose of the study is the creation and the description of the construction tiles that can be considered sustainable using waste tires ash (TA) and silica fume cement (SFC) to improve durability. The specific objectives are:

- To prepare tile samples with different tire ash concentration (0, 5 and 15) with constant silica fume (15) and tungsten carbide (15) concentration by using the powder metallurgy technique.
- To analyze the mechanical performance by using surface hardness test according to ASTM E384 standards.
- To evaluate durability property by ASTM G99 criteria by corrosion resistance testing, the mass loss and corrosion rate during 72 hours of exposure will be monitored.

- To determine the most appropriate tire ash content that will maximize the mechanical and durability characteristics and also enhance sustainable waste usage.
- To support the principles of a circular economy by showing that the recycling of waste tires into value-added construction materials is a feasible process to follow.

2 Materials and Methods

In general composites are usually entails taking a matrix material where reinforcement particles or fibers are scattered throughout the material to improve the overall characteristics. In the current study, copper matrix is most preferred based on its outstanding capability in heat, electricity, relatively lower weight and density, high specific and corrosion resistance, ductility, fatigue resistance, and machine-ability. The powder of pure copper is presented in fig 2a. It is also the tungsten carbide that is reinforced in a powder form (Fig. 2b) because it is highly hard, its ability to withstand higher temperatures, excellent electricity conducting properties, high melting and boiling points, high corrosive resistance, and low electrical resistivity. The Tire ash powder frequently demonstrated its characteristics to exhibit high strength with carrying less weight, causes pleasant wear resistance, cast-ability, and fabrication friendliness. Fig. 1 represents the research design.

2.1 Composite Matrix

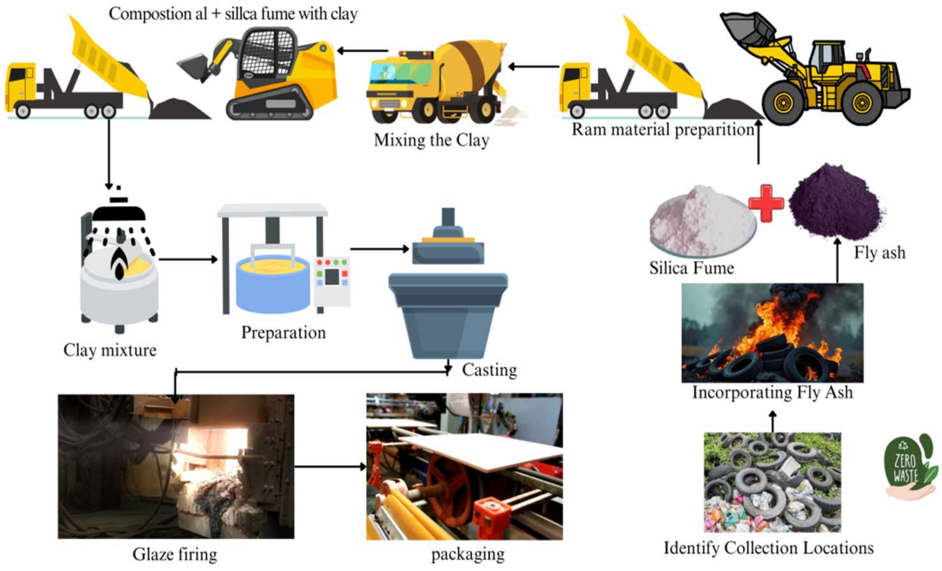

Fig. 1 Ceramic Tile Manufacturing Process Overview with Zero waste Management

Fig. 1 shows (a) silicon-based powder in its pure form, which is mainly made of the high-purity silicon particles with good thermal and electrical conductivity; and (b) silica-based cement powder, that is, Portland Silica Fume Cement, which is a combination of Portland cement and silica fume. The latter improves mechanical performance, resistance, and tolerance to the chemical attacks by improving the microstructure and permeability as well, so it is best applied in high-performance concrete applications. This paper aims at assessing the effect of tire ash (TA) as an additive to silica cement. In particular, it discusses the improvement of mechanical and durability of cement by adding TA and silica fume (SF) as shown in Fig. 2. Tire ash has been identified due to its high reactivity, pozzolanic property and resistance to aggressive environment, strength, and durability in cementitious system. The experimental design is a mix design that is aimed at maximizing the integration of TA in silica-based cement.

The cement matrix that is being studied includes ordinary Portland cement (OPC), silica fume (SF), and tire ash (TA). Cement is used as the main binder and silica fume is used in required proportions to increase compressive strength and performance. Addition of tire ash in small amount is mentioned to get to know how it influences in enhancement of mechanical and chemical qualities of cement. Table 1 and Fig. 1 below provide a detailed description of the research plan. The cement mix proportions will be given as follows: the mix-1 will be 85% OPC and 15% silica fume with 0% tire ash; the mix-2 will be 80% OPC, 15% silica fume, and 5% tire ash; and the mix-3 will be 70% OPC, 15% silica fume, and 15% tire ash. It aims to determine the impact of different TA content on the cement setting time, compressive strength and durability. Ordinary Portland cement, silica fume, and finely ground tire ash were used as materials in the study as revealed in Figs. 1a and 1b. Waste tires (Fig. 2a) were picked and the tires thoroughly washed off impurities and then they were burnt down to produce tire ash and shown in Fig. 2b.

