Experimental Study of Strength and Durability Properties of Hybrid Fiber Reinforced Concrete for M25 Grade

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Abstract - *Among all the construction materials that are available for construction, we know that concrete is a widely used construction material for building of various civil engineering structures. Concrete will give better durability and also its costs during construction as well as maintenance are very low whe As we know that concrete is strong in construction and weak in tension and tends to fail because of its deficiencies such as low tensile strength, low strain at fracture. The weakness of concrete is due to the presence of micro cracks at mortar aggregate interface. To overcome the existing problems addition of fibers in the concrete has been come in to practice. In fiber reinforced concrete the fibers are added to the concrete mix so that those are discontinuous fibers will be uniformly distributed in the mix and improve the concrete properties in all directions. To get more improvement in the mechanical properties work has been done by combining two different types of fibers knows as hybridization.*

In present experimental work forM25 grade of concrete can be designed according to IS 10262:2009 with four different proportions of hybrid fibers are added with concrete ingredients. The proportion of steel and polypropylene fibers are added by 50% each with different hybridization ration i.e. 0%,0.5%, 1.0 %, 1.5% and steel fibers are added by volume of concrete and polypropylene is added by weight of cement. For strength parameters compressive, tensile, flexural, impact strength specimens are casted and cured for 28 days and tested for hardened of hybrid fiber reinforced concrete. To evaluate the strength parameters different tests are conducted and results are tabulated. From the present work results show that 1.5 % addition of hybrid fiber gives maximum results in all the strength parameters compare to other different hybrid ratios.

***Key Words*: Steel fibers, Polypropylene, Compressive tensile strength, Flexural strength, Impact strength.**

1. INTRODUCTION

In ancient days the most of the construction are of mud and lime. Later in the construction field Concrete became a boon of construction and its strength properties created tremendous revolution in construction practice. Due its high strength and durability properties it is largely used in all the sectors (like multi story buildings, irrigation structures, pavements, reservoirs, foundations, dams etc.). As Concrete is exposed to different environmental condition to with stand the environmental effects the properties of conventional concrete had to be increased. This may be achieved by introducing admixtures or fibers to concrete.

Conventional concrete have good compressive strength and it is poor in tension as well as in flexural strength. So for increasing concrete tension as well as flexural strength it's required to add any innovative materials like fibers, admixture, and waste material having good pozzolanas properties, construction chemical. Cement mortar and concrete made with Portland cement is a kind of most commonly used construction material in the world. These materials have inherently brittle nature and have some dramatic disadvantages such as poor deformability and weak crack resistance in the practical usage. Also their tensile strength and flexural strength is relatively low compared to their compressive strength. The weakness in tension can be overcome by the use of sufficient volume fraction of certain fibers like steel, polypropylene, nylon, polyester, glass; carbon fibers are used to increase the strength of normal concrete.

1.1 Fiber Reinforced Concrete:

Fiber reinforced concrete (FRC) is concrete obtained by the addition of fibers to concrete (short discrete fibers that are uniformly distributed). Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers. The weakness in tension can be overcome by the use of sufficient volume fraction of certain fibers. In order to improve the mechanical properties of concrete it is good to mix cement with fiber which have good tensile strength. Adding fibers to concrete greatly increases the toughness of the material. The use of fibers also alters the behavior of the fiber matrix composite after it has cracked, thereby improving its toughness. In the beginning, FRC was primarily used for pavements and industrial floors but currently, the FRC composite is being used for a wide variety of applications including bridges, tunnel and canal linings, hydraulic structures, pipes, explosion-resistant structures, safety vaults, cladding and roller compacted concrete. The use of FRC in structural members such as beams, columns, connections, slabs and pre-stressed concrete structures is being investigated by a number of researchers at present in India and abroad.

1.2 TYPES OF DIFFERENT FIBERS

Different type of fibers is manufactured with different technology. Every fiber has different properties with good strength parameters and most commonly used fibers in concrete are as follows.

1. Steel fiber.
2. Polypropylene fiber.
3. Nylons fiber.
4. Polyesters fiber.
5. Asbestos fiber.
6. Glass fiber.
7. Carbon fiber.

