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Effect of Addition Silica Fume to the workability, Strength and Permeability of Concrete

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Abstract The main objective of this paper is to determine the effect of silica fume on the workability, compressive strength, and permeability of concrete. Many experiments were carried out by replacing cement with different percentages of silica fume. The silica fume was replaced by 0%, 5%, 10%, 15% and 20% for water-cement ratios 0.38. For all mixes, compressive, permeability, and workability were determined at 3,7,14, and 28 days. The results showed that the compressive strength of 51.24 MPa, 53.01MPa, 54.38MPa, 57.77 MPa, and, 63 MPa respectively. The optimum of specimen's replacement percentage is 15% silica fume had the highest strength 63MPa. Results of the permeability showed that specimens containing silica fume have low permeability and it also showed that specimens containing 15%, 20% optimum specimens.
Keywords: Silica Fume; Compressive strength, workability, permeability of concrete.

تأثير إضافة غبار السيليكا على قابلية وقوة ونفاذية الخرسانة

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الملخص الهدف الرئيسي من هذه الورقة هو تحديد تأثير غبار السيليكا على الضغط والنفاذية وقابلية التشغيل على الخرسانة عالية القوة. أجريت العديد من التجارب من خلال استبدال الأسمنت بنسب مختلفة من غبار السيليكا. تم استبدال غبار السيليكا بنسبة 0٪ ، 5٪ ، 10٪ ، 15٪ و 20٪ لنسب المياه الاسمنت 0.38. لجميع الخلطات، تم تحديد الضغط والنفاذية وقابلية التشغيل في 3، 7، 14، و 28 يوما. أظهرت النتائج أن قوة الضغط تبلغ 51.24 ميجا باسكال و53.01 ميجا باسكال و54.38 ميجا باسكال و63 ميجا باسكال و57.77 ميجا باسكال على التوالي. النسبة المئوية المثلى لاستبدال العينات هي 15٪ من دخان السيليكا الذي يتمتع بأعلى قوة 63 MPa. أظهرت نتائج النفاذية أن العينات التي تحتوي على غبار السيليكا لها نفاذية منخفضة وأظهرت أيضًا أن العينات التي تحتوي على عينات مثالية بنسبة 15٪ و 20٪.

الكلمات المفتاحية: غبار السيليكا، قوة الضغط، قابلية التشغيل، نفاذية.

1. Introduction

The American Concrete Institute (ACI 234R-96) defines silica fume as "very fine non-crystalline silica produced in electric arc furnaces as a byproduct of the production of elemental silicon or alloys containing silicon". Silica fume is also known as micro silica, condensed silica fume, volatilized silica or silica dust. It is usually a grey colored powder, somewhat similar to Portland cement or some fly ashes. It can exhibit both pozzolanic and cementations properties. Silica fume has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent. The use of silica fume (SF) for the production of high strengtht concretes is very common. Many extensive experiments were carried out by many researches around the world indicated that the use of silica fume in concrete increases the concrete strengths, modulus of elasticity, chemical and abrasion resistance, in addition to enhancing durability, corrosion protection, and mechanical properties. But there is not a clear, unique conclusion regarding the optimum silica fume replacement percentages, although some of the researchers have reported different replacement levels [1, 2, 3].The use of silica fume in concrete has engineering potential and economic advantage. It is reported by most researchers [4, 5] that workability is reduced on silica fume inclusion however Kadri and Dual [6]. Reported an increase in workability on replacement of cement by silica fume. The main

