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An Experimental Study on Strength Characteristics of Hybrid Fiber Reinforced Concrete Containing Copper Slag as a Partial Replacement of Fine Aggregate

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Abstract: In the study of the mechanical properties of hybrid fiber reinforced concrete containing waste copper slag with different percentage of fibers like polypropylene fiber and steel fiber is done. The use of two types of fibers in suitable combination would help to improve the properties of concrete. Copper slag is the waste material produced from refining of copper and each ton of copper produces up to 2.5 ton of copper slag. The use of copper slag gives the promising future to the construction field. In this experimental work, use of two different types of fibers such as polypropylene fiber of 6mm length and flat crimped steel fiber of length 35mm with aspect ratio 50 with different mix proportion of fibers to form the hybrid fiber reinforced concrete. The main aim of this experiment is to study the strength properties of copper slag fiber reinforced concrete of M25 grade with 0%, 0.05% & 0.35%, 0.1% & 0.7%, 0.15% & 1.05% and 0.2% & 1.4% of polypropylene fibers and steel fibers respectively are used by volume of concrete with addition of constant 20% copper slag by volume of fine aggregates. It was seen that, polypropylene & steel fibers ratio 0.15% & 1.05% gives maximum result in strength parameters such as compressive strength, split tensile strength and flexural strength compared to other proportions.

Keywords: Hybrid Fiber Reinforced Concrete, Copper Slag, Polypropylene Fiber, Flat Crimped Steel Fiber, Compressive Strength, Split Tensile Strength, Flexural Strength.

I. Introduction

Over a period of time, waste management has become one of the most complex and challenging problem in the world which is affecting the environment. The rapid growth of industrialization gave birth to numerous kinds of waste by-products which are environmentally hazard and creates problems of storage. Sand is a major material used for preparation of mortar and concrete. In general consumption of natural sand is high, because of large use of concrete and mortar. Demand of natural sand is very high in developing countries to satisfy the rapid infrastructure growth. The developing country like India facing shortage of good quality natural sand and particularly in India, river sand deposits are being used up and causing serious threat to environment. In India, 450 million cubic meter of concrete consumes annually and which approximately comes to 1 tonne per Indian. We still have a long way to go by global consumption levels. Can we have enough sand? Options for various river sand alternatives, such as offshore sand, quarry dust. Physical as well as chemical properties of fine aggregate affect the durability, workability and also strength, so fine aggregate is important constituent of concrete and cement mortar. Recently river sand is becoming a very costly because of its demand in the construction industry due to this condition research began for cheap and easily available alternative material to river sand. Some alternatives materials have already been used as a replacement of river sand such as fly-ash, quarry dust or limestone and siliceous stone powder, filtered sand, copper slag are used in concrete and mortar mixtures as a partial or full replacement of natural sand.

Copper slag is one of the materials that are considered as a waste material which could have a promising future in construction Industry. Sustainable construction mainly aims at reduction of negative environmental impact resulted by construction industry which is the largest consumer of natural resources. Copper slag is generated as a by-product material which obtains during the matte smelting and refining of copper.

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To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material. The slag is black glassy particle and granular in nature. It has a similar particle size range like river sand. The specific gravity of the slag is ranges from 2.9 to 3.9. The bulk density of granulated copper slag varies from 1.9 to 2.15 kg/m^3 which are almost similar to bulk density of river sand. The presence of silica in slag is about 20% to 26%, which is desirable because it is one of the constituents of the natural fine aggregate used in normal concrete mix design. The fineness of copper slag is relatively same as sand. It shows that copper slag may be used as a partial replacement for river sand as fine aggregate.

A composite can be termed as hybrid, which derives benefits from each of the individual fibers and exhibits a synergetic response. Reinforcement of concrete with single type of fiber may improve the properties to a certain level. However, by using the concept of hybridization with two or more different types of fibers incorporated in a cement matrix. one type of fiber, which is stiffer and stronger, improves the first crack stress and the ultimate strength of concrete and the second fiber, which is more flexible, and ductile leads to improved impact resistance and strain in the post-cracking zone. Durable type of fiber can increase the strength and toughness. If one type of fiber is smaller, so that it bridges between micro cracks and second type of fiber is larger, so that it arrests the propagating macro cracks. In our experiment, five different types of sample were prepared of M25 grade of concrete and each sample has 3 sub samples. First sample PR1 is prepared without fiber and copper slag and other samples are made with the fraction of fiber is 0%,0.4%, 0.8%, 1.2%, 1.6% respectively and sand is partially replaced by copper slag of constant percentage in all sample. The steel fiber and the polypropylene fiber are mixed in different proportion of each fraction in single sample.