Steel fibers are probably the most widely used fibers for many applications, other types of fibers are more appropriate for special applications. Fiber addition in the concrete brings a better control of its cracking and improves its mechanical properties. Particularly, it imparts to the material a post cracking load carrying capacity, ductility. The metal and, more particularly, steel fibers are most largely employed. Initially used in pavements and slabs on soil, their applicability is now extended to the case of structural elements such as piles, beams and self-supporting cladding elements (generally prefabricated), spread linings, and repairs or reinforcements of tunnels, walls, or floors. Polypropylene/Nylon Fiber are Suitable to increase impact strength of concrete. Possess high tensile strength but their low modulus of elasticity and higher elongation do not contribute to the flexural strength.

1.3 HYBRID FIBER REINFORCED CONCRETE

Every Fiber has different strength characteristic and gives strength to concrete. When two different fibers added to concrete to make the composite structure gives maximum strength to concrete that type of concrete is hybrid fiber reinforced concrete (HFRC). Addition of fibers like steel and polypropylene, steel and glass, glass and polypropylene, steel and polyester etc these are hybrid ratio of HFRC with different mix proportion and variation of fibers in concrete. By using HFRC the concrete become stronger because of the fibers which we added they may have good in tensile strength, crack resistance, avoids initial cracks, shrinkage of concrete may be reduced.

HFRC gives more strength and gives best results compare to fiber reinforced concrete due to the addition of two different fibers in concrete. one type of fiber which is stronger and stiffer helps in improving first crack stress and ultimate strength, and second type of fiber improves in toughness and strain in post cracking zone of the concrete. HFRC concrete may increases the tensile strength with holding the crack of concrete. HFRC improves the strength of toughness of concrete due to addition of fibers in concrete compare to other normal concrete.

2. OBJECTIVES OF THE STUDY

1. To study the different strength parameters like compressive strength, tensile strength, flexural strength of hybrid fiber reinforced concrete with different mix proportion of fibers forM25 grade concrete.
2. To determine impact resistance properties on the hybrid fiber reinforced concrete and comparing with the conventional concrete.
3. To know the optimum percentage of addition of fibers to concrete and finding maximum hybrid ratio.
4. To determine workability of hybrid fiber reinforced concrete by the addition of fibers in concrete mix.
5. To study the durability properties of hybrid fiber reinforced concrete.

3. MATERIALS

This chapter deals with the materials used in the project and the various tests conducted on them and also along with methodology of mix proportion with various proportions of addition of steel fibers in the concrete. In this chapter properties of the materials which are used for the project are discussed and also along with their permissible limits according to the standards. The place from where the materials are taken also mentioned. The following are the materials used in the experimental work.

1. Cement.
2. Fine aggregate.
3. Coarse aggregate.
4. Water.
5. Steel fibers.
6. Polypropylene fibers.

3.1 Cement:

Cement used is ordinary Portland cement (OPC) having 53 grade as per IS 12269-1970 cement used as a binding material in the present investigation. The preliminary tests like normal consistency (amount of water to be added), specific gravity, initial and final setting time, soundness of cement tests is conducted and results are listed below.

Table-3.1: Physical properties of cement.

Properties	Results
Specific gravity	3.12
Soundness of cement	5 mm
Normal consistency	32%
Initial setting time	42 minutes
Final setting time	300 minutes

3.2 Fine aggregate:

Locally available sand used as fine aggregate for experimental work and passing through 4.75mmas per IS 383-1978.Sand is brought from Swarnamukhi river bed near Tirupati. The preliminary tests like specific gravity, water absorption, and fineness modules are tested and results are tabulated below.

Table-3.2: Properties of fine aggregate.

Specific gravity	2.40
Water absorption	1.5%
Fitness modules	2.0
Type of sand	River sand
Zone	III

3.3 Coarse aggregate:

Locally available 20 mm down size coarse aggregate with retained on 4.75mm sieve has been used in the present work. It is brought from Perruru crusher, Bangalore highway road. Different test conducted on coarse aggregate are specific gravity, water absorption fineness modules. The properties of coarse aggregate as follows.

Table-3.3: properties of coarse aggregate.

Specific gravity	2.73
Water absorption	11%
Shape of aggregate	Angular
Fitness modules	4.0

3.4 Water

Potable water which is available in laboratory is used for casting of specimen and as well as curing of specimen as per IS 456-2000.

