

Strength Modification of Steel Slag Concrete Due to Silica Fume

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ABSTRACT: Concrete is the most widely used composite material for design requirements because of it possessing properties which make it to undergo harshest weather conditions with required strengths. Its limits can be enhanced with the help of chemical admixtures as well as with supplementary cementitious materials with OPC. In current paper, it features the study of effect due to addition of silica fumes to the OPC as well as slag cement which is one of most popular SCMs to develop higher earlier as well as later strength along with steel slag aggregate as partial replacement of aggregate. Since these days the amount of waste materials originating from industries is increase day by day which contains SCMs generally. With the use of SCMs there is also reduction in carbon dioxide emission hence also proves to be beneficial for preventing pollution. Since lesser work has been carried out in the study of these SCMs' addition hence it can be assumed that the present work will be beneficial for the determination of effect on the strength of concrete due to addition of these SCMs. The main parameter in this study is determination of compressive strength, flexural strength and porosity of the concrete with the mix design of M20 in which a proportion of silica fume was used in 0, 10 and 20 percent respectively as a partial replacement on OPC as well as SC. Fly ash and slag cement are the two SCMs which are most commonly used in concrete. The use of SF in OPC does not make any significant change in the unit weight but produces high strength concrete with lesser permeability. Similarly the steel slag also exhibits the properties of aggregate with little limitations and hence can be partially replaced.

KEYWORDS: Supplementary cementitious materials (SCMs), Slag cement (SC), Fly ash cement (FSC), Silica fumes (SF), Capillary absorption (CA).

I. INTRODUCTION

Concrete is the most widely used composite material around the globe for the construction purposes. It is having this much importance because of it possessing the properties which makes it withstand the harshest conditions of the weather conditions and environment. Because of its high demand and due to its wide acceptance, since last decades it has been the centre of focus for researchers to improve its limits in the terms of durability and other various mechanical properties along with reducing its negative impacts. There are various supplementary cementitious materials available and plays an important role for this purpose. Due to the industrialisation the amount of waste materials coming from various industries is increasing day by day. It is mainly due to the higher demand in the developing countries and strict environmental policies by the government. The various waste materials which can be utilised as supplementary cementitious material includes fly ash that can be obtained from the chimneys since it is a by product of the burning of the coal, silica fumes that is a by product of silicon metal production or ferrosilicon alloys production, blast furnace slag that is obtained from blast furnace of iron industries, steel slag which is a mixture of metal oxides with silicon dioxide is a waste produced from the steel making industries. These supplementary cementitious materials holds good property enhancements when a partial replacement is done with cement or aggregate e.g. steel slag aggregate can be used as partial replacement of the normal aggregate and hence they play a dual beneficial role i.e. enhancing the properties as well as reducing the cost along with negative impacts on the environment to prevent pollution. The reason for high importance of concrete can be derived from the property of concrete to withstand the harshest conditions of the environment. Silica fume is a non-crystalline form of silica. It is obtained in fine powder form which can be collected

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Vol. 6, Issue 1, January 2017

in the production of the silicon alloy production as a by product. Because it has silica content in greater extent and is extremely fine hence it forms a good pozzolanic material. Silica fume improves the properties of ordinary cement as increase in compressive strength and also in abrasion value and hence can be beneficial to improve both mechanical and chemical properties of the cement. It also reduces the permeability of concrete and hence protects the reinforcement from weather effects as corrosion. Due to this the concrete with such modifications can be used in the situations where the wet weather situations are and also in under water situations as piers of bridges. Steel slag, is generated during the steel making as a by product when the molten steel is separated from the impurities. The slag formed is in molten state which contains silicates and oxides. After cooling it solidifies and steel slag aggregate is formed which is used in many practices as in highway for pavements and in fills or in embankments. The specific gravity of steel slag aggregate is higher than the normal aggregate and hence has a high abrasion value and therefore can be used as partial substitution of the normal aggregate. But since it more water absorption and is alkaline in nature hence only partial replacement of natural aggregates is advised. Since it reduces the overall cost and also has environmental benefits so is the suitable alternative for partial replacements.

