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Durability and Case Study of Fiber Reinforced Polymer (Frp)

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Abstract: *Fiber reinforced polymer (FRP) composites have become important materials for the new structures and application of FRP is efficient in repairing and strengtheningconstructionswhich werearchitecturallyweak. For applications of structures, an overview of different FRP composites are provided by various polymer composites and in civil structures FRP composites are used for reinstatement or firming up the elemental constituent. Now a days various researches are going oninternationally regarding the use of FRP, wraps, laminates and sheets in the renovation and hardening concrete members.FRPis an alternate process to renovation of structures which is also economical. FRPis being usingeffectively in various cases like lessload, high strength and stability. The purpose of this paper is to discuss about different properties, types, applications of FRP. Some case studies & practical applications used in worldwide are also discussed in this paper.*
Keywords: *FRP, Properties of FRP, Advantages and Drawbacks of FRP, Application.*

I. Introduction

The materials used in civil structures for restoration or firming up the elemental constituent are the fiber-reinforced polymer (FRP) composites.[1]FRPis a compound made up of reinforced fibers of polymer matrix. These are like glass, aramid,basalt and carbon,wood,paper,asbestos etc. FRP composite materials have a significant advantages that includes high stiffness and tensile strength properties, low weight, easy touse, adaptableness to curved surfaces and corrosion proof. Further it is realized that the use of FRP is often governed bystrain limits, due to its brittle characteristics[2]. In 1994, Saadatmanesh and Schwegler, were the first researchers to examine the useof FRP for the consolidation of masonry structures[3].Since then, FRPs are used tostrengthen structural masonry components as walls, vaults, arches and to confine columns. Currently, the principal issue associated with the use of externally bonded FRP composite systems for hardening concrete and masonry structures is toughness, specially the aspects associated tofire and environmental agents. There are very less studies which were conducted for FRP-strengthened masonry elements but much more studies were done on the properties of dampness and temperature effects on the joining performance of external FRP-hardened concrete elements.In civil engineering stability refers to the conditions under which a structure is still considered advantageous. Astructurally stable and sound structure is always considered fit,in spite of its cost issues, it has significant practicaladvantagein long term and durability performance in civil engineering[4].

II. Fiber Reinforced Polymer

FRP is a compound made up of reinforced fibers of polymer matrix. The collection of FRP bars for depends on numerousmatters according to structural point of view. Fiber plastics have various application due to its corrosion resistance, light weight, and non-magnetic propertywith high tension strength, good toughness, less mechanical reductionand resistance in high fatigue[5].Generally, due to its initial and maintenance cost these composite materials were restricted in RC construction use. Excessivecorrosion due to climate of coastal belt and continuous use as ice reducing material on roads and bridges are sufficiently captivated so as to studyfor corrosion lessFRP materials. Numeroustypes of FRP bars for structural purposes havingmass-produced now a days starting from 1-D bars and cables to 2-Dlattices and networks. Different types ofcomponents are shown below.

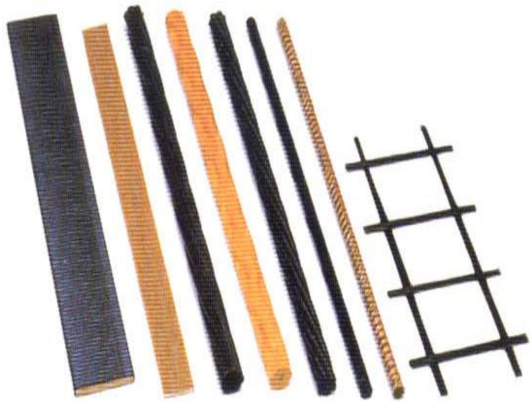


Figure 1: Types of FRP Bars

The characteristics of GFRP and CFRPreinforcements and tendons with steel barsare highlighted in Table 1.

