EXPERIMENTAL INVESTIGATION ON DURABILITY CHARACTERISTICS OF PLAIN CEMENT CONCRETE USING CRUSHED CERAMIC WASTE AS COARSE AGGREGATE

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Abstract

Concrete that incorporates waste materials as the coarse aggregate, such as electrical insulator ceramic scrap, can have beneficial properties. Because durability is an essential element of concrete performance, researching the durability properties of concrete made from waste materials is essential to ensure its long-term dependability. Permeation characteristics like water permeability or chloride permeability are widely used to evaluate the durability of concrete. This study quantifies the qualities of ingress, chemical assaults, and corrosion of the reinforcing steel to assess the concrete's resistance to several types of degradation, including moisture. It improve the long-term durability of concrete structures while also reducing waste output by creating sustainable concrete technologies and using waste materials as aggregates. For "Green" concrete to be used widely and consistently, it is crucial to keep researching and enhancing its durability qualities. Its usage reliability will also improve as a result of studies into its durability. Permeation features are widely used to gauge the durability properties of concrete. The results of an experimental research on the permeation features (volume of voids and water absorption (ASTM C642-06), chloride penetration (ASTM C1202-10), and sorption of concrete with ceramic electrical insulator waste coarse aggregate, hereafter referred to as recycled aggregate concrete) are compared in this study with cement replacement by silica fume with 0%, 5%, 10%, 15%, m-sand as fine aggregate, and coarse aggregate replacement by ceramic insulator (0% to 100%). From this result experimentally various combination carried out 10% of silica fume and 80% of ceramic insulator better durability properties of concrete. When compared to the control mix, CC MS, the water absorption of the mixture CW80 SF10 was reduced by 3.2%. At 28 days of immersion in (H2SO4), the weight loss percentage for the CW80 SF10 mix is 16% lower than that of the control concrete. After 28 days of immersion in (H2SO4) solution, the identical mix's compressive strength decreased by 4.41%, which is 18.2% less than the control concrete. 1.4% less concrete was immersed in (MgSO4) for 28 days than the control concrete. At 28 days of immersion in (MgSO4) solution, the same mix's percentage compression strength reduction is 8.52% lower than that of control concrete.

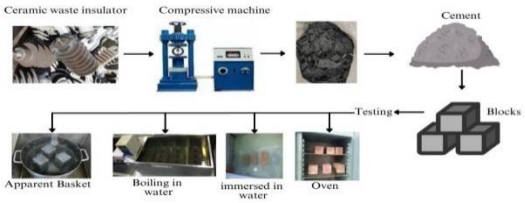
Keywords: Green concrete Durability of Ceramic Waste Coarse Aggregate silica fume and m-sand Sorption for Permeation

1. INTRODUCTION

Crushing, screening, and other treatment steps are used to transform waste materials into substitute aggregates that fulfil the standards needed for construction. The generated alternative aggregates can be utilised for a variety of tasks, such as making concrete, building foundations, and roads [1]. The use of recycled building debris as aggregate could have a number of advantages. These include the possibility for cost savings in construction projects, a decrease in the amount of waste transported to landfills, and the preservation of natural resources. Recycling demolition debris into aggregate helps

the construction sector find a sustainable solution to the shortage of traditional aggregates [2]. The main goal of recycling materials, including industrial waste, is to lessen the extraction and depletion of natural resources. For example, by using industrial waste in concrete, we can preserve crushed granite, which is becoming scarce in some desert areas [3]. In fact, the development of "Green" concrete and sustainable concrete design can benefit from the use of inorganic industrial waste in the production of concrete [4]. Several environmental and sustainability advantages can be realised by using inorganic industrial waste materials as supplementary cementitious materials (SCMs) or alternative aggregates [5]. the requirement to create concrete using unconventional aggregates, driven by economic and environmental trends. Through thorough research into their usage in the manufacturing of concrete, there is tremendous potential to increase waste recycling because various industrial waste materials have qualities that are suited for making concrete [6]. Oil palm shells are a non-traditional sort of aggregate that can be used to make concrete. The outer layer of the palm fruit that is still present after palm oil has been extracted is known as an oil palm shell. They are regarded as agricultural waste products, although they can also be used to make concrete and other building materials [7]. Alternative Cementitious Materials: One strategy is to cut back on or substitute alternative cementitious materials for the cement used in concrete manufacturing. Fly ash, slag, silica fume, and other industrial by-products are examples of these materials. It is possible to lessen the dependency on cement manufacture, which consumes a lot of energy and produces carbon emissions. Recycled aggregates are used in concrete to reduce the need for new materials, save natural resources, and prevent trash from going to landfills. Examples of recycled aggregates include crushed concrete or masonry.

