MICROSTRUCTURAL CHARACTERISTICS AND CHEMICAL RESISTANCE OF CEMENT CONCRETE MADE USING SILICA FUME AND CERAMIC WASTE AS COARSE AGGREGATE

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Abstract

The most effective way to reduce the demand for natural resources in the manufacturing of concrete is to completely substitute traditional concrete ingredients with M-sand and electrical insulator ceramic waste aggregate (0 to 100) percent and cement replaced by silica fume (0, 5, 10, 15). The use of ceramic waste aggregate and silica fume could contribute to a more compact and dense concrete microstructure, which enhances the concrete resistance to the ingress of aggressive substances. The overall service life of concrete structures can be improved by incorporating ceramic waste aggregates, making methods of building more sustainable and economical with good resistance to chemical attacks such as alkaline resistance and Chloride penetration, Acid attack test HCI and microstructural properties. A more compact and stable ITZ can reduce the permeability of the concrete, which is essential for its durability. Lower permeability means reduced ingress of harmful substances like water, chlorides, and other aggressive agents, enhancing the concrete's resistance to chemical attacks and reinforcing its long-term durability. The test result showed that the morphology in comparison to natural aggregate-paste, the Silica fume with Ceramic waste aggregate-paste has a more compact and stable microstructure at the interfacial transition zone (ITZ).

Keywords: Microstructure properties, HCI, RCPT, Ceramic waste Aggregate

1. Introduction

Substitutions to concrete Reusing demolition ceramic debris as aggregate was studied in Durability of Concrete using Recycled Ceramic Aggregate. Even while this can partially address a pre-saturation technique, the fundamental issue with these aggregates is their excessive water absorption. Concrete's strength reduces as ceramic aggregate quality improves. Compared to the primary stone aggregates, the resistance tends to be lower. Researchers have looked into the viability of using industrial ceramic waste as a replacement for crushed stone aggregate in concrete. The findings show that ceramic waste works well as coarse aggregate and that its strength properties are similar to those of ordinary concrete. The current study examines the feasibility of incorporating ceramic waste into concrete. The results show that, despite a slight loss in strength, 20% replacement for cement in concrete improves durability efficiency. Permeation is the term used to describe the passage of gases, liquids, and ions through concrete. Diffusion, absorption, and permeability are three different permeation techniques that harmful compounds might use to pass through concrete. In reinforced concrete constructions, the absorption of water creates a pathway for the penetration of harmful substances like chloride and sulphate ions, which can cause the reinforcement to corrode. Concrete permeation properties can be measured to determine how long concrete will last. This article discusses the mechanical and physical characteristics of M-Sand and ready-mixed concrete made with M-Sand. The study concludes that M-Sand is a good and practical replacement for river sand and could be utilized successfully in RMC, providing enough strength and durability for the concrete. Rubber trash has been added to concrete to aid in the disposal of this solid waste. The implications of a chemical prior treatment with sodium hydroxide solution (NaOH) on the mechanical, microstructural, and physical properties of concretes with a pair rubber residue material as an alternative for natural fine aggregate and the inclusion of silica fume as a substitute for Portland cement were examined in this study. The effect of treating rubber and silica fume on the microstructure of concretes was examined using X-ray microtomography and scanning electron microscopy. To lessen concrete's demand on natural aggregates as its primary source of aggregate. Alternatives for the construction industry include artificially produced aggregates and artificial aggregates made from industrial waste. The fundamental methods for reducing the discharge of solid waste. The recovery of unusable materials and the decrease in waste production have been the main areas of concern. Wasted raw materials and making the best use of wasted raw materials.

[1] Alkali-activated geopolymer is a desirable way to reduce the negative effects of cement production. This study examines the effects of geopolymers including fly ash and silica fume on the environment. To complete a life cycle evaluation, 3 geopolymer concrete mixes—fly ash geopolymer, fly ash silica fume blend geopolymer, and fly ash silica fume blend geopolymer—are compared to traditional cement concrete.

[2] investigate the effects of adding nano-silica to cement concrete and mortar while also including silica fume and a plasticizer to ascertain their suitability and benefits for concrete construction. Optimizing the amount of nano-silica employed and testing various fresh and hardened features were the two main objectives of the study. This objective was achieved by looking at the flow properties of pastes and mortars when they were still wet as well as the features of concrete that has been hardened. The specimens' morphological characteristics were determined via SEM analysis. According to the experimental inquiry, increasing the amount taken of nano-silica led to an increase in regularity.