Tensile Propeties	Steel Bar	Steel Tendon	GFRP Bar	GFRP Tendon	CFRP Tendon
Ultimate Strength, ksi	70 - 100	200 - 270	75 - 175	200 - 250	240 - 350
Elastic Modulus, ksi	29,000	27 - 29,000	6 - 8,000	7 - 9,000	22 - 24,000
Specific Gravity	7.9	7.9	1.5 - 2.0	2.4	1.5 - 1.6
Tensile Strain, %	>10	>4	3.5 - 5.0	3.0 - 4.5	1.0 - 1.5
Thermal Coeff. $x10^{-6}/°F$	Longitudinal: 6.5	6.5	5.5	5.5	0.38 to -0.68

Table 1: Physical PropertiesFRP Composites and Steel Bars

Fibervolume, size, and loading grip system defines the effective properties of FRP composites[4]. Unlike steel, tensile strength of FRP bars totally depends on the bar diameter. FRP components shows responses like anisotropic,more tension strength in the initial condition. Eventually the FRP bar'sproperties aremoreat the time of measuring longitudinal direction which is parallel to the fiber, with priorto loading time, heat and dampness conditions. Ratio of young's modulus to stressis maximum in FRP compositesin comparison to reinforcement, and many jobsare done in order to improve its elasticity property.

1.1. The Formation of FRPs:

Basically, there are two processes through which a polymer is established: step-wise polymerization and additive polymerization[6]. Composite plastics are molded when a group of consistent material possessing different properties are combinedto form a concluding product havingwished characteristics in mechanical way. These are of two types, fiber reinforced and particle reinforced.Fiber reinforced plastic belongs to that category of mechanical strength and elasticity as incorporated in fiber materials[7].The matrixis the core material which is devoid of fiber reinforcement. It is hard but relatively weaker and must be hardened through the addition of powerful reinforcing fibers or filaments. This fiber is critical in differentiating the FRPparental polymer. Most of these plastics are made through different molding methods wherein a mold or a tool is used to put the fiber pre-form, constructing dry fiber or fiber holding a specific resin proportion. "Curing" occurs by 'wetting' dry fibers with resin, wherein the matrix and fibers assume the mold's form. There is irregular activities of pressure and heat in this stage[3].The variousprocessescomprise bladder molding, compression molding, autoclave, mandrel wrapping, wet layup, filament winding.

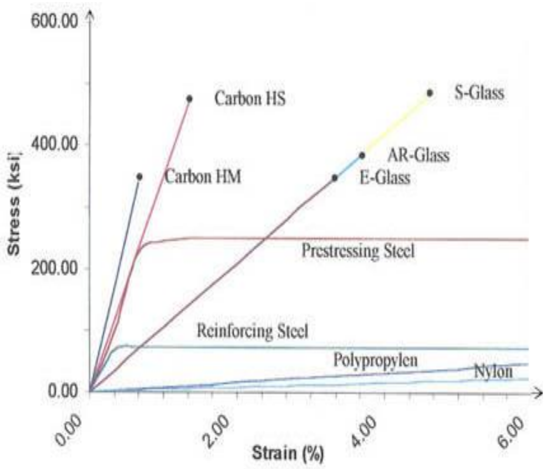


Figure 2: Schematic Diagram of Stress vsStrain With Respect to Behaviour of Reinforcing Fibersin Comparing With Steel.

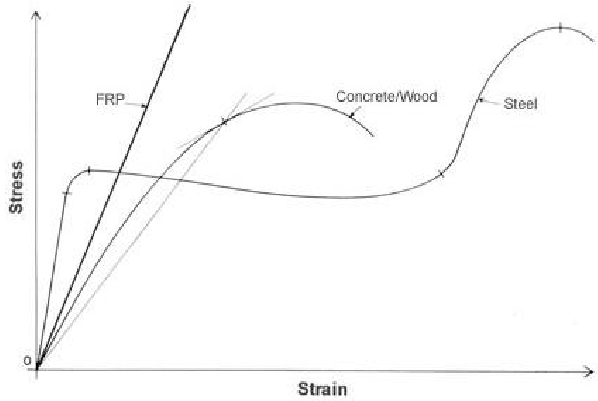


Figure 3: Tensile Stress-Strain Behaviour of Construction Materials.

