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Effective Reuse Of Marble Dust Powder In Cement Mortar.

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ABSTRACT

This paper describes the use of marble waste in the cement mortar as the partial replacement of fine aggregate. Marble dust powder gives better cohesive between the aggregates in concrete and mortar. It gives better performance to the concrete and mortar. The percentage replacement of the marble powder varied in the study includes 0 %, 10 %, 25%, 40% and 50 % of cement. The specimens to find the compressive strength, flexural strength were casted using various percentage and cured for three different curing time 7 days, 14 days and 28 day. The compressive and flexural strength of the marble powder replaced mortar between 0 % to 25 % replacement of marble dust powder and its strength decreases if the replacement is between 25 % and 50 %. The water absorption capacity of the marble powder cement mortar cube was increased rapidly for the first 3 hrs of the test and then increased gradually up to 120 hrs. The partial replacement of Marble dust in the mortar increases the compressive and flexural strength if the replacement of fine aggregate upto 25 %. The water absorption and sorptivity coefficient of the cement mortar cube with marble powder increases 40 % with increase in the % of the marble dust.

Keywords: Marble powder, compressive strength, flexural strength, sorptivity

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INTRODUCTION

Usage of waste material as a partial replacement of cement or sand in concrete is the recent research area. The waste material like copper slag, fly-ash, rice husk, blast furnace slag, silica fume, red mud, phosphogypsum and egg shell as partial replacement is widely used (Chandra, 1996). The durability of the concrete is increased by aggregates, industrial by-products such as fly-ash, stone dust, silica fume and blast furnace slag and generally it is used as filler material (Assié et al., 2007, Ünal et al., 2006, Felekog˘lu et al., 2006, Türkmen et al.,2003 and Sahmaran et al., 2006). As the number of thermal power plant is large in number, the by-product fly-ash is widely reused in concrete. Fly-ash with 30% and 40 % of total binders shows high increase in compressive strength from 65 to 85 MPa and the fly-ash reduces sorptivity and chloride ion (Nath, sarker, 2011). The usage of slag when used 50% lesser than fly-ash is more appreciable in concrete and cement with slag and fly-ash or slag alone gave better compressive strength (Teara et al., 2018). The compressive and drying shrinkage decreases with increase in furnace bottom ash and fine recycled aggregate decrease the compressive strength and increase shrinkage in concrete (Kou et al., 2009). When 80% of cement is reinforced with fibre and 20 % by fly-ash, the compressive strength and modulus of rupture increases til 9% weight of coconut fibre (Nadzri et al., 2012) Fine aggregates is replaced by ground plastic and glass by 20 % and coarse particles by crushed concrete by 20% showed the successful reuse of material (Batayneh et. al., 2007). Marble dust (MD) and crushed bricks combination in concrete results in increase in water: binder ratio (Hamza et al., 2017).

Apart from the above-discussed by-products, marble dust is largely generated and reuse of it or proper disposal is a challenge to the environment. Marble, a metamorphosed limestone largely used as a flooring material after processing and cutting. As per survey in 2006, crushed marble produced around the world is around 11.8 million tons. These marble are crushed into small blocks and polished leading to huge deposition of marble powder or dust. In marble cutting industries, the marble dust is settled by sedimentation and dumped causing environmental pollution. In current scenario, the steady increase for construction material likes sand leads to use the marble dust in concrete. Due to low thixotropy, the marble powder confers high cohesiveness to the concrete mixtures and increases the compressive strength by 10% replacement of sand: this reduces the water in mix proportions by 20% and achieved good compressive strength by 60% replacement of sand by MD (Corinaldesi et al., 2010, Kabeer and Vyas 2018). Use of marble aggregates shows increase in compressive and tensile strength significantly for 25%, 50% and 75% of substitution of sand (Hebhoub et al., 2011). Alyamaç and Aydin (2015) replaced sand with marble powder by 10%, 20%, 30%, 40%, 50% and 90% by volume used in feasibility evaluation and it shows usage upto 40% marble powder in concrete is suitable. Waste marble dust as additives in brick more than 10% of its weight increases the water absorption and decreases the mechanical properties (Bilgin et al., 2012). Buyuksagis et al., 2017 Marble powder is used in bonding mortar economically as it is 30% cheaper than dolomite. MD shows filler effect in the concrete and no notable proper hydration process with lower w/c ratio (Aliabdoet al., 2014). Apart from usage of Marble powder or dust in concrete, it is also used in self-compacting concrete (SCC) to increase the workability till the unit weight is increased to 200 kg/m3. In Turkey there is abundant of marble (40% of world resource) leading to reuse the MD as filler material in SCC (Bonavetti et al., 2003, Bosiljkov et al., 2003 and Yahaia et al., 2005). As many work of marble dust deals with SCC, an attempt is made to study its behaviour in cement mortar where the MD is used as partial replacement of fine aggregate (sand).

