FIBRE REINFORCED CONCRETE USING BASALT FIBRE

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doi: https://doi.org/10.21467/proceedings.179.27

ABSTRACT

Modern world demands high performance/ultra-high-performance concrete (HPC/UHPC) due to increasing infrastructural demands. In most cases, as the strength of the concrete increases with the higher powder content it becomes brittle in high strength concrete than in normal strength concrete. So, addressing this issue is important and therefore the possible increase in the ductile nature of the concrete with incorporation of different fibers needs an experimental investigation. An attempt to evaluate the fatigue performance of FRC using basalt fibers combinations as reinforcing agents. Improvement in performance in terms of flexural behavior, fatigue life and tensile strength is considered as governing parameters of so prepared FRC. Fibers of basalt material composition and size fractions are used as reinforcing elements in order to achieve intended research purpose.

INTRODUCTION

1.1 General

Concrete is the most widely used construction material. Concrete offers many advantages like better surface finish, fire resistance, flexibility in shape and size etc., in comparison with other materials. Conventional concrete is composite material having cement, coarse aggregates, and fine aggregates as its components where cement paste is the binding material. Cement reacts with other components to form hard matrix. Unlike other construction materials, concrete can be molded to any shape and size. This major advantage has led to tremendous increase in use of concrete. There have been continuous studies to improve its mechanical and physical properties as per changing requirements of construction industry. Other additives like mineral and chemical admixtures are used to alter and modify its fresh and hardened properties.

1.2 GGBS

The improvement of FRC requests cementitious material and low W/B proportion. Higher cement content alone will expand and result in the hydration in early ages. So as to decrease this, blast furnace slags like GGBS is included. GGBS reduces the heat of hydration as well as enhancesthe compressive strengthproperties.

1.3 Fibre reinforced concrete

It is known that concrete is a brittle material and so to improve its mechanical properties, particularly tensile and flexural quality, flexural strength and toughness, randomly conveyed strands have been added to superior concrete. The adequacy of improving the previously mentioned parameters relies upon the kind of fiber, its size, volume part and volume fraction and its proportion. the best advantages to be picked up by utilizing fiber support is improved long term workableness of the structure or item. Lot of studies has been carried out regarding effect of orientation, length, diameter and aspect ratio of these fibers. Basalt fiber is a promising material in its application in solids. Basalt fiber (BF) is a sort of inorganic fiber expelled from liquid basalt molten rock and is presently accessible economically. The manufacturing procedure of this sort of fiber is like that of glass fiber, yet with less complex and no

Proceedings DOI: 10.21467/proceedings.179; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-984081-7-4

added substances, which makes it less expensive than glass or carbon filaments. The procured basalt fibre is represented in the figure 1.2.

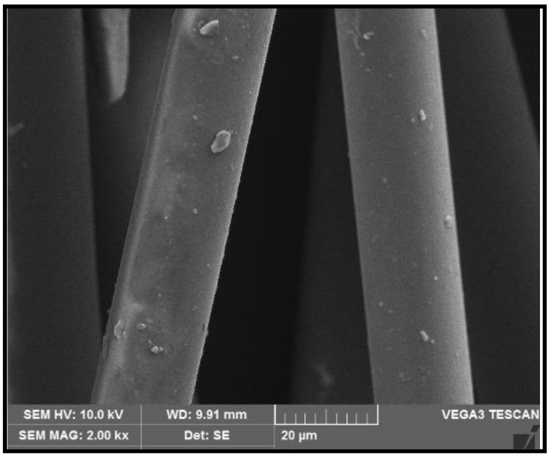

Figure 1.1. Procured Basalt fibre Figure 1.2. SEM Image of Basalt Fibre

1.4 Carboxyl Methyle Cellulose (CMC)

It is a cellulose subsidiary with carboxymethyl bunches (- CH_2-COOH) bound to a portion of the hydroxyl gatherings of the glucopyranose monomers that make up the cellulose spine. It is regularly utilized as its sodium salt, sodium carboxymethyl cellulose. It used to be advertised under the name Tylose, an enlisted trademark of SE Tylose. CMC is anionic cellulose ether; the appearance is whitepowder, odorless, tasteless, non-toxic; soluble in cold water or hot water to form a certain viscous transparent solution.CMCis also used for food, pharmaceutical, and dentifrice (toothpaste) applications.

