Properties of Cellular Concrete with Inclusion of Silica Fume in Presence of Emulsifying Foaming Agents

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ABSTRACT:- The present study has been structured on the use of two basic methodologies: one, review of literature and two, production of cellular concrete by adding Silica fume and introduction of foaming agents. In this study, mechanical properties of the produced cellular concrete were analyzed. Silica fume content was varied to investigate the effects on compressive Strength, split tensile strength and flexural strength at primitive and advanced ages.The experimental programme consisted of testing a total eighty one number of specimens for ascertaining various properties of concrete after exposure to different ranges of temperature and thermal shocks. Twenty four specimens for each property i.e. compressive strength for cubes and cylinders and flexural strength will be tested.

INTRODUCTION

Concrete is a centenary material, at present the most used material in the construction industry. However, the high density (volume weight) of conventional concrete being around 2350 kg/m^3 is an important factor and poses a drawback. The practical use of concrete especially in the construction of structures, where dead load is an important factor, is limited. Especially in case of floor slabs and roofs that are designed to withstand live loads of people and furniture, concrete is too heavy to be used. To withstand, the load is transmitted to the beams, then to the columns and finally to the foundation and the ground resulting in heavy construction with complex foundations, high camber beams and columns. Thus, the use of conventional concrete slabs with excessive dead weight results in a high cost of the work.

Since the early 80s, extensive research to correct the inadequate qualities of concrete experienced a great evolution with emergence of new concrete products. Nowadays, the properties of concrete are predominantly being controlled by knowledge of material, properties of the mixture, method of production of concrete and curing conditions etc. The popularity of the new concrete products is due to enhanced efficiency offered to civil engineers. Technological advances in recent years have offered a diversity that allows to accurately design a material suitable for each type of work including the nature of the projects, the implementation conditions and the structural requirements. The best approach lies in the reduction of the density of concrete by replacing a quantity of material by air leading to formation of air voids. These air voids can be incorporated to obtain Cellular concrete, increasingly used as a structural element of construction materials. Cellular concrete "cell" or "aerated" concrete proves to be most likely to fulfill the objectives of the modern construction system. Aerated concrete is a moldable material, ductile, lightweight, durable and relatively resistant with low cost. Untreated aerated concrete in an autoclave, requires little specialized and can be assembled without too machinery tooling.

In a global trend of ecological development, research tends to use different SCMs in the formation of cellular concrete, as new green material. Unlike the current research on this material, which aims to achieve greater strength in compression possible, the major challenge of this research is rather to optimize and adapt the characteristics to a defined system. This is to develop an efficient low density cellular concrete that would offer sufficient resistance for its application.

It is possible to include additives in cellular concrete to change and improve some of its characteristics. It is possible to add silica fume in the formulation of the Cellular concrete to improve its mechanical resistance. The fumed silica is a supplementary cementing which reacts with the cement and water from the concrete (pozzolanic action) and fills the interstitial voids between the aggregates of the concrete. Silica fume, silica powders and other materials containing silica can be used as agents pozzolanic cement.

METHODOLOGY

The objective of this program is to obtain the properties of the different constituent materials to be used for making the specimens for the experimental studies. The data is useful to classify the cement, sand, water, and Silica fume. These values will be used for further studies for the calculation of mix design. These values also confirm the quality of the materials used.The cement used for the experimental studies was Portland Pozzolana cement. The various values are shown in table1

Sr. No.		Characteristics	Experimental value	Specified Value as per IS: 8112-1989
1		Consistency of Cement	30 %	-
2		Specific gravity	3.14	3.15
3		Initial setting time	51 minute	>30 minute
4		Final setting time	340 minute	< 600 minutes
5		Comp. Strength (N/mm^2)		
	i)	3 days	27.53	>23
	ii)	7days	36.25	>33
	iii)	28 days	46.93	>43
6		Fineness (Dry Sieving)	6.2 %	< 10 %
7		Soundness (mm)	3.9	<10

Properties of Fine Aggregate

Characteristics	**Values**
Type	Natural (uncrushed)
Grading	Grading Zone II (IS: 383-1970)
Fineness Modulus	2.66
Specific Gravity	2.58
Free Moisture Content	Nil

Silica fume

The term Silica fume has been defined as "the finely divided residue resulting from the combustion of coal or finely ground waste and is carried in the gas flow."