2. RESEARCH METHODOLOGY



2. MATERIALS

2.1. Aggregate debris from ceramic electrical insulators

The nearby ceramic electrical insulator (CEI) (figure 1) company provided the waste ceramic electrical insulators, which were then physically deglazed with a chisel and hammer. The deglazed CEI wastes were crushed into coarse aggregate with a maximum size of 20 mm using a jaw crusher (Fig. 2). This coarse aggregate was then used as the foundation for concrete made from ceramic electrical insulator waste.

Fig.1.Ceramic electrical insulator waste.

2.2. Granite crushed for coarse aggregate

In typical concrete, coarse aggregate of crushed granite with a maximum size of 20 mm that complied with IS383-1970 was utilised. The characteristics of these combine. (table 1 and table 2)

2.3. Other ingredients

Both the ceramic electrical insulator waste coarse aggregate concrete and the normal concrete mixes employed ordinary Portland cement 53Grade complying to IS 12269-1987, river sand of specific gravity 2.61 and fineness modulus 3.68, conforming to IS 383-1970, and potable water.

Fig.2. Ceramic Insulator aggregate and Coarse aggregate

Table 1. Properties of Coarse aggregate

S.NO	Property	Ceramic waste	Crushed Stone
1	Specific gravity	2.72	2.74
2	Maximum size {mm}	20	20
3	Fineness modulus	6.98	7.13
4	Water absorption 24 h percent	0.70	1.22
5	Impact Value (%)	19	17
6	Crushing Value	24	20

Table 2. **Proportion of ceramic insulator coarse aggregate with silica fume concrete mixes**

Mix Id	Cement	Silica Fume	Msand	Coarse Aggregate	Ceramic Waste	Water
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
		38.9				

CW 80SF10	350.1		648	242	961.6	175
CW40 SF15	330.65	58.35	648	726	480.8	175

2.4. Mix Proportion

Standard mix design methods are unable to adequately account for the diversity in aggregate properties. The absolute weight approach was employed to create the concrete mix for the ceramic electrical insulator waste coarse aggregate used in this experiment. Trial mixtures were created, and their proportions were tweaked to achieve the perfect mix ratio, which was then applied throughout the inquiry. Cement was replaced with silica fume in the concrete mixes for ceramic electrical insulator waste coarse aggregate at 0%, 5%, 10%, and 15%, and ceramic insulator waste coarse aggregate was substituted in the range of 0% to 100%. Preliminary studies showed that a minimum of 175 l/m3 of operational water was required. Due to this, the maximum size of coarse aggregate was employed, and all mixes 20mm were mixed with 175 l/m3 of water.

3. EXPERIMENTAL PROGRAMME

3.1. Testing specimen

According to ASTM C642-97, the information supplied describes a test protocol for evaluating the density, percentage of water absorption, and percentage of voids in hardened concrete. 15 concrete cubes with measurements of 150 mm x 150 mm x 150 mm are cast in total For each mix, three cubes are prepared, and subsequent calculations take into account the average values.

3.2. Curing:

To enable the concrete to firm and build strength, the cubes are cured for 28 days in a curing tank or similar suitable curing environment. Oven Drying: The cube samples are removed from the curing tank after the curing period and put in an oven to dry. A constant temperature of 100–110 °C should be maintained in the oven. To calculate the initial dry mass, the cubes are dried in the oven for a minimum of 24 hours.