II. RELATED WORK

Dilip Kumar Singha Roy and Amitava Sil [1] in august 2012 in their study “Effect of partial replacement of cement by silica fumes in hardened concrete” studied the effect of partial replacement of the cement with silica fumes. In this study it was concluded that with 10 percent replacement of the silica fumes the compressive strength is increased at an average of 17 percent. Also there is increase in the [8] flexural strength by an average of 30 percent. Meena Murmu [2] of NIT Rourekela in her study “Strength characteristics of properties of lime activated slag cement” has studied the hydrated matrix of steel slag and concluded that partial replacement of steel slag as aggregate along with hydrated lime increases the strength of concrete. D. Karthik, J. Doraikkannan [3] have studied the effect of addition of Silica Fume and Steel Slag as partial replacement with the cement in Concrete and various results were conducted on Compressive strength, split tensile strength, flexural strength after 7, 28, 56 and 90 days respectively. The durability and the resistance to acid attack were also studied. Alla M Rashad, Hosad El-Din H. Saleem and Amr F. Shaheen [4] has studied the effect of silica fume and steel slag on properties like abrasion resistance and compressive strength of HVFA concrete by replacing Portland cement with class F fly ash at a level of 70% high volume Fly ash concrete named F70. Further it was modified by replacing fly ash by 10% and 20% with silica fumes, with blast furnace slag (granulated) and with their equal combination. Ratul Das, Rama Debbarma [5] of NIT Agartala in their study “Effect of corrosion inhibitor on properties of concrete and mortar made with different admixtures” has concluded that there is delay in initial as well as final setting time of ordinary Portland cement as well as slag cement due to the addition of sodium nitrate as corrosion inhibitor. Also there was decrease in 28 days strength in both type of the cements but in the case of flexural strength, the flexural strength in the case of steel slag cement it was greater than the ordinary Portland cement. S. Tanveer Hussain, K.V.S.Gopala Krishna Sastry [6] has studied strength properties by using micro silica and nano silica and concluded that Nano materials like nano silica, nano titanium oxide, carbon nano tubes, nano alumina etc can be used to modify the strength properties of concrete. Various strength properties like Compressive strength, split tensile strength and flexural strength of M40 and M50 grades of concrete with the use of nano silica (1%, 1.5%, 2%, 2.5%) and micro silica (5%, 7.5%, 10%, 15%) as partial replacement of cement were studied. Des King [7] of UK studied the effect of silica fume on the properties of concrete and the effect of blast furnace slag (ground granulated), fly ash and silica fumes along with limestone fines on the various properties of the concrete. Also the properties of concrete in fresh state and in hardened state were compared. M.D.A. Thomas, M.H. Shehata [8] of university of Toronto in their study “The effect of fly ash composition on the expansion of concrete due to alkali silica reaction” studied the partial replacements of silica fume and fly ash along with Ordinary Portland cement and determined the improvements. D.F. Lin a , K.L. Lin b , W.C. Chang c , H.L. Luo, M.Q. Cai (2008) [9] in their study “Improvements of nano-SiO₂ on sludge/fly ash mortar ” studied the effect of partial replacement of silica fumes in fly ash cement mortar and its effect on the compressive strength and permeability. Jan Bijen [10] in his study ‘Benefits of slag and fly ash in construction and building material’ has studied the effect of fly ash and steel slag on ordinary Portland cement and the variation in compressive strengths were studied. S.A. Barbhuiya, M. I. Russeli. J.K. Gbagbo and P.A.M. Basheer [11]

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have studied the properties of fly ash concrete and silica fumes modified with hydrated lime resulted in the improvement of early day's strength and durability of concrete. Hisham Qasrawi, et al. [12] studied the use of low Calcium Oxide (CaO) unprocessed steel slag in concrete to be used as fine aggregate. They concluded that compressive and tensile strengths of concrete steel slag are much better for concretes of lower strengths. O. Boukendakdji et al. [13] carried out research work in Effect of slag on the fresh concrete properties. They concluded that slag can produce better self compacting concrete. Mateusz Radlinski, Jan Olek and Tommy Nantung [14] in their study 'Resistance of Ternary concret' studied the results of the laboratory study of the resistance by concrete containing fly ash and silica fumes and concluded that with the addition of 20 percent silica fumes was less sensitive for scaling resistance as compared to the 30 percent replacement of the fly ash. J. G. Cabrera and P. A. Claisse [15] carried out their work entitled Oxygen and water vapour transport in cement pastes, and different transmission rates for oxygen for different mechanisms of transmission was studied.

III. MATERIAL AND METHODOLOGY

Ordinary Portland cement, Jindel Panther slag cement, sand of zone II, silica fumes of 920 D grade along with steel slag and normal aggregate was used in mix proportion of M20.