II. LITERATURE SURVEY

Vijayaprabha Chakrawarthi, Brindha Darmar, Ashok Kumar Elangovan [June 2015] published a paper titled "Copper Slag concrete admixed with polypropylene fibers." In this research project, the analysis of using copper slag (CS) and polypropylene (PP) fibers in concrete was done. PP fibers content should be up to 0.4%. The copper slag when mixed with PP fibers gives maximum 7 days strength up to 90% of the mean strength as well as the 80% copper slag replacement does not reduce in strength at 28 days curing compared to the normal mix. Therefore, it can be seen that, up to 40% of CS with 0.4% of PP fibers can be used and by adopting a proper combination of admixture, the percentage of replacement can be increased.

T.Ch. Madhavi, Arindam Mallick, M.B. Sohail, Soumyadeep Nath, Mohit Jain [July 2015] published a paper titled "Effect of Copper Slag on Strength of Polypropylene Fiber Reinforced Concrete." In this paper, copper slag was used for the replacement material for sand and the effect of copper slag was studied for the strength of concrete. Polypropylene fibers were added to increase the strength and ductility in the ratios of 0.1%, 0.2%. 0.3% and 0.4% content. The sand was replaced by copper slag on the proportions of 10%, 20%, 30%, 40%, 50%, 60% and 100%. When 40% replacement of sand with copper slag, the maximum strength was obtained and further addition decreases the strength. Only 0.2% of fibers were added, when fibers added beyond 0.2%, it results in decrease in strength.

Binaya Patnaik, T. Seshadri Sekhar and B. Chandra Sekhar [Nov. 2015] published a paper titled "An Experimental Investigation on Strength Properties of Copper Slag Fiber Reinforced Concrete." In this paper, the experimental study of the mechanical properties of copper slag fiber reinforced concrete (CSFRC) with the fiber content of 0%, 0.5%, 1% and 1.5% and comparison between different mechanical properties and non-destructive tests properties of concrete was done. Concrete grade M20 and M30 were used with crimped steel fibers and having aspect ratio of 60. Maximum compressive strength is observed with concrete containing copper slag at 1% crimped steel fiber by volume. In case of split tensile strength and flexural strength, the comparison was done between normal concrete and concrete containing copper slag and result was seen that the strength of concrete containing copper slag increases with percentage increase of crimped steel fiber content.

V.G. Premlal, A. Nizad [Sep 2015] published a paper titled "Strength and Durability Characteristics of Steel Fiber Reinforced Concrete Containing Copper Slag as Partial Replacement of Fine Aggregate." In this paper, the parameters like strength and durability of steel fiber reinforced concrete with copper slag as partial replacement of sand. The tests were done and copper slag and steel fibers were added in M20 grade concrete. Sand was replaced with copper slag in proportions of 0%, 10%, 20%, 30%, 40%, 50% and 60%. In all these mix proportions, the steel fiber is kept constant at 0.2% by volume of concrete. All these hybrid mixes were tested and result would found that 40% of copper slag steel fiber reinforced concrete gives maximum strength and durability.

S.P. Vimarsh, S.N. Basavana Gowda, B.R. Ramesh [Sep 2014] published a paper titled "Study on Strength Properties of Fiber Reinforced Concrete by

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Partial Replacement of Sand by Copper Slag." In this paper, two phases were done in this study. First phase includes copper slag as sand by preparing concrete mix of M30 grade and finding out mechanical properties of concrete. 40% of copper slag gives optimum result. Second phase includes copper slag and steel fibers in various percentages. The variation percentage of steel fiber is taken from 0.5% to 1.75% by weight of cement. The result obtained from this was that, compression strength was maximum with 1% of steel fiber for hooked end and crimped steel fiber. When comparison was done between concrete containing hooked end fiber and concrete containing crimped fiber, the result comes out was that, hooked end fiber gives more compressive, tensile and flexural strength compare to others.

