

CHARACTERISTICS OF HARDENED CONCRETE INCORPORATING CEMENT KILN DUST (CKD) AND SILICA FUME (SF)

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ABSTRACT

In this research characteristics of hardened concrete containing cement kiln dust and silica fume as a partial replacement of cement were studied. These characteristics inclusion on compressive strength, electrical conductivity, water sorptivity and accelerated corrosion, for each mixture X-ray diffraction were carried out for determined mineralogical analysis of the representative concrete sample. Concrete specimens were prepared with different ratios of CKD and constant ratio 15% SF as a partial replacement by weight of cement. The test results had revealed that The use of CKD as partial replacement of cement in combination with SF in concrete were shown best performance than use CKD only. The amount of 20% CKD in the presence 15% SF as a partial replacement by weight of cement were the optimum ratios can be used in concrete mixtures without lower on compressive. At 5%, 10% and 15% CKD with constant 15% SF at frequencies 0.12, 1.0 and 10 kHz, the electrical conductivity were increased with increased CKD amount, whereas beyond 15% CKD efficiency of electrical conductivity were decreased with increase CKD amount at all frequencies. But at (10% to 25%) CKD, sorptivity value were increased with increase CKD amount when comparison with control mixture. The replacing of cement with CKD and SF, give – about - the same corrosion rate which clear shown from XRD analysis.

KEYWORDS: Partial replacement of cement, Cement kiln dust (CKD), Silica fume (SF), Compressive strength, Electrical connectivity, Water sorptivity, Accelerated corrosion, XRD.

خصائص الخرسانة المتصلبة التي تحتوي علي غبار فرن الاسمنت وغبار السليكا فيوم

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الملخص

الغرض من هذه الدراسة هو كيفية الاستفادة من غبار فرن الأسمنت الذي ينتج بكميات كبيرة في المصانع أثناء عملية تصنيع الأسمنت ويتم التخلص منه. ويهدف هذا البحث الي دراسة خصائص الخرسانة المتصلدة التي تحتوي علي غبار فرن الأسمنت و غبار السليكا فيوم كاستبدال جزئي للأسمنت في الخرسانة. وتتضمن هذه الخصائص مقاومة الضغط والتوصيلية الكهربائية وامتصاص المياه بالخاصية الشعرية والتآكل المتسارع للحديد ، كما تم تحديد المعادن الرئيسية لكل خلطة عن طريق تحليل (اكس ار دي). وقد تم تجهيز العينات بنسب مختلفة من غبار فرن الأسمنت مع نسبة ثابتة في كل الخلطات من غبار السليكا فيوم كاستبدال جزئي بالوزن من الأسمنت. وأظهرت النتائج أن استبدال الأسمنت بغبار فرن الأسمنت مع غبار السليكا فيوم يحسن من أداء الخرسانة أفضل من الاستبدال للأسمنت بغبار فرن الاسمنت فقط. واتضح

أيضاً أن النسبة المثلى لاستبدال الاسمنت في الخرسانة هي ٢٠% غبار فرن الاسمنت و ١٥% غبار السليكا فيوم دون أي نقصان في مقاومة الضغط. تزداد التوصيلية الكهربائية بزيادة نسبة غبار الاسمنت من ٥% حتي ١٥% مع ثبات نسبة ١٥% غبار السليكا فيوم لكل الخلطات عند الترددات ٠.١٢ و ١.٠ و ١٠ كيلو هرتز، في حين يزداد امتصاص المياه بالخاصية الشعرية بزيادة نسبة غبار فرن الأسمنت من ١٠% حتي ٢٥% مع ثبات نسبة ١٥% غبار السليكا فيوم لكل الخلطات وذلك عند المقارنة بالعينة المرجعية. كما لوحظ أيضاً من تحليل (اكس ار دي) أن استبدال الاسمنت بغبار فرن الاسمنت وغبار السليكا فيوم يعطي معدل تآكل للحديد متشابه لكل الخلطات ذات النسب المختلفة من غبار فرن الاسمنت مع ثبات نسبة غبار السليكا فيوم.

الكلمات المفتاحية: الاستبدال الجزئي للأسمنت ، غبار فرن الاسمنت ، غبار السليكا فيوم ، مقاومة الضغط ، التوصيلية الكهربائية ، امتصاص المياه بالخاصية الشعرية ، والتآكل المتسارع للحديد ، تحليل الـ اكس ار دي .

