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Research Paper

MECHANICAL PROPERTIES OF WOVEN FABRIC BASALT/JUTE FIBRE REINFORCED POLYMER HYBRID COMPOSITES

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Composites are emerging as realistic alternatives to the metal alloys in many applications like automobiles, marine, aerospace applications, sports goods, etc. Fiber composites offer many advantages such as low specific gravity, tensile strength and modulus, compressive strength and modulus, better fatigue strength, etc. Due to the low specific gravity the strength weight ratio and modulus weight ratio of these composite materials are markedly superior to those of metallic materials. In this work it is concerned general purpose poly ester-based polymer composites are developed by reinforcement of basalt fabric and jute fabric into general purpose poly ester matrix by compression moulding technique. This study describes the basalt fiber and jute fibre reinforced hybrid composites with poly ester resin with different stacking sequence. Fabricated composite plates subjected to mechanical properties like Flexural strength, Impact strength test of the various specimens are calculated by using computer assisted Universal testing machine and Charpy Impact testing machine. From the results it is found that pure basalt fibre combination maintains higher values in both flexural and tensile test. But for impact test basalt fibre is slightly lower than jute fibre reinforced composite.

Keywords: Composite materials, Fabrication process, Testing process, Results, Discussion

INTRODUCTION

Composite materials have a long history of usage. Their beginnings are unknown, but all recorded history contains references to some form of composite material. For example, straw was used by Israelites to strengthen mud bricks. Plywood was used by ancient Egyptians when they realized that wood could be rearranged to achieve superior strength and resistant to thermal expansion as well as to swelling owing to the presence of moisture. Medieval swords and armor were constructed with layers of different materials.

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Jute Fiber, developed in the late 1940s, was the first modern composite and is still the most common. It makes up about 65% of all the composites produced today and is used for hulls, surfboards, sporting goods, swimming pool linings, building panels and car bodies. Fiber reinforced resin composites that have high strength to weight and stiffness-to-weight ratios have become important in weight-sensitive applications such as aircraft and space vehicles. This chapter dealt with the basic introduction about composites and the types of composites. It gives the introduction about the fiber reinforced composites.

Many of our modern technologies require material with unusual combination of properties that cannot be met by the conventional metal, ceramics and polymeric materials. This is especially true for materials that are needed for automotive, aerospace, and other transportation applications. For example, material engineers are increasingly searching for structural materials that have low densities, are strong, stiff, and abrasion and impact resistant, and are not easily corroded. This is a rather formidable combination of characteristics. Frequently, strong materials are relatively dense; also, increasing the strength or stiffness generally results in a decrease in impact strength.

High strength, light weight, non-magnetic and non-corrosive properties, and good fatigue endurance are among some of the favorable properties that would favor the use of FRP bars. High initial cost, low modulus, linear stress strain behavior until failure, and durability issues are some obstacles to the adoption of FRP materials in transportation infrastructure.

COMPOSITE MATERIALS

Basalt Fiber

Basalt fiber is dark colored, fine grained solidified volcanic rock. It chiefly consist of Silicone Dioxide (SiO_2), Aluminum Oxide (Al_2O_3), Iron oxide ($FeO+Fe_2O_3$), Calcium Oxide (CaO), Magnesium Oxide (MgO), Sodium Oxide Basalt is an environment friendly natural material.It is used for basalt fibers production. 1/3 of the Earth's crust consists of basalts and eruptive rock, so this material is easily found worldwide. Primary fusion, enrichment and homogenization of basalt breeds are made by nature. Basalts have being laying on the surface of the Earth for many millions years. Basalt breeds are one of the strongest natural silicate breeds.