2. LITERATURE REVIEW

2.1 Inference

- There is detailed information on the effect of basalt fibres with respect to the mechanical properties of concrete. Basalt fibres of diameter 17μm and length 24mm was used as an additive to develop FRC. Mechanical parameters have shown a increase in compressive strength by 4 to 8%. However, increase in tensile strength is observed up to 19% by end of 28 days of curing.
- The dispersion of basalt filaments were conveyed by the technique of sonification, i.e. using ultrasonic waves. Indeed, even circulation of basalt fiberwas acquired when it was dispersed utilizing ultrasonic waves with carboxymethyl cellulose (CMC) as a dispersant.The outcomes demonstrated that the viability of fiber relies upon the level of dispersion in mortar composites.
- The fatigue tests were conducted on two sizes of basalt FRP (BFRP)-reinforced sea sand concrete beams. The minimum load was set as zero, the maximum loads as 0.5, 0.6, and 0.7 of its ultimate capacity.The load-deflection relationship showed a bilinear relationship for BFRP-reinforced concrete beams.

2.2 Scope of the work

Minimum grade as per IRC and ICAO (International civil aviation organization) of concrete for precast bridges and runway is minimum M-40, but the fatigue and flexural strength required is much higher than that of M-40 grade concrete Therefore in this study we are trying to achieve required flexural and fatigue strength of concrete with minimum 40Mpa compressive strength.

2.3 Objectives of the work

- Characterization of Cementitious and Fibrous materials suitable for developing FRC.

Proceedings DOI: 10.21467/proceedings.179
ISBN: 978-81-984081-7-4

Series: AIJR Proceedings
ISSN: 2582-3922

- To develop Fibre reinforced Concrete by studying the fresh and hardened properties of concrete.
- To verify the possibility of improving Young's modulus and flexural toughness of concrete.
- Microstructure studies of optimized mixes to understand the hydrated structure of concrete

3. Laboratory Investigations

3.1 Aggregates

The aggregates were procured from different crushers. The basic tests were carried out on the aggregates and it was found that aggregates procured from KMS crusher-Bagalur, Karanataka were found to be within the required limits as per IS:383-1987, MoRTH and IRC 15-2011. The basic test results are depicted in Table 1.

Test on Coarse Aggregates

Property	Test	Results	Limits	Reference Code	Test method
Strength	Aggregate Crushing Value	21.30%	< 30%	IS 383-2016 for pavements	IS-2386(Part-4)
Toughness	Aggregate Impact Value	16.08%	< 18%	IS 383-2016 for pavements	IS 2386 (Part-4)
Abrasion	Los Angeles Abrasion Value	17.52%	< 25%	IRC-15 2011 and MORTH Clause No: 602.2.6.1	IS 2386 (Part-4)
Quality	Specific Gravity	2.69	-	-	IS 2386 (Part-3)
Absorption	Water absorption	0.2%	Max 2%	MORTH Clause 602.2.6.2	IS 2386 (Part-3)

For research purpose in this work the fine totals utilized are manufactured sand in place of regular river sand in view of normal sand exhausting step by step and the maintenance issue. Table 2 shows gradation of M-sand and it conforms to Zone II of IS 383-2016 having a fineness modulus of 2.2.6. Table 2 and 3 shows the quality test results conforming to IRC15-2011.

Sieve analysis of fine aggregates

Sieve size in mm	Wt. retained in grams	Cumulative Wt. retained	% Wt. retained	Cumulative %Wt. Retained	% of Passing	Standards as per IS 383
4.75mm	-	-	-	-	100	90-100
2.36mm	84	84	8.4	8.4	91.6	75-100
1.18mm	291	375	29.1	37.5	62.5	55-90
600µ	175	550	17.5	55.0	45.0	35-59
300 µ	179	729	17.9	72.9	27.1	8-30
150 µ	159	888	15.9	88.8	11.2	0-10
Pan	112	1000	11.2	100	0	-
Total weight taken =1000gms						
Fineness modulus = total Cumulative % mass retained up to 150 µ sieve /100 = 262.6/100 = 2.626						

Quality test results of Fine Aggregates

Test	Results	Limits	Reference code	Test Method
Specific Gravity	2.62	-	-	IS 2386 (Part 3) 1963
Water absorption	1.5	Max 2%	IRC 15 2011	IS 2386 (Part 3)1963

3.2 Cement

As a good and effective binding element, cement used is 53-grade Ordinary Portland Aditya Birla Cement in accordance with IS 12269-2013.It was procured from a reputed cement producing company practicing advanced quality production and guaranteed chemical composition of cement. Initial investigation and preliminary Starting examination and lab tests were done on concrete as acquired from the provider, to meet the physical necessities.