S. Arivalagan [2013] published a paper titled "Experimental Study on the Flexural Behaviour of Reinforced Concrete Beams as Replacement of Copper Slag as Fine Aggregate." In this experimental study, sand was replaced by copper slag to find out the compressive, flexural and split tensile strength. To find out the results of concrete containing copper slag and sand, proportions were taken from 20% to 100% in the interval of 20%. In 40% replacement, the maximum compressive strength i.e. 35.11 Mpa was obtained. The results were also increased for the flexural as well as split tensile strength and energy absorption characters. Slump value would be obtained as 90 to 120mm and flexural strength is also increased by 21% to 51% due to replacement of copper slag.

R.R. Chavan and D.B. Kulkarni [2013] published a paper titled "Performance of Copper Slag on Strength Properties as Partial Replace of Fine Aggregate in Concrete Mix Design." In this investigation, tests were conducted for different proportions of copper slag which was replaced with sand from 0 to 100% for M25 grade concrete. The obtained results showed that, at 40% replacement of sand by copper slag, compressive strength was increased by 55% as compared to normal concrete. At up to 75% replacement gives maximum strength. In case of flexural strength, the concrete cured for 28 days gives higher strength i.e. 14% more compare to normal concrete for 20% replacement of sand by copper slag. Because of high toughness of copper slag, the strength would be increased.

III. OBJECTIVE OF RESEARCH

1) To investigate the effect of copper slag as partial replacement of river sand in concrete mix.
2) To determine the mix proportion of concrete mix with addition of composite fibers and copper slag to achieve the desire needs.
3) To evaluate the compressive strength, split tensile strength & flexural strength of hybrid fiber reinforced concrete containing constant percentage of copper slag and comparing the results of different proportions.

IV. PROPOSED METHODOLOGY

A. MATERIALS USED

Cement: I have used Ordinary Portland cement (OPC) with 53grade conforming to **IS: 12269-1987**. The specific gravity of cement is 3.15. Standard Consistency was 32%.
Fine aggregate: In this experimental work, we used locally available river sand. The result of sieve analysis confirms to zone – ii according to IS: 383-1970. Sand having specific gravity of 2.63 and fineness modulus 2.49 was used. The water absorption was 1.11%.
Coarse aggregate: Crushed angular aggregate passed from 20mm sieve and retain on 10mm sieve size having specific gravity of 2.73 and fineness modulus of 6.85 was used. The water absorption was 1.05%.
Copper slag: Irregular, glassy black, air cooled copper slag with specific gravity of 3.45 and fineness modulus of 3.4 was used. The water absorption was 0.3%.
Steel fiber: Steel fiber of flat crimped type having aspect ratio 50 was used which is provided by Stewols India Pvt. Ltd. Nagpur, Maharashtra. The length of fiber was 35mm. The Ultimate Tensile Strength of the fibers was found to be 1100 MPa.
Polypropylene fiber: In this experiment, KEM FIBER 84 monofilaments fine polypropylene fiber is used. The fibers were supplied by KEM FIBER ltd. The length of polypropylene fiber was 6mm.
Superplasticizer: In this investigation, Super plasticizer used is Perma Plast Super PS34. It is a retarding dark brown Super plasticizer with Integral Water Proofing ability. Specific gravity of superplassticizer is 1.2@25C. It complying with ASTMC494: 1977 type A, B, D, E & F.

