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"EFFECT OF M40 CONCRETE WITH PARTIAL SUBSTITUTE OF OPC WITH MICRO SILICA AND REPLACEMENT OF FINE AGGREGATE WITH 50% MANUFACTURED SAND ALONG WITH ADDITION OF STEEL FIBER"

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ABSTRACT : *The aim of this study is to evaluate the mechanical and durability characteristics of M40 grade concrete having mix proportion 1:1.56:2.98 with w/c ratio as 0.40, containing micro silica by replacement of OPC at various percentages of 4%, 8%&12%. Also M-sand by 50% replacement of natural river sand with additional crimped steel fibers of diameter 0.5mm and length 30mm with an aspect ratio of 60(1.5% by weight of cementitious material has been used to enhance the mechanical properties of hardened concrete). The optimum dosage of micro silica is found to be at 8% replacement by OPC.*

Keywords: **Micro Silica, M-Sand, Crimped Steel Fiber, Compressive Strength, Split Tensile Strength, Flexural Strength, Water Permeability, Chloride Attack**.

1. INTRODUCTION

Now a day's the Concrete is using widely as construction material for the various types of structures due to its well durability. For a long span it was considered to be a durable and sustainable Material which requires less maintenance during its life span. Concrete plays a very important role for achieving high strength at early age of time to fulfill the requirement of the structures. The less and endurable life of conventional concrete under the different types of climatic conditions conventional concrete possesses major deficiencies like low bond strength, low tensile strength high permeability and also develop more cracks. Micro silica is one of the most commonly used mineral admixtures in high strength concrete. It has become the chosen best for high strength concrete, Adding micro silica to the concrete mix will imparts the workability, strength & impermeability of concrete while it makes the concrete durable against chemical attacks, abrasion & reinforcement corrosion, which intern increases the Comprehensive Strength. One of the most uses of micro silica in conventional concrete is because of its physical and chemical properties. Since it is a very fine highly reactive pozzolona. Micro silica is usually grayish or whitish color non-crystalline powder, fairly Similar to OPC. It exhibits both pozzolonic and cementiteous properties. The function of Micro-Silica is in High-strength concrete improved the mechanical properties and also it improved the constructability of concrete.

It is a effective pozzolana material due to its fine particle size and high purity of silicon-di-oxide (sio2) [99.5%] content. To prevent shrinkage cracks and to achieve high tensile strength durability concrete small steel fibers are added during the mixing of concrete with an aspect ratio 60, and thus it improves concrete properties. Hence the replacement of micro-silica with addition steel fibers in normal concrete improved the properties such as flexural strength, tensile strength, toughness, brittleness, corrosion resistance & ultimately increased life span of the structure.

M-sand is an alternative material of natural sand for the various constructions; this sand is obtained from basalt stone by crushing in a crusher yard. Because of the faster growing construction activities, the demand of sand has increased in a large excess. The reason for using M-Sand is its availability and Transportation Cost and it can easily be available at the locality place, which intern reduces the cost of transportation.

M-sand is one such latest fine aggregate material used in Construction to fulfill the required specifications. It is available in plenty of number. The M-sand has fineness which acts like a pores filling material which increases the strength of concrete. The natural river sand becomes very expensive and less availability due to the corresponding increasing daily demand in the area of construction. Hence manufactured sand can easily be utilized as Partial replacement of natural sand.

2. OBJECTIVE

- To Find the Optimum dosage of Micro Silica as Partial replacement of OPC.
- To find the effects of micro silica dosages on Compressive strength, Split Tensile strength and flexural strength of the concrete.

- Comparison of test Results of conventional concrete with micro silica Concrete.
- To determine the durability tests

(i).Water permeability test on hardened concrete.

(ii). Chloride attack test on hardened concrete.

3. MATERIALS USED

3.1 cement

Ordinary Portland Cement Ultra Tech 53 Grade Conforming to IS 12269-1987 has been utilized in this Project work.

Table-1 Properties of cement

SL NO.	Properties of cement	Laboratory result
1.	Consistency (%)	32%
2.	Specific gravity	3.15
3.	Initial setting Time(mins)	120
4.	Final setting Time(mins)	210
5.	Fineness of Cement(mm)	2%
6.	Soundness(mm)	1

3.2 Steel fiber

In this experiment crimped type steel fiber is used which is obtained from Atul enterprises Ltd, Nagpur, Maharashtra. A constant percentage of steel fiber i.e, 1.5% by weight of cementitous material has been added uniformly in the concrete.