[3] The nanotechnology movement has greatly intensified in various scientific fields over the past few years. The research on the efficient use of nanoparticles in the development industry has gained prominence. The use of nanotechnology has had a bigger impact on the implementation of sustainability in buildings, but more research is still required. The extraordinary physical and chemical characteristics of nanoparticles allow for their usage as superior building materials, which improves their properties.

[4] Zinc oxide (ZnO) nanoparticles (NPS) can be used in green buildings since they have special photocatalytic and antibacterial capabilities. The effect of partial cement replacement with ZnO nps in composite types of cement using silica-fume is the main topic of the investigation.

[5] Nanomaterials are now being used more frequently to improve ultrahigh-performance composites made of cement Therefore, graphene oxide (GO) was identified as one of the nanomaterials with an opportunity to improve the durability and strength of composites using cement. GO provides an exceptional variety of qualities. GO contains a variety of reactive oxygen operating chemical groups, making it an ideal material for combining with binder particles.

[6] looks into whether silica fume replacement is beneficial. Due to these developments, there has been a lot of study interest in the use of wastes, especially ceramics, as replacement aggregate materials for buildings.

Aggregates made from ceramic waste can be utilized to handle difficult issues including the lack of materials on building sites and lower environmental waste.

[7] Electrical resistivity is a crucial concrete physical characteristic that is closely related to the corrosive process brought on by chloride. This study examines the structural portable waste material concrete's bulk and surface resistivities. Waste materials, including red ceramics fine aggregate and artificially expanded clay rough aggregate, were used in the analyzed concrete mixture. Red ceramic is one of the least usable construction wastes and is frequently left over after building demolition or poor building material manufacture.

[8] Recommends three self-curing regimes for NSC AND HSC based on a) compressive strength achieved, b) durability, and c) mechanical and durability performance of concrete subjected to high temperatures. First: the SC regime with a combination of 2% PEG and 10% PCWA achieved the maximum compressive strength of concrete that was reported to be 14.7% and 19.3% higher for NSC and HSC, respectively, compared to the water immersion curing technique. Second: the SC regime with a dose of 3% PEG (NCP3) achieved the optimum durability properties of NSC and HSC that were studied in this research. Third: SC regime, replacing coarse aggregate by PCWA up to 25%, that reduced the deleterious effects of high temperature on density loss and compressive strength.

Based on the mechanical as well as durability characteristics of concrete exposed to extreme temperatures, durability, and the acquired compressive strength, [8] proposes three self-curing protocols for HSC AND NSC. [9] One of the most widely utilized construction materials is concrete. Compared to steel, wood, plastic, and aluminum, its consumption is used twice as much globally. The components of concrete include fine aggregate, cement, water, and coarse aggregate. The carbon dioxide released by cement accounts for 8% of the carbon dioxide that is annually released worldwide. Other cementitious materials can substitute cement and fine gravel in concrete in whole or in part. The disposal of ceramic waste powder endangers farmers and public health and causes significant ecological degradation.

The usage of RWCA in concrete and its impact on aspects of concrete including mechanical qualities, durability, and workability are fully reviewed in [10] along with all published studies on the subject. Additionally, this study analyses information about RWCA's microstructure gleaned via scanning electron microscopy to investigate the impact of RWCA on durability. According to the results, using RWCA as a partial substitution decreases workability while increasing flexural, durability, and compressive qualities. Future study is suggested, and observations are made.

[11] As the world's population grows, more solid waste must be generated to satisfy consumer demand, necessitating the construction of huge landfills. The problem of landfills may be resolved by converting this solid waste into other potential resources, which will lessen the demand for non-renewable resource materials. The use of solid waste in the manufacturing of concrete, a crucial component of the building, has come to light in numerous research.

[12] Minimizing the environmental effect of building design and enhancing the thermal performance of structures during their lifetimes are thought to be the two main obstacles to sustainable building design. Following the development of concrete technology, recycling of wastes and aggregates has been increasingly important in recent years in decreasing the environmental effects of the building sector. However, there hasn't been a simulation of the thermal stability of concrete using recycled aggregates and garbage that has been exposed to sunlight and heat yet. The design, simulation, and assessment of the thermal and mechanical properties of concrete formed from used ceramic electrical insulator waste were the main objectives of this work.

