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# Influence of Bottom Ash as Partial Replacement for Fine Aggregate on the Properties of Hybrid Fiber Reinforced Cement Concrete

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*Abstract:* **The major problem the world is facing today is environmental pollution. In the construction industry mainly the production of Portland cement will cause the emission of CO2 which results in environmental pollution. On the other hand, the problem of depleting natural resources can be solved by the usage of industrial by-products obtained from the construction industry. concrete technology is heading towards an entirely new era by the use of Bottom ash, polypropylene fibers & Steel fibers in concrete. Concrete when mixed with fibers, give fibrous concrete. The mechanical property of fibrous concrete is superior to that of ordinary concrete. Bottom ash will be evaluated for use as supplementary Fine aggregate material in Fine aggregate based system, the performance of Bottom ash mixtures will be compared to controlled mixtures and mixtures incorporating Bottom ash as replacement for Fine aggregate.**

**In this present study, the effect of bottom ash on strength parameters and durability properties of hybrid fiber reinforced concrete are assessed. Fine aggregate is replaced with bottom ash by 5%,10%,15%,20%,25% and 30% in concrete specimens with 1% of hybrid fibers. Hybrid fiber (0.5 % of steel fibers and 0.5 % polypropylene fibers) were taken by total volume of concrete. The experimental studies show that bottom ash can be used in concrete as partial replacement for the fine aggregate without any effect on strength and durability.**

*Index Terms:* **Bottom ash, steel fibers, polypropylene fibers, strength parameters.**

## I. Introduction

The present research work was aimed to explore the possibility of use of low-calcium coal bottom ash as a construction material in place of the river sand. The appearance and particle size of coal bottom ash is similar to that of river sand. [1] The physical properties of coal bottom ash attract it to be used in concrete as fine aggregate either in partial or total replacement of river sand. In the literature published during the last decade, coal bottom ash has been targeted as fine aggregate in concrete. The published research data which is confined to strength properties only indicate that coal bottom ash is a viable material as sand replacement in concrete.[2] The present research study was motivated by the ecological concerns over the disposal of coal bottom ash and scarcity of natural sources of river sand in the country. The ultimate objective of the present research study was to explore the feasibility of use of low-calcium coal bottom ash either in partial or total replacement of natural river sand in manufacturing of concrete. [5-8]

## II. Literature Review

Kiran M Sannakki & Sanjith[1] Present study investigates the effect of coal bottom ash as partial replacement to sand in concrete. Compressive strength characteristics of M40 grade concrete were studied with bottom ash varying from 0% (Conventional concrete), 10%, 20%, and 30% replacement and at different curing periods. Analysis of results showed that maximum strength of 49.56 N/mm2 by replacing 20% of bottom ash as replacement fine aggregate Sand quarrying is done to extract sand for construction purposes. The workability of concrete decreased with the increase in bottom ash content due to the increase in water demand, which is nullified by increasing the content of super plasticizer. The compressive strength and Split Tensile strength for 7, 14 and 28 days were increased up to 20% replacement and after that gradually decreased for further replacement.

Kylasnath M, Ranjan Abraham [2], the study was carried out to evaluate the suitability of utilizing bottom ash as a partial replacement to fine aggregate in high strength concrete (M60 grade). Experiments were conducted by replacing fine aggregate with bottom ash in varying percentages 0%, 5%, 10%, 15%, 20%, 25% and 30%. Mechanical properties such as compressive strength, splitting tensile strength and flexural strength were evaluated. Test results indicated that bottom ash is suitable for improving the mechanical properties of concrete. Increase in water demand was incorporated by increasing the content of superplasticizer. The optimum replacement percentage of fine aggregate with bottom ash was found to be 20%. Compressive strength for 3, 7 and 28 days were increased up to 20% replacement and after that gradually decreased for further replacement. Bottom ash mix showed about 3.9%, 4.2% and 6.5 % increase in the 3-day, 7 day and 28 day compressive strength as compared to control mix

M. Purushothaman[3] & RM. Senthamarai[4], this paper reports the results of an experimental program to investigate the effect of using thermal power station bottom ash as a replacement of natural fine aggregate on the properties of High-performance concrete (HPC). A Total of 10 mixes were prepared for these tests. Out of which five are Bottom ash Concrete (BAC) and five are Conventional Concrete mixes (CC). BAC mixes were evaluated for compressive, tensile and flexural strengths development for the concrete ages of 7 days,28 days,56 days and 90 days and the results were compared with those of CC mixes. The incorporation of 10% silica fume and 40% bottom ash in concrete results in significant improvements in its mechanical properties of BAC compared to the control mix. It should be noted that further research work is needed to explore the effect of bottom ash as fine aggregates on the durability properties of concrete.