1-INTRODUCTION

Both of Cement kiln dust (CKD) and silica fume (SF) are a by-product materials during manufacturing. using CKD and SF in concrete production more significant for dispose of them in usefully produce. It was found from the experimental tests and previous research, the use of CKD individually as a partial replacement of cement in concrete lead to decrease in strength. It was observed a progressive decrease in flow ability and mechanical strength properties of concrete with increasing CKD content replacement [1]. XRD analysis of cement kiln dust have revealed that the major component was limestone (CaCO_3), whereas the minor components were quartz (SiO_2) together with small quantity of sodium chloride (NaCl), gypsum (CaSO_4), arcanite (K_2SO_4), sulfospurite [$2(\text{C}_2\text{S})\cdot\text{CaSO}_4$] and spurite [$2(\text{C}_2\text{S})\cdot\text{CaCO}_3$] [2]. Silica fume is a highly effective pozzolanic material due to its extreme fineness (0.1 microns) and consists primarily of amorphous (non-crystalline) silicon dioxide (SiO_2). While small particle size of silica fume is beneficial in particle-packing, it also results in increased water demand to achieve workability needed for good compaction[3]. It is possible to use of the CKD as partial replacement of cement , in combination with pozzolanic materials in certain mortar mixed designs without lowering the main characteristics of the product[4]. Pozzolanic materials such as silica fume is used in concrete because of its fine particles, large surface area and high SiO_2 content [5]. Silica fume as a pozzolana when properly used it as certain percent, it can enhance various properties of concrete both in the fresh as well as in hardened states like cohesiveness, strength, permeability and durability [6]. In the general applications, part of cement may be replaced by a much smaller quantity of silica fume. For example, one part of cement can be replaced with 0.25 to 0.33 part of silica fume (mass to mass) without losing in the strength, provided the content of water remains constant[7]. The optimum silica fume replacement percentage varies from 10% to 15% replacement level, compressive strength decreases when the cement replacement is above 15% of silica fume [8].

2- EXPERIMENTAL PROGRAM

2.1- Materials used

According to the Egyptian standard specifications for concrete aggregates [9], sand with fineness modulus equal 2.59 and specific gravity of 2.57 was used, whereas the coarse aggregate used was dolomite maximum normal size (5-14mm) and specific gravity of 2.74. Cement (CEM I-52.5N) used was fresh product from Sina factory and complies to E.S.S 4756/2013[10]. CKD was obtained from the El Nahda cement factory in Qena, Egypt. SF was obtained from Egyptian Company for Ferroalloys (Alferrosilicon), Edfo factory , Aswan , Egypt. SF was confirming to ACI 234R-96 [7]. The chemical composition of Portland cement, CKD and SF were shown in **table 1**. Potable water free from salts, oils, acids, sugars and other harmful substances was used for mixing and curing of specimens. Sikament-163M was used as super plasticizer, for highly effective water reducing agent, density (at 20°C) 1.200 ± 0.005 kg/liter (ASTM C494), Appearance / Colour is brown liquid and recommended dosage is 0.6 – 2.5 % by weight of cement, The experimental dosage was 2.0 % by weight of cement.

2.2- Mixtures Proportions

In this experimental investigation, control concrete mix to achieve compressive strength of 50 N/mm² at the age of 28 days was done according to ECP 203-2007[11].The use CKD with different percentages 5%, 10%, 15%, 20% and 25% and a fixed proportion of silica fume (SF)

15% as partial replacement by weight of (OPC). The mixtures proportions for 1m³ in all concrete mixtures were shown in **table 2**.

Table.1 Chemical composition of Cement, Cement kiln dust and Silica fume

Chemical Composition, %	Sample		
	CEM I (52.5N)	CKD	SF*
SiO ₂	20.48	12.27	93.79
Al ₂ O ₃	15.06	2.27	0.36
Fe ₂ O ₃	5.23	3.70	1.48
CaO	3.96	45.28	0.33
MgO	3.40	1.49	0.41
SO ₃	2.12	2.59	0.19
Na ₂ O	62.72	0.31	0.43
K ₂ O	0.33	5.68	0.62
Cl	0.27	8.06	0.05
L.O.I	0.02	17.38	1.63

*Note: These average values are supplied by the manufacturer.

Table.2 Mix Proportions

Mix*	Cement (kg/m ³)	water (kg/m ³)	crushed stone (kg/m ³)	sand (kg/m ³)	CKD (kg/m ³)	SF (kg/m ³)	SP (kg/m ³)
Control Mixture							
Mix-00-00	360	144	1260	630	0.0	0.0	7.2
Cement kiln dust with Silica fume Mixtures							
Mix-05-15	288	144	1260	630	18	54	7.2
Mix-10-15	270	144	1260	630	36	54	7.2
Mix-15-15	252	144	1260	630	54	54	7.2
Mix-20-15	234	144	1260	630	72	54	7.2
Mix-25-15	216	144	1260	630	90	54	7.2

*Mix designation is(Mixture-Cement kiln dust%-Silica fume%)

3- ANALYSIS OF TEST RESULTS

3.1- Compressive strength

The cubes specimens (150 mm X150mm X150 mm) was tested for compressive strength at the end of 28 days. The specimen was tested after the surface gets dried. The test is conducted in a Compression Testing Machine with a capacity of 2000 kN and loading rate 0.6 N/mm²/sec, according to Egyptian Code for the design and implementation of concrete structures , tests guide C203[12]. The load applied on the smooth sides without shock and increased continuously till the specimen failed. **Fig. 1** shows the variation of compressive strength in mixtures content cement kiln dust and silica fume versus control mixture at 28 days. When comparison with control mixture (0% Cement kiln dust and 0% Silica fume), its observed the compressive strength for mixtures; (5% Cement kiln dust and 15% Silica fume), (10% Cement kiln dust and 15% Silica fume), (15% Cement kiln dust and 15% Silica fume) and (20% Cement kiln dust and 15% Silica fume) are increased with 18.34%, 11.48%, 6.17% and 3.55% respectively. Whereas at mixture (25% Cement kiln dust and 15% Silica fume),

compressive strength are decreased with 3.69%.