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[13] A promising technological advancement is the ability to make geopolymer concrete without cement by using industrial by-products. The creation, evaluation, and optimization of geopolymer concrete formed from ground-granulated slag from blast furnaces (also known as slag) and ceramic waste particles have not yet been studied. The durability and mechanical characteristics of geopolymer concrete that contains CWP and slag are examined in this research. The goal of [14] is to thoroughly study the ASR potential of SWC wastes along with the impacts of w/c ratio, reactive powder content, and permeability on the ASR-induced expansions.

2. MATERIALS AND MIX PROPORTION

2.1. Crushed granite coarse aggregate

In typical concrete, coarse aggregate made of crushed granite with a maximum size of 20 mm was utilized. The characteristics of these aggregates are shown in Table 1 as well.

2.2 Ceramic electrical insulator waste coarse aggregate

A hammer and chisel were used to manually remove the waste material's surfaces after it was received from a neighbouring ceramic electrical insulator manufacturer (Fig. 1).

Fig.1 Process making of ceramic insulator waste as an aggregate

Using a jaw crusher, the deglazed electrical dielectric wastes were reduced to coarse gravel with a max size of 20 mm (Fig. 2).

Figure 2 (a)Ceramic insulator waste coarse aggregate (b) Crushed granite coarse aggregate

The trash from ceramic electrical insulators was used to make concrete, and this material was used as coarse aggregate. The traits are listed in Table 1.

Table 1. Table.1 Properties of coarse aggregates

SI.No	Property	Ceramic waste	Crushed stone
1	Bulk density (kg/m^3) Loose Compacted	 1498 1550	 1540 1669
2	Crushing value	24	20
3	Fineness modulus	6.98	7.13
4	Impact (%)	19	17
5	Maximum size (mm)	20mm	20mm
6	Specific gravity	2.72	2.74
7	Water absorption is 24 h percent	0.70	1.22

2.3. Superplasticizer

To achieve the necessary droop when employing the aforementioned procedure, a superplasticizer must be added. Conplast Sp 430 was employed as a superplasticizer to attain this water-reducing admixture goal.

2.4 Silica fume

When silicon is produced in a submerged arc electric furnace using high-purity coal and quartz, silica fume was a waste byproduct. It is a very reactive pozzolanic substance. Gravity specification 2.63.

2.5 Other ingredients

Regular Portland cement 53Grade by IS 12269-1987 and complying with IS 383-1970, and also potable water, were used for both the regular concrete mixtures and the ceramic electrical insulation waste coarse aggregate material. Table 2 shows the ceramic waste proportion.

Table 2. Proportion of ceramic waste insulator coarse aggregates with silica fume concrete mixes

Mix Id	Cement (kg/m^3)	Silica Fume (kg/m^3)	Msand (kg/m^3)	Coarse Aggregate (kg/m^3)	Ceramic Waste (kg/m^3)	Water (kg/m^3)
CC MS	389	0	648	1210	0	175
CW70SF0	389	0	648	363	841.4	175
CW50SF5	369.55	19.45	648	605	601	175
CW 80SF10	350.1	38.9	648	242	961.6	175
CW40 SF15	330.65	58.35	648	726	480.8	175

2.6. Manufacture sand as fine aggregate

Produced sand is used in this study to refer to crushed rock or gravel that has undergone processing to provide aggregate material with a particle size of less than 4 mm for construction usage. Compared to non-refined waste from the production of coarse aggregate, produced sand is a material of exceptional quality 2.61 Specific gravity

2.7 Mix proportion

M25 grade concrete has been used in this experimental investigation's concrete mix design by the instructions provided in Indian Standards IS: 10262-2019 and IS 456-2000. The water-cement ratio was kept at 0.45 (based on IS 456-2000's moderate exposure condition). Using the following mix ratio. In this investigation, coarse aggregate was substituted with ceramic waste coarse aggregate in a range of percentages (0 to 100%), and cement was partially replaced with silica fume at 0%, 5%,10 and 15%. To examine concrete's many characteristics. Different mixtures of silica fume and ceramic waste aggregate in concrete were poured into concrete cubes the specimens, tested, and used to calculate various strength characteristics. To conduct the HCI, Alkaline resistance test, RCPT test and, 150mmx150mmx150mm cube was cast. Concrete's microstructural characteristics.