Ramesh kanagavel, Arunachalam Kalidass [5], Mechanical properties of hybrid fibre reinforced quaternary concrete Quaternary blending cement concrete with fibres is studied in terms of compressive, split tensile, and flexural strength properties, and impact resistance. Fly ash, rice husk ash, and limestone powder are used as partial replacement of cement. Steel, carbon, and polypropylene fibres, are used in different fractions. The results show that the steel-carbon and steel-carbon-polypropylene hybrid fibre reinforced concretes perform better with regard to compressive, split tensile, and flexural strength properties, and impact resistance. There is a positive synergy in SCPHFRC mixes at the 0.5 % volume fraction of steel fibres, compared to SCHFRC mixes. However, this synergic effect disappears at the 1 % and 1.5 % volume fraction of steel fibres along with carbon and PP fibres. SCHFRC mixes perform better than SCPHFRC mixes at the 1 % and 1.5 % volume fraction of steel fibres. Mono CFRC mixes performed poorly with respect to impact load. SCHFRC and SCPHFRC specimens resisted high impact loads prior to complete failure. The specimens with steel-carbon-PP hybrid fibres exhibited the highest impact resistance and the maximum percentage of increase in the post crack resistance of about 69.8 % in the S3C1P1 mix, compared to the control concrete at 28 days. In the S3C1P1 mix, the energy required to produce the first crack increased by 5.82 times and the energy required for complete failure increased by 9.84 times, compared to the control concrete at 28 days.

## III. Experimental Study

### A. Cement

Ordinary Portland Cement of 53 grade conforming to IS:8112-1989 was used in the present study.

### B. Aggregates

The physical properties of Fine aggregate and Coarse aggregate used in the present study are presented in Table I.

TABLE I.
PHYSICAL PROPERTIES OF AGGREGATES

| Physical property | Fine aggregates | Coarse aggregates |
|---|---|---|
| Specific gravity | 2.70 | 2.72 |
| Fineness Modulus | 2.83 | 7.6 |
| Water Absorption | 1.7% | 0.9% |

- Fine aggregate conforming to grading zone II of Table 4 of IS 383.
- Coarse aggregate in the concrete mix was taken in proportion to 20mm passing.

### C. Water

Potable water was used in the preparation of concrete.
Water used for concrete conforms to IS:456-2000.

### D. Bottom ash

Coal bottom ash has angular, irregular, porous and rough surface textured particles. The particles of coal bottom ash range from fine sand to fine gravel. Coal bottom ash has appearance and particle size distribution similar to that of river sand. Coal bottom ash is usually a well-graded material although variations in particle size distribution can be encountered from the same power plant.

TABLE II.
PHYSICAL PROPERTIES OF COAL BOTTOM ASH

| Sl. No | Properties | Value |
|---|---|---|
| 1 | Specific gravity | 2.66 |
| 2 | Water absorption | 1.52% |
| 3 | Fineness modulus | 2.55 |
| 4 | Maximum Size | 20mm |

### E. Chemical Admixture

Super plasticizer used in the present study was a conplast: SP-430. 1% to 1.5% Super plasticizer is taken by the weight of the binder in a concrete mix to increase workability.

### F. Steel fibers

Hooked end steel fibers of 0.4mm diameter and aspect ratio of 30 and 12mm length were used.

### G. Polypropylene fibers

Polypropylene fibers were formerly known as Steal the, these are micro reinforcement fibers and are 100% virgin homopolymer polypropylene graded monofilament fibers.

