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EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF RUB-FIBRE REINFORCED CONCRETE

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ABSTRACT

In recent times the Automotive Transportation is massively increased and rubber tyres is one of the most wear and tear material in it. These rubber tyres after its life time are dumped in landfills which take a very long time to decompose and become an environment effecting substance**.** Concrete is weak in tension which can be met with use of rub**-**fibres in concrete. The specimens are casted of M25 grade, rub**-**fibres are used as additives in 0**.**25% and 0.5% to the weight of concrete. Hence the utilization of cycle tyre rubber fibres in concrete elevates the mechanical and ductile properties through a sustainable way**.**

Key words: Compression strength, Flexural strength, Split tensile strength, Impact strength, Young**'**s modulus, Fibre reinforced concrete, Cycle tyre rubber.

INTRODUCTION

The modernization has paved the way to massively increasing number of vehicles and transportation around the world, resulting in disposal of huge amount of consumed rubber tyres after its life time. The growing amount of waste rubber, produced from tires, has resulted in an environmental problem[1]. Accumulations of stockpiles of Tyres are dangerous because they pose a potential environmental concern, fire hazards and provide breeding grounds for mosquitoes that may carry disease[2]. Innovative solutions to solve the tyre disposal problem have long been in development[3]. Cementbased concrete is a kind of brittle material in general and is of high rigidity[4]. At the same time tyre rubber is causing threat to environment. Hence by adding rubber as fibres to concrete, its tensile strength and ductility can be increased.

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Past research

Ilker Bekir Topcu et al.[5] has used bits of scrap automobile tyres as replacement to fine and coarse aggregate the authors have carried out experimental studies on modulus of elasticity of rubberized concrete and have derived equations for the same**.** Malek k Bataneyh et al.[6] has adopted crumb tyre rubber to study the workability and mechanical properties of rubberized concrete by replacing fine aggregates in concrete mixes**.** Authors report reduction of workability and mechanical properties with the increase in crumb tyre rubber in concrete**.** Magda I. Mousa[7] has studied the effect of temperature on rubberized concrete by replacing fine aggregate and coarse aggregate with recycled rubber and has found that incorporation of rubber in concrete as coarse aggregate adds to the temperature resistance of concrete. C. X. Qianet al.[8] has used hybrid polypropylene-steel fibres in concrete. The authors suggest usage of smaller size of fibres than larger fibres to achieve good mechanical strength.R**.** YU et al.[9] has reported higher mechanical properties with the use of polypropylene fibres in light weight concrete. Eun**-**Beom Jeon et al.[10] has reported enhancement of flexural strength with the addition of carbon fibre in polymer concrete.

In the past research ground tyre rubber and Crumb rubber from automobiles has only been used to increase the mechanical properties of the concrete where as in present study cycle tyre rubber has been adopted. Waste rubber has been used only in the form of aggregates, crumbs and chips but in present paper covers the usage of waste cycle tyre rubber as fibres.

EXPERIMENTAL

Materials used

Cement and aggregates

53 grade Ordinary Portland cement conforming to IS 12269:1987[11] with specific gravity 3.15 was used. River sand obtained from Chennai and the locally available blue granite crushed stone aggregates of size 20 mm were used as fine aggregates (FA) and coarse aggregates (CA), respectively in the present investigation. Their physical properties Table 1 like specific gravity, bulk density, percentage of water absorption and fineness modulus were tested in concurrence with IS: 2386:1963[12].

Water

Potable water was adopted as the liquid for mixing and curing of specimens through out the experimentation.

Table 1: Physical properties of aggregates

Type	FA	CA	Rub-Fibre
Maximum size (mm)	-	20	10 x 50
Specific gravity	2.67	2.6	1.14
Fineness modulus	2.36	4.81	-
Water absorption (%)	0.5	1.21	-
Bulk density, kg/m^3	1628	1562	477

Fig. 1: Hand shredded cycle tyre

Rub-fibres

Rub-fibres was prepared from cycle tyre. The rub-fibres were hand shredded to a size of 10 mm x 50 mm. The rub-fibres were added to concrete at dosages of 0%, 0.25% and 0.5% by weight of concrete to form the rub-fibre reinforced concrete (RFRC) as shown in Fig. 1, Table 1 gives the physical properties of Rub-fibres.