The current work has been done in 3 different combinations. In the first combination the experimental work was carried out on mortar mix of ordinary Portland cement modified with addition of silica fumes in different percentages as of 0%, 10% and 20% along with partial replacement of the aggregate with steel slag aggregate in concrete mortar. In the second combination the experimental work was carried out on mortar mix of slag cement modified with addition of silica fumes in different percentages as of 0%, 10% and 20% along with partial replacement of the aggregate with steel slag aggregate in concrete mortar. In final combination the experimental work was carried out on mortar mix of Portland cement with slag cement in the ration of 1:1 modified with addition of silica fumes in different percentages as of 0%, 10% and 20% along with partial replacement of the aggregate with steel slag aggregate in concrete mortar.



Fig (a) Moulds for compressive strength determination

The mix was properly mixed in appropriate proportion along with water and required workability was achieved. The mix was placed in high cylinder and in moulds and was compacted properly on vibrating machine. In this way the various blocks with different quantities of the silica fumes in Portland cement as well as in slag cement were prepared. After 7 and 28 days respectively, different test for the determination of the properties of the cement were done as compressive strength, flexural strength and porosity of the concrete blocks.

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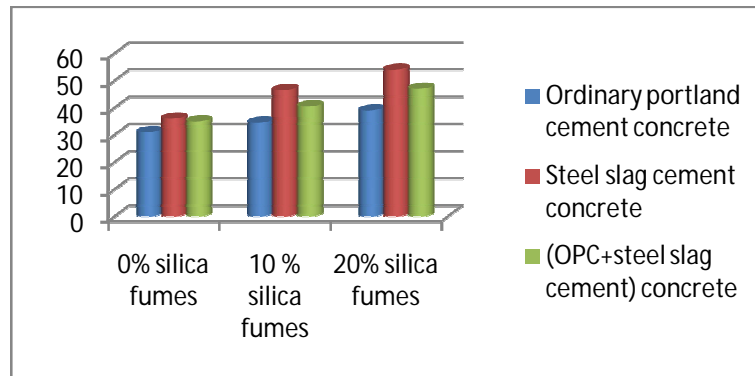
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IV. EXPERIMENTAL RESULTS AND DISCUSSION

The experimental results can be divided into two segments which are in fresh state of concrete and in hardened state of concrete and are as

A. Fresh concrete

Due to the addition of the silica fumes there is more cohesiveness in both type of the cements i.e. in ordinary Portland cement as well as in steel slag cement there is more cohesiveness. But in the case of workability, when more than 10 percent addition of silica fumes is there, the workability of the concrete shows a little decrease. The normal consistency of the mortar is shown in the graph 1 below as

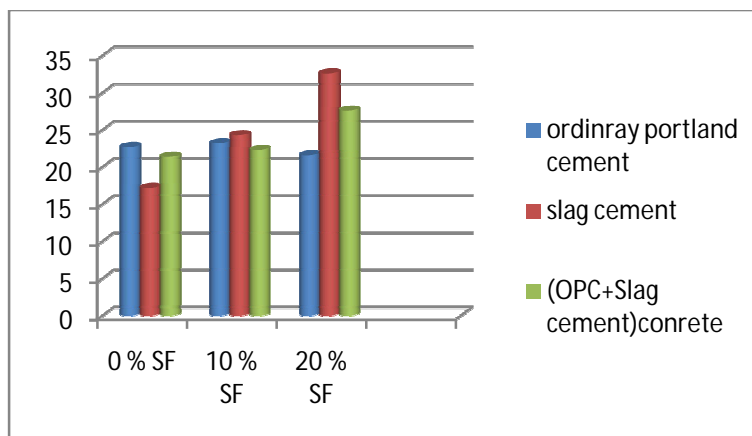


Graph 1. Normal consistency for the different mortar

It is found that the increase in the amount of silica fumes the requirement of the water increases. It is because of the fineness of the particles present in the silica fumes. Hence the water consistency of the mix increases with the increase in the silica fumes. The requirement of the water is more in the case of slag cement because of its higher fineness.

B. HARDENED CONCRETE

Compressive strength: the variation of the strength is shown in the graph 1 (a) and 1 (b) which shows that with the addition of the silica fumes there is increase in 7 and 28 days compressive strength.