TABLE III.
PHYSICAL PROPERTIES OF POLYPROPYLENE FIBERS

| Sl.No | Parameter | Value |
|---|---|---|
| 1 | Appearance | Short cut staple fibre |
| 2 | Thickness | 20 Micron |
| 3 | Length | 6-12 mm |
| 4 | Colour | white |
| 5 | Specific gravity | 0.9 |

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### H. *Mix proportion*

M40 grade is adopted and the mix proportion is 1:1.56:2.23 is obtained as per IS10262:2009.

- Cement = 437.6 kg/$m^3$
- Fine aggregate = 713 kg/$m^3$
- Coarse aggregate = 1099.12 kg/$m^3$
- Water = 191 kg/$m^3$

## IV. TEST RESULTS

### A. *Workability*

Slump test is performed to determine the workability of concrete. Normal conventional concrete with bottom ash as replacement.

TABLE IV.
WORKABILITY OF NC

| Mix | Fine aggregate % | Bottom ash % | Slump (mm) |
|---|---|---|---|
| Mix 1 | 100 | 0 | 68 |
| Mix 2 | 95 | 5 | 63 |
| Mix 3 | 90 | 10 | 60 |
| Mix 4 | 85 | 15 | 56 |
| Mix 5 | 80 | 20 | 53 |
| Mix 6 | 75 | 25 | 50 |
| Mix 7 | 70 | 30 | 45 |

- Conventional concrete with bottom ash as replacement along with 1% of hybrid fibers (0.5% of steel fibers +0.5 % of polypropylene fibers) and 1% to 1.5% of super plasticizer by weight of binder are added to concrete.

TABLE V.
WORKABILITY OF HFRC

| Mix | Bottom ash % | Hybrid Fibers % | Super Plasticizer % | Slump mm |
|---|---|---|---|---|
| Mix 1 | 0 | 1 | 0 | 55 |
| Mix 2 | 5 | 1 | 0 | 50 |
| Mix 3 | 10 | 1 | 0 | 49 |
| Mix 4 | 15 | 1 | 1 | 48 |
| Mix 5 | 20 | 1 | 1 | 46 |
| Mix 6 | 25 | 1 | 1.5 | 43 |
| Mix 7 | 30 | 1 | 1.5 | 41 |

### B. *Compressive strength*

Compressive strength of the concrete is obtained by casting and testing of cubes (size 100mm ×100mm × 100mm) after the curing period of 7 days and 28 days.

The obtained results are tabulated in below table

TABLE VI.
COMPRESSIVE STRENGTH OF NC AND HFRC (7 DAYS)

| Mix | B.A % | NCC avg 7 days strength | HFRC avg 7 days strength |
|---|---|---|---|
| Mix 1 | 0 | 33 | 36.5 |
| Mix 2 | 5 | 30 | 33.2 |
| Mix 3 | 10 | 33.2 | 35.8 |
| Mix 4 | 15 | 35.4 | 39.9 |
| Mix 5 | 20 | 33.7 | 38.4 |
| Mix 6 | 25 | 31.4 | 36.1 |
| Mix 7 | 30 | 30 | 35 |

Compressive Strength of NC and HFRC (28days)

| Mix | B.A % | NCC avg 28 days strength | HFRC avg 28 days strength |
|---|---|---|---|
| Mix 1 | 0 | 49.3 | 52.9 |
| Mix 2 | 5 | 43.9 | 48 |
| Mix 3 | 10 | 46 | 53 |
| Mix 4 | 15 | 48.6 | 54.2 |
| Mix 5 | 20 | 45.1 | 49 |
| Mix 6 | 25 | 42.8 | 46.1 |
| Mix 7 | 30 | 41 | 44 |