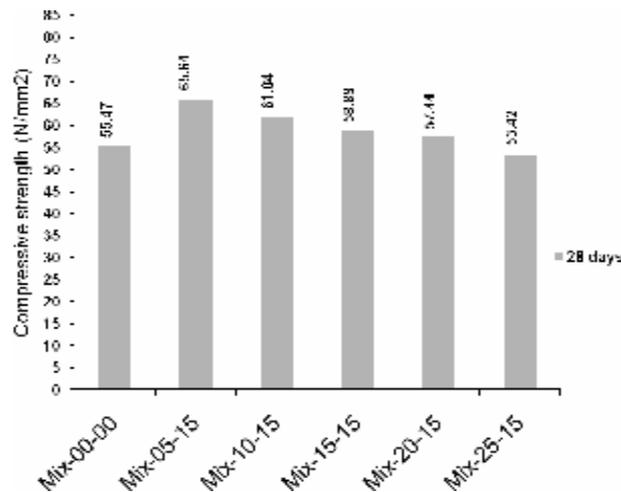


Fig.1 Compressive strength of mixtures content CKD 5 %,10%,15%,20% and 25% with constant 15% SF versus control mixture at 28 days

3.2- Electrical conductivity

Two electrodes (copper plate with 0.50 mm thick) were placed and fixed with cement paste over the entire two face of the specimen (150mmx150mmx150mm cube). It was applied to maintain a constant and uniform stress distribution. Measurements is performed by using alternating current (AC) at room temperature over frequency range of (0.12, 1.0, 10 and 100 kHz) using a RCL bridge model [Stanford Res. Model: SR-720] at age of 28 days. The setup of the experiment is shown schematically in **Fig.2**. Test were conducted on samples of control mixture and mixtures contained of cement kiln dust and silica fume to measurement the electrical conductivity (σ) and dielectric constant (ϵ) of concrete.

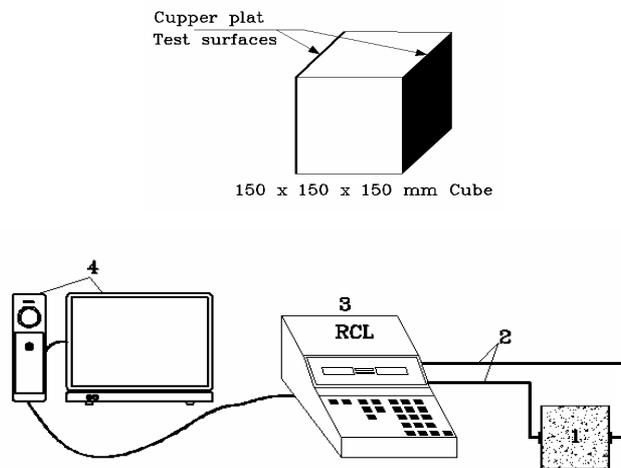


Fig.2 A schematic representation of RCL bridge setup

- 1-Sample with side copper plates,
- 2-Well shielded current,
- 3-RCL bridge,
- 4-Controlling computer.

Fig.3 show the effect of Cement kiln dust (5%,10%, 15%, 20% and25%) with constant ratio 15% of Silica fume on electrical conductivity (σ) at frequencies 0.12, 1, 10 and 100 kHz after 28 days. The electrical conductivity (σ) increase with increase cement kiln dust up to ratio 15% at frequencies 0.12, 1and 10kHz. A slight increase by frequency increasing up to 10kHz for this three mixtures; (5% Cement kiln dust and 15% Silica fume), (10% Cement kiln dust and 15% Silica fume) and (15% Cement kiln dust and 15% Silica fume).

The electrical conductivity (σ) for mixture (20% Cement kiln dust and 15% Silica fume) less than control mixture (0% Cement kiln dust and 0% Silica fume), but its value increase with increase AC frequency. The smallest value for electrical conductivity (σ) are observed for mixture (25% Cement kiln dust and 15% Silica fume), but this value increase with increase AC frequency. Generally it is observed the value of electrical conductivity (σ) directly proportional to the increase of AC frequency for all mixtures. The presence of CKD affected the location and height of the conductivity peaks. By increasing the CKD from 2.5% to 7.7%, the conductivity maximum increased. With further addition (10%), the height of the conductivity maximum decreased [13].