1.2. Common Properties of FRPs:

These composite components generally indicate high strength and low weight[8]. These components are very strong and these are used by the automotive industry forreplacing some of the metal in cars. Fiber reinforced plastic are as strong as some metals but they are lighter and more fuel efficient.The characteristics of fiber reinforced plastics are customized to suit a wide range requirement. FRP composites have compressive and impressive electrical properties. They display high grade environmental resistance. The manufacturing process is an important factor and it is quite cost effective. This process makes FRP materials a favorite among various industrial sectors. The productivity rate is medium to high and a ready bonding is indicated with different components.The other independent characteristic of fiber reinforced plastics include laudable thermal insulation, fire hardness, structural integrity along with UV radiation stability, resistance to chemicals and other eroding materials.The properties of fiber reinforced plastics are subjected to some factors like the relative volume of both these components, mechanical properties of the fiber and matrix, and the length of the fiber and orientation within the matrix.

1.3. Common Fibers Include:

- **Glass:-**It is a good insulating component. It constructs glass reinforced plastic or fiberglass, whenmixed with the matrix[9]. It is less strong, less rigid, less brittle, less expensive than carbon fiber.
- **Carbonbasedfiberreinforcedplastics:-**Temperature, high tensile strength, tolerance, stiffness, chemical resistance are offered by carbon based fiber reinforced plastics along with low thermal expansion and weight. The carbon atoms construct crystals which lie usually along long axis of the fiber. The ratio of strength to volume is made high by this classification. This classification makes the material strong.

Figure 4: Bidirectional/Unidirectional/Mixed Knitted/Construction reinforcement carbon fiber fabrics

- **Aramid:-**It has vast usefulness in various industries. Robust and heat-resistant synthetic fibers are the results of aramid fiber components.

Figure 5: Carbon Aramid Hybrid Fabric Cloth

- **Epoxy:-** It is used to transmitloads between the fibers which holds the fibers tightly and protect the fibers from damages occurs from environmentalandmechanical conditions.

Figure 6: Seamless Epoxy Floor Resurfacer Covers Damaged Floors

- **Filler:-** It is used to improve the performance by lowering the compound cost. They control the shrinkage, make the surface smooth and it is used as a crack resistance.
- **Additive:-**It enhance the durability and usefulness of the polymer.

III. Types of Frp

There are many categories of FRP in world-wide which are being used in various construction work due to their Eco-friendly nature and sustainability[10].

➢ **Natural FRP:-**this fibers are not synthetic or man-made but are sourced from renewable and non-renewable resources such as oil-pump, sisol, flax and jute. The plans which produce cellulose fibers can be classified into bast fibers, seed fibers, leaf fiber, grass and reed fiber and core fibers.

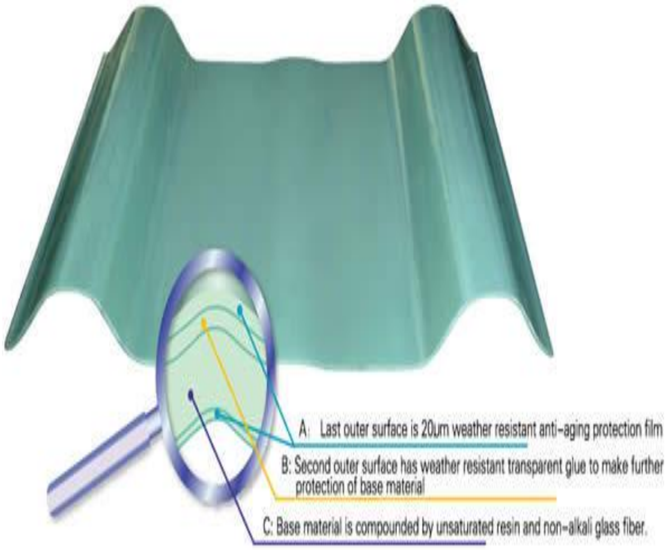


Figure 7

➢ **Glass FRP:-** these fibers are dissimilar from other form of glass fibers used to insulated application. They vary in groupings of silica, Calcium Oxide, Magnesium Oxide in mixture form. These are melted at a temperature of 1300 degree Celsius.

Figure 8

➢ **Carbon FRP:-** Carbon fibers are created by oxidation and thermal pyrolysis at high temperature. These fibers having the diameter ranging from 9-17 micrometers.