Mix design

Based on the trial mixes the final design mix was prepared for M25 grade of concrete as 1:1.79:2.92 with water cement ratio 0.5 as per IS 10262:2009[13]. The concrete mix proportions were as shown in Table 3. The rub-fibers were added into dry mix of concrete in the percentages of 0%, 0.25% and 0.5% by weight of concrete.

Preparation of test specimens

Standard steel moulds were used for casting cubes of size 150 mm x 150 mm x 150 mm, cylinders of 150 mm diameter and 300 mm height, prisms of size 100 mm x 100 mm x

500 mm, circular discs of size 150 mm x 65 mm. ninecube specimens, twelve cylinder specimens, six prism specimens and six discs were cast for each mix. The concrete mixes obtained by means of hand mixing were placed uniformly with proper finishing of top surface. These specimens were demoulded 24 hrs after casting and were cured under water until the age of testing.

Workability

The workability of fresh mixes of control and RFRC were determined with the help of slump cone apparatus pertaining to IS7320-1974[14].

Scanning electron microscopy (SEM) & energy dispersive spectroscopy (EDS)

The SEM/EDS testing was performed in accordance with ASTM E1508[15] on rub-fibres before subjecting to any loading.

Tests for mechanical properties

The compression test, flexural test, split tensile tests and Impact test were carried out as per IS516:1959[16] IS5816:1999[17] and ACI 544.2R[18]

Compressive strength

The compressive strength test was performed on cubes in a compression testing machine (CTM) of 200 tones capacity at the age of 7, 14 and 28 days, respectively. The reported strengths are the average of three test specimens.

Flexural strength

The flexural strength of PFRC was found out by subjecting the simply supported prism to two-point loading on a CTM of 200 tones capacity at the age of 7 and 28 days. The reported strengths are the average of three test specimens.

Split tensile strength

The split tensile test on cylinders was also carried out at the age of 7 and 28 days by placing the cylinders horizontally on a CTM of 200 tones capacity. The reported strengths are the average of three test specimens.

Modulus of elasticity

Modulus of elasticity of control and RFRC cylinders were determined at the age of 28^{th} day placing the cylinders vertically in CTM using a compressometer frame.

Impact strength

The impact strength test was performed at the age of 28 day son discs subjected to repeated application of impact load in the form of blows, using a 44.5 N hammer falling from 457 mm height on the steel ball of 63.5 mm diameter, placed at the centre of the top surface of disc as shown in Fig. 6. Number of blows that caused the first visible crack and failure respectively was noted as first crack strength and the failure strength of the sample. The reported strengths are the average of three test specimens.

RESULTS AND DISCUSSION

Workability and slump

The slump test was carried out on the fresh control and RFRC mixes with the standard slump cone in order to find the workability of it. The slump test was carried out on the fresh control and RFRC mixes with the standard slump cone in order to find the workability of it. It is clearly evident from Table 4 and Fig. 2 that the addition of rub-fibres to concrete creates great impact on the workability of concrete.

Table 2: Slump values

Specimen	Slump (mm)	Decrease in workability (%)
CONTROL	70	0
RFRC 0.25	49	30
RFRC 0.5	45	35.71

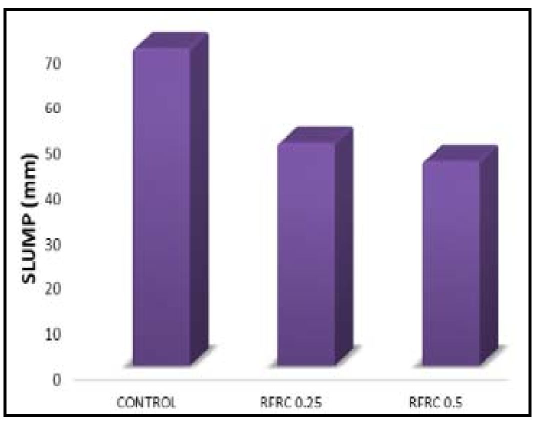


Fig. 2: workability of RFRC

Fig. 3: Slump of RFRC

The percentage of decrease in workability and fibres added are inversely proportional, which is in good agreement with Andressa F. Angelin et al.[19] The slump of control mix, RFRC 0.25 and RFRC 0.5 were found to be 70 mm, 49 mm and 45 mm, respectively. The addition of 0.25% and 0.5% rub-fibres by weight of volume of concrete decreased the workability by 30% and 35.71%, respectively. Hence the degree of increase in percentage of rub fibres results in the degree of decrease in workability. The phenomena may be on the grounds of moisture admitting properties of rubber. Fig. 3 shows the measure of slump on fresh RFRC mix

