NJ-2

Effect of Addition of Silica Fume and/or Superplasticizer on Shrinkage of Cement Mortars

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Introduction

The concrete undergoes some volume change due to the following: settlement of the fresh concrete, chemical combinations of high alkali cements with certain reactive aggregates, changes in moisture content, changes in temperatures and due to applied loads. During the process of the hydration of cement there occurs change in volume due to the reduction in volume of the cement paste. When the cement paste is plastic, it undergoes a volumetric contraction whose magnitude is about one per cent of the absolute volume of dry cement. This shrinkage is known as plastic shrinkage, as it takes place while the concrete is still in the plastic state. Plastic shrinkage occurs mainly due to the settlement of the cement paste and bleeding of water to the top, which finally evaporates. Sometimes concrete may swell thus increasing the volume. This occurs when continued hydration takes place in the presence of water. Volume change of sealed concrete is due to the causes other than the moisture movement, change in temperature, amount and rate of loading. Such shrinkage is known as autogeneous shrinkage. This occurs in the interior of large concrete mass.

Drying Shrinkage

When the concrete is exposed to unsaturated air, it gets dried and in that process water is drawn from the concrete, leading to the shrinkage of concrete, known as drying shrinkage. A part of the shrinkage is reversible if the concrete is exposed to humid atmosphere. In fact the shrinkage is not equal to the volume of the water removed. The removal of free water causes little or no shrinkage. During the process of drying, absorbed water, the water held by the surface forces of the gel particles, is removed and this is responsible for the drying shrinkage. It is also due to the removal of zeolitic water, i.e the water held between the surface of the certain planes in a crystal. The drying shrinkage, due to the loss of surface moisture, causes the differential shrinkage to set up in large mass of concrete. In addition to the drying shrinkage, concrete shrinks due to carbonation. Carbondioxide present in the atmosphere reacts with hydrated cement minerals in the presence of water and forms calcium carbonate to be deposited in the free space available in the concrete. This increases the compressibility of the paste. The carbonation shrinkage increases at intermediate humidities.

Silicafume

Silicafume, a pozzolanic material, has received a great amount of attention recently. Several organizations have become increasingly involved in research aimed at energy conservation in the cement and concrete industry. This in part, is being accomplished by encouraging the use of cementitious meterials such as fly ash, slag and pozzolans. Some attention has been given to the use of silicafume as a possible additive to enhance the property of concrete. Silicafume is a byproduct resulting from the reduction of high purity quartz with coal in electric arc furnaces in the production of silicon ferrosilicon alloys. Silicafume which contains more than 80 to 86% of silica in the amorphous form in suitable for use in the cement and concrete industries.

To achieve no shrinkage concrete and for resistance to atmospheric and chemical attacks, the addition of silicafume is useful. But several investigations (1-4) indicated contradicting results from this point of view. Hence, in the present investigation the effect of addition of silicafume and/or superplasticizer on drying shrinkage of cement mortar is studied.

Experimental Programme

The experimental programme consisted of casting and testing of 144 standard mortar specimens of size 25.4 x 25.4 x 282 mm divided into two series. The first series of specimens cast, without using superplasticizer, consisted of 96 specimens divided into two groups based on grade of cement (43 and 53), each 48. In each group water to cement + silicafume ratio (W/(C+SF) = 0.35, 0.40, 0.45 and 0.50), the precentage replacement of cement with silicafume (0, 5, 10 and 15%) were varied to give 16 set of specimens. Each set consisted of three identical specimens. In the second series, 48 specimens were cast, using superplasticizer as water reducing agent. The variables in the second series were the dosage of superplasticizer (2, 4, 8 and 10 litters/ 100 kg of cement + silicafume) and water to cement + silicafume ratio (0.35, 0.40, 0.45 and 0.50). For each variation, three identical specimens were cast and tested.

Materials Used

Cement: Cement used was ordinary portland cement of 53 grade and 43 grade confirming to IS 12269 and IS 8112 respectively.

Aggregates: The aggregates used in each mix is the standard sand which confirms to IS 650 - 1991. specific gravity of thre standard sand used = 2.44

Water: Potable water was used for mixing and curing purposes.