2.8 Acid test HCI

Make the concrete cube samples. According to the specified mix proportions, cast concrete cubes measuring 150 mm x 150 mm x 150 mm. Each blend will require three cubes. Fig 3 shows the specimens of the HCI Acid test.

Fig.3 Specimens immersed in HCI acid

Curing

It is indicated to keep the freshly cast cubes in a curing tank and give them 28 days to cure there. Keep the curing temperatures in line with the specifications. preliminary evaluation of weight: Remove the cubes from the curing tank after the prescribed 28-day curing period is complete, and let them air dry for 24 hours. Each cube should be weighed separately on a scale before those weights are recorded as the beginning weights. creation of an acid solution by mixing 5% Hydrochloric acid (HCI) by volume with water, it is possible to get a pH of around 2. Use a pH meter to measure and rectify the acidity. Use a pH meter to determine how acidic the solution is and to make any necessary modifications. exposure to acid. Keep the acid solution in situ throughout the test period, and check its concentration once a week. Place the cubes in the acidic solution and soak them for 30 days. The basis for this contact period is the ASTM C 1898 standard. ultimate weight determination removing the cubes from the acid solution once the 30-day soaking period has passed. Use a wire brush to scrub the cubes to remove any unstable compounds that the acid may have released from them. Dry each cube and measure it separately to determine the final weights of the cubes. Execute tests for compression on the cubes that were exposed to the acid using an apparatus for compression testing. Record the figures after measuring each cube's compressive strength.

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2.9. Alkaline resistance test

Cube Casting and Curing: Cube specimens of size 150 mm x 150 mm x 150 mm are cast using the desired concrete mix. These cubes are then placed for curing in a curing tank or under suitable curing conditions for 28 days. After 28 days of curing, the cubes are taken out from the curing tank and allowed to air dry for 24 hours. Once they are dried, the initial weights of the cubes are measured and recorded Preparation of Sodium Hydroxide (NaOH) Solution A 5% sodium hydroxide (NaOH) solution is prepared by taking the required volume of water and adding sodium hydroxide to it. The solution is then diluted to achieve a pH value of approximately 13. The pH can be adjusted using litmus paper or a pH meter Immersion in NaOH Solution The cubes are immersed in the prepared NaOH solution. Ensure that the solution covers the entire surface of the cubes. The cubes should be fully submerged and kept in the solution for 30 days Using the initial weight, final weight, and compressive strength values obtained from the testing. Specimens are given in Fig 4.

Fig.4 Specimens immersed in NaOH solution

2.10 Rapid Chloride penetration test

A test was performed by ASTM C1202-2012 to ascertain the electrical conductivity of concrete mixtures after 28 days of cure. Sorptivity samples were used to make migration cells, with a 3.0% NaCl solution acting as the cathode and a 0.3 N NaOH solution acting as the anode. To hasten the admission of chloride, a continuous 60 V potential was given to the system for 6 hours after it was connected. A maximum of six hours' worth of measurements of the total charge transmitted were made by protocol. The test setup for the RCPT and related schematic drawings are given in Fig 5.

Fig.5 RCPT test setup

The specified voltage and other parameters are checked every half-hour by the data logging system. uses the information to calculate the current value of each cell. RCP setup is demonstrated in Fig 6. The total charge that passed through the sample is then calculated using the equation below.

$Q = 900(I_0 + 2\,I_{30} + 2I_{60} + \ldots + 2I_{330} + I_{360})$
Where,

Q - Coulombs of charges
I0 - Current at first applied voltage (ampere)
It – Current at 't' minutes after 'ampere' (voltage)