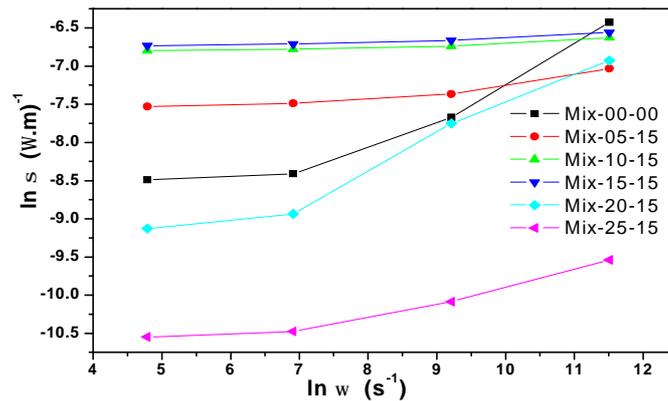


Fig.3 Effect of CKD (5%,10%, 15%, 20% and25%) and constant 15% SF on electrical conductivity (σ) at frequencies 0.12, 1, 10 and 100 kHz at 28 days.

Fig.4 show the effect of Cement kiln dust (5%,10%, 15%, 20% and25%) with constant ratio 15% of Silica fume on dielectric constant (ϵ) at frequencies 0.12, 1, 10 and 100 kHz after 28 days. In general for all mixtures contained of cement kiln dust and silica fume, the dielectric constant (ϵ) less than control mixture at all frequencies. That's mean by using cement kiln dust and silica fume in concrete mixtures lead to decrease the dielectric constant. For mixture (20% Cement kiln dust and 15% Silica fume) at frequency 1.0 kHz the dielectric constant (ϵ) increase with 4.22% when compared with control mixture. Whereas mixture (15% Cement kiln dust and 15% Silica fume) at frequency 0.12 kHz the dielectric constant (ϵ) a slight decrease with 5.01% when compared with control mixture. For all mixtures, the dielectric constant (ϵ) are decrease with increase AC frequency. It is observed the value of dielectric constant(ϵ) inversely proportional to the increase of AC frequency for all mixtures.

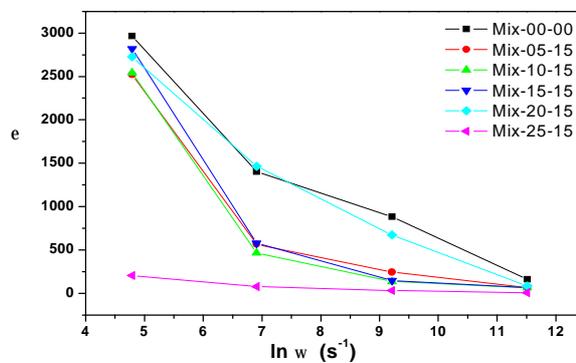


Fig.4 Effect of CKD (5%,10%, 15%, 20% and25%) and constant 15% SF on dielectric constant (ϵ) at frequencies 0.12, 1, 10 and 100 kHz at 28 days.

3.2.1- Relationship between electrical conductivity and compressive strength

The relationship between the electrical conductivity (σ) and compressive strength for concrete mixtures containing on different ratios 5%,10%, 15%, 20% and 25% of cement kiln dust and 15% silica fume after 28 days are showing in **Fig.5**. At all frequencies 0.12, 1, 10 and 100 kHz , it was found the electrical conductivity (σ) increase with decrease compressive strength up to 15% cement kiln dust, whereas observed beyond 15% cement kiln dust, the electrical conductivity (σ) sharp decreases with decrease compressive strength up to 25% cement kiln dust.

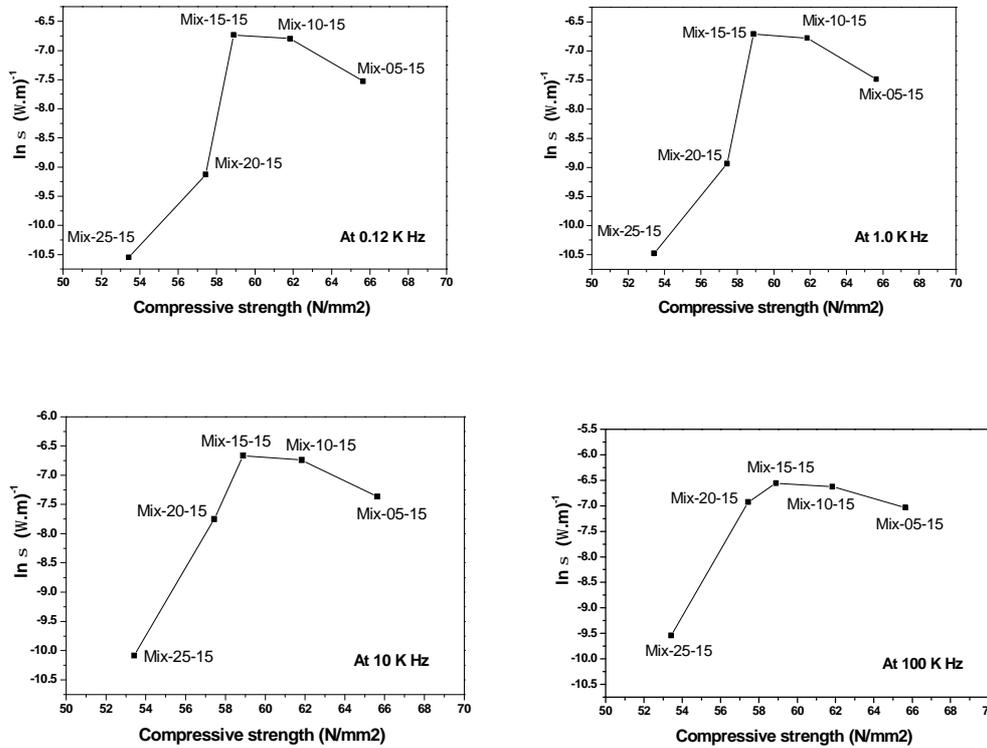


Fig.5 Relationship between electrical conductivity (σ) and compressive strength for mixtures content different ratios 5%,10%, 15%, 20% and 25% of CKD and 15% SF at different frequencies (kHz)