Properties of cement

Test	Results	Limits as per IS 12269-2013	Test method
Standardconsistency	34%	-	IS 4031(P4)-1988
Initial setting time	80 minutes	Min 30 minutes	IS 4031(P5)-1988
Final setting time	330 minutes	Max 600 minutes	IS 4031(P5)-1988
Specific Gravity by Le-Chatelier's	3.15	-	IS 4031(P11)-1988

3.3 GGBS

For the present study GGBS is procured from JSW and the properties are as shown in Table 5.

Properties of GGBS

Properties	Results
Specific Gravity	2.8
Fineness	297m^2/kg

3.4 Proporting of BFRC mixes by least void technique

In the present investigation, just 12.5mm down measured coarse aggregates (held on 4.75mm sieve) and 4.75mm down estimated squashed stone sand (FA) are used. The least voids feasible for various ratio mixes of CA and FA mixed together are examined formerly. In the first place, the particular specific gravity and density of various ratio mixes of coarse and fine aggregates were determined and then by utilizing the formulae percentage voids is determined. The formulae used to compute % voids is

$$\text{Percentage of voids} = 100 \times (G_s - r) / G_s$$

Percentage voids for coarse and fine aggregates

% Weight		**Density (g/cc)**	***% voids***
CA	**FA**		
100	0	1.624	*36.31*
60	40	1.938	*23.55*
55	45	1.979	*22.17*
50	50	1.972	*21.02*
45	55	1.997	*20.69*
40	60	1.97	*21.98*
35	65	1.964	*21.81*
0	100	1.92	*24*

As appeared in Table 6 least voids and highest density was acquired for the blend of 45:55 (CA: FA). The level of least void got was 20.69%. In view of the least void set up by total aggregate proportioning.

3.5 Proporting of BFRC mixes by Control mix preparation

To accomplish higher paste content and improve the mix consistency, Supplementary Cementitious Materials like GGBS is utilized at required amount as for concrete substance for a particular mix. Cement content substance is worked out from 360kg/m^3 to 450kg/m^3. The final preliminary mixes are planned by fixing GGBS content at 30 % by weight of cement substance dependent on past investigations. Water content is kept up consistent for the blends at the water to the cement proportion of 0.38. Powder substance was not adjusted, and super plasticizer doses were changed by remembering the base 100mm slump for the pump able concrete. Basalt fibers are added to the control mixes i.e. fibers are included in percentage varieties of 0.1 %,0.2%,0.3% and 0.4% by weight of cementitious material. Table 7 gives the mix details.

Mix proportions for different mixes

MIX	Cement (kg/m^3)	GGBS (kg/m^3)	Basalt fiber (kg/m^3)	Water (kg/m^3)	CA (12.5) (kg/m^3)	FA (kg/m^3)	SP Dosage(% cementitious material)
Control	360	108	-	177.8	911	871	0.5
0.1%BF	360	108	0.468	177.8	911	871	0.5
0.2%BF	360	108	0.936	177.8	911	871	0.5
0.3%BF	360	108	1.404	177.8	911	871	0.5
0.4%BF	360	108	1.872	177.8	911	871	0.5