3.3. Second Oven Drying:

The cubes are held in the hot air oven for a further 24 hours after the initial drying. They are then weighed to determine the second dry mass.

3.4. Comparison of Dry Mass:

The first dry mass that was previously acquired is contrasted with the second dry mass. It shouldn't be more than 0.5% different between the two. The oven-drying procedure must be repeated until the mass is reduced below this limit if the difference is greater than 0.5%. Oven-Dry Mass: The resultant oven-dry mass value is denoted as A after being confirmed to be within the permitted range (below 0.5% difference). (figure 3) Further calculations utilise this value. This process makes sure that the cube samples consistently reach a dry condition so that the density, water absorption, and voids in the hardened concrete can be accurately determined. It's crucial to remember that depending on the edition of ASTM C642 used, the precise information and computations may change. For thorough and precise testing techniques, it is advised to refer to the pertinent ASTM standard (in this case, ASTM C642-97).

Fig.3. Cube sample in oven

The following phase in the test process, as outlined in the provided information, entails submerging the cube specimens in water at a temperature of 21°C for at least 48 hours after achieving the oven-dry mass value (marked as A). Immersion in Water: The cube specimens are fully submerged in water that is kept at a constant 21°C temperature. To guarantee saturation, they are kept undisturbed in the water for at least 48 hours.

3.5. **Surface Drying:**

The cube samples are removed from the water when the immersion time has passed. To eliminate any extra water, the samples' surfaces are gently dried with a cotton cloth or towel.

3.6. Mass Determination:

The cube samples are weighed after the surfaces have dried. The resultant mass is referred to as B following immersion and surface drying. In this step, the mass of the cube samples that were soaked with water will be found.(figure 4) To determine the proportion of water absorption in the concrete samples, divide the oven-dry mass (A) by the surface-dry mass after immersion (B).

Fig. 4. Cube samples immersed in water

The cube specimens are boiled in water for five hours after the immersion and surface drying steps. The specimens are then allowed to cool for 14 hours at 20–25°C room temperature. Cubed test subjects are constantly boiled for five hours in boiling water. Cooling is usually done with the use of a suitable container or tool. After boiling, the specimens are taken out of the water and let to cool for a total of 14 hours. (figure 5) The specimens will arrive at a constant room temperature thanks to this

chilling process. The surfaces of the cube samples are dried with a cotton cloth or towel once the cooling process is finished to get rid of any surface moisture. The weight of the cube specimens is done after surface drying. After boiling and surface drying, the resultant mass is given the letter C. This step's objective is to calculate the mass of the sample cubes after they have been boiled and subsequently cooled. The percentage of voids in the concrete specimens can be determined by comparing the surface-dry mass after immersion (B) to the mass after boiling and surface drying (C). To guarantee precise mass measurements are recorded and that the boiling and chilling periods are followed, trustworthy test results must be obtained.

Fig.5. Cube samples boiling in water

According to the material given, the last step entails suspending the cube specimens with a wire in an apparent basket. After that, the specimens are weighed underwater to assess their apparent mass.(figure 6) The letter D stands for this seeming mass. Calculations can be done to ascertain the desired outcomes, such as density, percentage of water absorption, and percentage of voids, after receiving the values for A, B, C, and D. But without the precise formulas or calculating techniques described in the material provided

Fig 6 cube sample apparent basket

3.7. Sorptivity

The unsaturated flow of fluids into the concrete caused by capillary suction is measured by the sorptivity of concrete. The concrete's one-way capillary movement of moisture is represented by the sorptivity measurement. Preparation of Specimens The preparation of concrete discs with a 100 mm diameter and a 50 mm thickness. These discs are saw-cut from cylinders measuring 100 mm by 200 mm. Each disc has an impermeable epoxy coating applied to the side surfaces to stop absorption through the sides during the test. The prepared specimens are dried in an oven for 105 5°C until they

reach a consistent weight. After the specimens drop to ambient temperature, their initial weights are recorded. In a water tray with tiny supports, the specimens are put. Only the lowest 3-5 mm of the specimens are immersed in water; the water level in the tray is kept constant. Up to a total of 361 minutes, the weights of the specimens are continually measured at predetermined intervals (e.g., 9, 16, 25, 36, and so on). To make it easier to plot the graph, these time intervals are selected so that the value of t1/2 (square root of time) is a whole number. (figure 7) The amount of water that has been absorbed through the specimen's bottom at any given time, t, is determined by subtracting the original weight from the weight at that moment. The sorptivity, S, is calculated using the water absorption values collected at various time intervals. A linear regression of the cumulative water absorption per unit area (i) vs the square root of time (t1/2) plot can be used to determine the sorptivity (S). The formula can be used to determine the sorptivity.