Safe and abundant, basalt rock has long been known for its thermal properties, strength and durability. Cost of extraction of basalt raw material is very low. The technology of production process is not hazardous for environment. It does not produce any emission or waste. Basalt (solidified volcanic lava) is known for its resistance to high temperatures, strength and durability. Basalt fiber is extruded

Figure 1: Basalt Rocks

from molten basalt rock at diameters generally between 13 to 20 μm. Basalt fiber products are available in commercial quantities from various sources including from China. BFRP fiber products are available in various forms such as bars, mesh, cages, spirals, fabric, and chopped fiber Basalt fiber is environmentally and ecologically armless, and free from carcinogens and other health hazards. In construction industry, basalt fiber can be provided at a cost considerably less than carbon, silica and other fibers. The properties that are superior in basalt fiber are: good range of thermal performance (–435 °F to 1760 °F), high tensile strength, high resistance to alkalis and acids, superior electro magnetic properties, inertness, resistance to corrosion, resistance to radiation and UV light, and good resistance to vibration. Basalt chopped strands are good for use in friction materials. Brake pads based on Basalt fiber have better and more stable friction coefficient and higher endurance than glass fiber ones. Also, basalt fibers provide many benefits as filler for car mufflers showing great silencing properties and good resistance to thermal cycling Basalt fibers reinforcement provides much better recycling ability for polymer composites. During the incineration of regular glass fiber reinforced plastics the melted glass deposits onto the incinerator walls and floor, while basalt fiber reinforced plastics transform into fine powder, which is easy to remove from the Equipment and to recycle. Basalt fibers have 150 °C more heat resistance than regular glass fibers.

Basalt woven fabrics and mats ideally suited for heat and sound insulation of car interior and engine parts.

Figure 2: Basalt Rocks in Molten Stage

Figure 3: Woven Basalt Fiber

Basalt fibers have higher strength and elastic modulus than conventional E glass getting close to special high strength S glass and carbon fibers. So they offer for car makers an opportunity for significant cost reduction of SMC/BMC parts while keeping high strength and stiffness. The dielectric properties of basalt fibers are equal to ones of glass fibers. And switch from glass to basalt does not change radar transparency.

Jute Fiber

Jute is a long, soft, shiny vegetable fiber that can be spun into coarse, strong threads. It is produced from plants in the genus Corchorus, which has been classified in the family Tiliaceae, or more recently in Malvaceae. Jute is one of the most affordable natural fibers and is second only to cotton in amount produced and variety of uses of vegetable fibers. Jute fibers are composed primarily of the plant materials cellulose (major component of plant fibre) and lignin (major components of wood fiber). It is thus a ligno-cellulosic fibre that is partially a textile fibre and partially wood. It falls into the bast fiber category (fiber collected from bast or skin of the plant) along with kenaf, industrial hemp, flax (linen), ramie, etc. The industrial term for jute fiber is raw jute. The fibers are off-white to brown, and 1-4 meters (3-12 feet) long.

Figure 4: Jute Plant

Properties of Jute Fiber

- Jute fiber is 100% bio-degradable and recyclable and thus environmentally friendly.
- It is a natural fiber with golden and silky shine and hence called The Golden Fiber.
- It is the second most important vegetable fiber after cotton, in terms of usage, global consumption, production, and availability.
- It has high tensile strength, low extensibility, and ensures better breathability of fabrics. Therefore, jute is very suitable in agricultural commodity bulk packaging.
- It helps to make best quality industrial yarn, fabric, net, and sacks. It is one of the most versatile natural fibers that have been used in raw materials for packaging, textiles, non-textile, construction, and agricultural sectors. Bulking of yarn results in a reduced breaking tenacity and an increased breaking extensibility when blended as a ternary blend.
- The best source of jute in the world is the Bengal Delta Plain in the Ganges Delta, most of which is occupied by Bangladesh.
- Advantages of jute include good insulating and antistatic properties, as well as having low thermal conductivity and a moderate moisture regain. Other advantages of jute include acoustic insulating properties and manufacture with no skin irritations.
- Jute has the ability to be blended with other fibers, both synthetic and natural, and