Silica Fume: The mineral admixture used to reduce drying shrinkage of concrete mix was indigenously available silica fume. This is also known as micro silica, condensed silica fume or silica dust. It is obtained from nearby

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Shrinkage Strains and Flow Values of the specimens tested

		Shrinkage Strains (10^{-6})												Flow Values (%)		
		7 Days			14 Days			21 Days			28 Days			35 Days			
W/(C+SF)	%SF	43 G	53 G	43 G +SP	43G	53G	43G +SP	43 G	53 G	43G +SP	43 G	53 G	43 G +SP	43 G	53 G	43 G +SP	43 G	53 G	43 G +SP
0.35	0	286.792	291.782	292.760	618	528	431	717	665	499	802	672	553	862	747	581	21	13	28
0.35	5	290.472	293.330	292.320	592	511	383	633	588	451	780	620	486	837	651	554	15	11	20
0.35	10	291.610	291.184	293.160	548	440	371	627	515	400	744	587	448	821	618	485	14	10	17
0.35	15	290.986	291.800	292.550	504	417	301	616	500	314	696	535	332	811	567	451	12	9	16
0.40	0	286.590	294.370	291.780	626	459	459	768	720	548	836	734	583	889	802	610	23	15	30
0.40	5	290.570	292.880	291.010	618	575	419	688	601	481	812	649	536	851	678	591	17	12	22
0.40	10	290.414	293.333	291.410	585	500	398	632	535	412	777	626	453	840	641	567	15	11	18
0.40	15	292.160	292.760	292.560	550	460	316	621	527	331	735	599	396	822	618	478	13	10	17
0.45	0	287.370	291.997	292.240	717	658	472	803	788	587	867	801	628	954	870	648	25	18	34
0.45	5	291.164	292.150	293.990	640	602	428	723	649	503	840	678	612	885	739	619	20	14	25
0.45	10	293.564	293.032	291.660	623	588	423	686	620	480	803	699	579	852	714	612	17	13	20
0.45	15	292.360	293.692	292.780	584	548	344	666	598	396	767	620	465	848	688	533	15	12	18
0.50	0	292.784	293.634	292.390	724	668	502	859	798	612	915	852	643	998	927	673	30	20	39
0.50	5	292.596	288.366	292.490	657	609	444	799	729	574	879	772	628	902	805	641	23	16	30
0.50	10	291.782	294.050	290.560	643	646	482	734	690	528	849	714	619	868	752	632	19	14	23
0.50	15	293.060	292.316	293.780	621	585	366	689	602	433	799	636	520	853	705	575	16	13	19

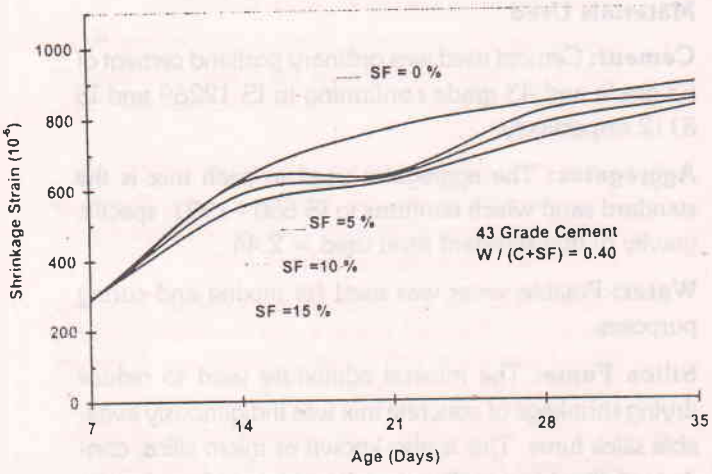

Fig 1. Shrinkage Strain vs Age for different percentage of Silica Fume

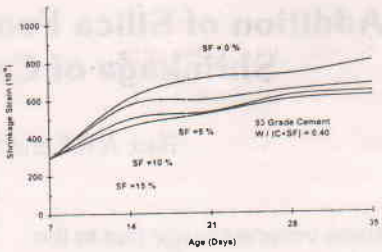

Fig. 2. Shrinkage Strain vs Age for different percentage of Silica Fume

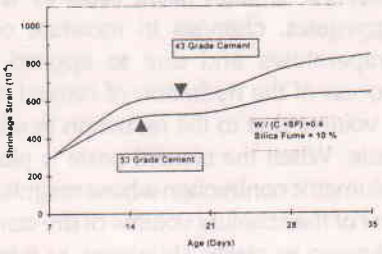

Fig. 3. Shrinkage Strain vs Age for different grades of cement

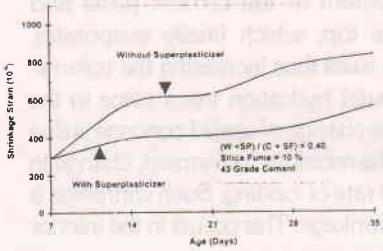

Fig. 4. Shrinkage Strain vs Age with and without superplasticizer

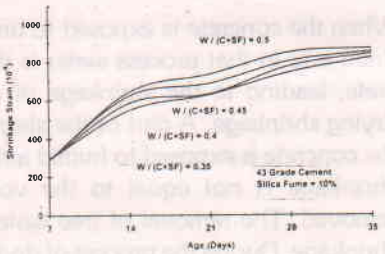

Fig. 5. Shrinkage Strain vs Age for different water to cement + Silica Fume ratio

ferrosilicon industry (Navabharat Ferro Alloys Limited, Palvancha). The properties of silica fume are as follows:

Specific gravity : 1.84
Lime reactivity : 2.34 mpa

Superplasticizer: In order to achieve the required workability, a superplasticizer known as CONPLAST 430 was used mainly as water reducing agent. It is a product of sulphonoid naphthalene polymers and is available as a brown liquid instanly dispersible in water. It has been specifically formulated to give high water reduction upto 25% without loss of workability or to produce high quality concrete of reduced permeability. The properties of CONPLAST 430 as given by the manufacturer are as follows:

Specific gravity : 1.220 to 1.225 to 35 degree C.
Chloride content : Nil as per IS 436 and BS 5075
Compatibility : Can be used with all types of cement except high alumina cements.

Casting and Curing of Test Specimens

For determining the drying shrinkage, prism specimens were cast in a mould of internal dimensions 25 x 25 mm size and 282 mm length and tested according to IS 4031-1988, Part-10. The length of specimens were measured using length comparater at the age of 7, 14, 21, 28 and 35 days after curing. The average difference in lengths of three specimens to the nearest 0.01 per cent of the effective gauge length was reported as the drying shrinkage. The values of shrinkage strengths and flow values of the mix obtained are tabulated in the Table-1. The variation in the values of drying shrinkage for typical combinations of grade of cement, water to cement silica fume ratio, dosage of super plasticizer are shown in Figs. 1 to 5.

Results and Discussions

Effect of Variation of

Silica Fume on Drying Shrinkage

The experimental results presented in table 1 and from the Fig. 1, indicates that the shrinkage strains decreases with increase in percentage of silica fume replacing cement, irrespective of the other variables such as grade of concrete and water to cement + silica fume ratio. It is also observed from the Fig.1 and 2 that at about 15% of replacement of cement with silica fume, the mix attains least shrinkage strain. As the precentage of addition of silica fume varies from 0 to 15%, the decrease in the shrinkages strain ranges from 747 to 567 micro strains at 2l 100 kg of (C + S) after 35 days for 53 grade cement at 0.35 water to cement + silica fume ratio. Fig. 3 indicates that the drying shrinkage is less for 53 grade cement compared to 43 grade with the presence of 10% silica fume.

Silica Fume and/or Superplasticizer on Drying Shrinkage

The experimental results (Fig.4) indicates that the addition of superplasticizer has a tendency to reduce the drying shrinkage. The reduction in drying shrinkage is more in the mixes containing silica fume and superplasticizer compared to the mixes with silica fume as a partial replacement of cement.

W / (C+S) Ratio on Drying Shrinkage

Table 1 and Fig.5 indicate that for any mix as the Water to Cement + Silica fume ratio is increasedthe shrinkage strains were increased simultaneously.

Silica fume and/or super plasticizer on workability of mortars

As the quantity of silica fume (as a partial replacement of cement), is increased, the workability of mortars, (indicated by the flow values in Table 1) is gradually decreased for a constant Water to Cement + Silica fume ratio. The addition of super plasticizer has increased the workability of mortars for all percentages of silica fume.

Requirement of Superplasticizer with Variation of Silica Fume Content

The requirement of superplasticizer to maintain a constant workability, increases with increase in silica fume content. The quantity of superplasticiser added from 2 ml/kg (Cement + Silica) to 10 ml/kg (Cement + Silica fume) of each mix (i.e. 0.35, 0.40, 0.45. and 0.50 (w + sp)/(c+s) ratios) and the percentage replacement of cement by silica fume was varied from 0 to 15%.

Conclusions

Based on the experimental investigations the following conclusions were drawn:

* For any percentage of silica fume added, the shrinkage strain increases with increase in w/(c + s) ratio. For.w/(c + s) = 0.5 there is more shrinkage strain.
* For any w/(c + s) ratio, the shrinkage strain decreases with the increase in percentage of silica fume.
* When superplasticizer is added to the mix, the workability increases and thereby the shrinkage strain decreases to a comparable extent upto 15% silica fume.
* As the percentage of silica fume that is added to the mix increases the water requirement increases and the workability decreases. Least shrinkage strain is observed at 15% replacement of cement by silica fume.

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