B. EXPERIMENTAL PROGRAMME

Compressive strength test: The compressive strength of concrete is determined by the crushing strength of cube 150mm x 150mm x 150mm, at age of 7 and 28 days. After the completion of curing, cubes are taken away from the curing tank and wiped the water with dry cloth. Determine the density by taking the weight of specimen. Measure the dimension of load bearing area of cube. Now get the sample into the compression testing machine. Load is apply slowly, till the specimen fails to obtain further load and note down the maximum load taken up by the specimen. Also other specimens are tested and load is taken down. The compressive strength of the concrete in terms of pressure was then calculated using the Equation:
Compressive strength (σ) = P / A

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Where, P = Maximum applied load, A = Bearing surface of area (mm^2)

Fig.1 Compressive strength test of cube

Fig.2 Cube failed under the Load

Split tensile strength test: The cylindrical specimens of size 150 mm of diameter and 300 mm height are used for determining the spilt tensile strength. This test was conducted for cylinder after the age of 7 and 28 days curing. The specimens are tested in the universal testing machine. Note down the maximum load taken up by the specimen. The spilt tensile strength of the specimen is expressed as (f_{ct}).

$$f_{ct}= 2P/ \pi ld$$

Where, P = maximum load in Newton applied to the specimen, l = length of the specimen in mm, d = cross section dimension of the specimen in mm.

Fig.3 Split tensile test of cylinder

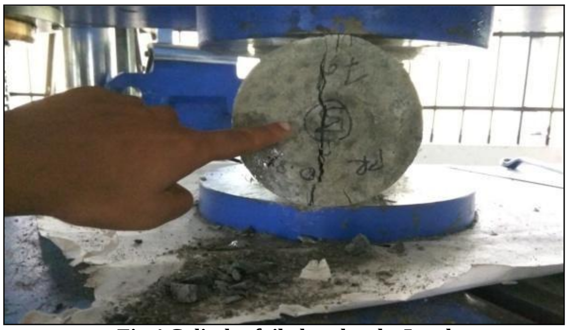

Fig.4 Cylinder failed under the Load

Flexural strength test: The beam specimens of size 500mm x100mm x100 mm are used for determination of flexural strength. Beams are taken out from water tank after the age of 7 and 28 days curing and wiped with the cloth. The specimens are tested in the universal testing machine. The rate of loading is 2 kN/sec the load is increased until the beam specimen fails and the maximum load applied to the specimen during the test is recorded. The flexural strength of the beam is expressed in the term of modulus of rupture (f_b). According to the IS: 516 – 1959.

$$f_b= Pl/bd^2$$

(When „a" is greater than 200 mm for 150 mm specimen or greater than 133 mm for a 100 mm specimen)

Where, f_b= modulus of rupture, N/ mm , b = measured width in mm of the specimen, d = measured depth in mm of the specimen at the point of failure, l = length in mm of the span on which the specimen is supported, P = applied load, in Newton, a = distance between line of fracture and the nearer support.

Fig.5 Flexural strength test of beam

Fig.6 Beam failed under the load

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C. MIX DESIGN AND SAMPLE PREPARATION

A per the code book IS: 10262 -1979, the mix design was done for M25 grade mix and the amounts of materials were calculated. Table-2 gives the quantities required for M25 grade of concrete Mixes. The optimum percentage of copper slag has been established as 20% for partially replacing sand in preparation M25 grade concrete. In this investigation, various mixes were prepared by adding flat crimped steel fibers and polypropylene fibers of different volume fraction (0%, 0.4%, 08%, 1.2% & 1.6%) to copper slag concrete. The water binder ratio of concrete mix was 0.43. Here „PP" and „S" represents polypropylene and flat crimped steel fiber respectively whereas the suffix represents the percentage of material replaced and used. Table-1 gives the fiber fractions for various mixes.

TABLE 1

FIBER FRACTIONS

Percentage of fiber fraction (%)	PR1 (0%)		PR2 (0.4%)		PR3 (0.8%)		PR4 (1.2%)		PR5 (1.6%)	
	S	PP	S	PP	S	PP	S	PP	S	PP
	0	0	0.35	0.05	0.7	0.1	1.05	0.15	1.4	0.2

TABLE 2

DETAILS AND QUANTITIES OF MATERIALS

Samples	Water (Kg/ m3)	Cement (Kg/ m3)	Copper slag (Kg/ m3)	Fine Aggregate (Kg/ m3)	Coarse Aggregate (Kg/ m3)	Admixture (Kg/ m3)	Flat crimped Steel fiber (Kg/ m3)	Polypropylene fiber (Kg/ m3)
PR1	165.12	384	0	686.43	1225.77	3.84	0	0
PR2	165.1	384	180.09	549.11	1225.77	3.84	8.77	1.25
PR3	165.12	384	180.09	549.11	1225.77	3.84	17.55	2.50
PR4	165.12	384	180.09	549.11	1225.77	3.84	26.33	3.76
PR5	165.12	384	180.09	549.11	1225.77	3.84	35.11	5.01