$i = S/ t^{1/2}$

where t is the amount of time that has passed in minutes, S is the sorptivity of concrete, and i is the total amount of water absorbed by the inflow surface per unit area in g/mm2. S can be calculated from a plot of i vs t 1/2 with linear regression.

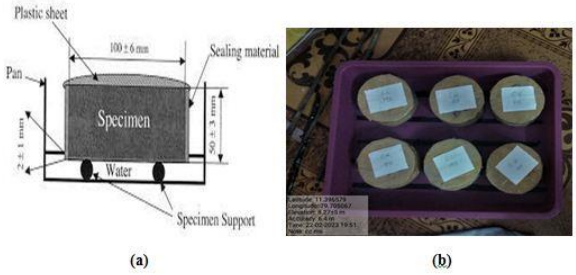


Fig.7. Schematic Procedure of sorptivity (ASTM C1585-13 2013) & (b) Samples placed in the sorptivity pan.

4. RESULT AND DISCUSSION

4.1. Saturated water absorption

The maximum quantity of water vapour that may be dissolved or absorbed by a given volume of air at a particular temperature and pressure is known as saturated water absorption. The air has reached its maximum capacity for storing moisture at that specific temperature and pressure, and any further moisture would cause condensation or precipitation. Concrete and other porous materials' porosity, pore structure, surface characteristics, and composition can all have an impact on how much water they absorb. To precisely assess the water absorption properties of certain materials or waste products, regulated experimental testing is typically required.(figure 8-12) The experimental study you described compares recycled aggregate concrete with ceramic electrical insulator waste coarse aggregate on the basis of its permeation properties to more traditional concrete mixtures. In terms of a number of different characteristics, such as the volume of voids, water absorption, chloride penetration, and sorption, the study investigates the impacts of replacing cement with silica fume and replacing coarse aggregate with ceramic insulator waste.

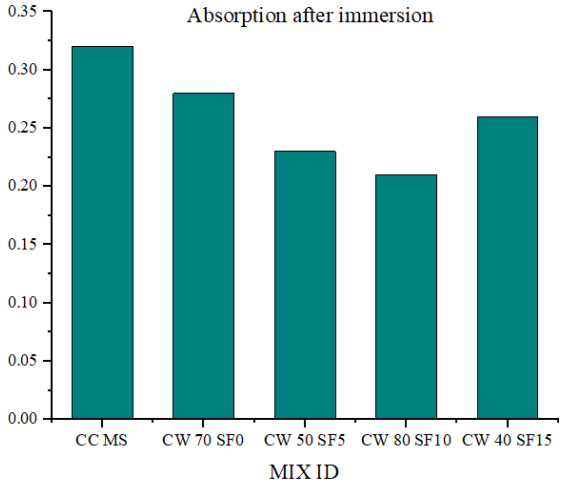


Fig. 8. Relationship between cement +silica fume and ceramic insulator coarse aggregate and water absorption after immersion

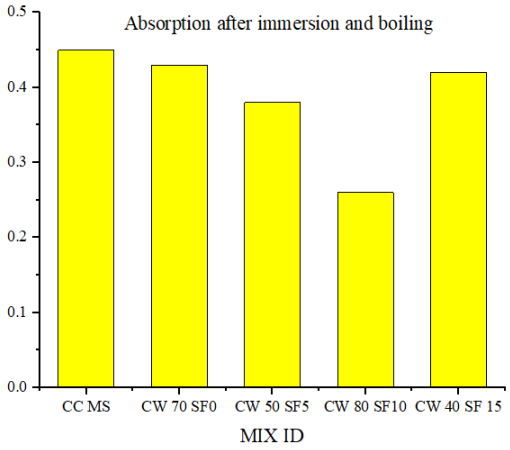


Fig.9. Relationship between cement +silica fume and ceramic insulator coarse aggregate Absorption after immersion and boiling