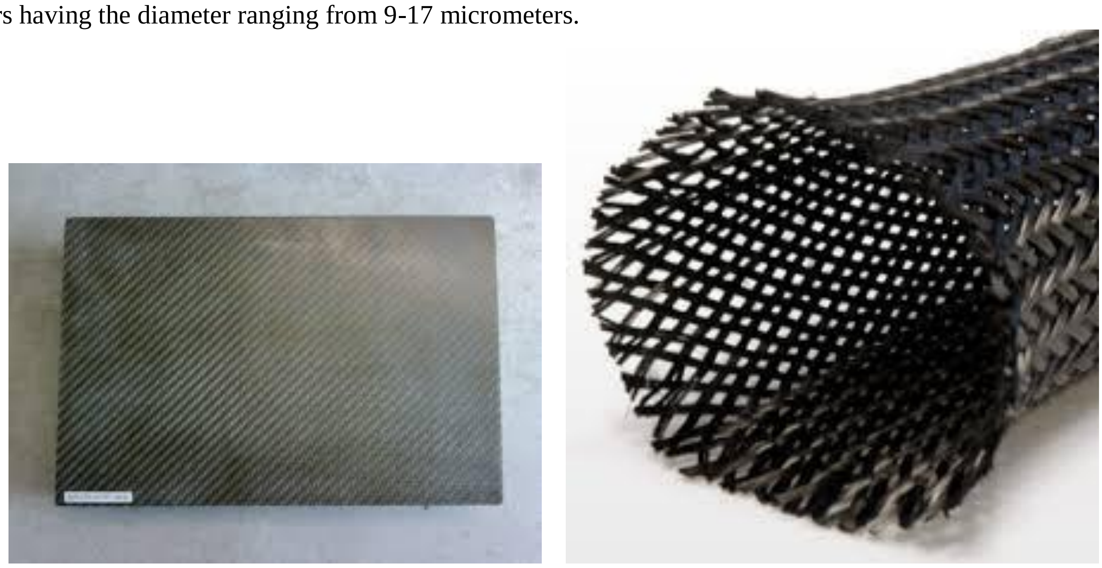


Figure 9

1.4. Environmental Condition[11]:

1. Temperature:- 22 degree Celsius, 50% humidity.
2. Alkali Solution:- Submersed in pH 10,12, and 13.7 Sodium Hydroxide solution atthirty-eight degree Celsius.
3. Void Ratio:- 7.2 %
4. Properties of TYFO fiber wrapsystem, GFRP and CFRP are given in the following table-2

Property	Carbon (SCH 41) FRP	Glass (SHE 51) FRP
Ultimate Tensile Strength (N/mm/layer)	850-950	490-560
Rupture Strain (mm/mm)	0.0142	0.0197
Nominal thickness of the Fabric (mm)	1.04	1.24
Weight of the Fabric (grams/m^2)	658	923
Weight of FRP Sheet gr/mm^2/layer	1660	2500
Coefficient of Thermal Expansion/ °C	-0.5×10^{-6}	7.7×10^{-6}

Table-2

1.5. Specimen:

Concrete cylinder having 75 mm diameter, 150 mm long are casted. The wall surfaces of the cylinder to be wrapped where framed with sand papers to remove any loose material. The cylinders were coated with epoxy and left to cure for 7 days and then grounded into control and exposed batches.

IV. Result and Discussion

About 1.8 increase in factor of compressive strength is gained in one layer of CFRP wrap. This is about 30% to 40%. A factor of 14 and 11 is increased in the energy absorbing capacity of the control cylinders with CFRP wrap and GFRP wrap respectively.

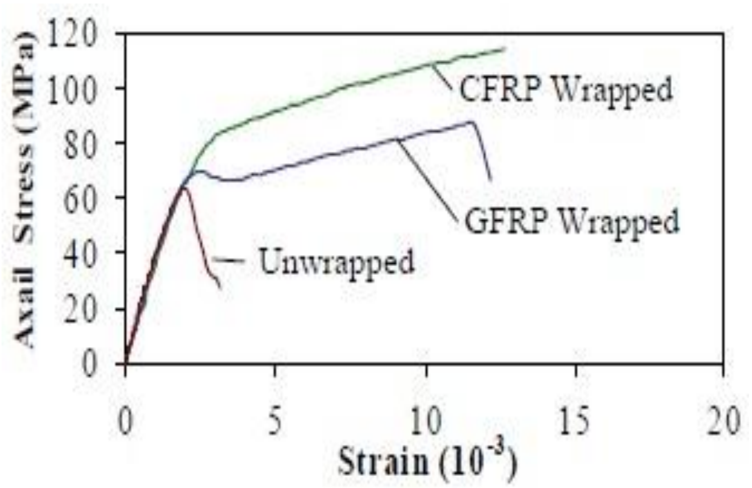


Figure 10

2. Advantages of FRP:

The following are the major advantages of FRP-

- Corrosion Proof
- Higher Young Modulus
- Light Weight
- Ratio of Strength to Weight is very High
- High Fatigue Resistant
- Easy to Transportation and Installation
- Reduction of stress and creep