Chemical Composition

Constituent	**%age**
Silica SiO2	58%
Alumina Al2O3	21%
Ferric Oxide Fe2O3	3.8%
Titanium Dioxide TiO2	0.8%
Manganese Oxide MnO	0.4%
Calcium Oxide CaO	7.0%
Magnesium Oxide MgO	1.5%
Sodium Oxide Na2O	0.6%
Potassium Oxide K2O	0.9%
Iron Fe2O	0.2%
Phosphorus P2O5	0.1%
Alkali metal's Oxide	1.1%
Sulphur Trioxide SO3	1.1%
Magnesium oxide MgO	0.4%
Loss on Ignition	4.1%

Test Particulars	Results
Specific Surface Area (Blaine Fineness)	320 to 360 (m2/kg)
Specific gravity	2.00 to 2.05
Bulk density	750 to 1800 (kg/m3)
Color	Grey or Tan
Physical form	Powder form
Class	F

Mix proportions used in the present study

Three different water binder ratio (water/(cement+ Silica fume) were taken as 0.40, 0.45 & 0.50 to have desired results. Nine cubes for each mix were cast to test for compressive strength after 7 days, 28 days and 90 days so in totality 27 cubes. Similarly cylinders and beams were casted for 7 days, 28 days and 90 days having three sample at each curing day for each mix resulting in total 27 cylinders and 27 beam samples Thus the other proportions of the other ingredients (by weight) of reference mix are:

Mix proportion foamed concrete at different water binder ratio

W/C+FA ratio	Cement (kg)	Silica fume (kg)	Fine sand (kg)	Water (kg)	Density (kg/m^3)
0.60	345	150	700	248	1450
0.50	395	170	837	256	1650
0.40	430	184	980	250	1850

CASTING OF SPECIMENS

The specimens were cast using the materials whose properties have been tabulated. The details of the specimens are tabulated in the Table 4.11 and 4.12. The standard moulds comprising of 150x150x150mm cubes, 150mmx300mm long cylinders, 100mmx100mmx300mm beams were cast after oiling the inner surface. These were securely tightened to correct dimensions before casting. Care was taken that there were left no gap where slurry could leak.

The dry ingredients like cement, sand, sand + Silica fume or Silica fume alone shall be fed into the mixer first and thoroughly mixed to ensure even distribution of cement. The appropriate amount of water shall be added thereafter continuing the mixing. The preformed foam, which is made by blending the foam concentrate, water and compressed air in predetermine proportion in a foam generator, calibrated for a specific discharge rate, shall be added in measured amount to the slurry of cement, sand, Silica fume and water in the batch mixer. After an additional mixing to get uniform consistency, the slurry form of foamed cellular concrete of desired wet unit weight shall be ready to be poured out into forms/moulds etc. The surface of the concrete was finished level with the top of the mould using a trowel. The finished specimens were left to harden in air for 24 hours. The specimens were removed from the moulds after 24 hours of casting. Then they were placed in the water tank, filled with potable water in the laboratory for curing for desired days.

Designation of Specimens

Sr. No.	Designation of Sample	Water/Binder Ratio	Description
1	FCC1	0.6	Compressive strength
2	FCC2	0.5	
3	FCC3	0.40	
4	FCT1	0.6	Split Tensile Strength
5	FCT2	0.5	
6	FCT3	0.40	
7	FCF1	0.6	Flexural Strength
8	FCF2	0.5	
9	FCF3	0.40	