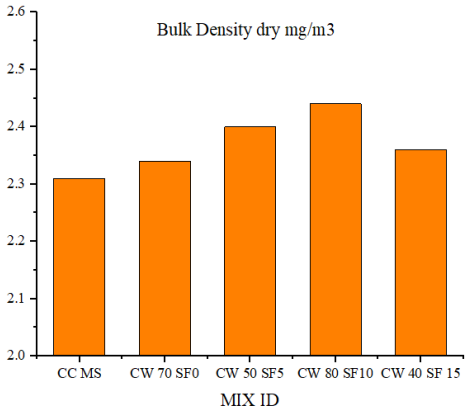


Fig.10. Relationship between cement +silica fume and ceramic insulator coarse aggregate Bulk Density dry mg/m^3

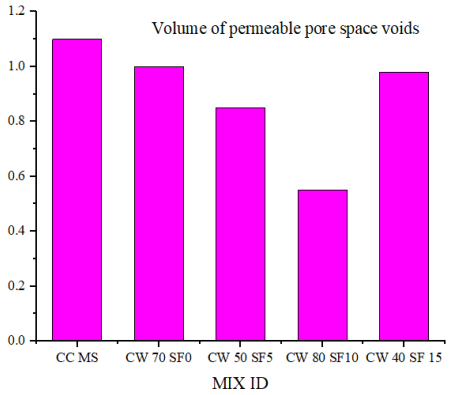


Fig.11. Relationship between cement +silica fume and ceramic insulator coarse aggregate volume of permeable pore space voids

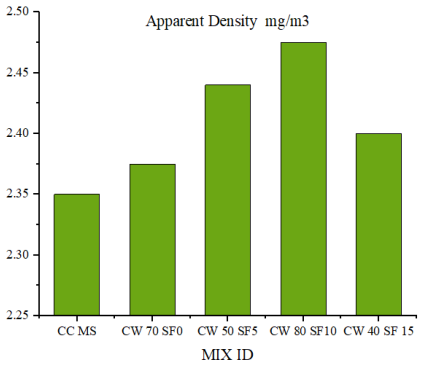


Fig.12. Relationship between cement +silica fume and ceramic insulator coarse aggregate Apparent Density mg/m^3

4.2. Sorptivity

The rate at which water is absorbed into a porous substance, like concrete, (figure 13) is referred to as sorptivity. Water quickly enters the bigger capillary holes inside the concrete during the early phases of sorption. The initial rate of water infiltration does, however, diminish as the water continues to permeate the concrete and eventually gains access to all the bigger capillary pores.

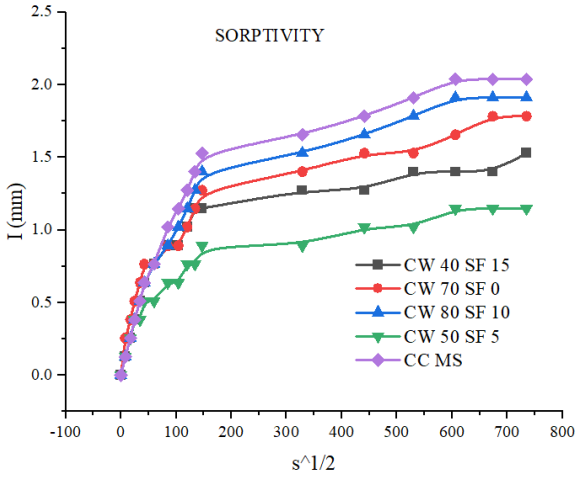


Fig.13 Relationship between cement +silica fume and ceramic insulator coarse aggregate