contribution of silica fume to concrete strength development at normal curing temperature takes place from about 3 to 28 days. The contribution of silica fume to strength development after 28 days is minimal [7]. Bhanja and Sengupta [8]. Reported that the inclusion of silica fume in the range of 5 – 25% increases compressive strength in the range of 6.25 – 29.85% for the water-cement ratio between 0.26 - 0.42. Sakr, [7]. reported that at 15% silica fume content gravel concrete, barite concrete, and ilmenite concrete showed increased compressive strength by 23.33%, 23.07%, and 23.52% respectively at 7 days, 21.34%, 20% and 22.58% respectively at 28 days, 16.5%, 18.7% and 22% respectively at 56 days and 18%, 7.14% and 22.80% respectively at 90 days. Khayat [9]. The addition of SF in concrete leads to a reduction in porosity of the interfacial transition zone between matrix and aggregate in the fresh concrete and provides the microstructure needed for strong transition zone reported that at 7.5% replacement level compressive strength increased in the range of about 10 – 17 % at a different water-cement ratio (w/c). When pozzolanic materials are incorporated into concrete, the silica present in these materials react with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C – S – H), which improve durability and the mechanical properties of concrete. [10]. The use of blended cement or supplementary cementing materials such as SF decreases the permeability, thereby increasing the resistance of concrete against corrosion [11]. Due to its high pozzolanic and its extreme fineness SF is considered to produce low permeability concrete. Evaluating the permeability of an existing the concrete structure is an essential and important parameter for the durability performance and service life, since permeability of concrete is an important parameter in deciding the durability of the structure [12]. In this paper, an experimental program was conducted to investigate the suitability of silica fume as partial replacement of cement and its effect on the compressive strength, permeability, and workability of concrete. The experiments were carried out over water-cement ratios 0.38 were prepared by replacing part of OPC with silica fume. The replacement levels were (0% control mix) 5%, 10%, 15%, 20% (by weight). This paper presents the results of this investigation For all mixes, were determined at 28 days.

2. Materials and Mix Proportions

The cementitious materials used in this study were Portland cement (OPC) type I equivalent the ASTM, c150-92 and silica fume (SF) meets the ASTM c1240-93 (1993). The chemical and physical properties of these materials are given in Table (1). The coarse aggregates size of 20 mm crushed granite was used. and ordinary mining sand was used in this investigation. For the present investigation, mixing all materials were precisely weighed mixing was done in a mixer. all materials were added into the mixer in the following sequence of coarse aggregate, fine aggregate, and silica fume. The proportion of the materials by weight was 1:1.89:2.17:0.48 (Cement, Fine aggregate, Coarse aggregate, Water). To investigate the effect of silica fume inclusion (as part replacement of cement), 100 mm cubes were cast for referral and other mixes having variable silica fume content. The cement was replaced by silica fume at the rate of 0% (as control mix) 5, 10, 15 and 20% (by weight from cement). The water/cement ratio was 0.38. Consequently, The slump of control high-strength concrete changed due to the effect of the different levels of silica fume. To get a homogenous mix. Table (2) description of workability and magnitude of a slump. The workability (Slump value) and the compressive the strength of different mixes were tested at 3, 7, 14 and 28 days as per the procedure laid down in IS: 516 - 1981. The proportion mix of materials as shown in Table (2).

Table 1. Chemical composition For cement and silica fume

Oxides (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	SO_3	Na_2O
Cement	20.25	5.04	3.16	63.61	4.56	0.51	1.42	0.26
S.F	85	1.12	1.46	0.8	0.7	1.2	0.87	-

Table 2. Proportions of concrete mixtures

Samples	Quantity m^3	Percentage of (SF%)	OPC (kg/m^3)	SF (kg/m^3)	Fine Agg (kg/m^3)	Coarse Agg (kg/m^3)	Water (kg/m^3)
Y1	0.051	0	30.19	0	30.39	49.58	11.48
Y2	0.051	5	28.68	1.51	30.39	49.58	11.48
Y3	0.051	10	27.17	3.02	30.39	49.58	11.48
Y4	0.051	15	25.66	4.53	30.39	49.58	11.48
Y5	0.051	20	24.15	6.04	30.39	49.58	11.48

3. Results and Discussions

3.1. Workability of fresh concrete

Figure (1) show the influence of the amount of silica fume on the workability requirement. The results of Figure (1) slump value were decreased with an increment of the percentage of silica fume content. The sufficient workability was found when there was no silica fume. This is because when increasing the amount of silica fume will absorb more water from the mix, hence decrease the water-cement ratio in which, will lead to decrease in the fluidity of the mix resulting in decreasing the workability. The figure showed that (5% - 10%) silica fume content mix proportion was sufficient four slump value. The workability of the spacemen with 15% and 20% replacement is within the ranged medium in construction work.