3.5 Steel Fibers

Steel fibers are short, discrete lengths of steel with different aspect ratio from about 30to 150 with different cross sections. Different types of Steel fibers are hooked ends, crimped, glue hooked end etc these are most commonly used fibers. Their shape will be Round of diameter 0.25 to 0.75mm. They Enhances flexural, impact and fatigue strength of concrete. Thin shells and plates have also been constructed using steel fibers. In the present work crimped steel fiber with flat end used. These steel fibers are brought from Bharat Steel Chennai Pvt.Ltd (BSC). The properties off steel fibers with their specifications are mentioned in the table below.

Table-3.4: properties of steel fibers.

Type of steel fiber	Crimped
Material	Low carbon drawn flat wire
Length of fiber	25 mm
Diameter of fiber	05 mm
Aspect ratio	50
Tensile strength	500-750mpa
appearance	Clear, bright, flat end crimped steel fiber
Applications	Tunnel shot create, industrial flooring road and pavement

3.6 Polypropylene fibers:

Polypropylene fiber is composed of crystalline and non-crystalline (amorphous) regions. The fiber range in size from fractions of a micrometer to centimeters in diameter. The manufacturing of this fiber have to two different types. First one is pulling wire procedure with circular cross section or by extruding the plastic film with rectangular cross section. And appearance of this fiber in fibrillated bundles, mono filament. These fibers have different length 12mm, 24mm; 40mm cut length is available. In the present investigation the polypropylene fibers with 12mm cut length is used. These polypropylene fibers are brought from Bharat Steel Chennai Pvt Ltd (BSC). The properties off polypropylene fibers with their specifications are mentioned in the table below.

Table-3.5: properties of polypropylene fibers.

Geometry of fiber	Fibrillated
Length of fiber	12 mm
Tensile strength	500 -750 nm

3.7 Percentage variation of fibers in mix:

The proportions of fibers used in concrete mix are at percentage of 0.5%, 1%, 1.5% and for each proportion equal quantity (50% of each) of fibers are added in the mix.

Table-3.6: Percentage variation of fibers in mix

Percentage of fiber added in overall concrete mix (%)	Steel fiber by volume of concrete (%)	Polypropylene fibers by Weight of cement (%)
0	0	0
0.5	0.25	0.25
1	0.50	0.50
1.5	0.75	0.75

3.8 Concrete mix design for M25 concrete (IS 10262:2009)

Stipulation for mix proportioning

Table-3.7: Stipulation for mix proportioning

S.No	Content	Mix Proportion
1	Grade destination	M25
2	Type of cement	OPC 53 grade
3	Maximum nominal size of aggregate	20mm
4	Minimum cement content	300 kg/m^3
5	workability	75mm
6	Exposure condition	Severe
7	Method of concrete placing	normal
8	Degree of supervision	good
9	Type of aggregate	Crushed angular aggregate
10	Maximum cement content	450 kg/m^3

4. EXPERIMENTAL METHODLOGY

To study the strength parameters of concrete it's necessary to conduct the certain tests on concrete. Concrete can be tested in fresh state as well as in hardened state with different mix proportion of fibers.

4.1 HARDENED CONCRETE:

1. Compressive strength.
2. Split tensile strength.
3. Flexural strength.
4. Impact test.
5. Sorpativity test.

4.2.1 Compressive strength test

In the present work Compressive strength test can be carried out by using cube size of 150mm×150mm×150mm cubes are casted for M25 grade concrete with different type of hybrid fibers present in concrete. The cubes are then de-moulded after 24 hours of casting and then cubes are kept in curing tank for 28 days. After 28 days curing period cubes shell be remove from water and keep it for drying. After that cubes should be tested in compression testing machine with machine having capacity of 2000KN and failure load of cubes can be note down with using appropriate formula compressive strength can be determined. For accurate valves 3 cubes shall be casted and tested and compressive strength can be calculated by following formula:

$$\text{compressive strength} = \frac{\text{failure load}}{\text{cross sectional area}}$$

4.2.2 Split tensile strength

For tensile strength test cylinders specimens can be casted with having dimension of 150mm diameter and 300mm length casted for M25 grade concrete with different type of hybrid fibers present in concrete. The cylinders are then demoulded after 24 hours of casting and then cylinders are kept in curing tank for 28 days. After 28 days curing period cylinders shell be remove from water and keep it for drying after that cylinders should be tested in compressive testing machine and taking of 3 average valve and tensile strength can be calculated using formula:

$$\text{Tensile strength}(N/MM2) = \frac{2P}{\Pi dl}$$

Where,

P = failure load,

D = diameter of cylinder,

L = length of cylinder and

h = height of cylinder.