4.3. **Acid Resistance:**

The concrete cube samples should be ready. Cast 150 mm x 150 mm x 150 mm concrete cubes in the specified mix proportions. For each mix, make three cubes. Curing Put the recently cast cubes in a curing tank and give them 28 days to cure. Maintain the curing conditions in accordance with the requirements. (figure 14)

Fig. 14 Specimens immersed in solution (H_2SO_4)

4.4. Initial weight measurement:

Remove the cubes from the curing tank after the 28-day curing time is complete, and let them air dry for 24 hours. Utilise a scale to independently weigh each cube, then record the results as the beginning weights. preparation of an acid solution to produce a pH of about 2, dilute 5% sulphuric acid (H_2SO_4) by volume in water. To check the acidity of the solution and make any necessary adjustments, use a pH metre. acid exposure Make sure each cube is completely submerged in the acid solution you've created. Throughout the test time, keep the acid solution in place, and check its concentration every week. For 30 days, leave the cubes submerged in the acidic solution. The ASTM C 1898 standard is the foundation for this exposure period.

4.5. **Final weight measurement**

Taking the cubes out of the acid solution after the 30-day immersion time is complete. To get rid of any unstable substances the acid may have leached from the cubes, clean them with a wire brush. To establish the final weights of the cubes, dry each cube and weigh it separately. (figure 15 to 16) Use a compression testing machine to run compression tests on the acid-exposed cubes. Each cube's compressive strength is measured, and the results are noted. Use the following calculations to get the weight and strength loss percentages for each cube:

Percentage Loss of Weight = ((Initial Weight - Final Weight) / Initial Weight) x 100%
Percentage Loss of Strength = ((Initial Strength - Final Strength) / Initial Strength) x 100%

Initial Strength and Final Strength both refer to the compressive strength before and after acid immersion, respectively.

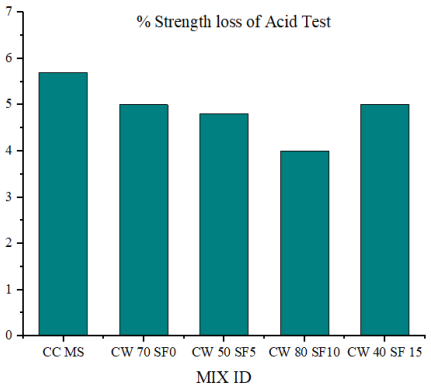


Fig.15. Relationship between cement +silica fume and ceramic insulator coarse aggregate Strength loss of acid test.

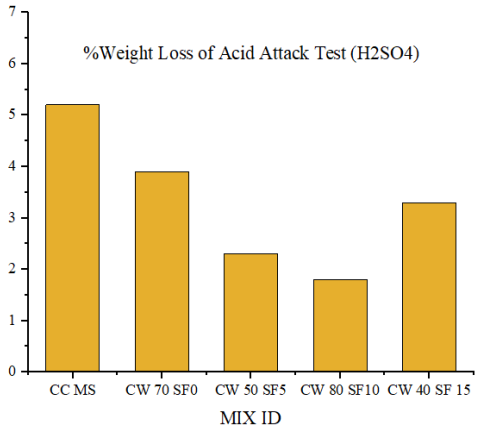


Fig.16. Relationship between cement +silica fume and ceramic insulator coarse aggregate weight loss of acid attack test (H_2SO_4)

4.6. Sulphate Resistance:

Concrete's sulphate resistance is its capacity to withstand the damaging effects of sulphate ions found in soil or water. Sulphate attack can cause concrete structures to deteriorate, which can result in cracking, a loss of strength, and general degradation. In order to assure concrete's longevity in sulphate-rich environments, it is crucial to evaluate its sulphate resistance. Three cubes are cast for each mix of the fifteen 150 mm x 150 mm x 150 mm cube specimens. For analysis, the average values are taken into account. For 28 days, the cubes are cured. The specimens are cleaned and weighed to determine the original weight after curing. The initial weight is noted for purposes of comparison. The amount of water needed for the experiment is used to make a sulphate solution with a 5% concentration of magnesium sulphate (MgSO4). The sulphate solution is produced by dissolving the MgSO4 in water. Immersion Period For 30 days, the cube specimens are completely submerged in the sulphate solution. The immersion is conducted at 23 2 °C, or room temperature. Throughout the test time, it is assured that the pH range of the solution stays between 6.0 and 8.0. The specimens are taken out of the solution and dried on the surface following the 30-day immersion period. In order to dry the specimens, extra moisture must be removed from their surface. After the specimens have been immersed in the sulphate solution, they are weighed, and this weight is noted as the final weight. During the immersion and drying process, any white-coloured deposition observed on the surface of the concrete specimens is noted.