V. Durability and Degradation Agents

Exposure can affect the performance of FRP strengthening systems to certain degrading agents. The deterioration level depends on a series of factors. The types are fibers and resin, manufacturing process and severity of exposure environments. Degradation may be divided into different mechanisms like physical, chemical and mechanical. These three basic mechanisms may interact with each other, with cumulative or subtractive effects on the material performance. Degradation of external FRP strengthening occurs due to matrix deterioration, fibers deterioration or bond deterioration at the interface of FRP-substrate. Substrate deterioration is also susceptible to occur. The most relevant environmental agents availing the deterioration of external FRP-strengthened structures consist of thermal cycling, creep, freeze-thaw cycling, moisture, fatigue, alkaline environment and ultraviolet light. For example, glass and aramid fibers are sensitive to moisture, but carbon fibers are comparatively different to such environment agent.

VI. Practical Applications of frp and Case Studies

FRP is being used in world wide.This polymer is widely used in different countries-

- Canada
- Europe
- Japan
- United State

In Canada, University of Manitoba and Queen's University in Kingston has providedthe development of FRP bars of concrete buildings.

In 1995, the foot-bridge was built by GFRP bars in Britain using glass FRP reinforcement.

In Japan, an advanced project by Sugiyama establisheduninterruptedFFP tubing and tested fundamental characteristics, stress concentrations and load displacements of a Ushaped section.

Europe and Japan have got a good idea for using FRP in creation; the US needs a great part forpresenting new skill full materials in differentstructureschemes.Forty three %of bridges in US.

2.1. Location:Australia

6.1.1FiberComposite Bridge[11]

Description:Thecomposite bridge is being designed which is created over conventional bridge concept, as in the high tensile stress, low weight characteristics of fiber composites was mixed with the high compression capacity of plain concrete The beam is made up of deep concrete compression flange of 100mm depth on top and 350mm deep box girders designed by glass reinforcedisophthalic polyester profiles. Excess carbon fiber reinforcement was assimilated into the foundation of deck to increase stiffness. The first application of fiber composites in a highway bridge in Australia occurred in 2005. The highway bridge, that was constructed using fibercomposite girders and reinforced concrete deck slab, is of two spans 10m and 12m, and retrieved an existing timber bridge. The bridge was opened to traffic in July 2005.

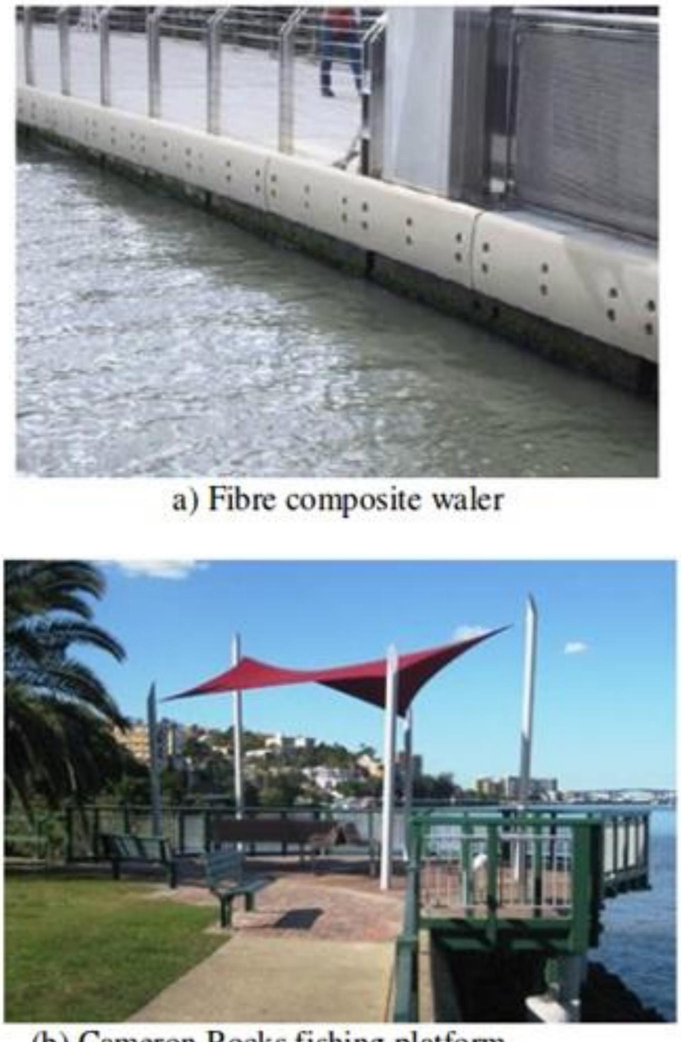
(a) First fibre composite bridge in Australia