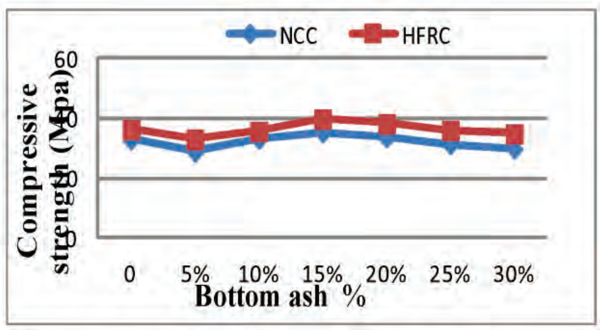


Figure 1. Average compressive strength of NC and HFRC at 7 days

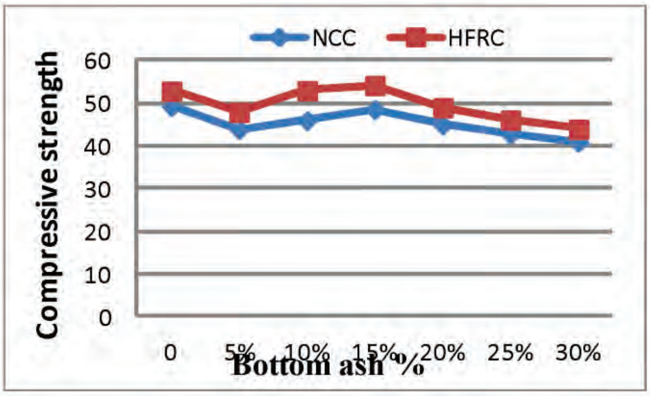


Figure 2. Average compressive strength of NCC and HFRC at 28 days

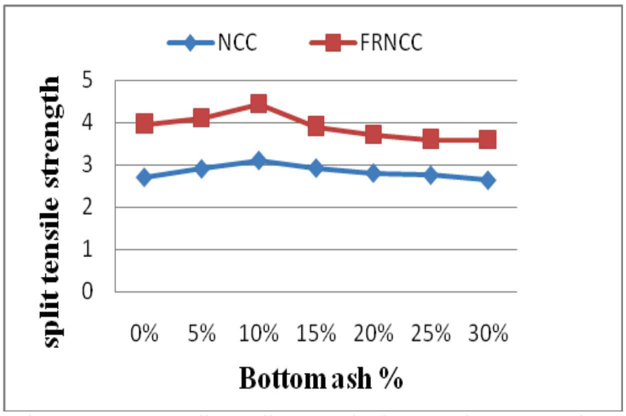


Figure 3. Average Split Tensile Strength of NCC and HFRC at 7 days

## *C. Split tensile strength*

Split tensile strength of the concrete is obtained by casting and testing of cylinders (size 300mm length and 150mm diameter) after the curing period of 7 days and 28 days.
The obtained results are tabulated in the table below.

TABLE VII.
SPLIT TENSILE STRENGTH OF NCC AND HFRC AT 7 DAYS.

| Mix | B.A % | NCC avg 7 days strength | HFRC avg 7 days strength |
|---|---|---|---|
| Mix 1 | 0 | 2.7 | 3.96 |
| Mix 2 | 5 | 2.9 | 4.1 |
| Mix 3 | 10 | 3.1 | 4.43 |
| Mix 4 | 15 | 2.92 | 3.9 |
| Mix 5 | 20 | 2.8 | 3.7 |
| Mix 6 | 25 | 2.75 | 3.6 |
| Mix 7 | 30 | 2.63 | 3.59 |

SPLIT TENSILE STRENGTH OF NCC AND HFRC AT 28 DAYS.

| Mix | B.A % | NCC avg 28 days strength | HFRC avg 28 days strength |
|---|---|---|---|
| Mix 1 | 0 | 3.94 | 5.95 |
| Mix 2 | 5 | 4.01 | 6.2 |
| Mix 3 | 10 | 4.3 | 6.42 |
| Mix 4 | 15 | 3.9 | 6.01 |
| Mix 5 | 20 | 3.82 | 5.86 |
| Mix 6 | 25 | 3.8 | 5.7 |
| Mix 7 | 30 | 3.75 | 5.62 |

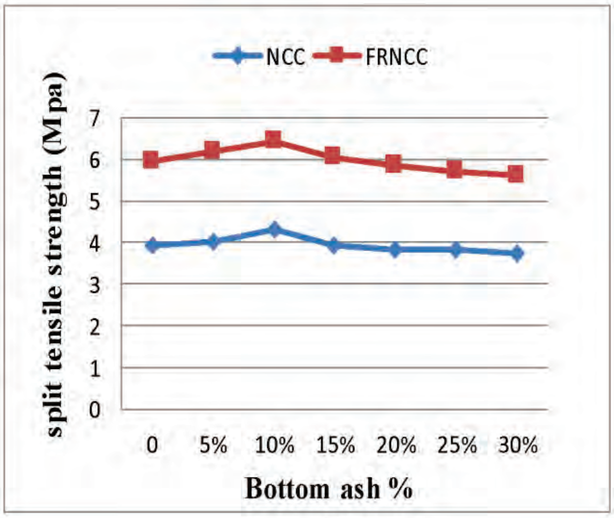


Figure 4. Average Split Tensile Strength of NCC and HFRC at 28 days

## *D. Flexural strength*

Flexural strength of the concrete is obtained by casting and testing of prisms (size 100mm ×100mm ×500mm) after the curing period of 7 days and 28 days.
The obtained results are tabulated in the table below.