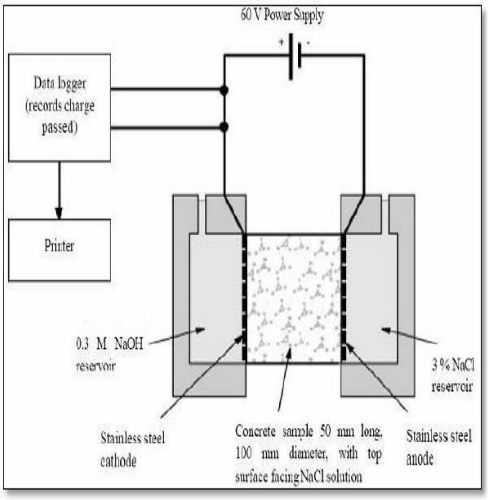

Fig.6 A schematic for the RCPT test

2.11 Microstructure Properties

Three components make up the heterogeneous structure of concrete: the cement paste between the aggregates and cement paste, the interfacial transition zone, and the pore structure. Increasing these three factors results in more durable and mechanically strong concrete. The binder material that keeps the particles together is cement paste. It is typically made up of cement, water, and other cementitious elements (such as silica fume or slag). The hydration of cement particles is a chemical process that results in the formation of a paste that hardens over time to produce a strong matrix. The total strength of the concrete can be increased by utilizing high-quality cement and proper water-to-cement ratios. Cement paste is the component that holds the aggregates together and forms a solid mass. It coats the particles' surfaces, filling spaces and ensuring that the concrete functions as a cohesive material. Cement hydration is the chemical reaction that occurs between cement and water. These components contribute to the concrete's strength and durability. A dense microstructure with limited permeability serves to reduce the intrusion of dangerous substances, increasing the longevity of concrete. A microstructure with a well-bonded interfacial transition zone (ITZ) ensures strong adhesion between concrete and steel reinforcement, improving the structural performance of reinforced concrete components. Concrete's microstructure refers to its microscopic internal layout, which includes the arrangement of cement paste, aggregates, and any extra elements such as admixtures or supplementary cementitious materials. The microstructure of concrete has a considerable impact on its strength, durability, permeability, and overall performance. The distribution and bonding of cementitious materials and aggregates in the microstructure are important in determining the tensile, flexural, and compressive strength of concrete. A well-bonded microstructure with little porosity often results in greater strength.

3. RESULT AND DISCUSSION

3.1 Test result on acid test

The test results of the Acid HCI test showed concrete resistance on samples of standard concrete and CCMS, CW70SF0, CW50SF5, CW80SF10 CW40SF15 (ceramic waste aggregate+msand+silica fume), and concrete

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are described below. The acid attack damaged both the calcium from the calcareous aggregate and the calcium-containing components of the cement paste created during the hydration phase of concrete. Concrete's structural stability is compromised by acid attack, which also reduces the material's toughness and usefulness. Display the percentages of mass loss and toughness loss for concrete specimens that have cured for 30 days, accordingly. The test findings showed that the CW 80+SF10 mix only slightly lost strength as a result given in Fig 7.

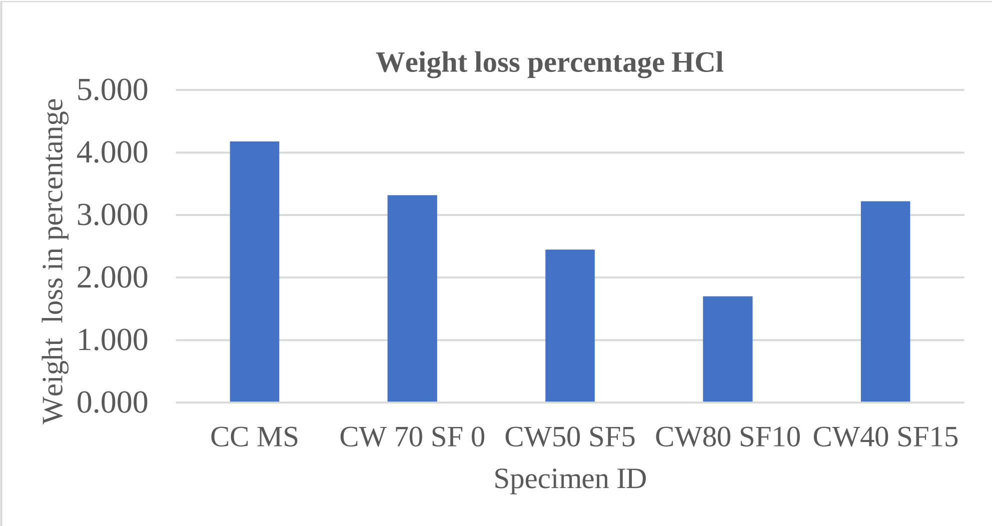

Fig.7 Percentage of Weight Loss on HCI Resistance Test

Both before and after immersion, the compressive strength of CCMS, CW70SF0, CW50 SF5, CW80SF10, and CW40SF15 were tested. Fig 8 demonstrates the percentage of Strengthen loss.