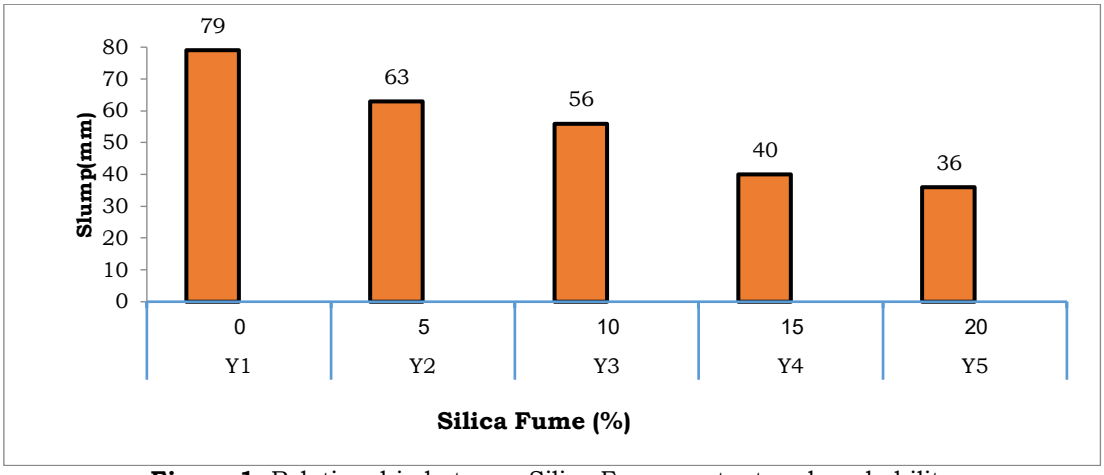

Figure 1. Relationship between Silica Fume content and workability

3.2. Compressive strength

Fig. 2. shows the effects of curing time on the compressive strength of all mixtures of the high strength concrete (Y1, Y2, Y3, Y4, and Y5). The study was conducted the compressive strength of concrete containing various percentages of silica fume. The control of specimen's concrete it was 100% cement which compared with the specimens concrete containing 5%, 10%, 15%, and 20% silica fume. The study was conducted based on 3, 7,14 and 28 days of curing time for the different concrete in order to establish their compressive strength development. It was observed that the compressive strength of the concrete increased with prolonged curing time. The 3-day compressive strength of 33.67 MPa was obtained in the control mix (Y 1). It increased by 0.652%, 2.69%, 8.02%, and 4.20% due to inclusion of 5%, 10% 15% 20%2 of Silica fume,
respectively in concrete. For high strength of control mix (Y1), about 51.77% of 28-d strength was gained in 3-day while 15% silica fume substitution, produced a concrete whose 28-day maximum strength was 63 MPa. There was high early strength development such that the difference between 3-day and 28-day strength was 72.74%. Silica fume has been used as additives to concrete 15% by weight of cement; the potential exists for very strong and brittle concrete. It increases the water demand in a concrete mix, however, dosage rates of less 5% will not typically require a water reducer. High replacement rates will require the use of a high range water reducer. (A.M Neville 1995).

The compressive strength decreased when the dosage of silica fume more than 15%. Microsilica is only effective at a secondary pozzolanic stage, reacting with Ca(OH)2, with reduced cement content, the primary hydration reaction stage decreased thus reducing the strength of the mix.