Graph. 2. (a) Compressive strength due to the addition of Silica fumes (SF) after 7 days

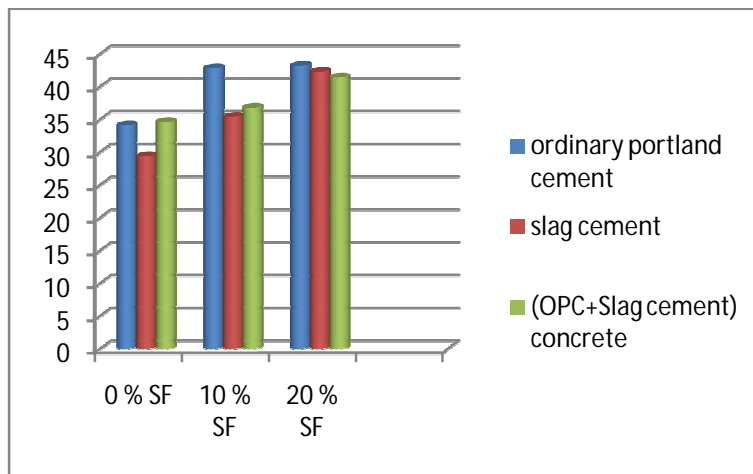
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Vol. 6, Issue 1, January 2017

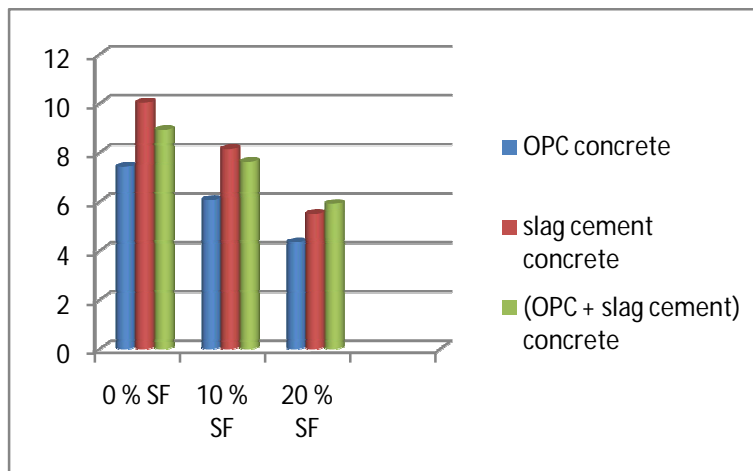
There is high early gain of strength in the case of ordinary Portland cement concrete while the later stage gain of strength is more in case of slag cement. It is because of the reason of fast reaction in Portland cement and silica fumes which is responsible for higher early strength while the slag cement is coarser in size due to which there is lesser early strength and hence the strength is gained at later stage which is higher as compared to the Ordinary Portland cement.



Graph. 2.(b) Compressive strength due to the addition of Silica fumes (SF) after 28 days

Hence it was concluded that up to 5 % addition of silica fumes increases the strength and the overall strength is increased in every case with up to 20 % replacement of the cement with silica fumes.

Porosity: Porosity test of different mortar was conducted to determine the porosity after 7 and 28 days respectively after curing and is represented in the graphs 3(a) and 3(b).



Graph. 2. (a) Porosity due to the addition of Silica fumes (SF) after 7 days

It was concluded that as we increase the amount of the silica fumes, the amount of porosity decreases because of the formation of the denser mixture which can easily prevent the water from entering and hence the reinforcement is

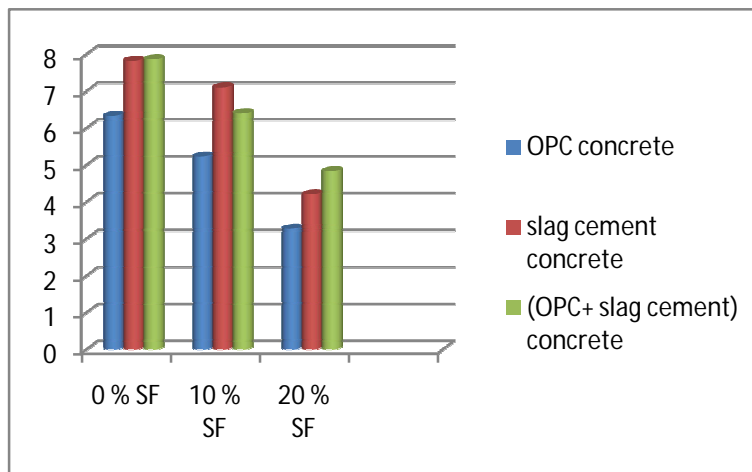
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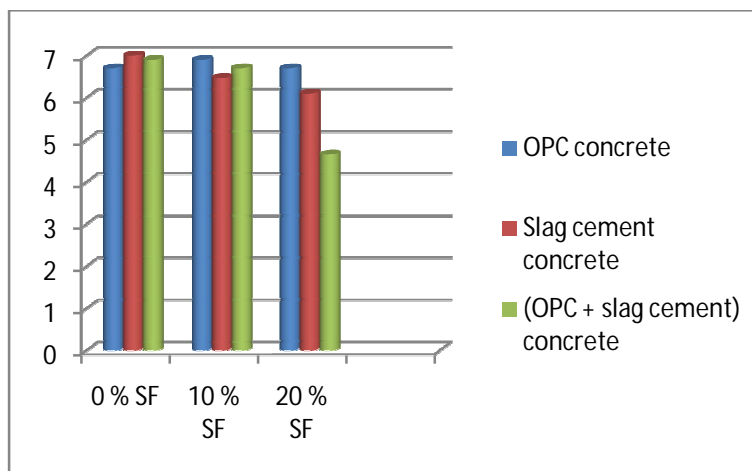
prevented from the corrosion in the areas where the humidity is high and with where with the simple mixture this resistance against porosity cannot be achieved.