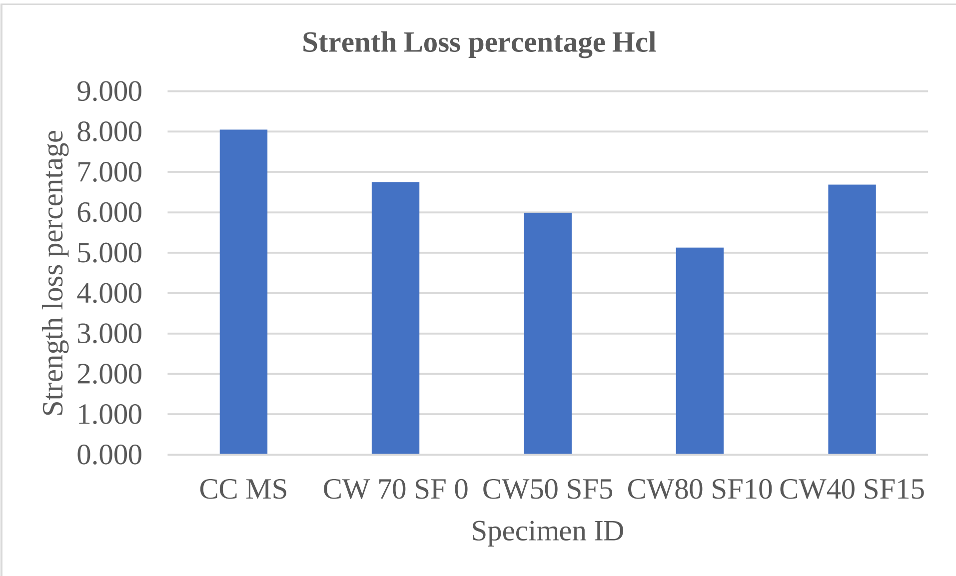

Fig.8 Percentage of Strength Loss on HCI resistance test

After 30 days of immersion in 5% diluted HCI Solution the strength loss of CCMS, CW70SF0, CW50SF5, CW80SF10, and CW40 SF15 was 8.05%,6.75%,5.99, 5.13, and 6.69 respectively.

Fig.9 After 30 days of immersion in HCl solution the visual appearances of the CCMS and CW80+SF10specimens

3.2 Alkaline resistance test

Once they are dried, the initial weights of the cubes are measured and recorded Preparation of Sodium Hydroxide (NaOH) Solution A 5% sodium hydroxide (NaOH) solution is prepared by taking the required volume of water and adding sodium hydroxide to it. The solution is then diluted to achieve a pH value of approximately 13. The percentage of Mass Loss on the Alkaline Resistance Test is shown in Fig 9.