accepts cellulosic dye classes such as natural, basic, vat, sulfur, reactive, and pigment dyes. As the demand for natural comfort fibers increases, the demand for jute and other natural fibers that can be blended with cotton will increase. To meet this demand, some manufactures in the natural fiber industry plan to modernize processing with the Rieter's Elitex system. The resulting jute/cotton yarns will produce fabrics with a reduced cost of wet processing treatments. Jute can also be blended with wool. By treating jute with caustic soda, crimp, softness, pliability, and appearance is improved, aiding in its ability to be spun with wool. Liquid ammonia has a similar effect on jute, as well as the added characteristic of improving flame resistance when treated with flame proofing agents.

- Some noted disadvantages include poor adaptability and crease resistance, brittleness, fiber shedding, and yellowing in sunlight. However, preparation of fabrics with castor oil lubricants result in less yellowing and less fabric weight loss, as well as increased dyeing brilliance. Jute has a decreased strength when wet, and also becomes subject to microbial attack in humid climates. Jute can be processed with an enzyme in order to reduce some of its brittleness and stiffness. Once treated with an enzyme, jute shows an affinity to readily accept natural dyes, which can be made from marigold flower extract. In one attempt to dye jute fabric with this extract, bleached fabric was mordanted with ferrous sulphate, increasing the fabric's dye uptake value. Jute also responds well to reactive dyeing. This process is used for bright and fast colored value-added diversified products made from jute.

Polyester [G.P]

Polyester resins are produced by the poly condensation of saturated and unsaturated dicarboxylic acids with glycols. Unsaturated polyester resins form highly durable structures and coatings when they are cross-linked with a vinyl reactive monomer, most commonly styrene. The properties of the cross-linked unsaturated polyester resins depend on the types of acids and glycols used and their relative proportions. Polyester resins are used in sheet molding compound, bulk molding compound and the toner of laser printers. Wall panels fabricated from polyester resins reinforced with fiberglass—so-called Fiberglass Reinforced Plastic (FRP)—are typically used in restaurants, kitchens, restrooms and other areas that require washable low-maintenance walls.

Unsaturated polyesters are condensation polymers formed by the reaction of polyols (also known as polyhydric alcohols), organic compounds with multiple alcohol or hydroxyl functional groups, with saturated or unsaturated dibasic acids. Typical polyols used are glycols such as ethylene glycol; acids used are phthalic acid and maleic acid. Water, a by-product of esterification reactions, is continuously removed, driving the reaction to completion.

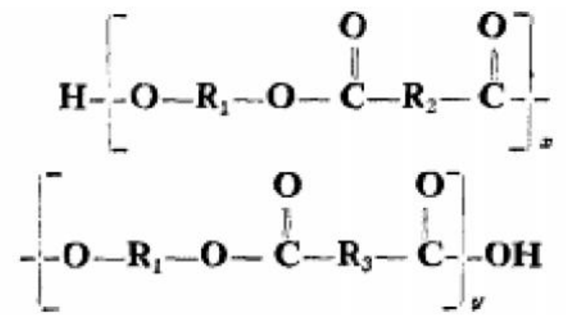
The use of unsaturated polyesters and additives such as styrene lowers the viscosity of the resin. The initially liquid resin is converted to a solid by cross-linking chains. This is done by creating free radicals at unsaturated bonds, which propagate in a chain reaction to other unsaturated bonds in adjacent molecules, linking them in the process. The initial free radicals are induced by adding a compound that easily decomposes into free radicals. This compound is usually and incorrectly known as the catalyst [citation needed]. Substances used are generally organic peroxides such as benzoyl peroxide or methyl ethyl ketone peroxide.

Polyester resins are thermosetting and, as with other resins, cure exothermically. The use of excessive catalyst can, therefore, cause charring or even ignition during the curing process. Excessive catalyst may also cause the product to fracture or form a rubbery material.