Graph. 2. (b) Porosity due to the addition of Silica fumes (SF) after 28 days

In all type of the combinations, with the increase in silica fumes replacement, the porosity decreases. If we compare the amount of porosity decreased then it can be computed that in the case of ordinary Portland cement if we compare the zero percent silica fume replacement with the 20 percent replacement then it can be said that the percentage decrease in the porosity is 41.50 percent after 7 days and is 48.34 percent after 24 days. Similarly in the case of slag cement the percentage decrease in the porosity is 45.16 percent after 7 days and 46.29 percent after 28 days. Finally in the case of combination of both the percentage decrease in the porosity 33.74 percent after 7 days and 38.54 after 24 days.

Flexural Strength: Porosity test of different mortar was conducted to determine the porosity after 7 and 28 days respectively after curing and is represented in the graphs 4(a) and 4(b).



Graph. 3. (a) Flexural Strength due to the addition of Silica fumes (SF) after 7 days

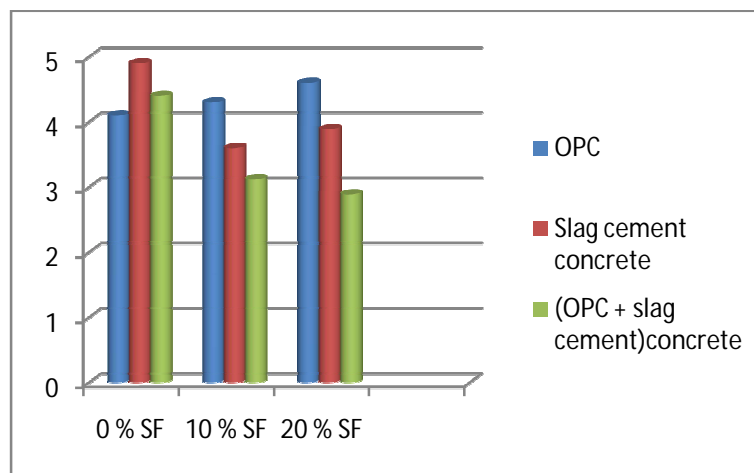
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In the case of flexural strength the final strength with the addition of admixtures is decreased in the case of slag concrete and the combination of ordinary Portland cement and slag cement but when it is the case of ordinary Portland cement concrete when all the final strengths are compared then it can be said that the final strength is increasing with the increase of the silica fumes content.



Graph. 3. (b) Flexural Strength due to the addition of Silica fumes (SF) after 28 days

But when there is comparison of the initial (28 days) and the final strengths (28 days), it can be concluded that the final tensile strength is lesser as compared to the initial one in all of the cases.

V. CONCLUSION

From the study the following results can be concluded which are as

1. Due to the addition of the silica fumes there is increase in cohesiveness in all the cases of the concrete mixtures. But it can hold true up to a certain percentage of replacement because the addition of the silica fumes reduces the workability of the concrete. Hence the addition is supposed to be in controlled manner.
2. Due to the inclusion of silica fumes there is considerable increase in the compressive strength in early as well as at later ages in all the cases.
3. There is decrease in the porosity with the addition of silica fumes in all type of the mixes.
4. The flexural strength due to the addition of the silica fumes is almost similar to the flexural strength of the normal Portland cement without the addition of the silica fumes.

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