(b) Taromeo Creek Bridge

Figure 11 Innovative applications of fiber composite bridges in Australia

6.1.2. Marine and floating structures

Description:The platform was constructed with composite supports fixed to the existing concrete piles with a absolutely composite substructure to ensure long life span in the highly corrosive marine "splash" zone.Composite decking was also equipped to develop the overall resilience and conservation return on this structure.In the January 2011, Brisbane floods, the structure remained unharmed and fit for continued use.



a) Fibre composite waler

(b) Cameron Rocks fishing platform

Figure 12: Marine and floating structures projects which uses fiber composites

6.2. LOCATION:Virginia, USA

6.2.1. Concrete filled Fiber Reinforced Polymer (FRP) Piles[12]

Description**:** Concrete filled FRP piles arefinished up of an outer FRP shell with an unreinforced concreteinfill. The main advantage of FRP shell is to offer a stay in placeconstructional framework for the concrete infill,that acts as corrosion lessbars, providing refinement to concrete in compression, saving concrete from harsh atmospherespecial effects. The concrete in-fill gives the internal capacity in compression region and boosts the toughness of member and avoids local crippling of the FRP tube. The piles are generally available in diameters which ranges from 203 mm- 610mm, with wall thicknesses ranging between 4.6 mm- 9.1 mm.

Figure 13: Degradation of traditional piles

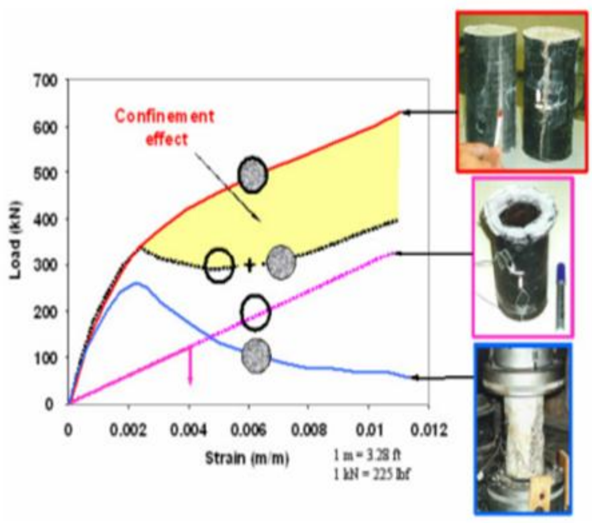


Figure 14: Confinement effect of FRP shell on concrete

VII. Conclusion

According to civil engineering point of view Fiber reinforced polymer is an innovative structural technique. Till date research on Fiber Reinforced polymer composites is insufficient[1].The fiber reinforced polymer composites will become more challenging when comparing to old-fashioned construction material and it would be possible to harness its potential in civil engineering structure[3]. In this paper we have focused on structural behavior, material types, durability of marine and floating structure, renovation of traditional piles,etc[5].The best advantages of these FRP mechanism is that we can reuse the FRP composites and finally we get a eco-friendly polymer. We have studied that the strength of composite is inversely proportional to the critical fiber length for which the internal adhesion strength increases due to slight decrease in the length of fiber.Therefore there is a requirement of case studies and practical applications to fully comprehend its property under various factors of degradation.

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