METHODS AND MATERIALS

A detailed literature study is done to select the waste material and to find the mix proportion. Figure 1 shows the methodology adopted to carried out the study.

Materials Used

Cement mortar is composed of one or more cementitious materials, fine sand and sufficient water to produce workable mixture.

Cement

The cementitious material, Ordinary Portland Cement (OPC) of grade 53 is used because of its common use, rich quality, high durability and basic ingredients present in it. By burning siliceous materials like limestone at 1400^{0}c and grinding it with gypsum, OPC manufactured. The specific gravity of the cement is 3.15, standard consistency found using Vicat's apparatus is 32% and initial setting times as 31 minutes, found using pycnometer.

Sand

The sand used for experiments is of river sand with fine texture, quality and it is mostly round in shape. These river sands are commonly used for construction purpose such as plastering and so on. It has a specific gravity of 2.7, co-efficient of uniformity c_u = 2.67 and co-efficient of curvature, c_c = 1.04; thus classified as poorly graded sand (SP) as per IS: 2720 – Part IV (1985 – Reaffirmed 2006).

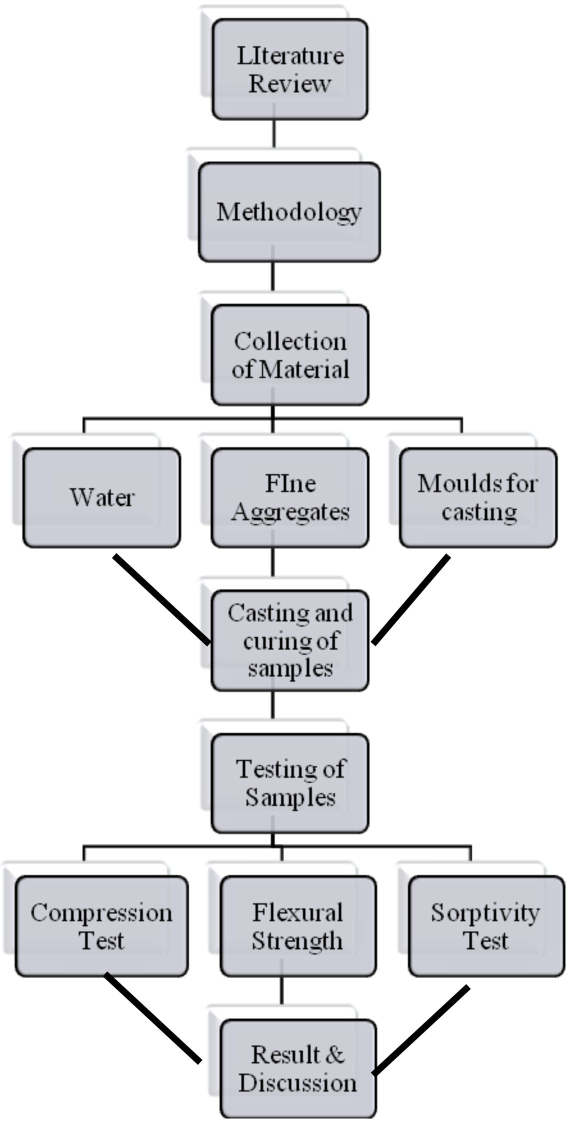

Figure 1: Flowchart for experimental methodology

Marble Powder

It is collected from the marble polishing industry located locally and the specific gravity of it is 2.8.