TABLE VIII.
FLEXURAL STRENGTH OF NCC AND HFRC AT 7 DAYS

| Mix | B.A % | NCC avg 7 days strength | HFRC avg 7 days strength |
|---|---|---|---|
| Mix 1 | 0 | 3.9 | 5.95 |
| Mix 2 | 5 | 4.5 | 6.2 |
| Mix 3 | 10 | 4.7 | 6.65 |
| Mix 4 | 15 | 5.1 | 7.02 |
| Mix 5 | 20 | 4.8 | 6.8 |
| Mix 6 | 25 | 4.65 | 6.45 |
| Mix 7 | 30 | 4.3 | 6.1 |

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FLEXURAL STRENGTH OF NCC AND HFRC AT 28 DAYS

| Mix | B.A % | NCC avg 28 days strength | HFRC avg 28 days strength |
|---|---|---|---|
| Mix 1 | 0 | 5.86 | 7.6 |
| Mix 2 | 5 | 6.82 | 8.62 |
| Mix 3 | 10 | 7.08 | 8.9 |
| Mix 4 | 15 | 7.3 | 9.55 |
| Mix 5 | 20 | 6.9 | 9.03 |
| Mix 6 | 25 | 6.76 | 8.7 |
| Mix 7 | 30 | 6.4 | 8.4 |

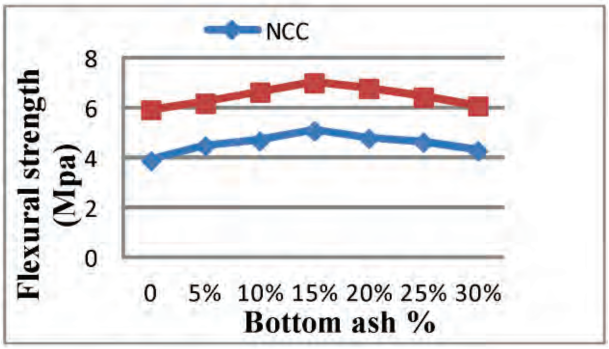


Figure 5. Average Flexural Strength of NCC and HFRC at 7 days

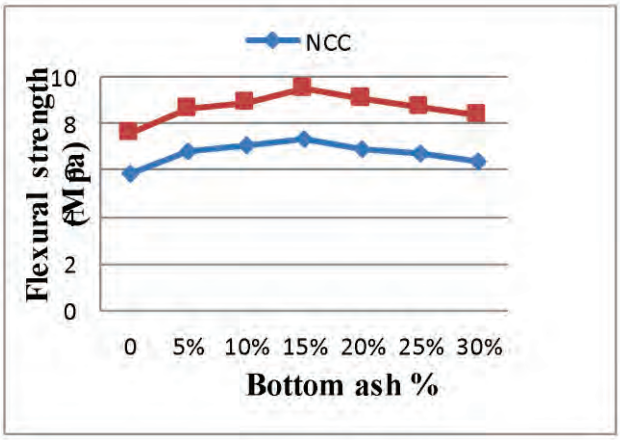


Figure 6. Average Flexural Strength of NCC and HFRC at 28 days

## I. *Durability*

Durability means the resistance to Physical or chemical deterioration of concrete resulting from interaction with the environment (Physical deterioration) or interaction between constituents (chemical deterioration) of concrete. Durability of concrete is related to its permeability. Permeability is the rate at which aggressive agents can penetrate to attack the concrete and the steel reinforcement. A durable concrete ensures corrosion resistance of embedded steel which in turn ensures a better longevity of the structure.