RESULTS & DISCUSSION

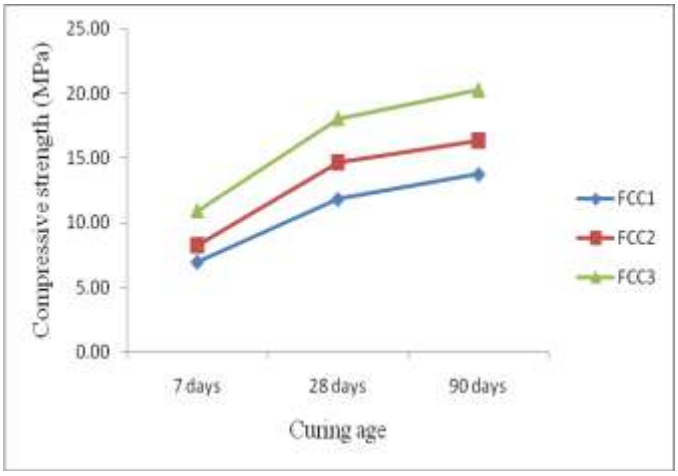
Cube Compressive strength

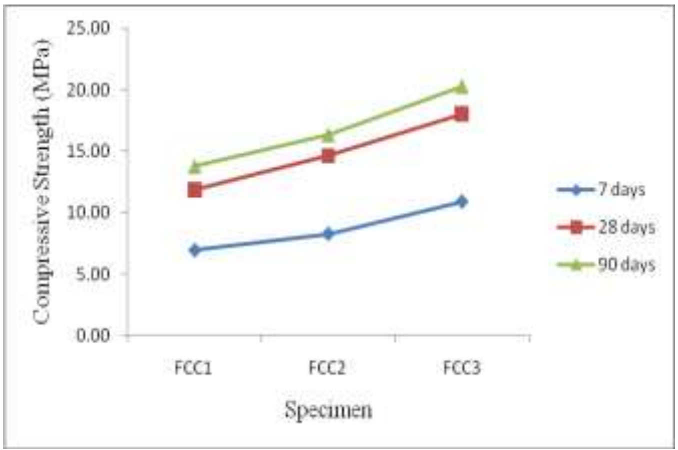
The tests were conducted according to IS: 516-1959 (reaffirmed 1999). Specimens were taken out from the curing tank at the age of 7, 28 and 90 days and tested at surface dried condition. The specimens were kept out to dry the surface before testing. The specimens were tested on 3000 KN capacity CTM. The position of the cube when tested was at right angles of that as cast. The axis of the specimens was carefully aligned with the centre of thrust of the spherically seated plate.

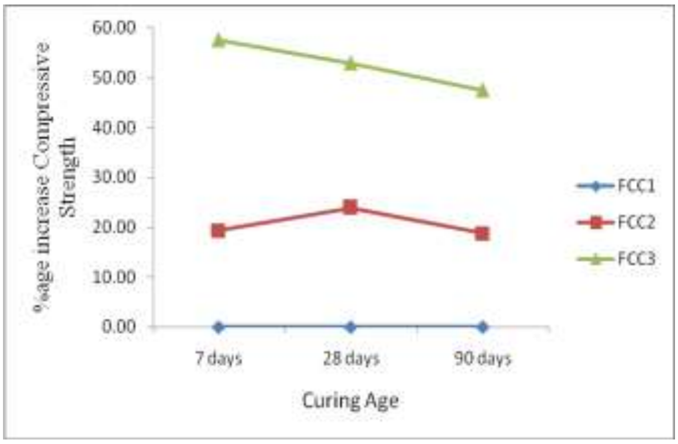
The load was applied gradually and without shock and increased continuously at the rate of approximately 5 KN/second till the failure of the specimens and thus the compressive strength was found out.

The test results for the various specimens are shown in the table 5.2. Based on these values the effect on compressive strength is evaluated.

It is clear from the result that there is substantial increase in compressive strength of cellular concrete when there is an addition of Silica fume in concrete. The compressive strength was found to increase with decrease in water binder ratio. The increase was observed to be 19% for water binder ratio of 0.5 and 58% for water binder ratio of 0.4 in comparison to cellular concrete having water binder ratio as 0.6 at 7 days. At 28 days the increase in compressive strength was found to be 24% and 53% at W/B ratio of 0. 5 and 0.4 in comparison to W/B as 0.6.