Table- 2 Properties of steel fiber

SL NO.	Properties	Dimensions
1	Length	30mm
2	Diameter	0.5mm
3	Aspect ratio	60

3.3 Micro silica

The micro silica is obtained from Astrra chemicals Chennai- 600006.

Table- 3 Physical properties of micro silica

SL NO.	PARTICULAR	SPECIFIED
1	Physical state	Micronized powder
2	Odour	odorless
3	Color	white
4	Particle size	< 1µm
5	Pack density	0.76gm/cc
6	PH of 5% solution	6.90
7	Specific gravity	2.63
8	Moisture	0.058%
9	Oil absorption	55ml/100grams

Table-4 Chemical properties of micro silica

SL NO.	PARTICULAR	SPECIFIED
1	Silica (SiO_2)	99.886%
2	Alumina(Al_2O_3)	0.043%
3	Ferric oxide(Fe_2O_3)	0.040%
4	Calcium oxide(CaO)	0.001%
5	Magnesium oxide (Mgo)	0.000%
6	Titanium oxide(Tio_2)	0.001%
7	Potassium oxide(K_2O)	0.001%
8	Sodium oxide(Na_2O)	0.003%
9	Loss of ignition	0.015%

3.4 Fine aggregate (F.A)

The river sand is obtained from Shahapur Taluka, Gulbarga, has been used in this project work. As per the sieve analysis conducted on the natural river sand and it is complied to zone II of IS: 383-1970.

Table- 5 Properties of fine aggregate

SL NO.	Test	Result obtained in laboratory
1	Specific gravity	2.65
2	Water absorption	1.14%
3	Fineness modulus	3.02
4	Bulk density	1666kg/m^3

3.5 Manufactured sand (M-sand)

Manufactured-sand is locally obtained from finely crusher ballast stone quarry. The M-sand used is 50% replacement by natural river sand and it is confines to Zone II origin.

Table-6 properties of M-sand

SL NO.	Test	Result obtained in laboratory
1	Specific gravity	2.68
2	Water absorption	1.21%
3	Fineness modulus	3.21

3.6 Coarse aggregate

The coarse aggregates are obtained from a local quarry and well graded aggregate of size 20mm (30%) and 12.5mm (70%) down has been used in this project work and tested as per IS: 383-1970 Specifications.

Table- 7 Properties of coarse aggregate

SL NO.	Test	Result obtained in laboratory
1	Specific gravity	2.85
2	Water absorption	1%
3	Fineness modulus	6.70
4	Bulk density	1436kg/m^3

3.7 Super plasticizer

Addage Plast PCE 840 super plasticizer has been used at an optimum dosage of 1.5% by weight of cementitious materials. The specific gravity of super plasticizer is 1.08. It is polycarboxylate ether based super plasticizer which is suitable for making high strength and high workable concrete. The marsh cone test were Carried out to determine the Optimum Dosage of super plasticizer for different Water Cement ratio as 0.46, 0.44, 0.42 & 0.4.

3.8 Water

Portable tap water was used for the preparation of concrete and for the curing of specimens.

4 MIX DESIGN

As per IS 10262 – 2009 code and using the above test results. The mix design producer was carried out for M40 grade of concrete. A Trail mix for M40 grade was obtained by mix design and the mix proportion obtained for M40 grade concrete is given in the below.

Table- 8 Mix proportions

Weight of the Material in Terms of kg/m^3 of Concrete				
Cement	Fine aggregate (FA)	Coarse aggregate	Water	Super plasticizer
418.96	654.151	1252.475	167.586	6.284
1	1.56	2.98	0.40	0.015

4.1. Methodology

A. Materials and Mixing Procedure

1. Batching: The batching of concrete was carried out by weight. All the required materials for preparing the concrete were weighed with an accuracy of 0.5 grams as per the required proportions.

2. Mixing: On the water tight platform, the concrete mixture was prepared by hand mixing. The cement and micro silica were thoroughly mixed in the dry state, and the sand was added to the mixture. The mixture was again thoroughly mixed and placed over the coarse aggregate. In case of fiber reinforced concrete, steel fibers were evenly sprinkled during mixing. Then water was added carefully with chemical admixture during mixing. Mixing was carried out until a workable mixture was obtained.