The experimental investigation has been done by testing of cubes, cylinders and beams. Five different sample mixes i.e. PR1, PR2, PR3, PR4, PR5 are prepared in the laboratory; each sample mix has three specimens of cube, three specimens of cylinder and three specimens of beam. Total 30 number of specimen were casted for each cube, cylinder and beam respectively. All results obtained are compared with the normal concrete mix.

V. EXPERIMENTAL RESULTS

Compressive strength test: The results in Table-3 shows the compressive strength of M25 grade concretes with varying fiber content and constant copper slag at different ages. It can be observed from Table-3 that the compressive strength of concrete increases with the increase of fiber but in case of copper slag concrete the maximum is perceived at 1.2% of fibers. After that the value of compressive strength was decreases. Total 30 cubes i.e. 5 samples for each trial mix (3 for 7 days & 3 for 28 days) was tested. The average strength of 7 days and 28 days strength results are shown in table-3 and Graph for 7 & 28 days compressive strength show in figure-7.

TABLE 3

THE RESULTS OF COMPRESSIVE STRENGTH (N/MM^2)

Sample	PR1	PR2	PR3	PR4	PR5
Average compressive strength (N/mm^2) for 7 Days	21.5	24.37	26.85	28.07	23.36
Average compressive strength (N/mm^2) for 28 Days	32.5	36.58	39.35	41.81	36.61
Percentage Increase in strength (%)	51.12	50.10	46.55	48.95	56.72

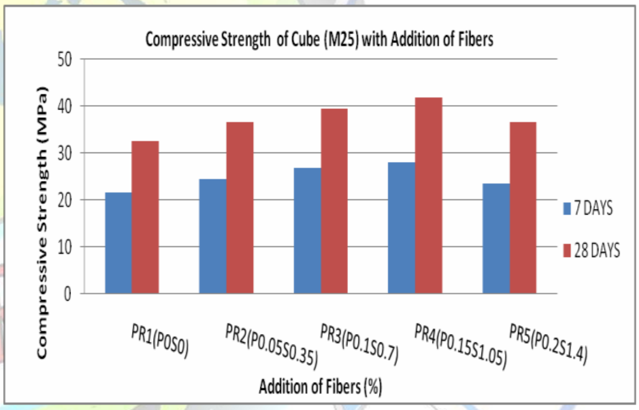

Fig.7 Bar chart of Compressive Strength test

Split tensile strength test results: The results in Table-4 shows the split tensile strength of M25 grade concretes with varying fiber content and constant copper slag at different ages. It can be observed from Table-4 that the split tensile strength of concrete increases with the increase of fiber but in case of copper slag concrete the maximum is perceived at 1.2% of fibers. After that the value of split tensile strength was decreases. Total 30 cylinders i.e. 5 samples for each trial mix (3 for 7 days & 3 for 28 days) was tested. The average strength of 7 days and 28 days strength results are shown in table-5 and Graph for 7 & 28 days split tensile strength show in figure-8.

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TABLE 4

THE RESULTS OF SPLIT TENSILE STRENGTH (N/MM^2)

Mix	PR1	PR2	PR3	PR4	PR5
Average split tensile strength (N/mm^2) for 7 Days	2.17	2.41	2.60	2.80	2.50
Average split tensile strength (N/mm^2) for 28 Days	3.13	3.43	3.62	3.97	3.56
Percentage Increase in strength (%)	44.24	42.32	39.23	41.78	42.4