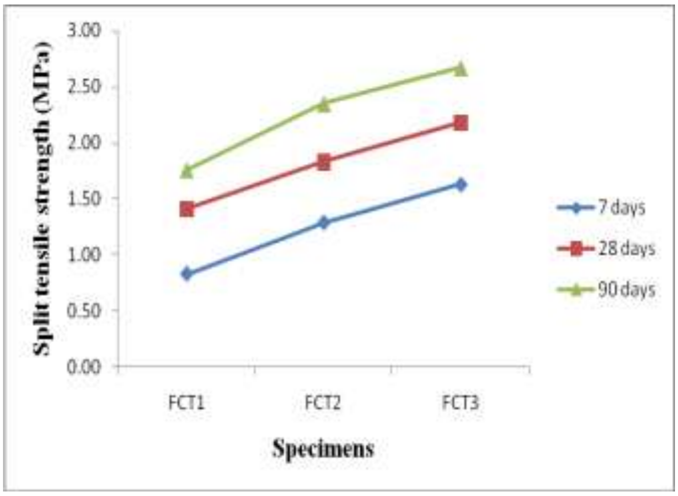


The similar trend was observed at hardened age of 90 days where the results obtained show an increase in compressive strength of 19% and 47% at W/B ratio of 0.5 and 0.4 in comparison to W/B as 0.6. The decrease in percentage of compressive strength at 90 days showed that the effect of Silica fume or reaction of Silica fume become slow after certain age. The maximum compressive strength obtained using Silica fume at 90 days with W/B ratio was 21.74MPa which shows that this concrete cannot be majority used for general construction purposes.

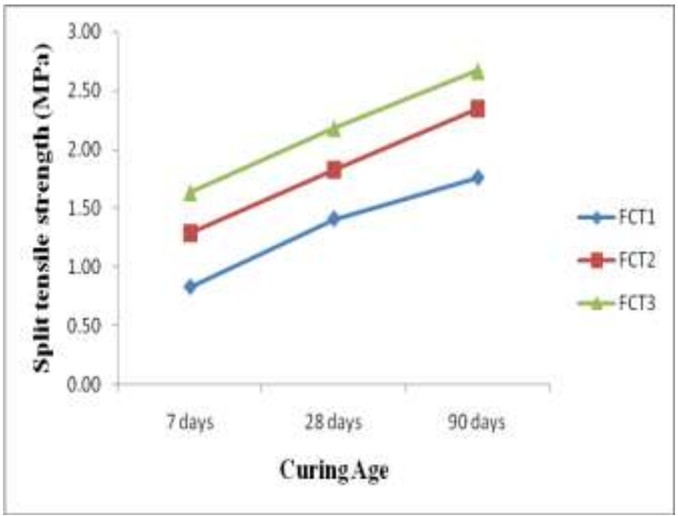
Split Tensile Strength

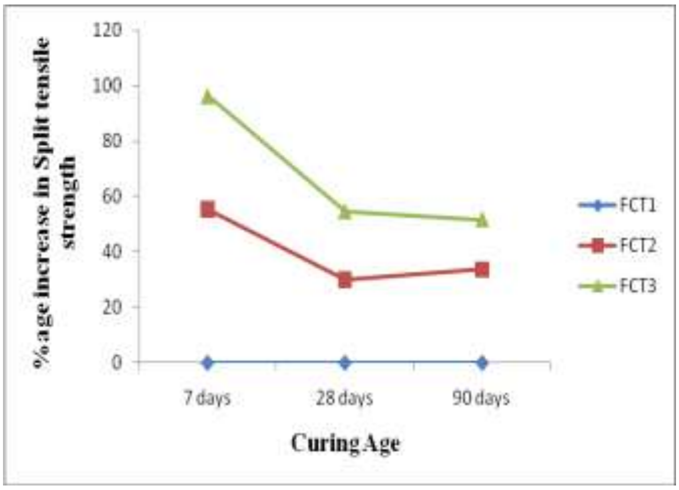
The tests were conducted according to IS: 516-1959 (reaffirmed 1999). Specimens were taken out from the curing tank at the age of 7, 28 & 90 days and tested at surface dry condition. To achieve surface dry condition the cylinders were kept out of curing tank for about 3 hrs. The specimens were tested on 3000 KN capacity CTM. The position of the cylinder when tested was at right angles of that as cast. The axis of the specimens was carefully aligned with the centre of thrust of the spherically seated plate.

The load was applied gradually and without shock and increased continuously at the rate of approximately 5 KN/second till the failure of the specimens and thus the compressive strength was found out.



It is clear from that the similar results were obtained in case of split tensile strength as obtained in case of compressive strength of concrete. The split tensile strength was found to increase with increase in silica fume upto certain extent and then decrease due to unreactivity of excess silica fume which rather fill the pores upto certain extent and its value increases with decrease in water binder ratio. The increase was observed to be 55% for water binder ratio of 0.5 and 96% for water binder ratio of 0.4 in comparison to cellular concrete having water binder ratio as 0.6 at 7 days. At 28 days the increase in split tensile strength was found to be 30% and 55% at W/B ratio of 0.5and 0.4 in comparison to W/B as 0.6.