Cross-links are bonds that link one polymer chain to another. They can be covalent bonds or ionic bonds. "Polymer chains" can refer to synthetic polymers or natural polymers (such as proteins). When the term "cross-linking" is used in the synthetic polymer science field, it usually refers to the use of cross-links to promote a difference in the polymers' physical properties. When "cross linking" is used in the biological milieu, it refers to the use of a probe to link proteins together to check for protein-protein interactions, as well as other creative cross-linking methodologies.

Cross-linking is used in both synthetic polymer chemistry and in the biological sciences. Although the term is used to refer to the "linking of polymer chains" for both sciences, the extent of cross linking and specificities of the cross linking agents vary. Of course, with all science, there are overlaps, and the following delineations are a starting point to understanding the subtleties.

Figure 5: Molecular Structure of Polyester Resin



FABRICATION OF COMPOSITES

Material

Basalt fibers were supplied by ASA.TECH Austria. Jute fiber was supplied by S.N brothers, Kerala, India. Polyester resin, Methyl Ethyl Ketone Peroxide (MEKP) and Cobalt napthenate was purchased from Sakthi Pvt. Ltd., Chennai, India. Finally, complete content and organization editing before formatting. Please take note of the following items when proof reading spelling and grammar.

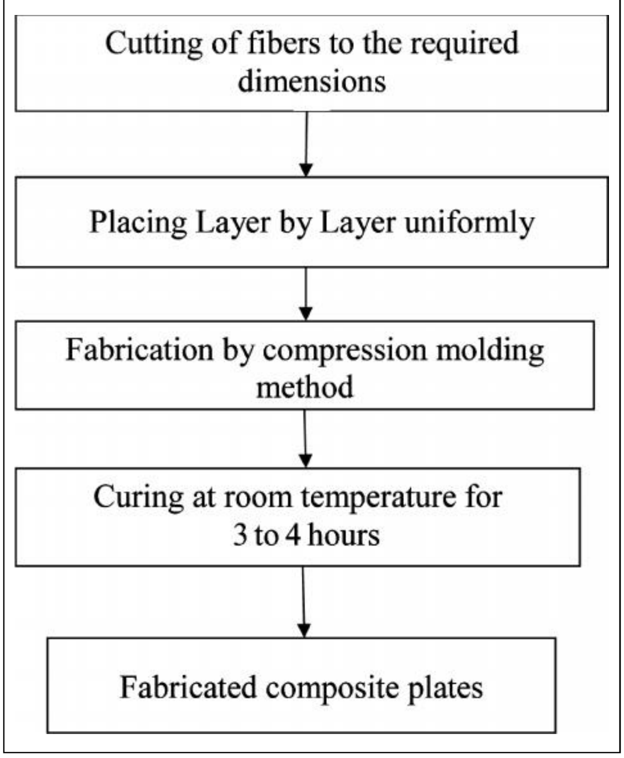
Fabrication of Composites

The basalt fibre/jute fibre reinforced polymer matrix composites were fabricated using compression moulding method. General polyester resin was used as matrix. For a proper chemical reaction cobalt peroxide and methyl ethyl ketones were used as accelerator and catalyst respectively. The Basalt fibres and jute fibres are cut according to the size of given required mould of 30 mm x 13 mm x 3 mm for corresponding 1:1 amount of general polyester resin. The curing of polyester resin was done by incorporation of one volume percent Methyl Ethyl Ketone Peroxide (MEKP) catalyst. One volume percent cobalt napthenate (accelerator) was also added. For achieving homogeneous condition of the mixture the stirring process carried with the use of Stirrer. Then these resin mixture was used to fabricate the mixture of basalt and jute fibres in the compression moulding technique via roller. The samples are allowed to cure about 3 to 4 hours at room temperature. Similar procedure adapted for the preparation of the basalt and jute reinforced polymer composites.