Table 1. Plan of Study

Specimen	Constituents	TA Addition (%)
Mix-1	OPC 85% + SF 15%	0%
Mix-2	OPC 80% + SF 15% + TA 5%	5%
Mix-3	OPC 70% + SF 15% + TA 15%	15%

Where: OPC - Ordinary Portland cement, SF - Silica fume, TA –Tire Ash

3 Synthesising of Silica-Based Cement

The cement matrix that is being studied includes ordinary Portland cement (OPC), silica fume (SF), and tire ash (TA). Cement is used as the main binder and silica fume is used in required proportions to increase compressive strength and performance. Addition of tire ash in small amount is mentioned to get to know how it influences in enhancement of mechanical and chemical qualities of cement. Table 1 and Fig. 1 below provide a detailed description of the research plan. The cement mix proportions will be given as follows: the mix-1 will be 85% OPC and 15% silica fume with 0% tire ash; the mix-2 will be 80% OPC, 15% silica fume, and 5% tire ash; and the mix-3 will be 70% OPC, 15% silica fume, and 15% tire ash. It aims to determine the impact of different TA content on the cement setting time, compressive strength and durability. Ordinary Portland cement, silica fume, and finely ground tire ash were used as materials in the study as revealed in Figs. 1a and 1b. Waste tires (Fig. 2a) were picked and the tires thoroughly washed off impurities and then they were burnt down to produce tire ash and shown in Fig. 2b.

3.1 Method of Manufacturing

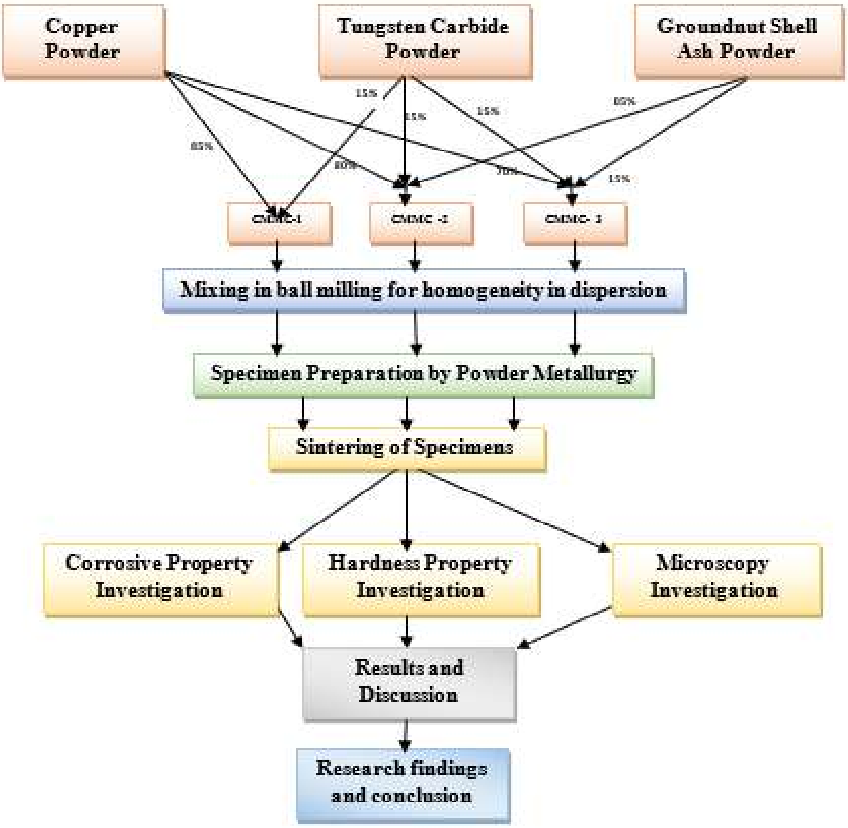

Fig 2. Specimen preparation techniques with Frame work

3.2 Blending and Sizing of Powders

The pre-treatment of the tire ash is heating processing whereby it is heated in a preheated oven (Fig. 3a and b) at 300 o C. This is done to provide assurance that the absorbed gases are eliminated off the ash particles and thus increase its compatibility in the cementitious matrix. The ash is pretreated and added to the cement mixture of silica. A ball mill is used to combine silicon and silica fume cement together with the preheated tire ash. The milling is done at 170 rpm spindle speed and one hour is taken to get even spread of the powders. Special attention is paid to the milling to prevent the possible difficulties of high temperatures, phase changes, including melting or sublimation, structural effects, including amorphization or polymorphic transformation. Thus, milling parameters such as the milling speed and milling time have a vital role in the production of the preferred characteristics of the silica-based cement.

Fig 3 (a) Preheating CSA Powders on Furnace **(b)** Blending and sizing of powders in Ball Mill

3.3 Compacting Of Specimens

Compacting refers to the process of forcing powdered materials into a given shape mold with the help of a hydraulic mechanism. It is done using a cylindrically shaped die of dimensions 50 mm in diameter and 40 mm in height. This study was using a hydraulic press of maximum capacity of 10 tons but compression force of 9.81 kN was used at 80 bar pressure. The die cavities are filled with the powder mixture after which the mixture is pressed to create a solid specimen as indicated in table 2. After the compaction is fully made, the resulting specimen is ejected out of the die with considerable caution. Final product density is based on pressure used. To achieve homogeneity and structural integrity that is discussed in Fig 4(a) and (b), cylindrical specimens, 50 mm in length of cylinder and 40 mm in thickness, were made under the following conditions to ensure uniform and structural integrity.

Table 2. Choice of manufacturing of silicon-based compounds.