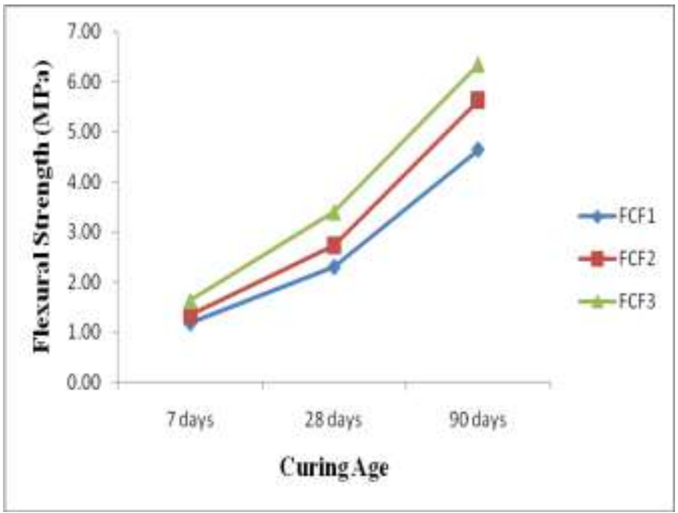


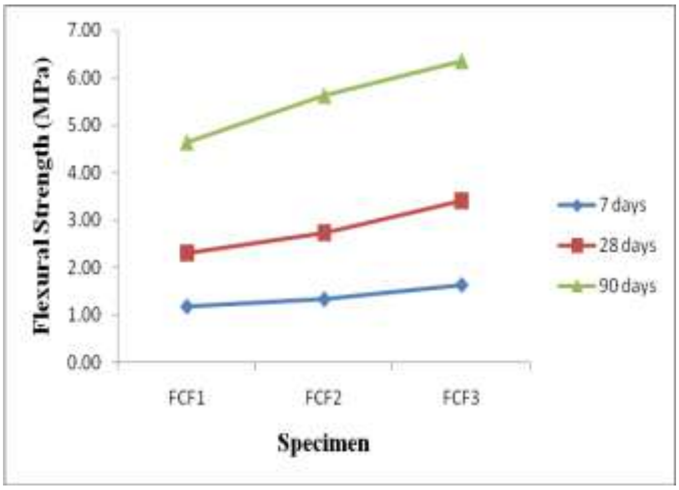


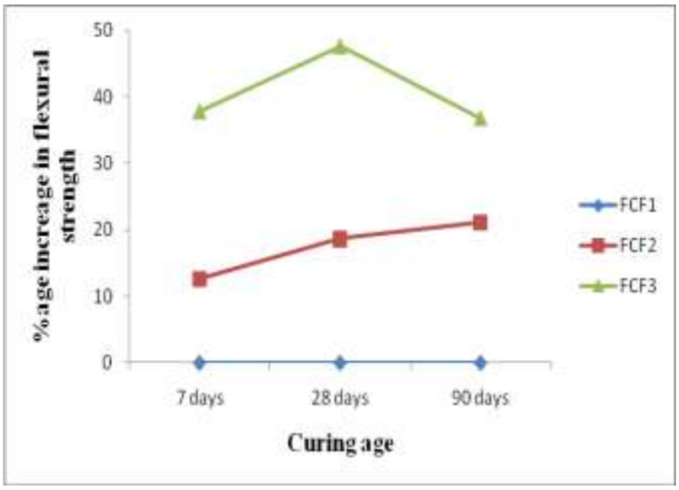
The similar trend was observed at hardened age of 90 days where the results obtained show an increase in split tensile strength of 34% and 52% at W/B ratio of 0.5 and 0.4 in comparison to W/B as 0.6. The decrease in percentage of split tensile strength at 90 days showed that the effect of Silica fume at more curing was less in comparison to that at early ages.