3.3- Water sorptivity

Water sorptivity test is a quick test to determined the rate of water absorption through dry concrete sample by capillary suction. The specimens with dimensions 70mm X 70mm and 30 mm height were dried in 70o C oven for 4 days and then left to cool for the following 24 hours in dry conditions. The sides of the test specimens were coated with water proof epoxy in order to achieve the conditions of unidirectional flow through test specimen. All specimens were dipped in the water in a vertical position with one surface in partially immersed to a depth of 5mm and the other open to the atmosphere. Weights of the specimen after epoxy coating were taken as initial weight at time 0. At fixed intervals time during the test (typically 3, 7, 9, 12, 16, 20, 25, 30, 60, 90, 120, 150, 180, 210, 240, 270 and 300 minutes) the samples were removed from water then excess water blotted off with cloth and the sample weighed. **Fig.6** shows schematic of sorptivity testing. Test were conducted on samples of control mixture and mixtures contained of cement kiln dust and silica fume at 28 days.

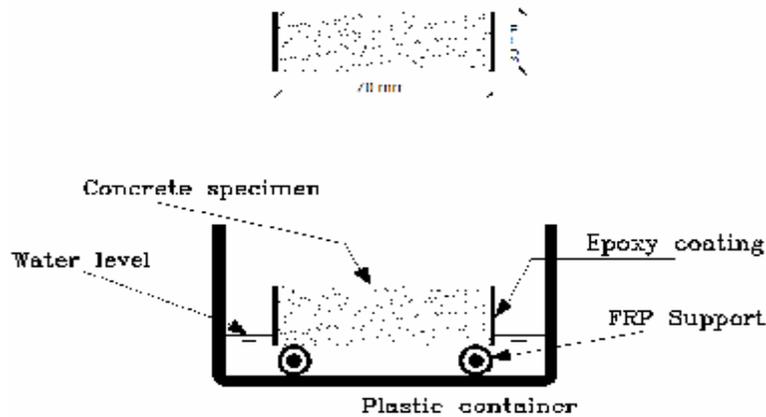


Fig.6 Schematic of Sorptivity Testing

Fig.7 shows the variation of sorptivity values for mixtures with different ratios of Cement kiln dust 5%, 10%, 15%, 20% and 25% in the presence 15% Silica fume versus control mixture at 28 days. it was observed at amount of (5% Cement kiln dust and 15% Silica fume) as partial replacement of cement, the sorptivity value was decreased with 18.34%. Whereas the sorptivity value were increased with 35.99%, 46.71%, 57.79% and 94.81% at amount of 10%, 15%, 20% and 25% Cement kiln dust in the presence 15% Silica fume as partial replacement of cement respectively when compared with control mixture.

When CKD was incorporated in all mixtures while keeping the amount of cement fixed, strength of mortars were higher than the control mix. However, it was found in the cases studied that there is no beneficial increase in strengths beyond 5% CKD addition. The sorptivity increased with the addition of CKD [14].

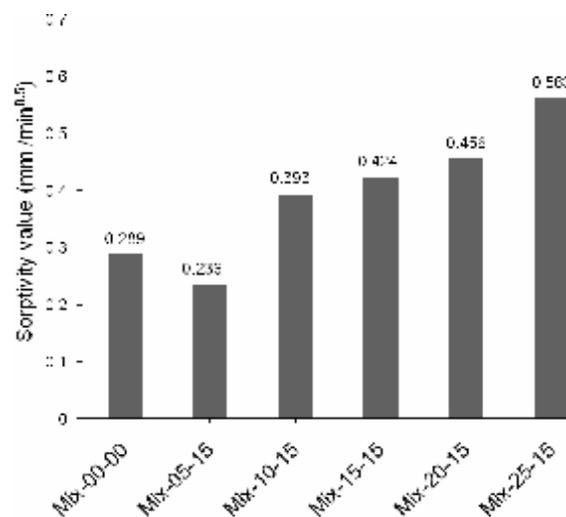


Fig.7 Sorptivity values for mixtures content CKD (5%,10%, 15%, 20% and 25%) and constant 15% SF versus control mixture at 28 days

3.3.1- Relationship between sorptivity and compressive strength

By analysis of the present test results to determined the relationship between the 28-day water sorptivity and compressive strengths of concrete mixtures with different ratios of content cement kiln dust in the presence 15% silica fume Fig.8, it was observed the water sorptivity increase with decreasing of compressive strength. It was found for mixture content 5% cement kiln dust and 15% silica fume which have the highest value of compressive strength are showed the smallest value of water sorptivity when comparing with the other mixtures.