Method	**Constraints of Shape and Size**	**Expected Yield of Material**	**Constraint of Volume Fraction**	**Status of Reinforcement**	**Expenditure**
Liquid Metallurgy or Stir Casting Process	Huge varieties of shapes permitted; but maximum mass not more than 500kg	Material yield is very high, greater than 90%	Maximum 0.3 is permitted	Very safe, i.e., no damage to silicon	Cheaper than other processes
Squeeze Casting Process	Restricted to a large variety of shapes	Material yield will be low	The volume fraction up to 0.45 is good	There will be severe damage to silicon	Moderate cost
Powder Metallurgy	Wide range; restricted size	High material yield is possible	-	Silicon fracture occurs due to high pressure and temperature	Costly
Spray Casting Process	Shapes are limited but not size	Medium-high material yield can be obtained	The permitted range is from 0.3 to 0.7	-	Costly

Fig 4. (a) Compacting of Specimens in Hydraulic Press **(b)** Sintering of specimens in Box Furnace

3.4 Sintering of Specimens

Curing or sintering is the process whereby compacted powders are converted to solid structures by using either heat or pressure. Thermal sintering process was used in this study. In this procedure, the specimens were subjected to heating in the box furnace by heating them at room temperature and progressively raising the temperature, at a controlled rate of 5 ^{0}C per minute up to 600 ^{0}C. The overall time of sintering was 2 hours (120 minutes) which was adequate to enable diffusion of atoms between particles and hence fusion of particles leading to formation of a cohesive structure, as shown in Fig. 5. To determine the mechanical and structural properties of the synthesized silica fume cement, the silicon-based silica cement specimens were characterized in different ways, which included hardness test, corrosion resistance test, and microscopic examination. Fig. 5a, Fig. 5b and Fig. 5c are silicon-based silica fume cement of various reinforcement levels SFC1 (0% TA Reinforcement), SFC2 (5% TA Reinforcement) and SFC3 (15% TA Reinforcement) that are synthesized.

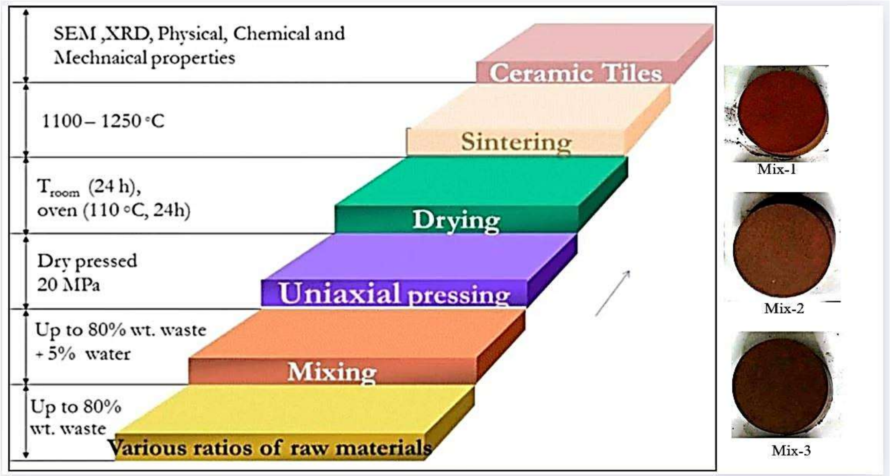

Fig 5. Synthesized Silicon fume cement cylindrical moulding

4 Characterization of Silicon Fume Compounds

4.1 Micro Hardness Investigation

Table 3. Surface Hardness of Copper and SFC specimens

Description of Measurements	**Description of Material**		
	SFC-1	**SFC-2**	**SFC-3**
First Trail	55.8	61.1	67.2
Second Trail	56.2	60.2	68.1
Third Trail	55.4	59.3	67.7
Average	55.8	60.2	67.67

Micro hardness testing is usually used to test materials, and to perform this paper, the micro hardness of the samples was done through a Micro Vickers Hardness Tester with a 0.01 mm level of precision. Vickers scale was used to measure the hardness, where a test load of 0.5 kg was used to apply a dwell time of between 10 and 15 seconds. One unit of measurement was made 0.1 kgf load. The instruments employed were the Wilson Wolpert Micro Vickers Hardness Tester manufactured in Germany that has a load range of 10-1000 g, and also the Vernier caliper that would be used to take the precise dimension measurements. To achieve an accurate result, the mean of three independent observations was calculated and the data is given in Table 3.

4.2 Corrosiveness Investigation

The analysis of corrosion is conducted in accordance with the ASTM G99 standard to guarantee reliability. An important part of this procedure is the preparation of the specimens that are formed in the shape of square prism with a size of 15 x 15 x 10 mm. To clearly view the effects of corrosion, the specimens are polished in succession using abrasive papers of different grits, starting with the coarse (180 grit) ones, then the finer ones (240, 300, and 400 grit) and finally, the specimens are thoroughly washed using soapy water to remove any particles of the polish balance and finally with distilled water to wash off the very little traces of soap. The dried samples in the desiccators and polarization tests in tests were carried out in an apparatus of make PGP 201, potentio-stat and galvano-stat apparatus, at a paradigm scan speed of 166.7 μV/s, which is reflected in Fig 6. The solution of NaCl was 3.5% with Seawater preferred to make Electrolyte solution. The corrosion polarization test at 500mV. The specimens were then cleaned with the non-aqueous solvent to make sure that there was no effect on the properties of the materials. The properties of corrosion test are as outlined in Table 4. The degradation process was followed during 72 hours and the time interval was regularly checked using USB camera and recording the material loss growth at different intervals to determine the degree of deterioration of the material. Table 5 shows the specifics of the periodical observations of the mass loss of compounds due to corrosion. Table 6 summarizes the corrosion rate each of the observations mm/yr. Table 7 gives the standard notation of mils per year.