Flexural strength

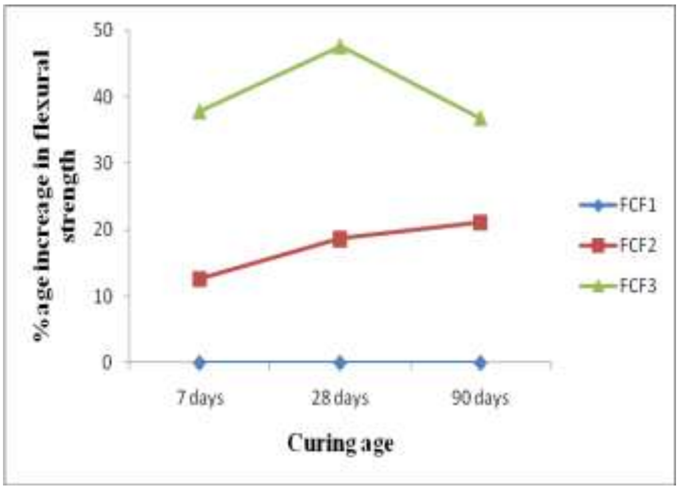
The dimensions of each specimen were noted before testing. No preparation of the surface was required. The bearing surfaces and loading rollers are wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen was then placed in the machine in such a manner the load is applied to the uppermost surface as cast in the mould, along two lines spaced 13.3 cm apart. The axis of the specimen was carefully aligned with the axis of the loading device. No packing was used between the bearing surfaces of the specimen and the rollers. The load was applied without shock and increasing continuously at a rate such that the extreme fibre stress increased at approximately at a rate 180 kg/min for the 10.0 cm specimens. The load was increased until the specimen fails, and the maximum load applied to the specimen during the test was recorded. The test results reveal that the flexural strength is more sensitive as compared to compressive strength.







It is clear from the result that there flexural strength of cellular concrete increases when the water binder ratio decreases from 0.5 to 0.4. The flexural strength of cellular concrete also increases with age but the percentage increase in flexural strength was more at early ages than at later ages. The increase was observed to be 13% for water binder ratio of 0.5 and 38% for water binder ratio of 0.4 in comparison to cellular concrete having water binder ratio as 0.5 at 7 days. At 28 days the increase in flexural strength was found to be 19% and 48% at water binder ratio of 0.5 and 0.4 in comparison to W/B as 0.6.



The results obtained at 90 days show an increase in flexural strength of 21% and 37% at water binder ratio of 0.5 and 0.4 in comparison to water binder ratio as 0.6. The decrease in percentage of flexural strength at 90 days has the same reason as discussed earlier.

CONCLUSIONS

The study was aimed to study the effect of three different water binder ratio (water/(cement+ Silica fume)i.e 0.40, 0.5 &0.60 at the cellular light weight concrete to have desired results. The study was carried out to investigate the effects on the compressive strength, split tensile strength and flexural strength at 7 days, 28 days & 90 days of curing ages on concrete.On the basis of this study, the following conclusions can be stated:

1. The compressive strength of specimens having lower water binder ratio have more compressive strength in comparison to specimens having higher water binder ratio. This is because of the enhanced microstructure and improvement in fine aggregate-paste bond which is due to the lesser water content and more CSH (calcium silicate hydrate).The compressive strength of the specimens increases with increase in density of cellular concrete.

2. The compressive strength increases for all the specimens with increase in content of Silica fume as obtained in the design mix.

3. The compressive strength and split tensile strength and flexural strength of concrete mix increases with age but the %age increase in compressive strength varies with the curing ages.

4. The percentage of compressive strength, split tensile strength and flexural strength increases with age upto 28 days and then decreases at 90 days for water binder ratio of 0.5 and 0.4 w.r.t W/B ratio of 0.6. This shows that the rate of reaction of Silica fume was more during early ages and it become less reactive at later ages.

5. The split tensile strength and flexural strength show similar behavior as observed in case of compressive strength for all the specimens of cellular concrete. This is because the fact that the binder material i.e cement and Silica fume have similar dispersion all across the specimen.

However, the present study needs to cover the following aspects in future:

1. Detailed study of the cellular concrete on more design mixes and with addition of certain admixtures to improve the mechanical properties of cellular concrete so that it can be used commercially at large scale.

2. The study has to be carried out for 180 and 365 days of curing ages.

3. The chemical durability of the cellular concrete mixes at different water binder ratio's.

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