Compressive strength

From Table 3 and Fig. 6, RFRC cubes were found to show increase in compressive strength compared to control concrete increase in dosage of fibres increases the compressive strength, which is contrary to the work carried by M. M. Reda Taha et al.[20]. At the age of 7, 14 and 28 days the compressive strength of RFRC cubes with dosage of 0.25% and 0.5% of rub fibres were found to be 21.77 N/mm^2,37.80 N/mm^2, 38.32 N/mm^2 and 21.57 N/mm^2, 34.12 N/mm^2, 35.93 N/mm^2; respectively, which is 1.48%, 3.27%, 7.23% and 2.38%, 7.97%, 9.35% more than the control cubes, those tested cubes are shown in Fig. 4 & 5.

Table 3: Compressive strength values

Specimen	Compressive strength (MPa)		
	7th day	14thday	28th day
Control	21.25	34.63	35.55
RFRC 0.25%	21.57	35.80	38.32
RFRC 0.5%	21.77	37.63	39.22

Fig. 4: 0.25% RFRC after testing

Fig. 5: 0.5% RFRC after testing

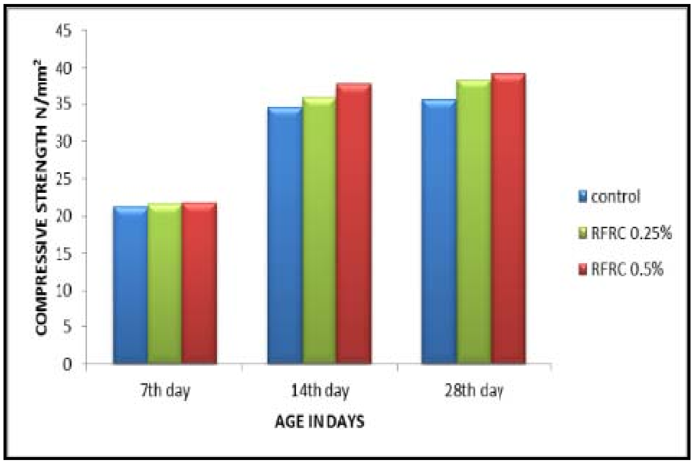


Fig. 6: Compressive strength of RFRC

Flexural strength

The flexural strength of RFRC prisms with 0.25% and 0.5% are given in Table 4 and Fig. 8 as 2.73 N/mm^2, 2.97 N/mm^2 and 4.27 N/mm^2, 4.4 N/mm^2 for 7th day and 28th day, respectively, which has increased by 0.21%, 24.57% and 14.98%, 17.5%. Also the theoritical flexural strength is calculated as per IS456-2000[21]clause 6.2.2. It is clearly evident from Fig. 9 that the theoritical results were found to be compatibe with experimental results. Fig. 7 shows the prisms after testing.

Split tensile strength

The split tensile strength of the concrete cylinders at the age of 7th and 28th day were found to be 2.84 N/mm^2, 2.95 N/mm^2 and 4.67 N/mm^2, 5.01 N/mm^2 with the addition of 0.25%, 0.5% rub-fibres, which has shown 11.62%, 14.92% and 20.99%, 26.35% increase in tensile strength respectively. Hence it is clear from Table 5 and Fig. 11 that similar to compressive and flexural strength, the split tensile strength of RFRC is in direct proportion with the increase in dosage of rub-fibres. This may be due to the imparting of tensile strength by the rub-fibres to the concrete also the splitting tensile strength can be calculated theoretically from compressive strength. In the present study based on the revised codes ACI318-1999[22] the theoretical split tensile strength was taken as $Fct_{TH} = 0.56\ (F_{ck})^{1/2}$, Where Fct_{TH} and F_{ck} are theoretical split tensile strength and cylinder compressive strength expressed in MPa ,It is seen from Fig. 12 that the experimental split tensile strength were found to be 17.6%, 21.01% and 33.61%, 37.32% more than theoretical split tensile strength for addition of 0.25% and 0.5% rub-fibres at 7 and 28 days. Hence rub-fibres are effectively increases the tensile strength of concrete.