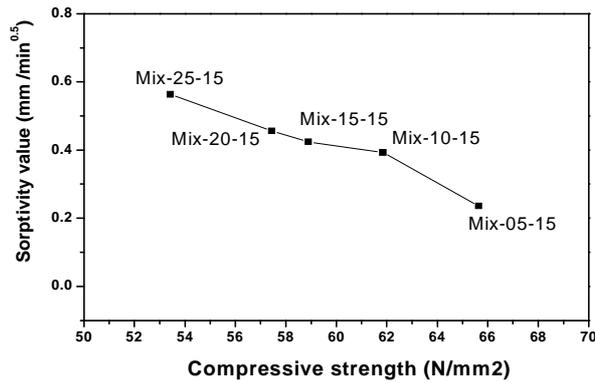


Fig.8 Relationship between sorptivity and compressive strength for mixtures content different ratios 5%,10%, 15%, 20% and 25% of CKD and 15% SF

3.4. ACCELERATED CORROSION

Accelerated corrosion test were conducted on samples of control mixture (0% Cement kiln dust and 0% Silica fume) and mixtures; (5% Cement kiln dust and 15% Silica fume), (10% Cement kiln dust and 15% Silica fume), (15% Cement kiln dust and 15% Silica fume), (20% Cement kiln dust and 15% Silica fume). (25% Cement kiln dust and 15% Silica fume) at age 28 days to investigate the effect of cement kiln dust with silica fume on corrosion resistance of concrete. Accelerated corrosion test were performed for all specimens based on ASTM G1-03[15]. The cube specimens (150 mm X150 mm X 150 mm) were built with steel bar 10mm diameter. Steel bar and concrete are only bonded in half length of the cubic specimen, in order to exclude an eventual confinement of the concrete surrounding the rebar due to the stress distribution on the specimen surface in contact with testing rig. During the specimen casting, concrete was placed in the moulds in the perpendicular direction of the bars as shown in **Fig.9**. The corrosion analysis was performed by A Potentiostat/Galvanostat (EG&G model 273). A three-electrode cell composed of a specimen as a working electrode, graphite counter electrode, and Ag/AgCl reference electrode were used for the tests as shown in **Fig.10**. Polarization tests were carried out at a scan rate of 0.2 mV/s at room temperature. Specimens with exposed surface area of 20 cm² were used as a working electrode. The Open circuit potential tests for all mixes were performed for 60 days. Specimens were immersed in 3.5%wt. NaCl solution for a period of 3 days before electrochemical tests. The PAR CalcTafel Analysis routine statistically fits the experimental data to the Stern-Geary model for a corroding system. The routine automatically selects the data that lies within the Tafel region (± 250 mV with respect to the corrosion potential). It then calculates the corrosion current and the corrosion rate. The solutions were prepared using analytical reagent grade chemicals and distilled water.

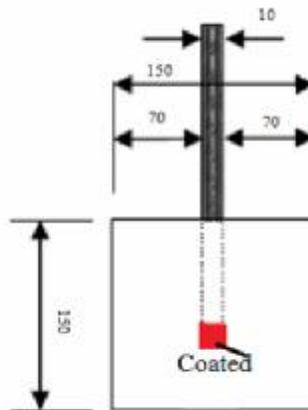


Fig.9 Cross-section of the corrosion specimens

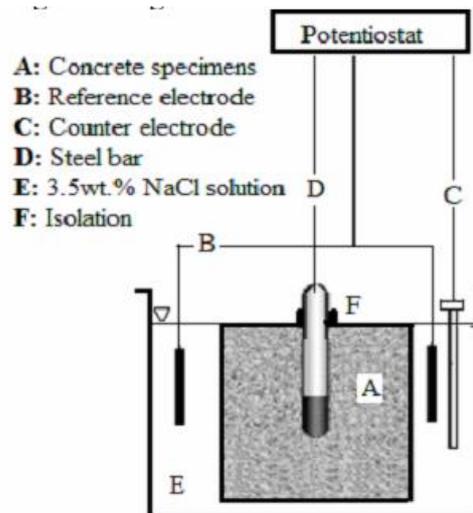


Fig.10 Experimental setup of electrochemical corrosion measurements

3.4.1. Open circuit potential (OCP)

Fig.11 shows the potential–time curves of steel bars imbedded in concrete for mixtures with different ratios of cement kiln dust 5%, 10%, 15%, 20% and 25% in the presence 15% silica fume versus control mixture at 28 days in 3.5 wt. % NaCl solution. The results show that replacing cement with cement dust kiln and silica fume, the OCP shifts in the negative direction. However, when passing more time the value of OCP is close to each other. This behavior is attributed to the same composition and structure as shown in SEM morphology.

3.4.2. The corrosion rate

Fig.12 shows the corrosion rate of steel bars imbedded in concrete for mixtures with different ratios of cement kiln dust 5%, 10%, 15%, 20% and 25% in the presence 15% silica fume versus control mixture at 28 days in 3.5 wt. % NaCl solution. The results indicate that replacing cement with cement dust kiln and silica fume, give close corrosion rate. The results are in agreement with potential–time values. This behavior is owing to the same composition and structure of concrete as shown in SEM morphology.