Fabrication

The procedure adopted in the fabrication of composite is represented in systematic diagram as shown below

Figure 6: Fabrication Procedure



Compression Molding Technique

Compression molding technique is a simple method for composite production. A mold must be used for Compression molding technique parts unless the composite is to be joined directly to another structure. The mold can be as simple as a flat sheet or have infinite curves and edges. For some shapes, molds must be joined in sections so they can be taken apart for part removal after curing. Before Compression molding technique, the mold is prepared with a release agent to insure that the part will not adhere to the mold. Reinforcement fibers can be cut and laid in the mold. It is up to the designer to organize the type, amount and direction of the fibers being used. Resin must then be catalyzed and added to the fibers. A brush, roller or squeegee can be used to impregnate the fibers with the resin. The Compression molding technician is responsible for controlling the amount of resin and the quality of saturation. Other fabrication processes such as vacuum bagging, vacuum resin transfer molding and compression molding can be used with Compression molding method improve the quality of the finished part or save time.

- Procedure for compression molding process.
- Wash the mould plate carefully with warm water and soft soap to remove any old PVC release agent, dust, grease, finger marks, etc.
- Dry the mould thoroughly.
- Check the mould surface for chips or blemishes. These should be repaired by filling with polyester filler. The odd small chip can be temporarily repaired filling with plasticine or plastic filler.
- If the mould surface is in good condition the mould release wax is now applied, with a circular motion, using a small piece of cloth.

- Apply the first layer of resin above the wax applied mould plate and spread it uniformly over the plate.
- Place the fabric and again pour the resin over it.
- Then spread the resin over it uniformly using the roller.
- Follow the same procedure for as many layers you want.
- Allow it for curing process for 3 to 4 hours.

Figure 7: Compression Molding Machine

MECHANICAL PROPERTY AND EVALUATION

Flexural Test

The 3-point bending test is used to find the flexural modulus, flexural strength and strain at break of the Basalt fiber and glass fiber reinforced polymer composites. Flexural test is conducted on the cured samples using universal testing machine with cross head speed of 2 mm/min according to ASTM 790-98. Five samples are taken from each test and the results are averaged.

Test parameters to configure a test system include load, speed of loading, test method type, support span, sample geometry, and maximum deflection of the test. Test sample thicknesses and types affect equipment requirements. Flexural tests monitor behavior of materials in simple beam loading; or transverse beam tests Specimens are supported as a simple beam, with the compressive load applied at midpoint, and maximum fiber stress and strain calculated. The three point bending flexural test measures bend or fracture strength, yield strength, modulus of elasticity in bending, flexural stress,

Figure 8: Flexural Testing Setup

Figure 9: Universal Testing Equipment

specimens are supported as a simple beam, with the compressive load applied at midpoint, and maximum fiber stress and strain calculated. The three point bending flexural test measures bend or fracture strength, yield strength, modulus of elasticity in bending, flexural stress, flexural strain, and flexural stress strain materials response. Flexural strength represents the highest stress experienced within the material at its moment of rupture.

Impact Test

Impact tests are designed to measure the resistance to failure of a material to a suddenly applied force. The test measures the impact energy, or the energy absorbed prior to fracture. The most common methods of measuring impact energy are the:

- Charpy Test
- Izod Test

Charpy Test

While most commonly used on metals, it is also used on polymers, ceramics and composites. The Charpy test is most commonly used to evaluate the relative toughness or impact toughness of materials and as such is often used in quality control applications where it is a fast and economical test. It is used more as a comparative test rather than a definitive test.

The impact test is used to find out the energy required to break the specimen. The un-notched Charpy impact test is conducted to study the impact energy according to the ASTM D256. The un-notched specimens are kept in cantilever position and the pendulum swings around to break the specimen. The impact energy (J) is calculated from the dial gauge, which is fitted on the machine. Five samples are taken for each test and the results are averaged.

Figure 10: Impact Testing Machine

Tensile Test

The tensile test is generally performed in universal testing machine. The dimension of the specimen is 165 mm * 13 mm * 3 mm. A thickness of 3 mm is maintained for the unfilled as well as particulate filled composite specimen. The tensile test is performed in UTM (capacity-3T) with a crosshead of 1mm/min and results are analyzed. ASTM Standards followed is ASTM D 638.