Fig-1 dry mixing

Fig -2 wet mixing

3. Casting: The concrete moulds were filled in three layers. In each of the layer, the concrete cubes will be compacted 25 times respectively. Vibration was given to the cube moulds using tapping rod . Vibrations were continued for one minute to ensure uniform compaction. The specimen were demoulded after 24 hours of casting and placed in a curing tank for 7 & 28 days.

4. Slump cone test & Compaction factor test

Workability is carried out by conducting slump test and compaction factor test as per I.S. 1199-1959 on ordinary concrete and micro silica reinforced concrete.

Table-9 slump and compaction factor values

SL NO.	Mix type (MS%, SF% & M-Sand %)	Obtained slump-value (mm)	Obtained compaction-factor	Description of Workability
1.	CC_1- (Conventional Concrete)	90	0.93	High
2.	MX_1 (4%, 1.5%, 50%)	71	0.88	Medium
3.	MX_2 (8%, 1.5%, 50%)	64	0.80	Medium
4.	MX_3 (12%, 1.5%, 50%)	55	0.74	medium

5. RESULT AND DISCUSSION

The Experimental Programme consists of casting and testing in total 48 no.s of cubes specimen, 24 no.s of prism (Beam) specimen and 24 no.s of cylinder specimen etc. Among the 48 cubes casted, 24 cubes were subjected for carrying the compressive strength test for 7 & 28days. 12 cubes were subjected for carrying the water permeability test, 12 cubes for carrying the chloride attack test. Among the 24 prism were subjected for carrying the flexural strength test for 7 & 28days. Among the 24 cylinder specimen were subjected for carrying the split tensile strength test for 7 & 28days.

5.1 Compressive strength test

A cube Specimen of Size (150mmX150mmX150mm)was casted and tested under universal testing machine (UTM). The Compressive strength tested as per IS -516: 1959 and can be calculated as given by,

$$f_c = (P / A)$$

Where, f_c = compressive strength of cube in N/mm^2
P = specimen failure Load in N
A = Area of cross sectional in mm^2

Table-10 Result of compressive strength at 7 & 28days

Mix designation (MS* , M-Sand % , SF%)	Compressive strength (N/mm^2)	
	7days	28days
CC Conventional concrete	37.64	53.628
MX1 (4%, 50%, 1.5%)	39.53	56.825
MX2 (8%, 50%, 1.5%)	42.58	59.296
MX3 (12%, 50%, 1.5%)	40.98	57.697

Graph 5.1 compressive strength of conventional concrete Vs different mix at 7 &28days

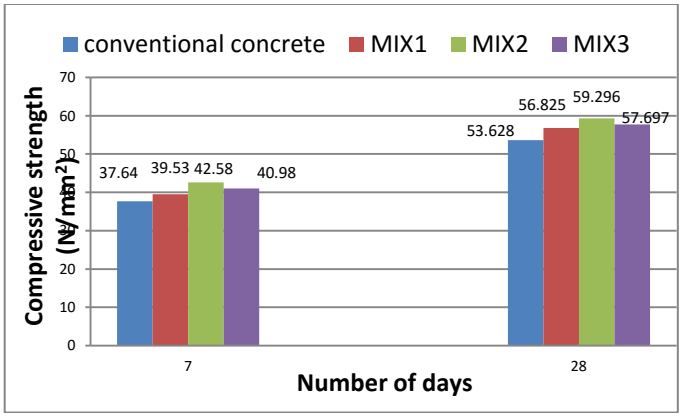


Fig- 3 test setup for cube under UTM

Fig- 4 failure pattern of cube under UTM

5.2 Split tensile strength test

A concrete cylinder of size 150mm (dia) x 300mm(height) were casted and tested under universal testing machine(UTM). To Study the Split tensile strength of Concrete the Test is carried out in Accordance with IS: 5816 -1970.