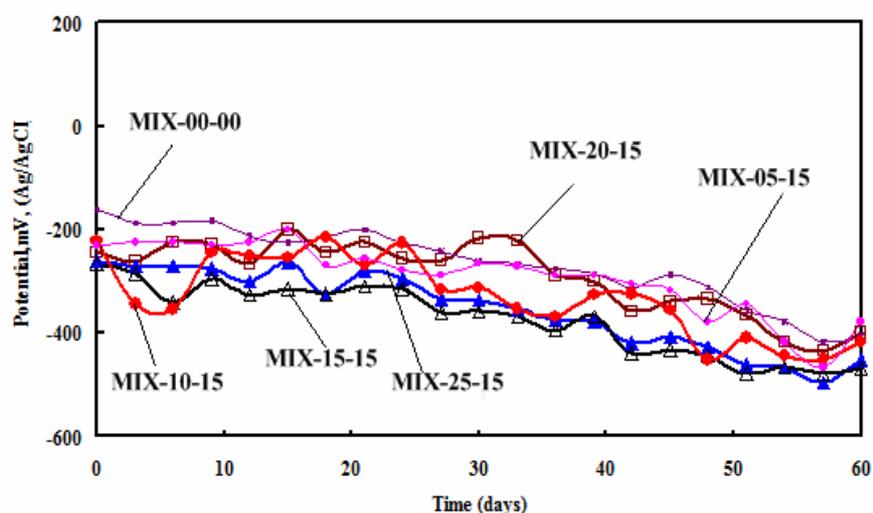


Fig.11 Potential–time curves of steel bars imbedded in concrete for mixtures (5%,10%, 15%, 20% and 25%) CKD and constant 15% SF and control mixture in 3.5 wt. % NaCl solution

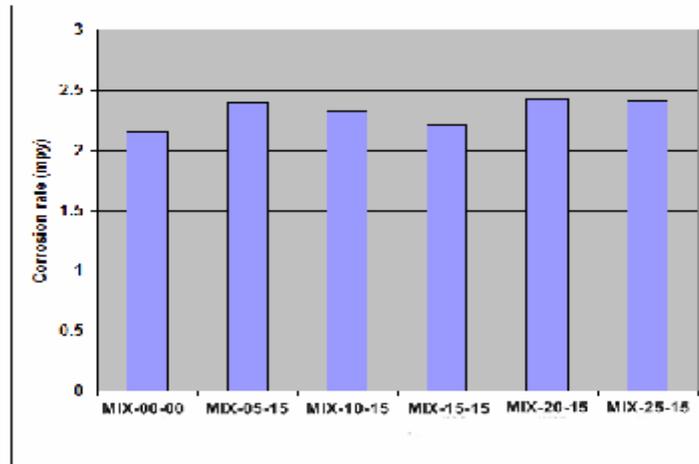


Fig.12 Corrosion rate of reinforced steel bars imbedded in concrete for mixtures (5%,10%, 15%, 20% and 25%) CKD and constant 15% SF and control mixture in 3.5 wt. % NaCl solution

3.4.3- Relationship between corrosion rate and compressive strength

Fig.13 shows the relationship between the 28-day corrosion rate and compressive strengths of concrete mixtures with different ratios of cement dust kiln 5%,10%, 15%, 20% and 25% in the presence 15% silica fume. It is observed at 5%, 10% and 15% cement dust kiln amount, corrosion rate are decreased by the decreasing in compressive strength, whereas at 20% and 25% cement dust kiln amount the role of compressive strength on corrosion rate can be neglected. By analysis of the present test results, ratio of corrosion rate are equal 3.65% to 4.51% from compressive strength **table.3**.

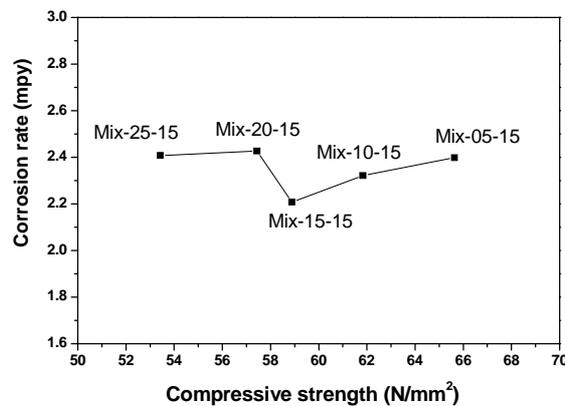


Fig.13 Relationship between corrosion rate and compressive strength

Table.3 Ratio of Corrosion rate from Compressive strength

Mix	Ratio%
Mix-00-00	3.88
Mix-05-15	3.65
Mix-10-15	3.75
Mix-15-15	3.75
Mix-20-15	4.23
Mix-25-15	4.51

3.5- X-RAY DIFFRACTION (XRD) ANALYSIS

When compare XRD analysis results for mixtures content different ratios 5%, 10%, 15%, 20% and 25% of cement dust kiln in the presence constant ratio 15% of silica fume with control mixture **Fig.14**. The same main minerals are observed for all mixtures in the shape of [Quartz or Quartz, syn (SiO_2), Dolomite ($\text{Ca Mg} (\text{CO}_3)_2$) and Calcite or Calcite, syn (Ca CO_3)]. The quartz or quartz, syn are was increase with increased cement dust kiln ratio up 25%, the dolomite was increase with increased cement dust kiln ratio up 20% and calcite or calcite, syn was increase with increase cement dust kiln ratio up 15%. In general no significant influence on main minerals of concrete mixtures with increase cement dust kiln ratio in the presence of 15% silica fume as a secondary agent.