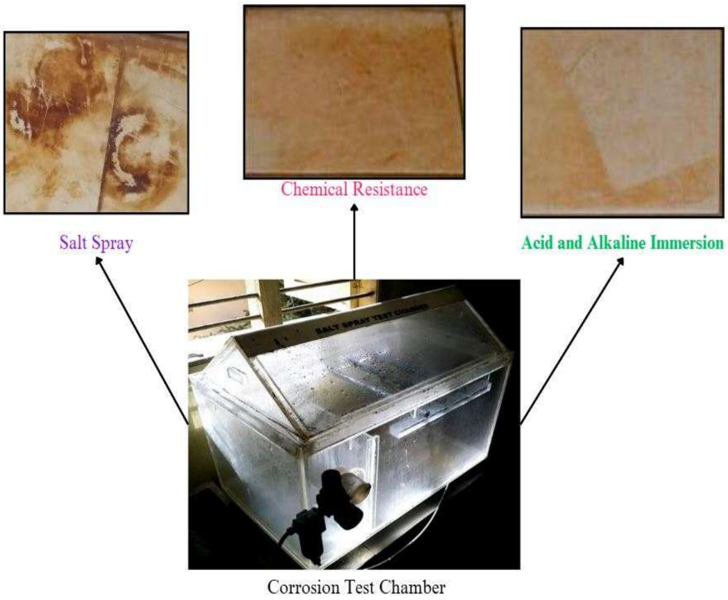

Fig. 6 PGP 201 potentiostat and galvanostat Corrosive Testing Equipment

Table 4. The Corrosive Test Parameters

S.No.	Process	Testing Parameters
1	Humidity	98%
2	Ambient Temperature	From 33^{0}C to35 ^{0}C
3	Ambient air Pressure while atomizing	Maintained in the range of 2- 3bar
4	Salt solution's Composition NaCl 5% , $MgCl_2$1% and Distilled water 94%	The contents applicable per litter of salt solution.
5	Required pH value	Buffer Solution employed to maintain the pH valued as 7.5
6	Frequency of Measurement of pH	Measured once in8hours
7	Holding of specimens	The specimens hanged with help of plastic wires between specimens and hangers

The corrosive testing instruments in the investigation include a 201 potentiostat and galvanostat, which are keys in testing the corrosion characteristics of the compounds in different environments. The parameters of the corrosive test as already indicated in Table 4 comprise of a humidity level of 98 with ambient temperature to be maintained between the ranges of 33 o C and 35 o C. The pressure in the surrounding atmosphere during the atomization of the salt solution is also kept between 2-3 bar. The salt solution that will be used in the testing is 5% NaCl, 1% MgCl2 and 94% distilled water with the composition applied per liter. To ensure that the PH remains at the necessary level of 7.5, a buffer solution is used and the PH is recorded after every 8 hours. Plastic wires are then used to retain the specimens between the specimens and the hangers.

The change in the description of the compounds of the synthesized silicon-based silica fume cement samples (SFC-1, SFC-2, and SFC-3) shows that the properties of the materials have changed progressively with an increase in the time in which they were exposed. The values were 1.807, 0.861, and 0.273 at 8 hours: respectively, SFC-1 (0% TA), SFC-2 (5% TA), and SFC-3 (15% TA). The values progressively increased with the increase in the exposure time in all of the compositions indicating that the structures changed because of extended exposure. SFC-1, SFC-2, and SFC-3 had values of 1.874, 0.892, and 0.284 respectively by 24 hours. The trend was followed, with significant increases in 40 hours (1.988, 0.947, and 0.301), which demonstrated the strengthening effect of TA. The maximisation was recorded at 72 hours with SFC-1 having its highest value of 2.249, SFC-2 a highest value of 1.074 and SFC 3 had its highest value of 0.341 which indicated that the greater the TA reinforcement, the lower the values of the compound description over time. The findings indicate that the more the TA reinforcement, the greater the silica fume cement stability and the composition, which may improve the mechanical or durability properties.

Table 5. Mass Loss in Grams by Corrosion of compounds over time

Time of Exposure (Hours)	Description of Compounds		
	SFC-1 (0% TA)	SFC-2 (5% TA)	SFC-3 (15% TA)
8	1.807	0.861	0.273
16	1.826	0.870	0.276
24	1.874	0.892	0.284
32	1.941	0.924	0.294
40	1.988	0.947	0.301
48	2.063	0.982	0.312
56	2.091	0.996	0.316
64	2.132	1.015	0.332
72	2.249	1.074	0.341

The corrosion rate of the synthesized silica fume cement specimens (SFC-1, SFC-2 and SFC-3) in mm per year showed a cumulative tendency over the years, as shown in table 6. At first, the rate of corrosion was 0.001374 mm/year with SFC-1 (0% TA), 0.000424644 mm/year with SFC-2 (5% TA) and 7.73416E-05 mm/year with SFC-3 (15% TA). With longer exposure period, there was a steady incremental pattern in all the compositions which showed gradual degradation of the material. Optimal rates of corrosion were realized at 72 hours of time with SFC-1 having 0.001710 mm/year, SFC-2 having 0.000531264 mm/year and SFC-3 having 9.64537E-05 mm/year. This indicates that the corrosion rate decreased considerably when TA was increased in silica fume cement matrix, and this made the material more durable when exposed to long term conditions.