Casting Moulds

Cubes of size 7 cm x 7 cm x 7 cm deep, moulds of 16 cm x 4 cm x 4 cm deep and mould of 10 cm diameter and 5 cm height with detachable arrangements is fabricated and used for the experiments (Figure 2)

Figure 2: Fabrication of mould and casting of specimens

RESULTS AND DISCUSSION

Compressive strength test, flexural strength test and sorptivity tests were conducted in the laboratory.

Compressive Strength Test of Mortar

Compressive strength of mortar is determined by using 7 cm cubes as per IS 4031 –part 6 – Standard Test Method for Compressive Strength of Cement Mortars. Common mix ratio of mortar used in masonry works is 1:3, 1:4 and 1:6 of cement to sand ratio. For important masonry structures such as brick walls, 1:3 ratio is used which was the mix for the specimen. Cement 200 gm and sand 600 gm is mixed with a ratio of 1:3 (by weight) with water quantity of p/4+3 %, where p is the water required to produce a paste of standard consistency. The mixing time is not less than 3 minutes and not more than 4 minutes. Place the mortar in the cube and prod with the help of a rod for about 20 times in 8 seconds to ensure the elimination of entrained air. After 24 hours, the cubes are removed from the mould and immediately submerge in clean water until testing. The sample is loaded at a uniform rate of 350 kg/cm^2/minute and the test are conducted for 3 cubes per percentage vice (0, 10, 25, 40, and 50 of MD by weight) and report the average value as the test result for 7 day, 14 day and 28 day as compressive strength. Compressive strength is defined as the ratio of failure load to the surface area of the sample. Figure 3 and Figure 4 shows the testing of the specimen in compression testing machine and influence of % variation of the marble dust in the mortar cube on compressive strength.

Figure 3: Testing of the specimens under compression

Maximum compressive strength at 7 day of curing period shows a peak value at 25% of MD mix attain 24.5 MPa and the increase in strength is by 37.96%. For 14 and 28 days of curing period, the maximum compressive strength is 26.8 MPa and 29.5 MPa with an increase of 24.88% and 16.61% at 25% and 24% of MD mix.

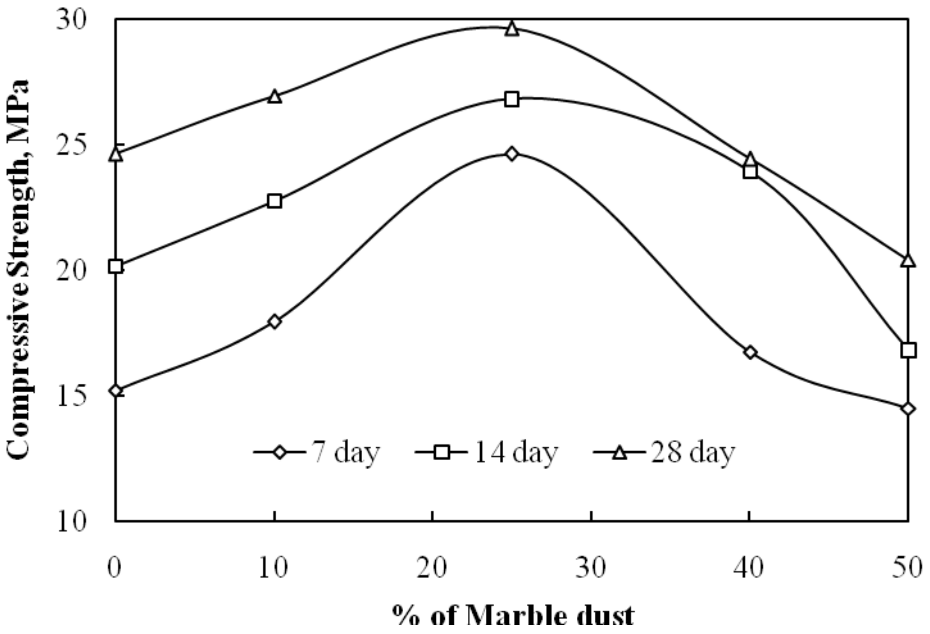

Figure 4: Influence of marble dust in compressive strength of mortar cube

Flexural Strength Test on Mortar

Flexural test evaluates the tensile strength of cement mortar indirectly and it tests the ability of unreinforced cement mortar beam to withstand failure in bending as modulus of rupture. Flexural test on cement mortar is conducted as per IS 4031 - PART 8 Indian standards by centre point load test (Figure 5) in wet condition.