Proceedings DOI: 10.21467/proceedings.179
ISBN: 978-81-984081-7-4

Series: AIJR Proceedings
ISSN: 2582-3922

Basalt fiber (BF) has plenty of favorable properties. The genuine viability of the fiber depends incredibly on its scattering degree in the composites. So, it is very much necessary to disperse the fiber effectively in the concrete. In this research work, a few trails were attempted to disperse the fiber consistently and uniformly. Fibers were scattered in shampoo, Conditioner, detergents and even in warmed water up to 100˚c however the scattering and dispersion were not more prominent. A later mechanical method for dispersion was attempted with financially accessible blenders and the results were not prominent. In this process, just dry mechanical friction idea was additionally used, similar to the materials that were dry mixed with fibers in pan mixer, cobalt mixer and with high speed rotating mixers. But the scattering and dispersing of fiber were not found. That implies making utilizing of friction and mechanical force independently it cannot well disperse and scatter the fiber. The scattering and dispersion of basalt fiber were analyzed with the various kinds of super plasticizers in the sonification procedure, yet the scattering was not attractive. The following procedure is followed during the dispersion. Basalt fiber was put into a 500mL measuring glass and filled into three-fifth of the entire water like. The measuring glass was vibrated by ultrasonic wave for around 10 to 20mins during which the temperature of water keeps somewhere in the range of 40 and 44 °C, the fiber will scatter. CMC is included into the beaker and stirred by hand and the mass portion of CMC in the aqueous solution was controlled somewhere in the range of 1.56% and 1.77%. The measuring glass is continuously vibrated by ultrasonic wave for another 10minutes resulting in the fiber is all around scattered and dispersed.

3.6 Specimen Preparation

The concrete ingredients are placed and mixed in the laboratory pan mixer in order to get a consistent and homogenous concrete mix. Coarse and fine aggregates are mixed altogether for 2-3 minutes. After uniform mixing of total aggregates, all the powder substance, for example, cement, GGBS are included and mixed altogether for another 2-3 minutes. Fibers are additionally considered as particles and are included with aggregates which are scattered and dispersed in the estimated amount of water. To acquire the required functionality SP is included alongside mix water according to obvious perceptions. The concrete is mixed further until a durable and cohesive mix is gotten. After getting the cohesive and homogenous mix, for further testing the fresh and hardened properties, the concrete cubes and beam specimens are cast to test at different ages. At least three samples are casted for testing reason. Cubes of 100mm sides, beams of 500 X 100 X 100mm are cast for all finalized mixes as shown. Every specimen is vibrated on the vibrating table so as to guarantee uniform compaction. Curing is must for concrete to maintain the moisture inside the core that will helps in hydration process and to attain the required strength of concrete. Concrete gain's it's strength with time in the presence of sufficient water. So after de-moulding, the specimens are kept for curing in the curing tank at ambient temperature before testing at different ages (7day and 28days).

4. Results and Discussions

4.1 Fresh property of concrete

Slump test was conducted to measure the slump or flow of each design mixes in its fresh state. It helps in checking the workability of a concrete. The visual stability of design mixes in terms of bleeding and segregation is also observed by slump test. Addition of fibers is observed to have decreased flow of concrete as compared to conventional concrete. Fibers could be consuming a part of the mixed water to coat themselves with available paste, possibly reducing the flow as the fiber content increases.

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Fresh properties of different mixes

Mix	BF (%)	Cement (kg/m^3)	GGBS (kg/m^3)	Water (kg/m^3)	Slump/Flow (mm)	SP Dosage %
Conventional	0	360	108	177.84	210	0.5
0.1% BF	0.1	360	108	177.84	170	0.5
0.2% BF	0.2	360	108	177.84	132	0.5
0.3% BF	0.3	360	108	177.84	87	0.5
0.4% BF	0.4	360	108	177.84	20	0.5

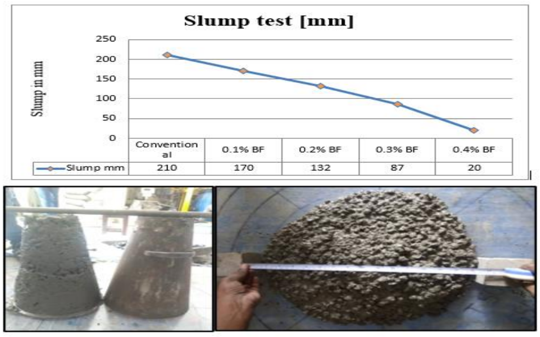

Figure 4.1. Slump observations with 0.4% BF (Left) and Conventional mix (Right)

4.2 Hardness properties of concrete

4.2.1 Compressive strength results

The basic function of the concrete is to resist the compressive stress in the structures and this turns into the exceptionally essential test of concrete. The compressive strength of the concrete cube of 100 mm at various ages under the compressive testing machine of 3000 kN limit. Outcome of average of three cubes was considered. Compressive strengths for 7and 28 days of all control mixes is represtend graphically in Figure 4.2.