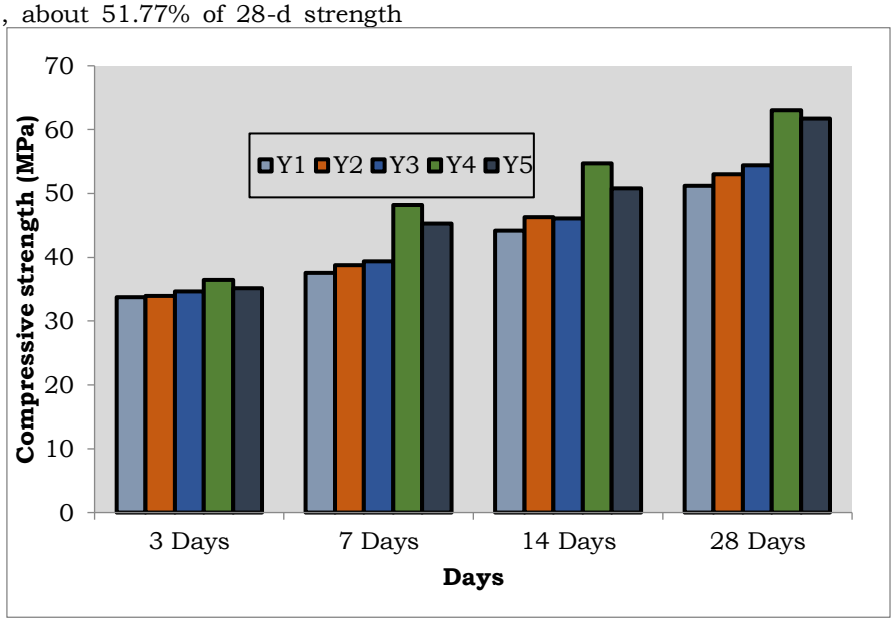

Figure 2: Effect of Silica Fume on the Concrete compressive strength

3.3. permeability

Permeability is a measure of the concrete ability to resist penetration or other substances. In this study used initial surface absorption test (ISAT). As specified in Bs 1881 part 208:1996. The result at age 28 days has been shown in figure (3). From

the results attained, it is evident that concrete cubes samples which contained silica fume has low permeability and it is also showed that the concrete containing 15% and 20% of silica fume of specific area which range around 1/100 the size of average cement particles pozzolanic reaction between silicon oxide, aluminium oxide and calcium oxide released by hydration of portland cement leads to the formation of (C-S-H and (C–A–S–H) gel. It is a very reaction pozzolan. The effects is a refinement of the pore structure when is added to the cementitious system.

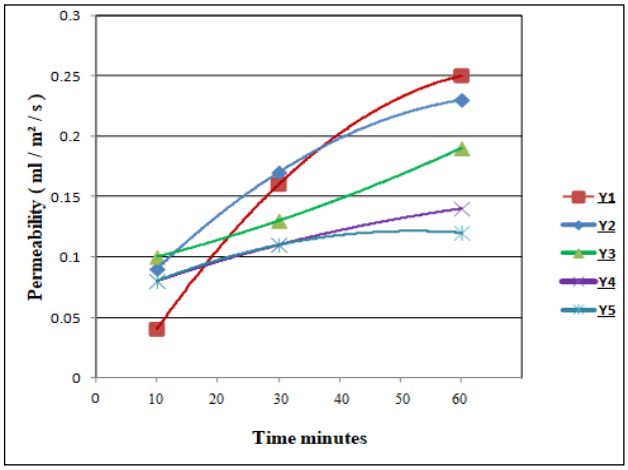

Figure 3: graph Pattern Permeability for the cubes at 28 days (Silica Fume 0%, 5%, 10%, 15%, 20%)

4. Conclusions

From the results, it is concluded that the effect of silica fume on compressive, permeability and workability. The silica fume is a better replacement of cement. The rate of strength gain in silica fume concrete is high. After performing all the tests and analyzing their result, the following conclusions can be derived:

(1) The optimum value of concrete contains 15% silica fume produce higher than anther value.

(2) The permeability of concrete is dramatically reduced as the silica fume replacement ratio is beyond 15%, and the permeability is lowered until the silica fume replacement ratio increases from 15% to 20%.

(3) The workability of concrete decreases with an increase with silica fume content.

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