M40 concrete specimens were kept exposed to 5% solutions of sulfuric acid, hydrochloric acids and sodium sulphate. As specimens were continuously immersed in the solution for up to 28 days and 56 days and 98 days. The response of the specimens to the solutions was evaluated through change in appearance, weight, compressive strength and dimensions of solid diagonals.

Factors affected by acid attack on NCC and HFRC

a) Acid strength loss factor (ASLF) = Sr×(N/M),
Where Sr was a relative strength at N days (%), N is number of days at which the durability factor was required, M is number of days at which the exposure is to be terminated. A lower value of ASLF indicates greater stability towards acid attack.

b) Acid Attacking Factor (AAF) = (loss of acid length after immersion / original length) ×100%.
AAF is meant to indirectly measure the change in the length of diagonal (referred to as diagonal loss) in a typical concrete specimen after immersion in acids and sulphate for a certain period of time.

c) Acid weight loss factor (AWLF) = (Loss of weight of specimen after immersion / Original weight of specimen before immersion) ×100%

Higher value of the AWLF indicates that the weight loss was greater

**Acid Durability Loss Factors (ADLF)**

ADLF = ASLF × AAF × AWLF

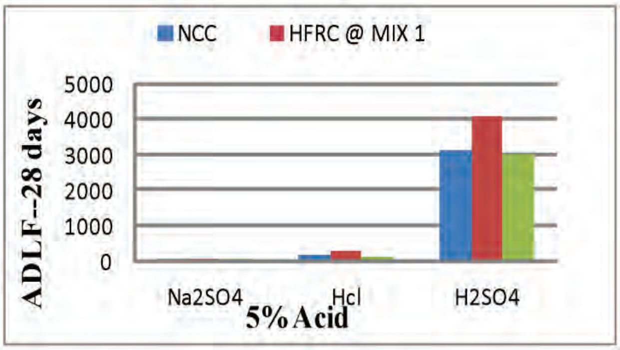


Figure 7. Acid Durability Loss Factors for NCC and HFRC at 28 days

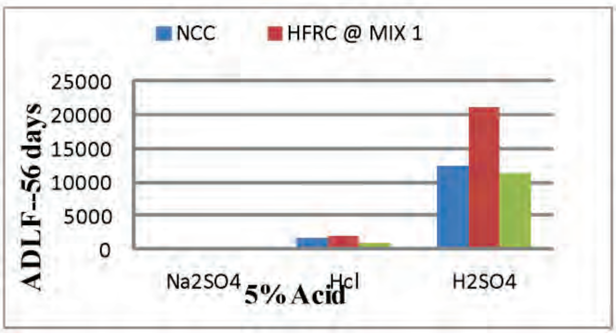


Figure 8 . Acid Durability Loss Factors for NCC and HFRCC at 56 days

TABLE IX.
ACID DURABILITY LOSS FACTORS FOR NCC AND HFRC AT 28 AND 56 DAYS

| Mix | Acid | Acid durability loss factors | |
|---|---|---|---|
| | | 28 days | 56 days |
| NHFC | $Na_2So_4$ | 5.4 | 41.73 |
| NC | | 10.63 | 75.70 |
| HFC | | 5.09 | 33.73 |
| NHFC | Hcl | 172.4 | 1628 |
| NCC | | 285.7 | 2106.6 |
| HFC | | 125.12 | 1024.3 |
| NHFC | $H_2So_4$ | 3131.5 | 12488.6 |
| NC | | 4099 | 21109 |
| HFC | | 3021 | 11362.14 |

## V. CONCLUSIONS

- The workability of fresh concrete is decreasing with increase in replacement of bottom ash.
- Test results states that compressive strength and flexural strength is achieved higher at 15% replacement of bottom ash in Normal conventional concrete (NC) and Hybrid fiber reinforced concrete (HFR).
- Split tensile strength is observed to be higher at 10% replacement of bottom ash in normal conventional concrete (NCC) and Hybrid fiber reinforced concrete (HFRC).
- With increase in period of immersion of the concrete in 5% of concentration of acid and sulphate like $Na_2SO_4$, HCL and $H_2SO_4$, there was damage of concrete near corners of cubes and such disruption in HFRC was less.
- When compared to Normal conventional concrete (NCC), the hybrid fiber reinforced concrete was
- found to be more durable against both acids and sulphate.

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