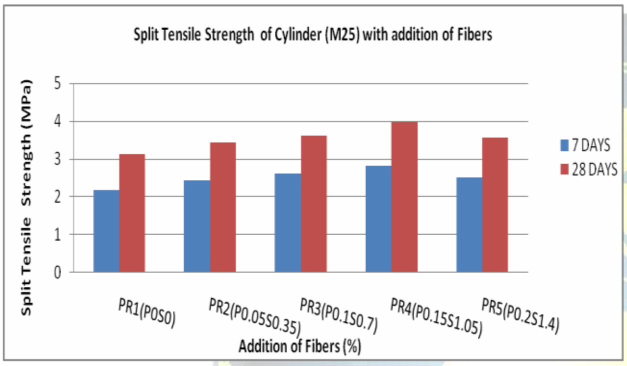

Fig.8 Bar chart of Split Tensile Strength

Flexural Strength test results: The results in Table-5 shows the Flexural Strength of M25 grade concretes with varying fiber content and constant copper slag at different ages. It can be observed from Table-5 that the Flexural Strength of concrete increases with the increase of fiber but in case of copper slag concrete the maximum is perceived at 1.2% of fibers. After that the value of Flexural Strength was decreases. Total 30 beam i.e. 5 samples for each trial mix (3 for 7 days & 3 for 28 days) was tested. The average strength of 7 days and 28 days strength results are shown in table-5 and Graph for 7 & 28 days Flexural Strength show in figure-9.

TABLE 5

THE RESULTS OF SPLIT TENSILE STRENGTH (N/MM^2)

Mix	PR1	PR2	PR3	PR4	PR5
Average flexural Strength (N/mm^2) for 7 Days	2.92	3.31	3.60	3.71	3.42
Average flexural Strength (N/mm^2) for 28 Days	3.60	4.12	4.38	4.77	4.28
Percentage Increase in strength (%)	23.29	24.47	21.67	28.57	25.15

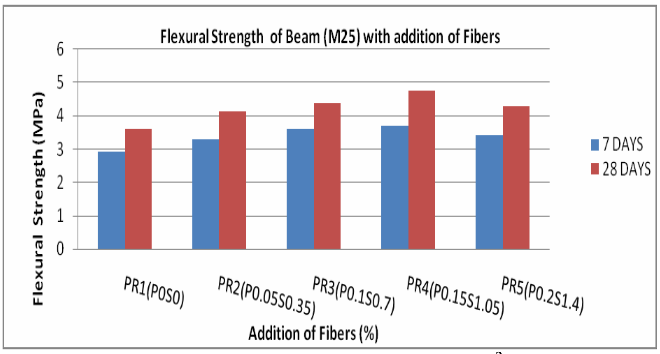

Fig.9 Results of Flexural Strength (N/mm^2)

VI. CONCLUSION

Compressive strength test : It is observed that compressive strength of hybrid reinforced concrete tends to increases with increase in percentage polypropylene fiber and steel fiber up to sample PR4.The maximum compressive strength of hybrid reinforced concrete is observed in sample PR4 that is about 28.07 N/mm^2 and 41.81 N/mm^2 of 7 days and 28 days strength respectively. The compressive strength is increased by 30.55% and 28.64 % as compared with normal concrete mix for 7 days and 28 days respectively. Compressive strength of concrete increases up to sample PR4 (i.e. 0.15% polypropylene fiber and 1.05% steel fiber), after that it shows degradation.

Split tensile strength test: It is observed that split tensile strength of hybrid reinforced concrete tends to increases with increase in percentage polypropylene fiber and steel fiber up to sample PR4. The maximum split tensile strength of hybrid reinforced concrete is observed in PR4 that is about 2.80 N/mm^2 and 3.97 N/mm^2 of 7 days and 28 days strength respectively. The split tensile strength is increased by 29.03 % for 7 days and 26.83 % for 28 days as compared with normal concrete mix. Split tensile strength of concrete increases up to sample PR4 (i.e. 0.15% polypropylene fiber and 1.05% steel fiber), after that it shows degradation.

Flexural strength test: It is observed that flexural strength of hybrid reinforced concrete tends to increases with increase in percentage polypropylene fiber and steel fiber up to sample PR4. The maximum flexural strength of hybrid reinforced concrete is observed in PR4 that is about 3.71 N/mm^2 and 4.77 N/mm^2 of 7 days and 28 days strength respectively. The strength is increased by 27.05 % for 7 days and 31.11 % for 28 days curing period as compared with normal concrete mix. Flexural strength of concrete increases up to sample PR4 (i.e. 0.15% polypropylene fiber and 1.05% steel fiber), after that it shows degradation.

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