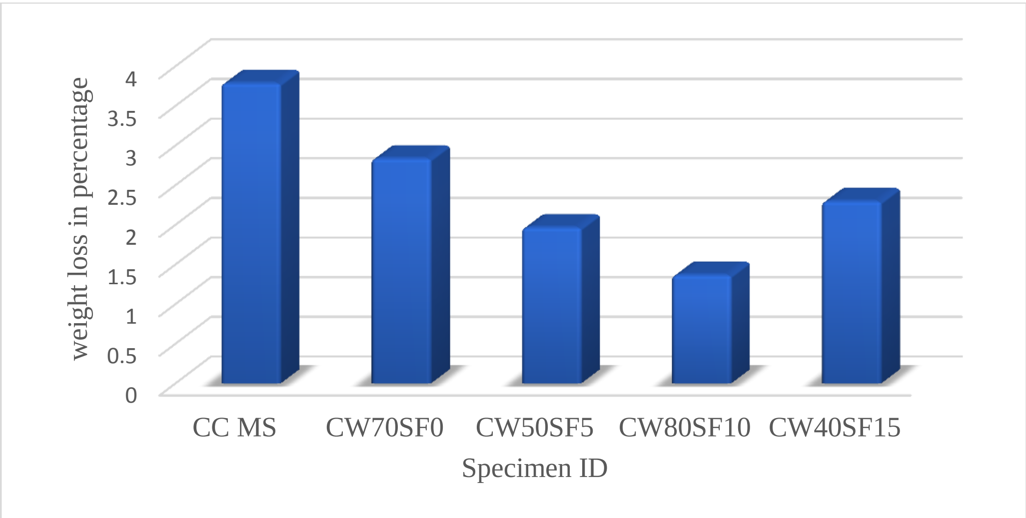

Fig.10 Percentage of Weight Loss on Alkaline Resistance Test

The test result of the alkaline resistance mass percentage weight loss from the graph CCMS, CW70SF0, CW50SF5, CW80SF10, and CW40SF15 respectively were 3.79%,2.84,1.97,1.37 and 2.3% and the both before and after immersion compressive strength of CCMS, CW70SF0, CW50SF5, CW80SF10and CW40SF15 from the graph result in 4.5%,4.2%,3.57%,2.11, and 4.1% of all combination mix compared to control concrete given in Fig 10.

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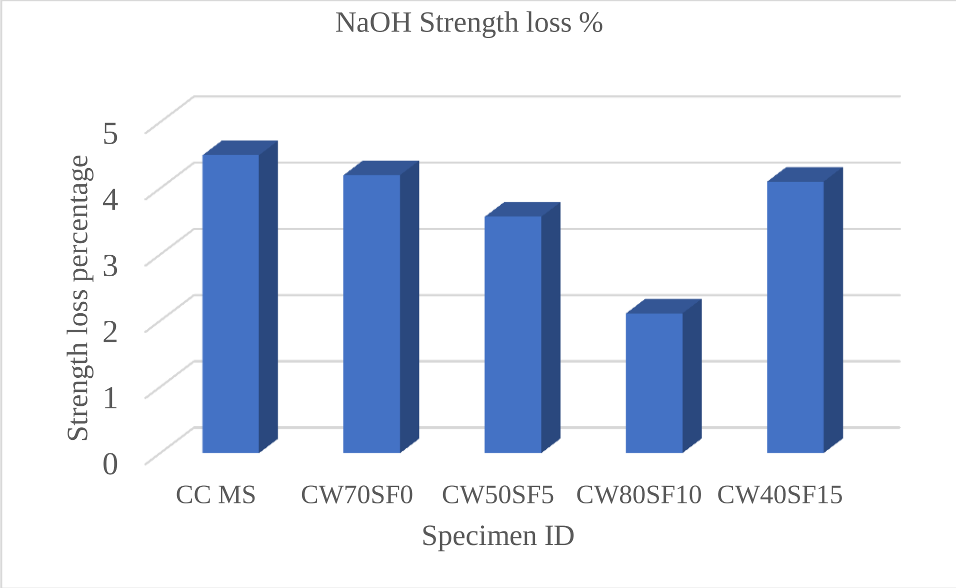

Fig.11 Percentage of Strength Loss on Alkaline Resistance Test

Fig.12 After 30 days of immersion in NaOH solution CCMS, CW70SF0, CW50SF5, CW80SF10 and CW40SF15 specimens

Fig.13 After 30 days of immersion in NaOH solution the visual appearances of the CCMS and CW80SF10 specimen

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3.3 Rapid Chloride penetration test (RCPT)

RCPT is a common test procedure used to evaluate a concrete's resistance to chloride ion penetration. In terms of charge-passing coulombs, chloride ions from de-icing salts or maritime conditions can cause the corrosion of steel reinforcing in concrete constructions with and without silica fume employing ceramic waste aggregate given in Fig 11. The variation in RCPT results for various mix CCMS, CW70 SF0, CW50 SF5, CW80SF10, and CW40SF15.In comparison to the control specimen, the concrete structure produced by the combination of all coulombs charge mixtures is better.