Table 6. Rate of Corrosion in mm per year of compounds over time

Time of Exposure (Hours)	**Description of Composite**		
	SFC-1 (0% TA)	**SFC-2 (5% TA)**	**SFC-3 (15% TA)**
8	0.001374	0.000424644	7.73416E-05
16	0.001388	0.000429091	7.81515E-05
24	0.001425	0.000440300	8.01930E-05
32	0.001476	0.000456025	8.30570E-05
40	0.001512	0.000467257	8.51028E-05
48	0.001568	0.000484672	8.82747E-05
56	0.001590	0.000491342	8.94895E-05
64	0.001621	0.000500953	9.39235E-05
72	0.001710	0.000531264	9.64537E-05

Table 7 Rate of Corrosion in Mils per year of compounds over time

Time of Exposure (Hours)	**Description of Compounds**		
	SFC-1 (0% TA)	**SFC-2 (5% TA)**	**SFC-3 (15% TA)**
8	0.648526	0.200432027	0.036505238
16	0.655316	0.202530791	0.036887492
24	0.672435	0.207821427	0.037851090
32	0.69645	0.215243621	0.039202914
40	0.713604	0.220545188	0.040168503
48	0.740202	0.228765350	0.041665664
56	0.750388	0.231913497	0.042239045
64	0.765066	0.236449889	0.044331896
72	0.80712	0.250756372	0.045526146

The corrosion rate in mils per year of the silica fume cement specimens (SFC-1, SFC-2 and SFC-3) demonstrated a slow progression with increasing exposure time as presented in Table 7. The initial 8-hour records at 0.648526 mils/year were of SFC-1 (0% TA), the 0.200432027 mils/year of SFC-2 (5% TA) and 0.036505238 mils/year of SFC-3 (15% TA). The rate of corrosion was increasing as the exposure time rose with the values of 0.672435 mils/year, 0.207821427 mils/year, and 0.037851090 mils/year attained at 24 hours by SFC-1, SFC-2, and SFC-3, respectively. At 48 hours, the values further went up to 0.740202 mils/year, 0.228765350 mils/year, and 0.041665664 mils/year. The maximum corrosion was calculated at 72 hours of where SFC-1 had 0.80712 mils/year, SFC-2 had 0.250756372 mils/year and SFC-3 had 0.045526146 mils/year. The findings have shown that TA reinforcement of the silica fume cement matrix enhanced a significant reduction in the rate of corrosion, which has shown greater corrosion resistance in the material over the long run.

4.3 Microscopy Investigation

In this analysis concentrated beam of electrons that is used to scan the specimen surface. The principle of such examination is: interaction of focused beam of electrons with test materials and produce informative signals to capture image. The image can be used to analyze the constituents of the test material and topography of its surface which was depicted in Fig 7. Therefore, through the scanning electron microscopy analysis (SEM), it is possible to ensure the uniform distribution of the reinforcement. The specifications of the equipment used are: the Resolution 3nmat30KV accelerating voltage, 1u probe current using tungsten filament in High Vacuum mode and4.0nm, The MagnificationTo1,00,000X. Fig 8 depicts the SEM images of SFC-1, Fig 9 the pics of SFC-2 and Fig 10 of SFC-3 of and reinforced silica-based compound e of the first and second kind respectively.

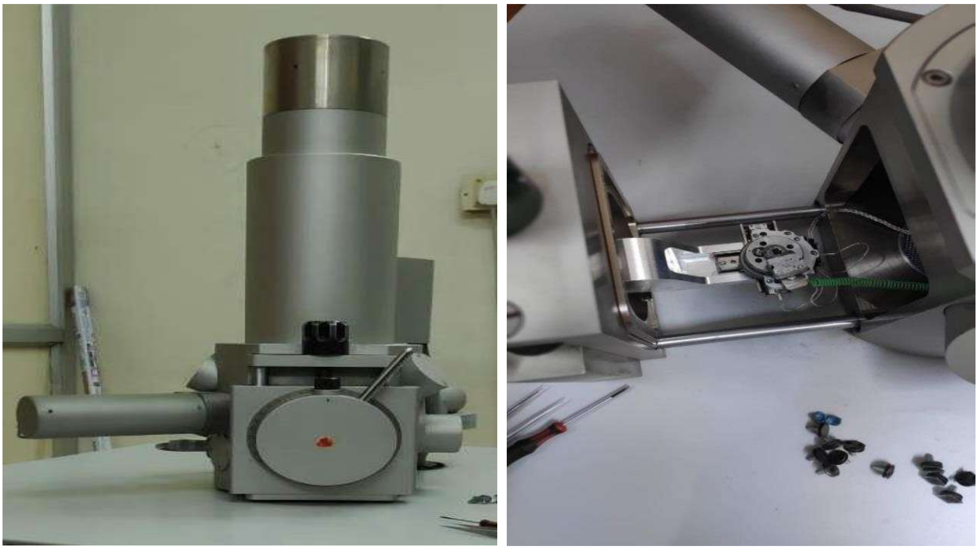

Fig 7. a) Scanning Electron Microscopy b) sample loading on the SEM

5 RESULTS AND DISCUSSION

The objective of this research was to prepare and characterize silicon fume cement, the first, second and third kinds of silicon fume cement in terms of surface hardness, corrosive property and scanning electron microscopic investigation. Discussion of the results of the characterization is below Fig 8.