Table 4: Flexural strength values

Specimen	Flexural strength F_{cr} at the age of 7 days (MPa)		Flexural strength F_{cr} at the age of 28 days (MPa)	
	Fcr_{Th} 7th day	Fcr_{Exp} 7th day	Fcr_{Th} 28th day	Fcr_{Exp} 28th day
Control	3.23	2.18	4.17	3.63
RFRC0.25%	3.25	2.73	4.33	4.27
RFRC 0.5%	3.27	2.97	4.38	4.40

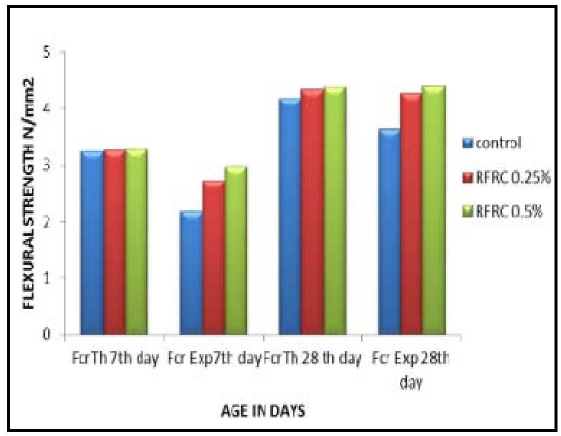


Fig. 7: Prisms after testing **Fig. 8: Flexural strength of RFRC**

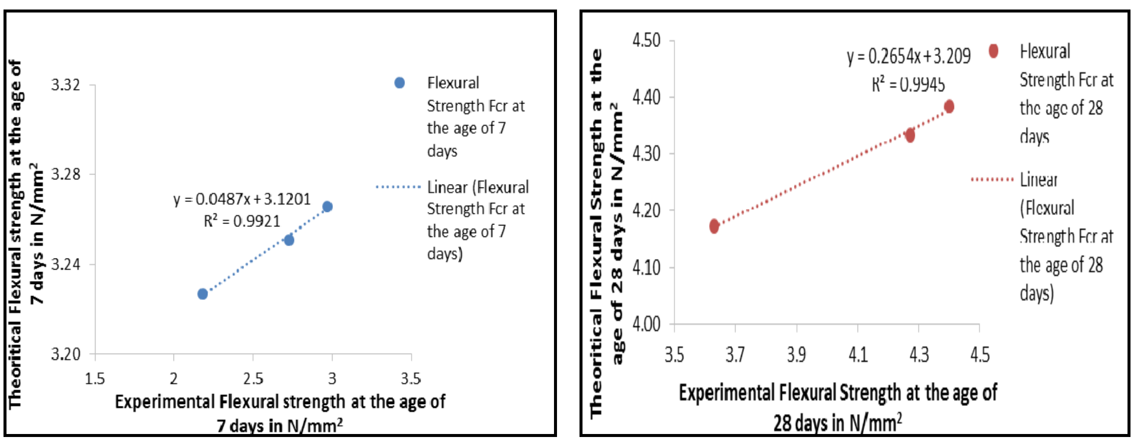


Fig. 9: Comparison of 7th and 28th day flexural strength

Table 5: Split tensile strength values

Specimen	Split tensile strength F_{ct} at the age of 7days (MPa)		Split tensile strength F_{ct} at the age of 28 days (MPa)	
	Fct_{TH} 7th day	Fct_{Exp} 7th day	Fct_{TH} 28th day	Fct_{Exp} 28th day
Control	2.31	2.51	2.99	3.69
RFRC0.25%	2.34	2.84	3.10	4.67
RFRC 0.5%	2.33	2.95	3.14	5.01