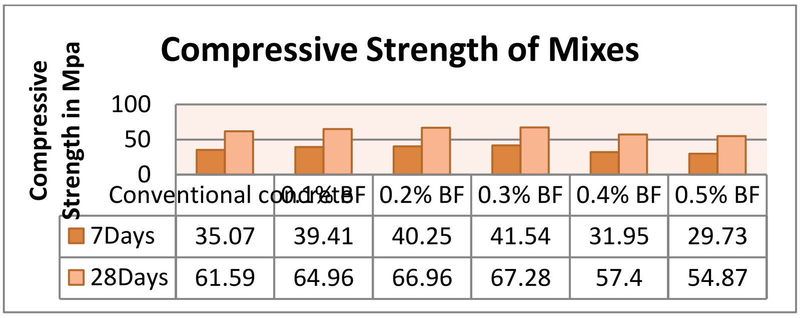

Figure 4.2. Compressive strength of different mixes

From the outcome, it is observed that there is a slight significant improvement in the compressive strength of concrete with the addition of basalt Fiber. However, past investigations have demonstrated that with the increase in basalt Fiber dosage beyond 0.3%, the compressive strength will tend to decrease.

4.2.2 Flexural Fatigue test

The fatigue test is applied on beam made up of mix design of Conventional, 0.1% BF, 0.2% BF, 0.3% BF and 0.4% BF of mix designed specimens. The load amplitude connected on the specimen is represented as ‘Stress ratio’. The beams are tried for stress ratios like 0.65, 0.7, 0.75, 0.8 and 0.85. The

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ISBN: 978-81-984081-7-4

Series: AIJR Proceedings
ISSN: 2582-3922

load amplitude is sufficiency kept up consistent for a specific beam at given stress ratio. The fatigue life of all the best mixes is represented in the Table 9. The stress ratios are in increasing order.From the Table 9, at stress proportion 0.65, each one of the examples can take cycles more than 250000 numbers. As stress proportion increases the beam takes lesser number of cycles or it will fail early.

Fatigue life of specimens

Stress ratio	Criteria as per IRC:58-2015, minimum number of cycles	Specimen name (No. of cycles to failure of the specimen)				
		Conventional	0.1% BF	0.2% BF	0.3% BF	0.4% BF
0.65	7700	>2,50,000	>2,50,000	>2,50,000	>2,50,000	>2,50,000
0.7	1970	158654	223234	224684	228010	238684
0.75	477	119672	190576	198792	203236	223238
0.8	119	97992	153983	158634	172636	192177
0.85	30	90412	99528	114066	128080	147616

The fatigue life for specimens is the number of cycles for which concrete beam resist. This can be represented utilizing a chart called S-N curve in which stress proportion 'S' is plotted on the Y-axis and the number of load cycles to failure 'N' on the X-axis (on a log scale).The S-N curves for 0.4% BF of mix designed specimens casted are appeared in Figure 4.3. The Table 10 demonstrates the Equations and R^2 values for concrete specimens.The concrete containing basalt strands can take a more prominent number of cycles for a given pressure proportion than other specimens tried without the fibers. The impact of basalt filaments in filling micro pores between the inter transition zones.This resulting outcome is delayed formation and propagation of cracks under the repetitive loads.

Relationship between fatigue cycle (N) and stress ration ®

Mix name	Equations	R^2
Conventional	ln(N)=(2.924-SR)/0.03	0.9271
0.1% BF	ln(N)=(3.282SR)/0.03	0.9269
0.2% BF	ln(N)=(3.721-SR)/0.03	0.9425
0.3% BF	ln(N)=(4.289-SR)/0.03	0.9405
0.4% BF	ln(N)=(4.585-SR)/0.03	0.9616