4.2.3 Flexure strength

For flexure strength test prisms should be casted with having an dimension of 100mm×100mm×500mm prisms are casted for M25 grade concrete with different type of hybrid fibers present in concrete. The prisms are then demoulded after 24 hours of casting and then prisms are kept in curing tank for 28 days. After 28 days curing period prisms shell be remove from water and keep it for drying. after that prisms should be tested in universal testing machine(UTM) having capacity of 1000KN failure load can be note down and flexural strength can be calculated by following formula:

$$\text{Flexural strength} = \frac{Pl}{bd\hat{\ }2}$$

Where,

p= failure load,

l= length of specimen,

d= depth of specimens,

b= breadth of specimens.

4.2.4 Impact Test

This test is carried on cylindrical specimen ¼ height of cylinder (75mm) and having diameter 150mm.and cast specimen is cured for 28days and tested in impact testing equipment. Weight of hammer is 4.54 kg, height of the drop is 450mm and number of blows should be note down and graph should be plotted between number of blows and % of fibers.

4.2.5 Sorptivity test

This test is conducted to find the water absorption rate. By measuring the capillary rise absorption rate by a homogeneous material the sorptivity can be determined. The fluid used for the test is water. The cube specimens were used for testing the absorption rate. The specimens having 150X150mm surface area were casted and cured for a period of 45 days. After curing the specimens were oven dried up to a temperature of 100 ℃ before used for testing. The specimen is coated with non absorbent material on all sides except on side of contact with the water. The liquid level should not be more than 5mm from the base of the specimen. The amount of liquid absorbed by the specimen in the time span of 30 minutes is noted by weighing the specimen in the weighing balance. The specimen is wiped cleanly before it is weighed with a piece of cloth. The property of a material which explains the nature of porous material to absorb and also transmit the water by capillarity can be defined as the Sorptivity. It is denoted by S.The increase in the cumulative water absorption per unit area of the inflow surface is due to the square root of the elapsed time " t"

The following formula is used for the calculation of sorptivity

$I=S.t^{1/2}$

$S=I/t^{1/2}$

Where:

S= measure of sorptivity in mm

t= the elapsed time in minutes

$I=\Delta w/Ad$

Δw= difference in weights = W2-W1

W1 = Oven dry weight of cube specimen in grams

W2 = Weight of cube specimen in grams after 30 minutes of capillary suction of water

A= surface area of cube specimen were the penetration of water takes place.

d= water density

From the present work of experimentation results of all the parameters are calculated and tabulated below.

5.1 COMPRESSIVE STRENGTH TEST RESULTS

Table - 5: compressive strength test results

S.No	Percentage of steel fiber	Percentage of polypropylene fiber	% Hybrid fibers	Compressive strength at 28 days (N/mm^2)	Percentage increase in strength
1	0	0	0	29.56	0%
2	0.25	0.25	0.5	32.74	10.75%
3	0.50	0.50	1	37.62	27.26%
4	0.75	0.75	1.5	39.55	33.79%

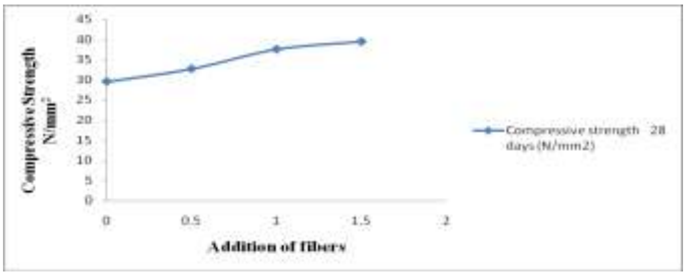

Figure- 5: Graph showing the results of compressive strength of HFRC.