Fig. 10: Cylinders after testing

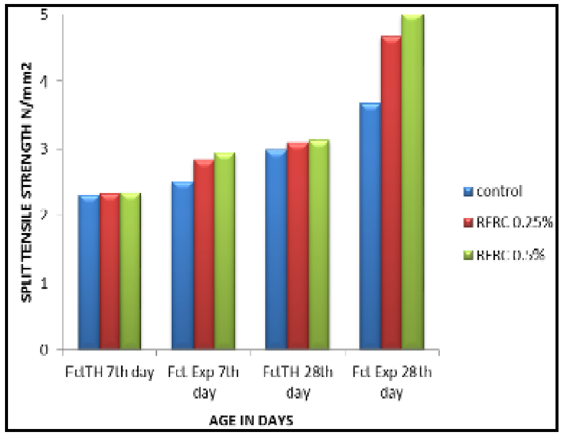
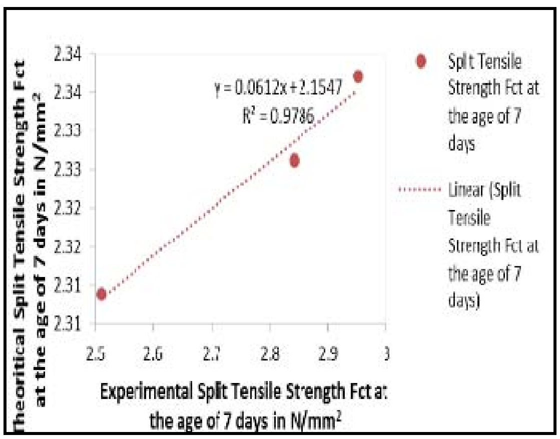


Fig. 11: Tensile strength of RFRC



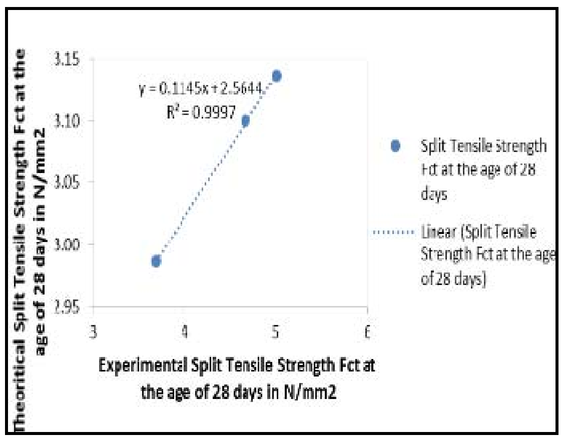


Fig. 12: Comparison of 7th and 28th day Split tensile strength

Modulus of elasticity

From Table 6 and Fig. 13 it is evident that addition of 0.25% and 0.5% rub-fibres increases the elasticity of concrete by 15.66% and 29.49%, respectively this is because rubber by itself has greater modulus of elasticity, by dispersing it in concrete as fibres imparts its elasticity to concrete by reducing the degree of brittleness.

Table 6: Modulus of elasticity values

Specimen	Elastic modulus (MPa)
	28^{th} day
Control	1.2896×10^4
RFRC 0.25%	1.5293×10^4
RFRC 0.5%	1.8291×10^4

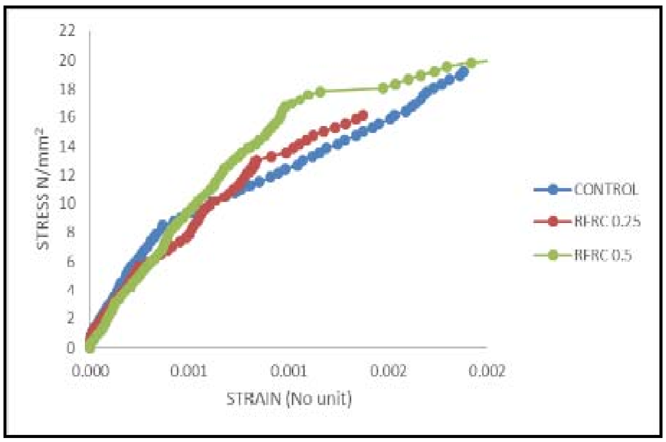


Fig. 13: Stress strain curve

Scanning electron microscopy (SEM) with Energy dispersive spectroscopy (EDS)

The surface characteristics of Rub-fibre before and after subjecting to load was analysed using SEM and elemental composition of control Rub-fibre was determined with the help of EDS. The acceleration voltage of 20 kV with the sample distance was 10 µm. Fig. 16 shows the images obtained from SEM and EDS analysis and Table 8 gives the details of elemental composition of rub-fibres. From Fig. 17 it is seen that the rub fibres after flexure test are not damaged much. But after subjecting to the rub-fibres to tensile force and stress there are only formation of minute pits observed on the surface.