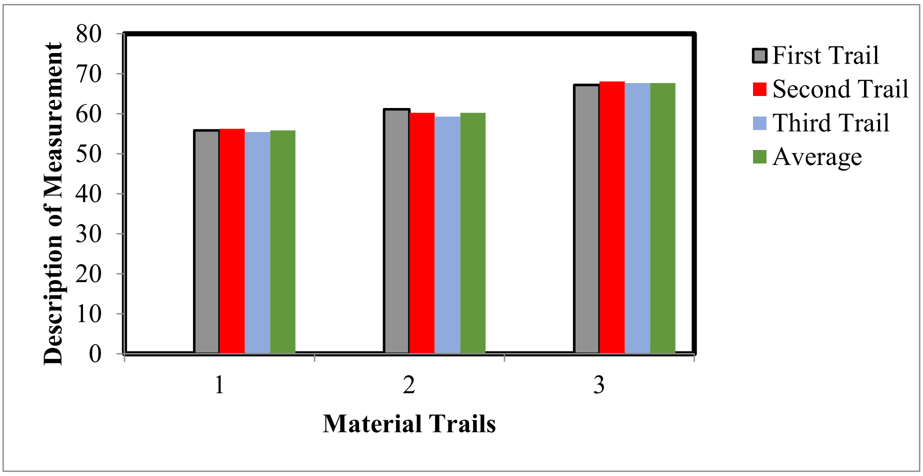

Fig. 8 Surface Harness of SFCs

5.1 Surface Hardness Of SFC

Fig 9 shows the hardness of surfaces of SFCs. CMM-1 is made of 85% copper and 0% TA reinforcement SFC-2 is made of 80% copper and 5% TA reinforcement and the SFC-3 is made of 70% copper but 15% TA reinforced. The outcome of the test shows that the enhancement of TA reinforcement enhances the property of surface hardness. Hardness of the specimen when reinforced with TA in every percent was found to improve by a factor of approximately 0.357 HV.

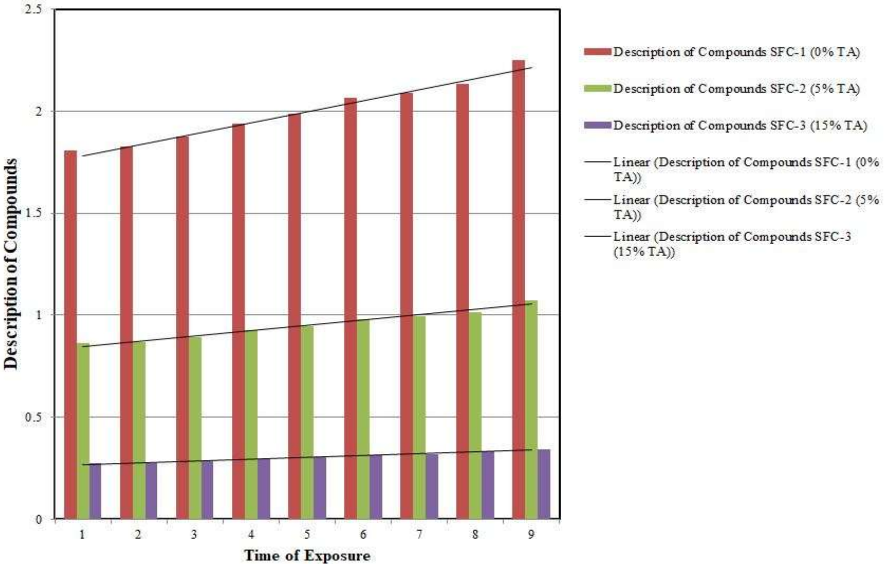

Fig. 9 Comparative Mass loss by corrosion of SFC

5.2 Corrosive Property Of SFC

Fig 9 demonstrates the hardness of surfaces of SFCs. CMM-1 is made of 85% copper and 0% TA reinforcement SFC-2 is made of 80% copper and 5% TA reinforcement and the SFC-3 is made of 70% copper but 15% TA reinforced. The outcome of the test shows that the enhancement of TA reinforcement enhances the property of surface hardness. Hardness of the specimen when reinforced with TA in every percent was found to improve by a factor of approximately 0.357 HV. According to standard the weight loss caused by corrosion is monitored every 8 hours of exposure and plotted in Fig 9.