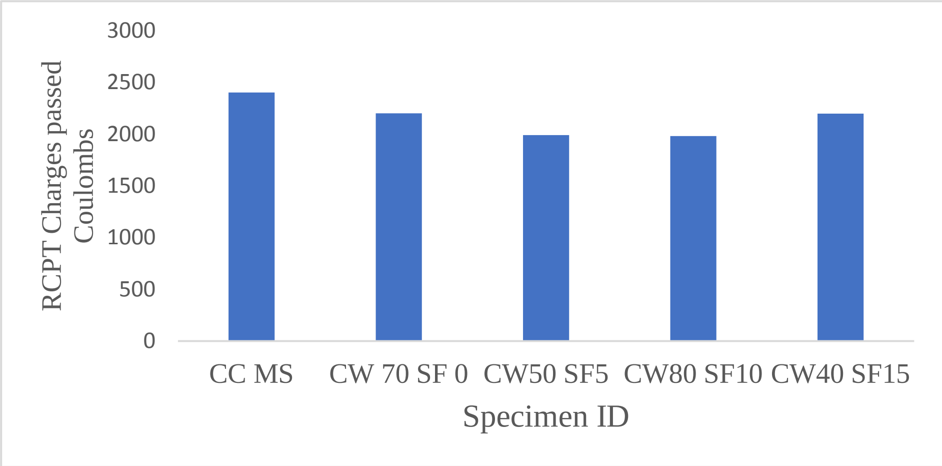
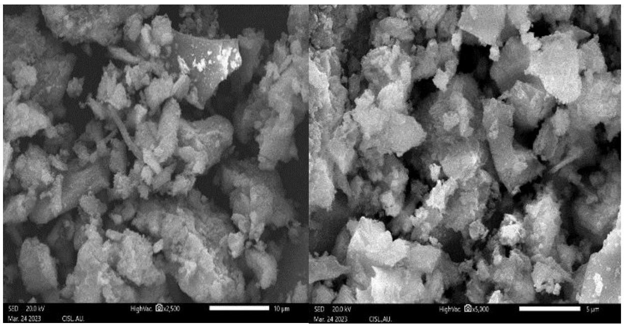


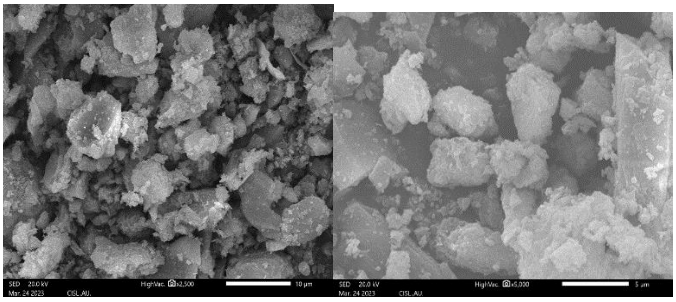
Fig.14. Charge passed in Ceramic waste aggregate with silica fume and without silica fume mix

3.4 Microstructural investigation

The images were taken at 10k magnification levels to monitor the status of the interfacial transition zone. The concrete mixtures were made by replacing cement with 10% of silica fume, Ceramic waste aggregate with 80 % Combination, and Conventional Concrete demonstrated in Fig 12. No more line cracking has been observed between the matrix and the aggregate. The magnification images also clearly show the information on hydration products and improved bonds at the interfacial transition zone. The presence of C-S-H made the cement matrix's binding comparatively robust. Scanning electron microscopy analysis of the damaged specimen yields information on the material's microstructure. This enables us to understand the tiny fissures, cavities, and observable alterations in the CSH gel and aggregate interface's microstructure.



(a)Conventional concrete with M-sand



(b)Ceramic insulator waste coarse aggregate with silica fume

Fig.15 Scanning Electron microscopy

3.5. Conclusion

Using the information provided, the following conclusion was reached. The parameters studied were covered by the test technique.

- The test results of the Acid HCI test showed concrete resistance on samples of standard concrete and CCMS, CW70SF0, CW50SF5, CW80SF10 CW40SF15 (ceramic waste aggregate+msand+silica fume). After 30 days of immersion in 5% diluted HCI Solution the strength loss of CCMS, CW70SF0, CW50SF5, CW80SF10, andCW40SF15was8.05%,6.75%,5.99, 5.13, and 6.69 respectively.

- The test result of the alkaline resistance mass percentage weight loss from the graph CCMS, CW70SF0, CW50SF5, CW80SF10, and CW40SF15 respectively were 3.79%,2.84,1.97,1.37 and 2.3%, and strength loss percentage of alkaline resistance 4.5%,4.2%,3.57%,2.11, and 4.1% of all combination mix compared to control concrete.

- From this result, the combination of all mixes has charge coulombs fall in the type of “moderate” and low. It shows the density of concrete has more.

- The concrete mixtures were made by replacing cement with 10% of silica fume, Ceramic waste aggregate with an 80 % Combination Compared to Conventional Concrete. The magnification images also clearly show the information on hydration products and improved bonds at the interfacial transition zone. The matrix structure was dense with reduced pores.

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