Similar to the compressive strength the cement and sand is proportioned for 1:3 ratios. The rate of loading is 50 kg/cm^2/minute and test was conducted for three sample specimens per percentage vice (0, 10, 25, 40 and 50%) and the average value for 7 day, 14 day and 28 day flexural strength. Figure 5 shows the schematic representation of flexural test.

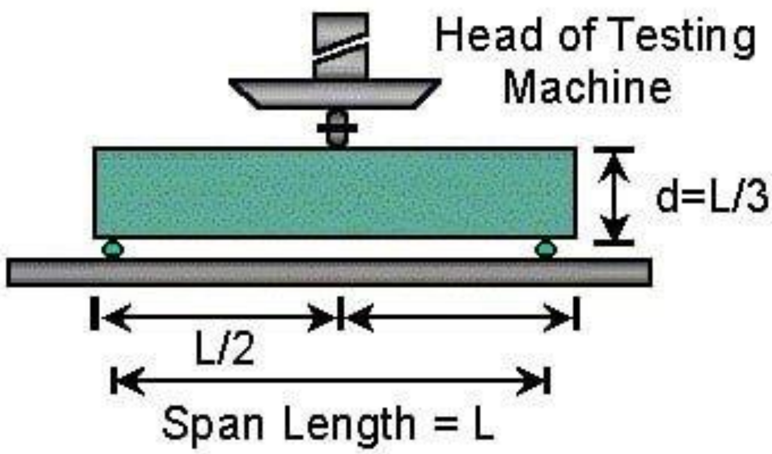

Figure 5: Schematic representation of flexural testing

Figure 6: Testing of the mortar specimen under flexure

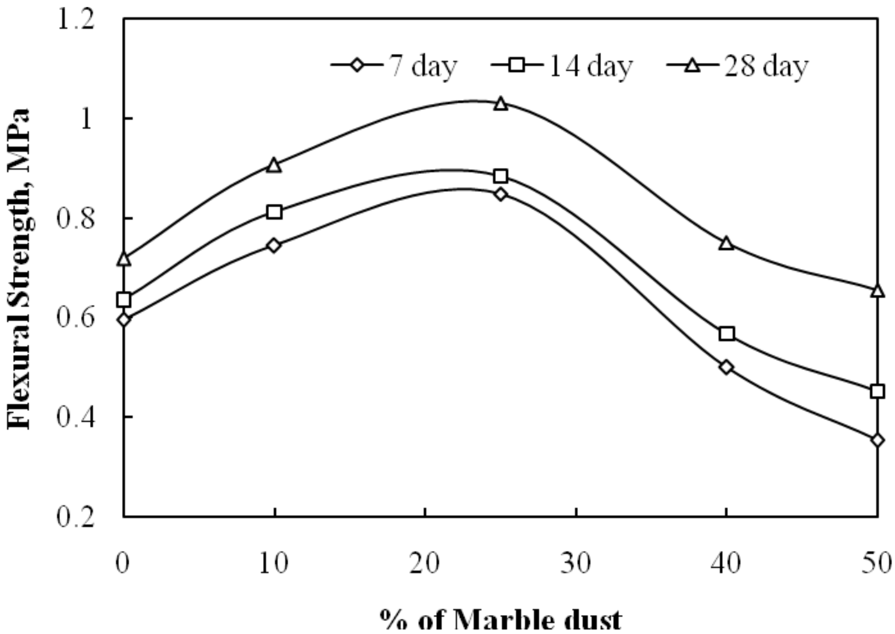

Figure 7: Flexural Strength of the Marble replaced mortar cube

Figure 6 shows the testing of the specimens in the universal testing machine. The flexural strength at 7, 14 and 28 curing is 0.86, 0.9 and 1.04 MPa at a maximum percentage of MD 22 %, 22 % and 23 % respectively. Figure 7 shows the variation of the flexural strength for different % of Marble dust in mortar cube.