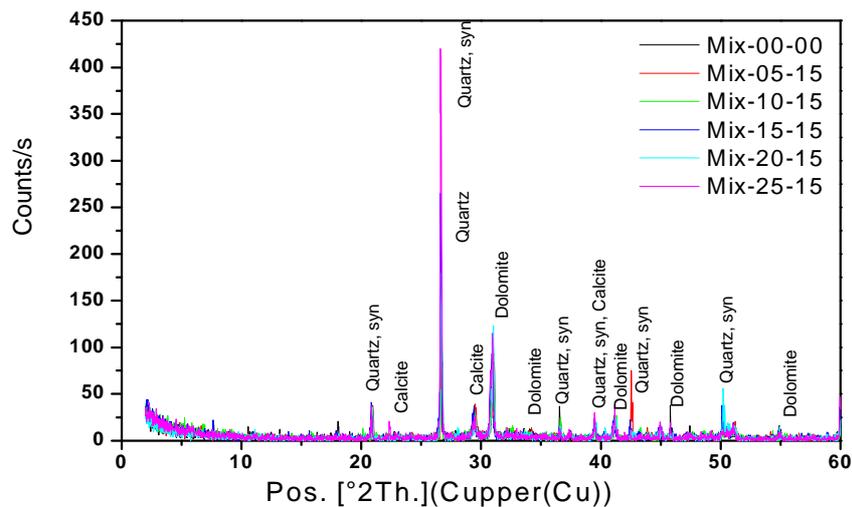


Fig.14 Comparison between XRD analysis for concrete mixtures at 5%, 10%, 15%, 20% and 25% CKD in the presence constant ratio 15% of SF and control mixture

4. CONCLUSIONS

1. We can use industrial wastes as CKD and SF to produce economic concrete. The use of CKD as partial replacement of cement in combination with SF in concrete were shown best performance than use CKD only.
2. The amount of 20% CKD in the presence 15% SF as a partial replacement by weight of cement were the optimum ratios can be used in concrete mixtures without lower on compressive. It is observed in mixtures at amount of 5%, 10%, 15% and 20% Cement kiln dust in the presence constant amount 15% Silica fume, the compressive strength are increased with 18.34%, 11.48%, 6.17% and 3.55% respectively. Whereas at mixture at amount 25% Cement kiln dust and 15% Silica fume, compressive strength are decreased with 3.69% when comparison with control mixture.
3. Generally it was observed the value of electrical conductivity (σ) directly proportional to the increase of AC frequency for all mixtures. For mixtures content 5%, 10% and 15% CKD in the presence constant 15% SF at frequencies 0.12, 1.0 and 10 kHz, it was observed the electrical conductivity (σ) are increased with increase CKD amount. Whereas beyond 15% CKD amount the electrical conductivity (σ) are decreased with increase CKD amount at all frequencies when comparison with control mixture.
4. For all mixtures contained of cement kiln dust and silica fume, the dielectric constant (ϵ) less than control mixture at all frequencies. That's mean by using cement kiln dust and silica fume in concrete mixtures lead to decrease the dielectric constant.
5. At all frequencies 0.12, 1, 10 and 100 kHz, it was found the electrical conductivity (σ) increase with decrease compressive strength up to 15% cement kiln dust, whereas observed beyond 15% cement kiln dust, the electrical conductivity (σ) sharp decreases with decrease compressive strength up to 25% cement kiln dust.

6. At amount of 5% CKD and 15% SF as partial replacement of cement, the sorptivity value was decreased with 18.34%. Whereas the sorptivity value were increased with 35.99%, 46.71%, 57.79% and 94.81% at amount of 10%, 15%, 20% and 25% CKD in the presence 15% SF respectively when compared with control mixture.
7. For all mixtures containing on CKD and SF as partial replacement of cement, the water sorptivity increase with decreasing of compressive strength.
8. The replacing of cement with CKD and SF, give close corrosion rate .The results are in agreement with potential–time values. This behavior is owing to the same composition and structure of concrete as shown in SEM morphology.
9. It is observed at 5%, 10% and 15% CKD amount in the presence 15% SF, corrosion rate are decreased by the decreasing in compressive strength, whereas at 20% and 25% CKD amount the role of compressive strength on corrosion rate can be neglected. The ratio of corrosion rate are equal 3.65% to 4.51% from compressive strength.
10. The presence of cement kiln dust and silica fume as replacing of cement not effect on the main minerals of concrete , it's clear shown from XRD analysis.

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