From the above fig 6.1 plainly at 0.5% expansion of filaments the compressive quality is 32.74 N/mm2.As the rate of strands is expanded to 1 % and to 1.5 % the compressive quality is 37.62 N/mm2, 39.55 N/mm2 separately. From this we can presume that as there is an augmentation in the fiber content there is additionally an addition in the compressive quality. In this way compressive quality increments with the expansion of expansion of filaments in the blend. At the point when contrasted and controlled cement the expansion in the compressive quality with fiber expansion in rates of 0.5%, 1%, 1.5% is 10.75%, 27.26%, 33.79% individually.

6.1 TENSILE STRENGTH TEST RESULTS

Table-6.1: Test results of tensile strength.

S.No.	Percentage of steel fiber	Percentage of polypropylene fiber	% Hybrid fibers	Split tensile strength at 28 days (N/mm^2)	Percentage increase in strength
1	0	0	0	2.71	0%
2	0.25	0.25	0.5	2.46	9.22%
3	0.50	0.50	1	3.39	25.09%
4	0.75	0.75	1.5	3.96	46.12%

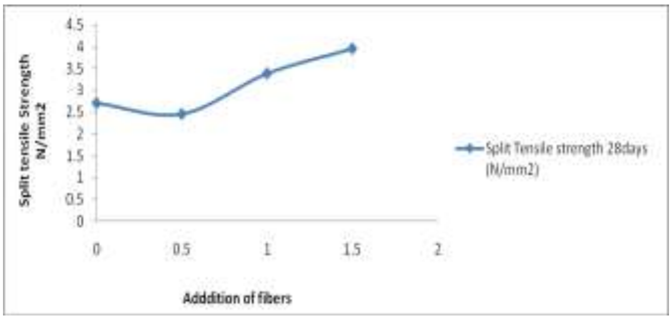

Figure- 6.2: Graph showing the results of split tensile strength of HFRC.

From the above fig 6.2 plainly at 0.5% expansion of filaments the elasticity is 2.46 N/mm2 and at 0.5 % expansion of strands there is declarations in quality contrast with traditional cement i.e. 2.71N/mm2. As the rate of strands is expanded to 1 % and to 1.5 % the split rigidity is 3.39 N/mm2, 3.96 N/mm2 individually. From this we can infer that for 0.5% expansion of filaments there is lessening in results from there on expansion of strands i.e. 1%,1.5% there may increment in quality When contrasted and controlled cement the increment in the split elasticity with fiber expansion in rates of 0.5%, 1%, 1.5% is 9.22%, 25.09%, 46.12% individually.

6.2 FLEXURAL STRENGTH TEST RESULTS

Table-6.3: Test results of flexural strength

S.No.	Percentage of steel fiber	Percentage of polypropylene fiber	% Hybrid fibers	flexural strength at 28 days (N/mm²)	Percentage increase in strength
1	0	0	0	3.90	0%
2	0.25	0.25	0.5	4.25	8.97%
3	0.50	0.50	1	4.68	20%
4	0.75	0.75	1.5	5.20	33.33%

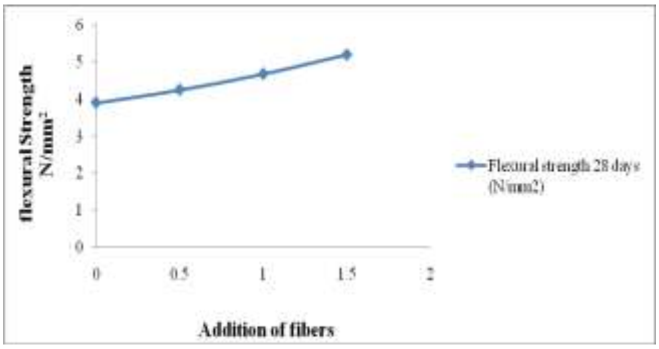

Figure -6.3: Graph showing the results of flexural strength of HFRC.

From the above fig 6.3 plainly at 0.5% expansion of strands the flexural quality is 4.25 N/mm2As the rate of filaments is expanded to 1 % and to 1.5 % the flexural quality is 4.68 N/mm2, 5.20 N/mm2 separately. From this we can presume that as there is an addition in the fiber content there is likewise an augmentation in the flexural quality. Hence, flexural quality increments with the expansion of expansion of filaments in the blend. At the point when contrasted and controlled cement the expansion in the flexural quality with fiber expansion in rates of 0.5%, 1%, 1.5% is 8.97%, 20%, 33.33% individually.