Sorptivity Test

Sorptivity, it is the measure of capacity medium to absorb liquid by capillarity (John Philip, 1957). Sorptivity co-efficient is indirectly proportion to the durability of t he material and directly proportion to rate of water absorption. If the sorptivity value is low the rate of water absorption is also low with high durability of the specimen. The sample is prepared in 1:3 ratio (cement: fine aggregate) for various percentage of MD (0%, 10%, 25%, 40% and 50%) in a 10 cm diameter and 5 cm height mould and cured for 28 days. To understand unidirectional adsorption, bottom of the specimen is coated with paint and dried in room temperature after curing. Then the specimen is exposed to 10 mm of water with coated side facing downward. The wet weight of the sample is measured at a regular interval of 15 min, 30 min, 1 h, 1.5 h, 3 h, 8 h, 24 h, 72 h, 96 h and 120 h by removing it from the water after drying the sample. The samples under water absorption are shown in Figure 8. It is again placed in the water once the measurement is noted by marinating the water level by 10 mm. Sorptivity is measured using the equation 1. From Figure 9 to 11, it is observed that % increase in Mable dust increases the water absorption and sorptivity coefficient by about 40 %. Table 1 gives the sorptivity coefficient of mortar cubes for varying % of Marble dust.

$$\frac{Q}{A} = k\sqrt{t} \qquad (1)$$

Where,

Q	-Volume of water absorbed, cm^3
A	-Cross section of the specimen that was in contact with water, cm^2
k	-Sorptivity coefficient, $cm.s^{-1/2}$
t	-time, s

Figure 8: Mortar cube with marble power under water absorption

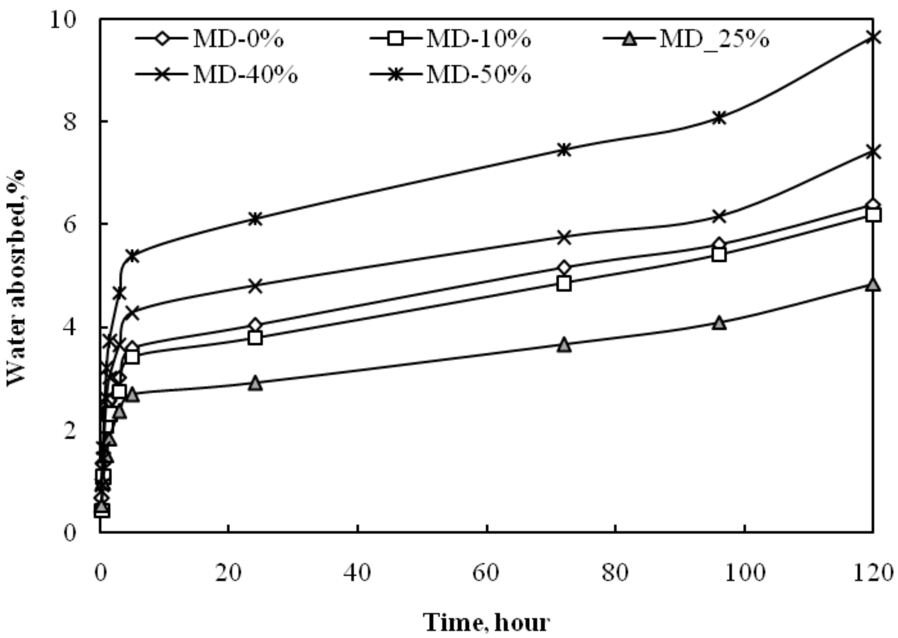

Figure 9: Rate of water absorption versus Time for the test samples

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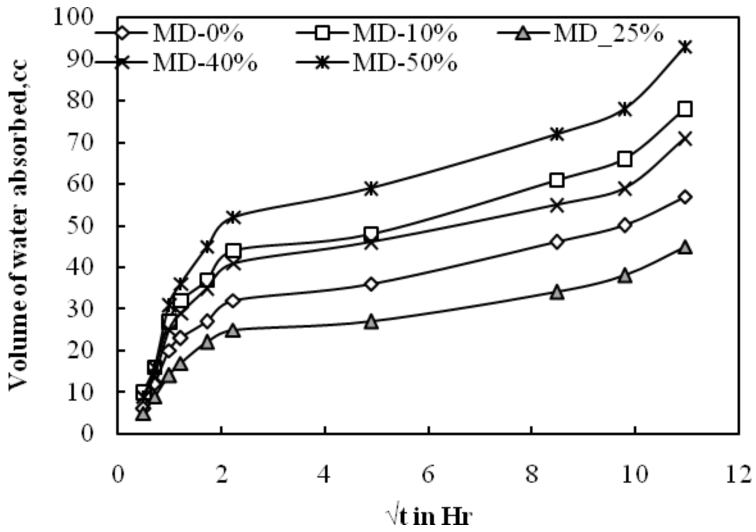