The spilt -tensile strength can be calculated by using the Formula given below:

$$\sigma = 2P/\pi DL$$

Where, σ is the Split tensile strength in N/mm^2

P = Applied Load in N

L = height of cylinder in mm

D = Diameter of cylinder in mm

Table-11 Result of Split tensile strength at 7 & 28days

Mix designation (MS* , M-Sand % , SF%)	Split tensile strength (N/mm^2)	
	7days	28days
CC Conventional concrete	2.451	3.815
MX1 (4%, 50%, 1.5%)	2.728	4.55
MX2 (8%, 50%, 1.5%)	3.422	5.57
MX3 (12%, 50%, 1.5%)	3.052	5.11

Graph 5.2 Split tensile strength of conventional concrete Vs different mix at 7 &28days

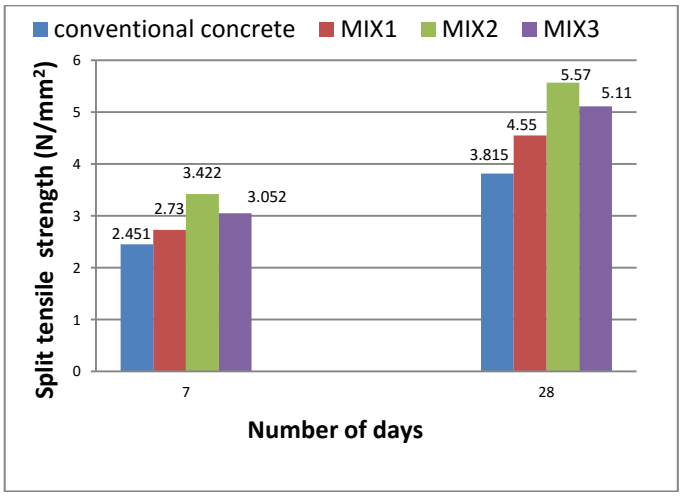


Fig-4 test setup of cylinder under UTM

Fig- 5 failure pattern of cylinder under UTM

5.3 Flexural strength test

Concrete prisms of size 100x100x500mm were casted and tested under UTM at two points loading. The test is performed according to IS: 516-1959.The flexural Strength is given below

$$F_{cr} = (P \times L) / (BxD^2)$$

Where, F_{cr} = flexural strength N/mm²

P = Applied load (N)

L = Length of beam (mm)

B = Width of beam (mm)

D = Depth of beam (mm)

Table-12 Result of Flexural strength at 7 & 28days

Mix designation (MS* , M-Sand % , SF%)	Flexural strength (N/mm²)	
	7days	28days
CC Conventional concrete	3.040	5.205
MX1 (4%, 50%, 1.5%)	3.825	5.787
MX2 (8%, 50%, 1.5%)	4.381	6.83
MX3 (12%, 50%, 1.5%)	4.087	6.24

Graph 5.3 Flexural strength of conventional Concrete Vs different mix at 7 &28days

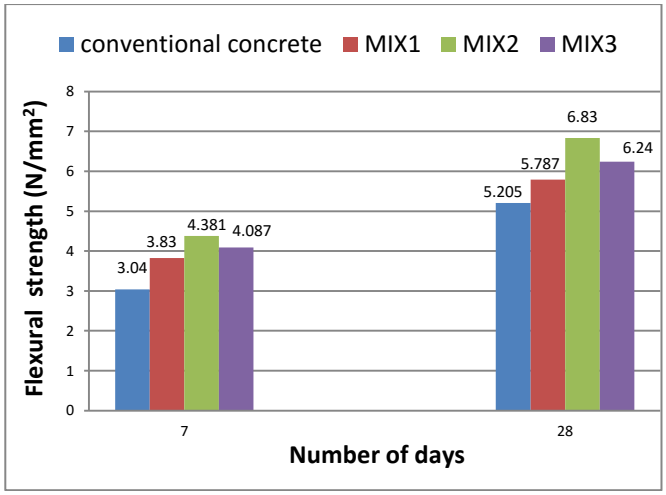


Fig- 6 Test setup of beam under UTM

Fig- 7 Failure pattern of beam under UTM

5.4 TEST RESULTS ON DURABILITY

5.4.1 Water Permeability of Test: A cube of size 150x150x150mm was casted for 28days curing period. After 28days of Curing the specimen was tested under water permeability apparatus. This test was carried out with reference to German code {DIN 1048:1991(part 5)}. The Maximum depth of penetration should not exceed 25mm.