4.7. Sulphate resistance Test

To establish the original weight after curing, the specimens are cleaned and weighed. The starting weight is mentioned for comparison's sake. The required volume of water is utilised to create a sulphate solution containing magnesium sulphate (MgSO4) at a concentration of 5%. The MgSO4 is dissolved in water to form the sulphate solution. Period of Immersion The cube specimens are fully immersed in the sulphate solution for 30 days. Room temperature, or 23.2 °C, is used for the immersion.1.4% less concrete was submerged in (MgSO4) than the control concrete. The identical mix percentage sulphate compression strength loss 8.52 lower than the control control concrete at 28 days of solution immersion.

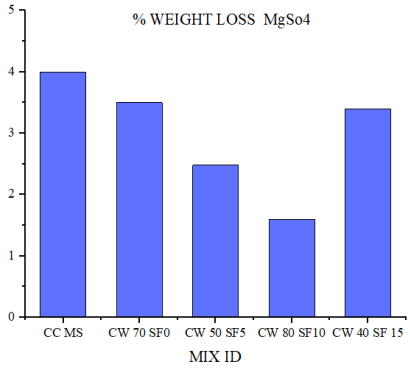


Fig.17 Relationship between cement +silica fume and ceramic insulator coarse aggregate weight loss of sulphate resistance.

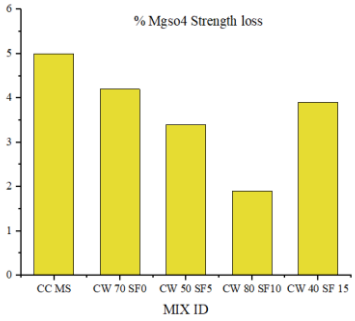


Fig.18. Relationship between cement +silica fume and ceramic insulator coarse aggregate strength loss of sulphate resistance.

5. CONCLUSIONS

Waste from ceramic electrical insulators can be used successfully as concrete's coarse aggregate. The permeation characteristics of the resulting concrete are not considerably different when this waste material is used as an aggregate component compared to ceramic electrical insulator trash, and the concrete still satisfies the standards as required. The greater strength seen may perhaps have been a result of using 80% ceramic coarse aggregate rather than conventional natural coarse aggregates. According to the test results, employing 10% silica fume and 80% ceramic coarse aggregate in concrete appears to produce a stronger product than using other combinations or regular concrete. The 10% silica fume addition as a cement substitute most certainly played a role in the concrete's increased strength. Due to its pozzolanic qualities, silica fume combines with the calcium hydroxide created during the hydration of cement to create new cementitious compounds. The concrete absorption, void volume, and other permeation-related properties are strengthened and more durable as a result of this reaction. Concrete made from ceramic electrical insulator waste has the potential to have its permeability properties improved by the inclusion of mineral admixtures including fly ash,

slag, and micro silica. To increase the performance and durability of concrete, these admixtures can be used in the mix design. When compared to the control mix, CC MS, the water absorption of the mixture CW80 SF10 was reduced by 3.2%. At 28 days of immersion in (H_2SO_4), the weight loss percentage for the CW80 SF10 mix is 16% lower than that of the control concrete. After 28 days of immersion in (H_2SO_4) solution, the identical mix's compressive strength decreased by 4.41%, which is 18.2% less than the control concrete. 1.4% less concrete was immersed in (MgSO4) for 28 days than the control concrete. At 28 days of immersion in solution, the same mix's percentage compression strength reduction is 8.52% lower than that of control concrete.

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