Figure 10: Water absorption of Mortar cubes with Marble powder

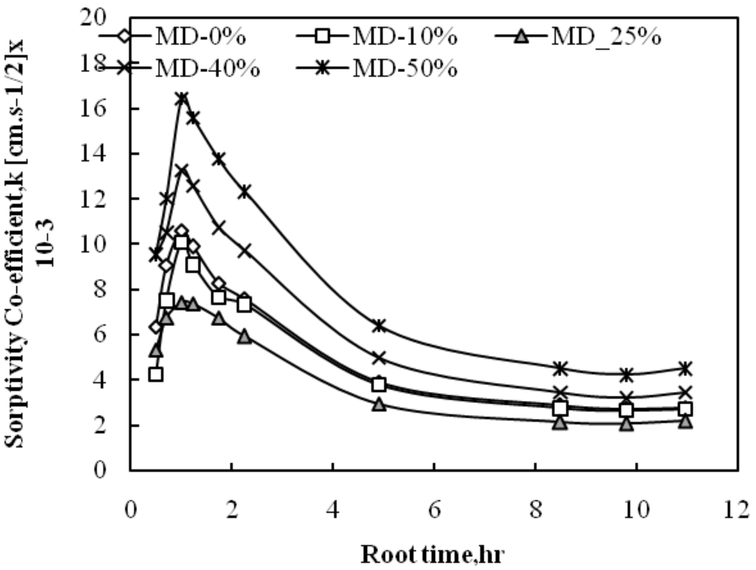

Figure 11: Sorptivity Coefficient of Mortar cubes with Marble powder

Table 1: Sorptivity Coefficient for the Mortar cube with the varying % of Mable dust

Sl.No	Time	√t sec	Q cm^3					A cm^2	Sorptivity coefficient k $[cm.s^{-1/2}]x\ 10^{-3}$				
			0%	10%	25%	40%	50%		0%	10%	25%	40%	50%
1	15 min	30.00	6	10	5	9	9	31.4	6.36	4.25	5.31	9.55	9.55
2	30 min	42.42	12	16	9	14	16	31.4	9.08	7.50	6.76	10.51	12.01
3	1 hr	60.00	20	27	14	25	31	31.4	10.6	10.08	7.43	13.27	16.45
4	1.5 hr	73.48	23	32	17	29	36	31.4	9.9	9.10	7.37	12.57	15.60
5	3 hr	103.9	27	37	22	35	45	31.4	8.27	7.66	6.74	10.73	13.79
6	5 hr	134.1	32	44	25	41	52	31.4	7.59	7.35	5.93	9.73	12.34
7	24 hr	293.9	36	48	27	46	59	31.4	3.9	3.79	2.93	4.98	6.39
8	72 hr	509.1	46	61	34	55	72	31.4	2.87	2.75	2.13	3.44	4.50
9	96 hr	587.8	50	66	38	59	78	31.4	2.70	2.65	2.06	3.20	4.23
10	120 hr	657.2	57	78	45	71	93	31.4	2.76	2.71	2.18	3.44	4.51

CONCLUSION

From the experimental investigation on partial replacement of fine aggregate with marble dust improved the properties of mortar like compressive strength, flexural strength and water absorption. The following conclusions were arrived from the study.

- The Compressive strength of cement mortar increases up to 25% for change in the percentage of Marble dust from 0 – 25 % and get decreases for change in the % of marble dust from 25 – 50 %.
- The Flexural strength increases by 22 % up to 25% replacement of Fine aggregate with marble dust and then decrease with increase in the percentage of replacement by marble dust.
- The water absorption and sorptivity of 10%, 25%, 40 % and 45% Marble powder replaced mortar shows higher water absorption and sorptivity coefficient.
- Use of the waste marble dust upto 25 % in the mortar cube leads to sustainable development in construction industry and environment

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