Table 7: Impact strength test values

Specimen		Control	RFRC 0.25%	RFRC 0.5%
No. of blows at crack	Initial	85	87	91
	Final	87	90	94

Fig. 14: Disc after testing

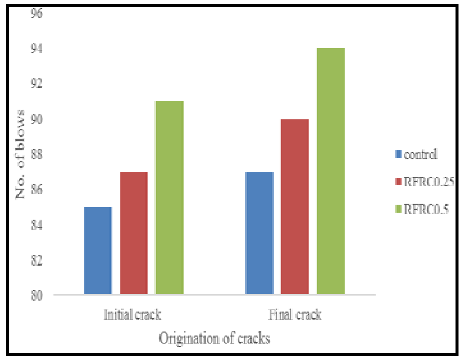


Fig. 15: Impact strength of RFRC

Table 8: Elemental composition of Rub-fibre

Element line	Weight %	Weight % error
O K	61.86	± 5.51
Al K	10.00	± 1.05
Si K	22.25	± 1.32
S K	5.88	± 1.35
Total	100.00	

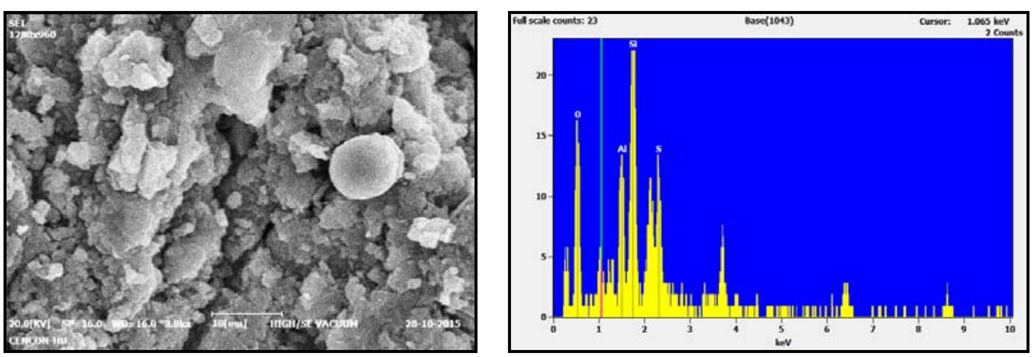


Fig. 16: SEM image and EDS analysis of Rub-fibre

CONCLUSION

The use of Rub-fibres increase the ductile and mechanical property of concrete and it can be concluded as:

(i). Workability of 0.25% and 0.5% RFRC reduces to 30% and 35.71%, hence the degree of increase in percentage of rub fibres results in the degree of decrease in workability.

(ii). Compressive strength of RFRC increases to 1.48% and 2.38% at 7th day, 3.26% and 7.92% at 14th day, 7.22% and 9.35% at 28th day, increase in compressive strength compared to control concrete increase with the dosage of 0.25% and 0.5%. The Flexural strength of 0.25% and 0.5% RFRC increases to 0.2% and 24.57% at 7th day, 14.98% and 17.5% at 28th day and the Split tensile strength of 0.25% and 0.5% RFRC concrete increases to 11.61% and 14.91% at 7th day, 20.98% and 26.34% at 28th day due to the fibres imparting tensile strength to concrete.

(iii). Modulus of elasticity of 0.25% and 0.5% RFRC concrete increases to 15.66% and 29.49% this is because rubber by itself has greater modulus of elasticity and sinceRubber absorbs shock and impact loads, Impact strength of 0.25% and 0.5% RFRC concrete increases to 3.33% and 4.25%.

(iv). The elemental composition of control Rub-fibre was determined with the aid of EDS. The surface characteristics of Rub fibres before and after subjecting to load was analysed using SEM. No damage was observed in Rub-fibres subjected to flexure and only formation of minute pits was observed on the surface when subjected to tensile force and stress

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