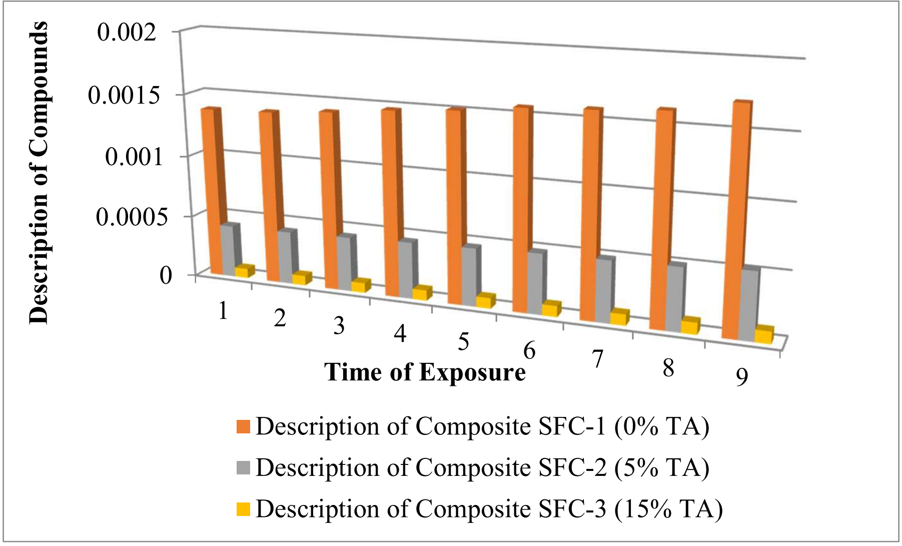

Fig. 10 Rate of Corrosion of SFC in mm per year

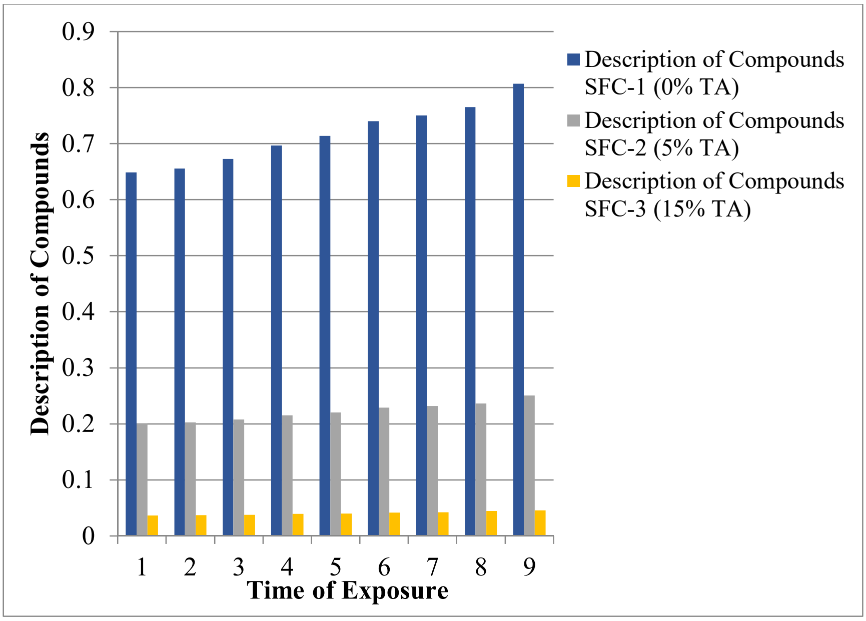

Fig. 11 The Rate of Corrosion of SFC in mils per year

The supposed rate of corrosion as determined by the same method as the dimensional change of the period gap of 8 hours of exposure and indicated in graphical form of Fig 10. Then the rate of corrosion was calculated in accordance with the investigation. The 72 Hrs exposure results of the corrosion condition of SFC-1, SFC-2 and SFC-3 are 0.807874016 Mils per year, 0.250393701mils per year and 0.045568677 Mils per year respectively. Fig 11 gave the same comparatively in all observations. Based on the demonstrative graph, one can realize that the higher the TA reinforcement, the lower the rate of corrosion.

5.3 Investigation on Dispersion Of compounds

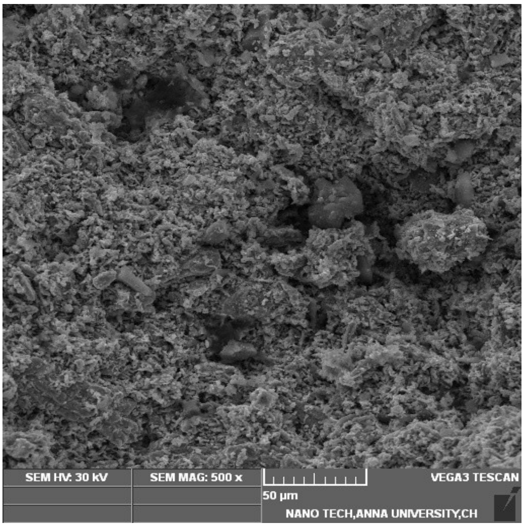

Fig. 12 SEM Image of SFC-1 (0% TA) showing uniform distribution of silica fume cement particles in silicon matrix

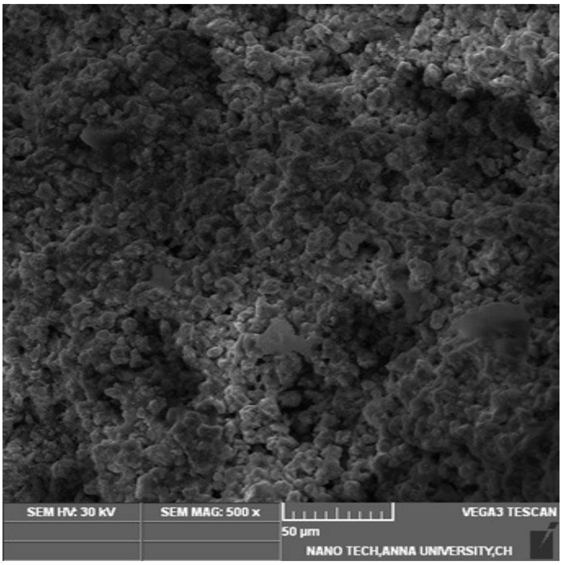

Fig. 13 SEM Image of SFC-2 (5% TA) showing uniform dispersion of tire ash and silica fume cement particles

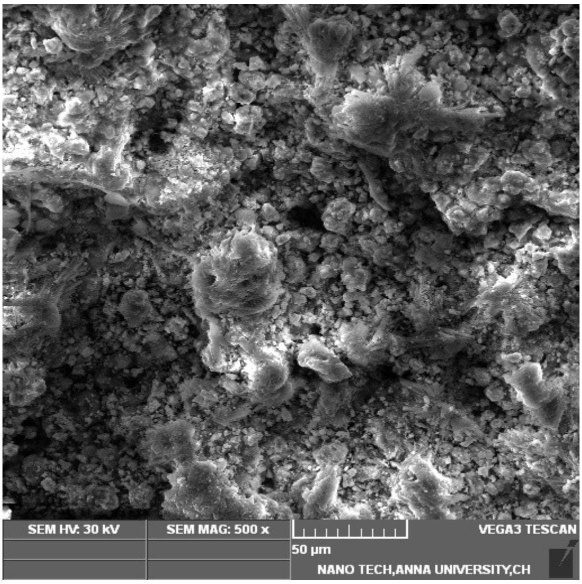

Fig. 14 SEM Image of SFC-3 (15% TA) showing uniform distribution of tire ash and silica fume cement particles with denser microstructure

Strong microscopy can be used to study the topography of specimens. The SEM analysis is utilized in this study to take the picture of topography of specimens. The apparatus used to utilize concentrated beam of electrons to record the inside data of the material. The synthesized SFC-1, SFC-2 and SFC-3 tested and image of the same, fig 12 shows the SEM image of SFC-1. The same image proves that the silica fume cement particles are uniformly distributed in the silicon compounds. Fig 13 is a SEM image of SFC-2 whereby the silica fume cement spreads uniformly throughout the silicon compounds together with the TA. TA density is low since it was 5%. Fig 14 attests to the homogenous distribution of both silica fume cement and TA. In these compounds, the TA, and silica fume cement are both 15 percent in equal quantities used in reinforcing the silica compounds.