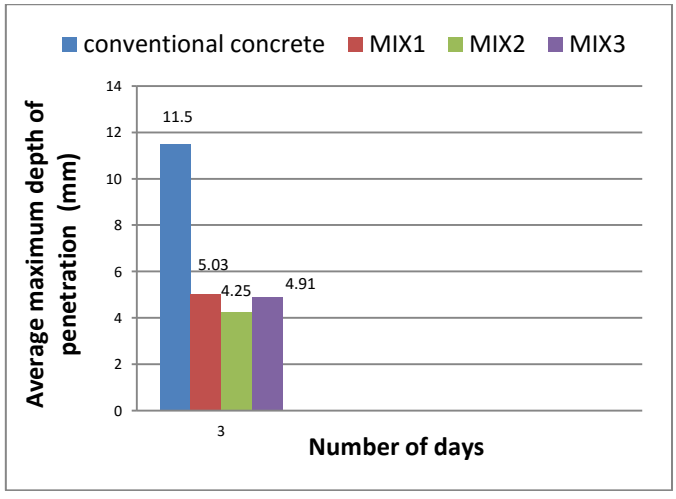
5.4.2 Test procedure: Keep the concrete cube specimen in the three water penetration cells and tightened the nuts with the help of hardware tool. Fill the water reservoir with water up to the above zero mark of the water gauge. Before filling the water the pressure and water regulator should be shut or closed. Now open the pressure regulator as well as water regulator. Apply the pressure of 5kg/cm^2 for 3days and keep maintaining the same pressure till 3days. After 3days shut the pressure regulator and water regulator. Slowly remove the nuts and takeout the cubes out and break it apart in compression testing machine. After breaking the cube mark the depth of water which is penetrated the cube by a marker pen and measure the maximum depth of penetration. More the depth of water penetration less will be the Durability of concrete.

Fig- 8 Water Permeability apparatus setup

Table-13 Result of water permeability at 3days water penetration

Mix designation (MS* , M-Sand % , SF%)	Average maximum depth of penetration (mm) at 3days of water penetration
CC Conventional concrete	11.5
MX1 (4%, 50%, 1.5%)	5.03
MX2 (8%, 50%, 1.5%)	4.25
MX3 (12%, 50%, 1.5%)	4.9

Graph 5.4 Average maximum water permeability of conventional concrete Vs different mix at 3days of water penetration



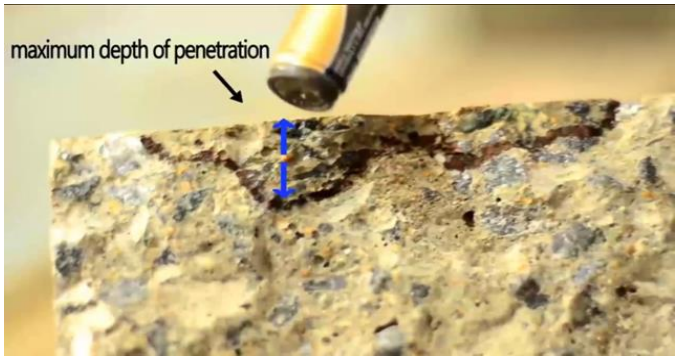


Fig-9 Maximum depth of water permeability at 3days of water penetration

5.4.2 Chloride Attack test

Preparation of NaCl solution

1. NaCl solution were prepared by adding a quantity of about 5% of sodium chloride powder by taking weight of water to the required amount of water .
2. The water is uniformly stirred till the particles of sodium chloride gets clear solution.
3. The cube specimen of various concrete proportions of size (150X 150 X 150mm) was casted and kept them for 28days of curing.
4. After 28days curing takeout the specimen from water tank and allow them to dry for 24hrs.
5. The initial weight of cube specimen were taken as W_1
6. After taking the initial weights the specimen were immersed in a NaCl solution water container for 28days.
7. After 28days of immersion takeout the cube specimen and allow them to dry and take the final weight as W_2
8. Now these dry specimens were tested under compression which gives the compressive strength.
9. The resistance of concrete to chloride attack was found by the % loss of weight of cube specimen and the % loss of compressive strength.

Table-14 Result of chloride attack test after 28days immersion in Nacl sol.