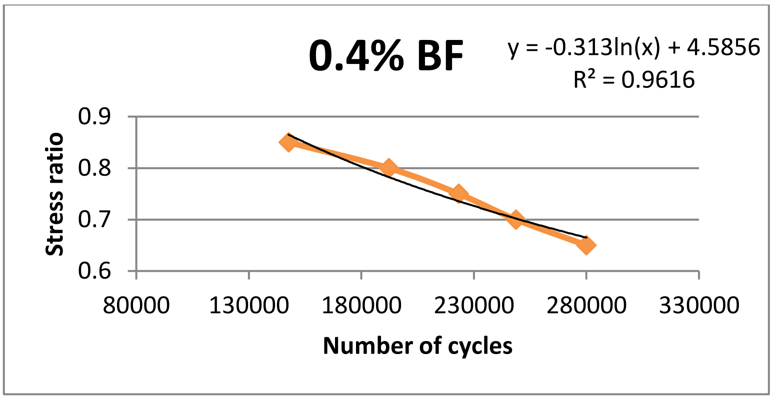

Figure 4.3. S-N Curve for 0.4% basalt fibre mix

4.3 Micro structure analysis of concrete

The Microscopic image of conventional mix with 0.4% basalt micro fiber is depicted in Figure 4.4. Formation of hydration products around the Basalt micro fibers seems comparatively less disturbed than that of macro fiber mix. Even though Basalt fiber is able to connect hydration products at micro level, because of material nature basalt fibers have failed by breaking during compression which can be visualized from the image. Also because of its smooth surface texture the bonding between basalt micro fiber and hydration product under compression is expected to shear easily. Crystalline phases of CaOH can also be observed. Similar to macro fiber addition, addition of micro fibers beyond certain optimized quantities may cause more of discontinuity in hydration phases thereby contributing to the reduction in strength.

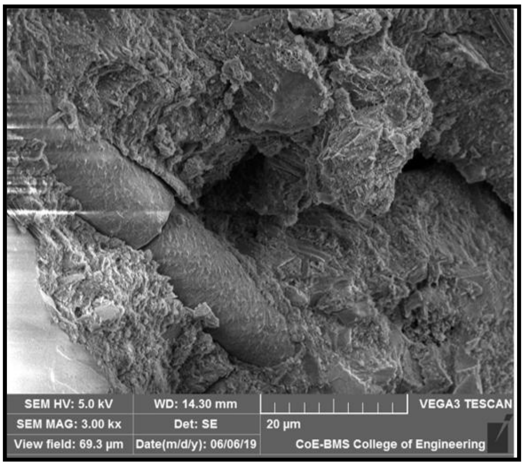

Figure 4.4. SEM Image fibre reinforced mix

5. Conclusions

The scattering and dispersion of basalt fiber is one of the most concerning issues in its utilization within cement and concrete composites. The primary objective of this study is to investigate the fatigue performance of fiber-reinforced concrete using strengthened concrete with basalt fiber while proposing an improved technique for its dispersion. Five types of concrete were considered: conventional concrete and variations with 0.1%, 0.2%, 0.3%, and 0.4% basalt fiber by weight of cement. Various tests were conducted to achieve the study’s objectives, and the best-performing combination was assessed for its suitability in pavements and runways. The results indicate that fiber-containing concrete exhibits greater

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ISBN: 978-81-984081-7-4

Series: AIJR Proceedings
ISSN: 2582-3922

slump loss than other mixes, requiring more water to wet the material's surface. Concrete with 0.3% basalt fiber demonstrated a 9.24% increase in compressive strength compared to conventional concrete at 28 days. The flexural strength of the 0.4% basalt fiber specimen reached 7.02 MPa, exceeding the minimum requirement for pavements. The percentage increase in early-stage strength was higher than that at the later stage, making it advantageous for pavement applications. The fatigue behavior of basalt fiber-reinforced concrete showed greater resistance to cyclic loads, enabling it to withstand a higher number of repetitive stress cycles, which delays crack formation and propagation, particularly in rigid pavements exposed to dynamic loading. Additionally, small-scale micro-modified concrete using basalt strands may offer solutions for impact cracks and structural damage caused by heavy vehicle movement. All concrete mixes tested met the requirements of IRC: 15-2011 and IRC: 58-2015.

Conflict of Interest : This paper is purely the authors research and it doesn't have any conflict of interest

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