6.3 IMPACT STRENGTH TEST RESULTS

Table-6.4: Test results of impact test.

S.No.	Percentage of steel fiber	Percentage of polypropylene fiber	% Hybrid fibers	Impact strength at first crack no. of blows (28 days)	Impact strength at failure no. of blows (28 days)
1	0	0	0	10	34
2	0.25	0.25	0.5	13	51
3	0.50	0.50	1	19	87
4	0.75	0.75	1.5	24	125

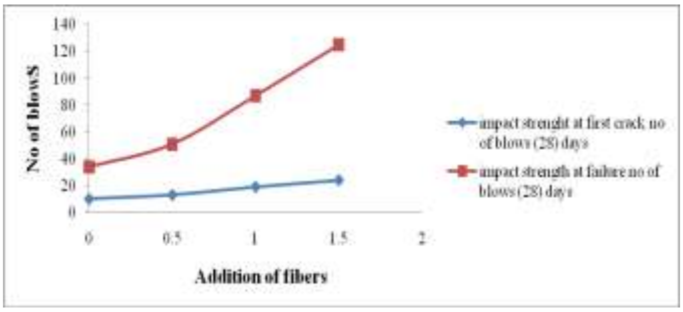

Figure- 6.4: Graph showing the results of impact strength of HFRC.

From the above fig 6.4 obviously at as the rate of strands expands the no of blows required to disappointment the example additionally increments. From this we can infer that as there is an augmentation in the fiber content there is likewise an addition in the effect valve or quality. In this manner sway quality increments with the expansion of expansion of filaments in the blend. At the point when contrasted and controlled cement the expansion in the effect quality with fiber expansion in rates of 0.5%, 1%, 1.5% separately.

7. CONCLUSIONS

From my experimental examination I finished up the accompanying focuses.

1. There is change in Compressive quality of HFRC contrast with traditional cement on account of expansion of strands. The greatest increment in compressive quality saw at having mixture proportion 1.5 % i.e. 0.75 % steel fiber and 0.75 % polypropylene fiber and When contrasted and

controlled cement the expansion in the compressive quality with fiber expansion in rates of 0.5%, 1%, 1.5% is 10.75%, 27.26%, 33.79% separately.

2. Tensile quality might be abatement for the proportion 0.5 % of filaments contrast with ordinary cement, from that point it might increment in rigidity and half and half proportion having 1.5% gives greatest quality contrast with other extent. From this we can infer that for 0.5% expansion of strands there is decline in results from that point expansion of filaments i.e 1%,1.5% there may increment in quality When contrasted and controlled cement the expansion in the split elasticity with fiber expansion in rates of 0.5%, 1%, 1.5% is 9.22%, 25.09%, 46.12% separately.

3. Flexural quality might be most extreme for mixture proportion 1.5% thinks about to customary cement. From this we can reason that as there is an augmentation in the fiber content there is likewise an addition in the flexural quality. In this way flexural quality increments with the expansion of expansion of strands in the blend. At the point when contrasted and controlled cement the expansion in the flexural quality with fiber expansion in rates of 0.5%, 1%, 1.5% is 8.97%, 20%, 33.33% separately.

4. Impact quality of HFRC increments as the rate of strands expands the no of blows required to disappointment the example additionally increments. Along these lines sway quality increments with the expansion of expansion of filaments in the blend. At the point when contrasted and controlled cement the expansion in the effect quality with fiber expansion in rates of 0.5%, 1%, 1.5% separately.

5. Slump cone valves are diminishing with Addition of filaments is expansions. It is so in light of the fact that as the strands are included the draining will be decreased and the blend will get to be unforgiving. From this we can reason that as the rate of fiber substance is expanded the workability will be diminished. As the rate increment in filaments the compaction variable qualities diminishes. From this we can infer that the workability of the blend diminishes as the fiber content in the solid increments.

6. Sorptivity will be more as the rate of strands expansion is increment. From results we can reason that 0.5% expansion of cross breed filaments gives same Sorptivity valve contrast with customary cement.

7. The ideal rate of filaments expansion is 1.5%. Expansion of strands up to 1.5% gives best results in all quality parameters contrast with other blend extent.

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