Mix designation (MS* , M-Sand % , SF%)	Weight of cube taken before immersing in Nacl sol. in kg	Weight of cube taken before immersing in Nacl sol. in kg	loss of weight in %	Average compressive strength after 28days N/mm²
CC Conventional concrete	8.75 8.768 8.765	8.40 8.36 8.43	4 4.65 3.82	51.31
MX1 (4%, 50%, 1.5%)	9.125 9.119 9.126	8.936 8.88 8.90	2.07 2.62 2.47	55.50
MX2 (8%, 50%, 1.5%)	9.277 9.270 9.266	9.102 9.124 9.110	1.88 1.57 1.68	58.44
MX3 (12%, 50%, 1.5%)	9.456 9.365 9.434	9.234 9.136 9.205	2.34 2.44 2.427	56.59

Graph 5.5 Average compressive strength of conventional concrete Vs different mix after 28days of immersion in Nacl sol.

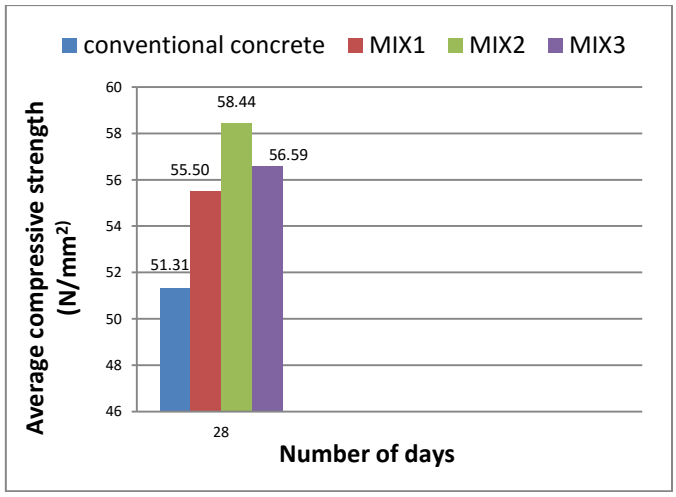


Fig-10 cubes immersed in Nacl sol. water

Fig-11 cubes after 28days immersion in Nacl sol.water

Fig-12 weight taken before 28days Immersing in Nacl sol. water

Fig-13 weight taken after 28days immersion in Nacl sol. water

6. CONCLUSION

- The Workability and Compaction factor of concrete decreases with increase in Micro silica content with addition of Steel fiber. The both parameters also decrease with 50% replacement of M-sand by river sand as compared with conventional concrete.
- The density of concrete increases as adding micro silica and steel fiber to concrete which imparts the properties of strength.
- The Compressive strength increases with the increase in Micro silica With Conventional concrete. The maximum Increase in Compressive strength was found up to 13.12%, 10.56% at 7days & 28days of curing period for Mix MX_2 (8% micro silica, 1.5% steel fibers & 50% M-sand).
- The Split Tensile strength increases with addition of Steel fibers to some extent. The maximum Increase in split tensile Strength was found up to 39.61%, 46% at 7days & 28days of curing period for Mix MX_2(8%micro silica, 1.5%steel fiber & 50% M-sand).
- The Flexural strength increases with the addition of 1.5% Steel fiber was more as Compared to Conventional Concrete. The Maximum increase in flexural strength was found up to 44.11%, 31.79% at 7days and 28days of curing period for mix MX_2 (8%micro silica, 1.5%steel fiber & 50%M-sand).
- The Optimum limit for replacement of Micro Silica by OPC was found at 8%. Beyond 8% the Compressive strength, split tensile strength & flexural strength slightly decreases.
- The 50% replacement of manufactured sand by natural river sand giving better strength as compared with 100% Natural River sand.
- The Water Penetration for mix MX_2 (8%Micro Silica, 1.5%steel fiber & 50% M-sand) is much less as compared to conventional concrete. Therefore it means that the concrete at (8%micro silica, 1.5 steel fiber & 50% M-sand) are more durable than conventional concrete
- The percentage Loss of weight in micro silica concrete is less in mix MX_2 (8%MS, 1.5%SF, & 50%M-sand as compared with conventional concrete.
- The Maximum Compressive Strength after 28days immersion in Nacl sol. was found in Mix MX_2 (8%MS, 1.5%SF, 50%M-sand).

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