6 CONCLUSION

The silicon compounds which reinforced by tire ash along with silica fume cement is discussed. Three kinds of compounds synthesized and characterized. The silica fume cement weight percentage was kept constant at 15%. The compounds synthesized by the powder lurgy process. The homogeneous distribution of reinforcement particles was confirmed by electron microscopy examinations for all three compounds. The tire ash powder weight percentage varied as 0%, 5% and 10%. The following conclusions derived.

- Tire ash reinforcement can be used to enhance the properties of silicon-based compounds. The hardness of silica fume cement which is 7.89 percent can be reinforced by 5 percent weight fraction of the tire ash. Tire ash reinforcement 15 weight fraction can be added to the 21.27% of hardness of the silicon-based compounds.
- In 52.36% of the mean mass loss through corrosion of silicon-based compounds can be lessened using 5% reinforcement weight of tires ash. Use of tire ash reinforcement in 15% weight fraction can be used in reduction of 94.35 percent average corrosion rate in mils per year corrosion of silicon-based compounds.

- ASTM G99 corrosion testing showed that increased TA reinforcement decreased the corrosion rates significantly. Exposure of SFC-1 in 3.5% NaCl electrolyte showed corrosion rate of 0.00171 mm/year, SFC-2 had rate of corrosion of 0.000531 mm/year (69 reduction), SFC-3 had rate of corrosion of 0.0000965 mm/year (94.4 reduction). The trends in mass loss were consistent with improved durability with the incorporation of TA.
- A combination of Mix-3 opc reinforcement proved to be the best composition based on the total analysis, as it delivered the most desirable hardness (67.67 HV) and corrosion resistance (94.4% reduction in corrosion rate).
- SEM analysis was used to verify that the dispersion of reinforcement particles was homogeneous in all the specimens. SFC-3 was the least agglomerated with the highest homogeneous distribution, which was why it exhibited superior mechanical and durability properties.
- This paper shows successful valorization of waste tires (around 1.5 kg of tire wastes used per 10 kg of tile manufacturing with 15% TA content), which can be added to the principles of the circular economy and sustainable construction.

References

1. Khan, M., Rehman, A., & Ali, M, Efficiency of silica-fume content in plain and natural fiber reinforced concrete for concrete road. Construction and Building Materials, 244, 118382 (2020)
2. Mucsi, G., Szenczi, Á., & Nagy, S, Fiber reinforced geopolymer from synergetic utilization of fly ash and waste tire. Journal of Cleaner Production, 178, 429-440 (2018)
3. Arunkumar, K., Muthukannan, M., & Ganesh, A. C, Mitigation of waste rubber tire and waste wood ash by the production of rubberized low calcium waste wood ash based geopolymer concrete and influence of waste rubber fibre in setting properties and mechanical behavior. Environmental Research, 194, 110661 (2021)
4. Sridhar, V., Xiu, Z. Z., Xu, D., Lee, S. H., Kim, J. K., Kang, D. J., & Bang, D. S, Fly ash reinforced thermoplastic vulcanizates obtained from waste tire powder. Waste Management, 29(3), 1058-1066 (2009)
5. Amin, M., Zeyad, A. M., Tayeh, B. A., & Agwa, I. S, Effect of ferrosilicon and silica fume on mechanical, durability, and microstructure characteristics of ultra high-performance concrete. Construction and Building Materials, 320, 126233 (2022)
6. Abbaspour, M., Aflaki, E., & Nejad, F. M, Reuse of waste tire textile fibers as soil reinforcement. Journal of cleaner production, 207, 1059-1071 (2019)
7. Mehta, A., & Ashish, D. K, Silica fume and waste glass in cement concrete production: A review. Journal of Building Engineering, 29, 100888 (2020)
8. Mastali, M., Dalvand, A., Sattarifard, A. R., Abdollahnejad, Z., Nematollahi, B., Sanjayan, J. G., & Illikainen, M, A comparison of the effects of pozzolanic binders on the hardened-state properties of high-strength cementitious composites reinforced with waste tire fibers. Composites Part B: Engineering, 162, 134-153 (2019)
9. Łach, M., Kiszka, A., Korniejenko, K., & Mikuła, J, The mechanical properties of waste tire cords reinforced geopolymer concretes. In IOP Conference Series: Materials Science and Engineering (Vol. 416, No. 1, p. 012089). IOP Publishing (2018)
10. Adil, G., Kevern, J. T., & Mann, D, Influence of silica fume on mechanical and durability of pervious concrete. Construction and Building Materials, 247, 118453 (2020).

11. Shariati, M., Afrazi, M., Kamyab, H., Rouhanifar, S., Toghroli, E., Safa, M., & Afrazi, H, A state of the art review on geotechnical reinforcement with end life tires. Glob. J. Environ. Sci. Manag, 10(1), 385-404. (2024)
12. Markpiban, P., & Sahamitmongkol, R, Workability, mechanical properties, and microstructure analysis of bottom ash mortar reinforced with recycled tire steel fiber. Buildings, 13(10), 2514 (2023)
13. Zhang, J., Huang, Y., Ma, G., & Nener, B, Mixture optimization for environmental, economical and mechanical objectives in silica fume concrete: A novel frame-work based on machine learning and a new meta-heuristic algorithm. Resources, Conservation and Recycling, 167, 105395 (2021)