RESULTS AND DISCUSSION

Impact Test

The stacking order of basalt, jute, jute fibre reinforced composite was 14.55% greater than the basalt, jute, basalt fibre reinforced composite. The stacking of altering combination of basalt and jute hybrid reinforced composite was 9.83% greater than the other stacking of six basalt and three jute fibre reinforced composite. Similarly, above stacking order which has maximum amount of basalt with jute fibre reinforced composite was 15.72% greater than the altering stacking of jute, basalt, jute fibre reinforced composite. The altering combination of above fibre reinforced composite was 8.02% greater than the alternating stacking of pure basalt fibre reinforced composite. The above pure basalt fibre reinforced composite was 6.01% greater than the basalt, jute, basalt fibre reinforced hybrid composite. Similarly, the basalt, jute, basalt fibre composite was 1.08% greater than the jute, basalt, basalt fibre reinforced hybrid composite. From, over all comparison of fibre reinforced composites stacking of only jute has more impact strength than other stacking sequence of hybrid fibre reinforced composite.

Figure 11: Specimen After Testing

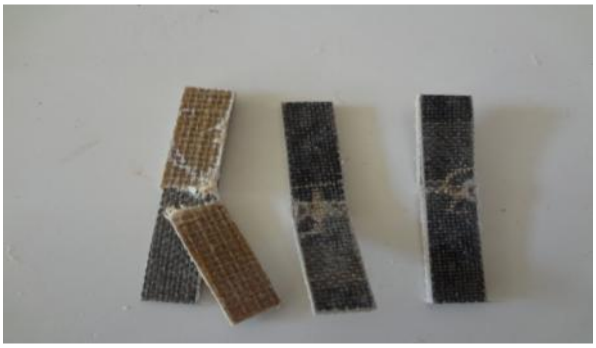
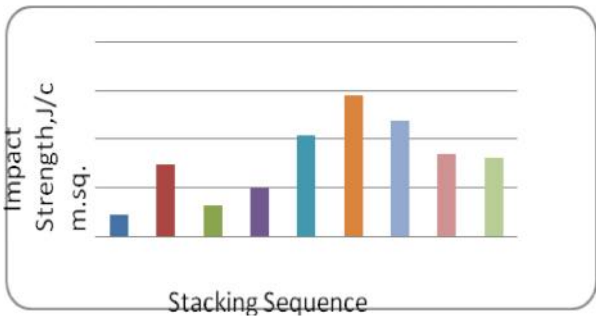


Figure 12: Effect of the Fiber Percentage on Impact Strength



Tensile Test

The large amount of stacking which has basalt was 3.04% greater than stacking of jute, basalt, jute. The stacking of above combination of altering jute and basalt fibresleads 2.08% than basalt, jute, jute stacking of fibre rein forced composite. Similarly, this stacking of basalt, jute, and jute is 2.45% greater than the stacking of jute fibre.Similarly,the combination of basalt, jute, basalt fibre rein forced composite has 2.02%

Figure 13: Effect of the Fiber Percentage in Elongation

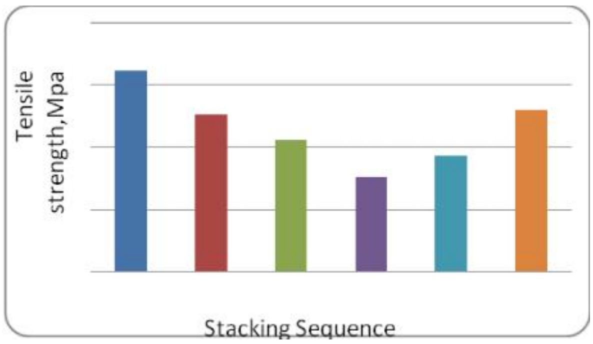
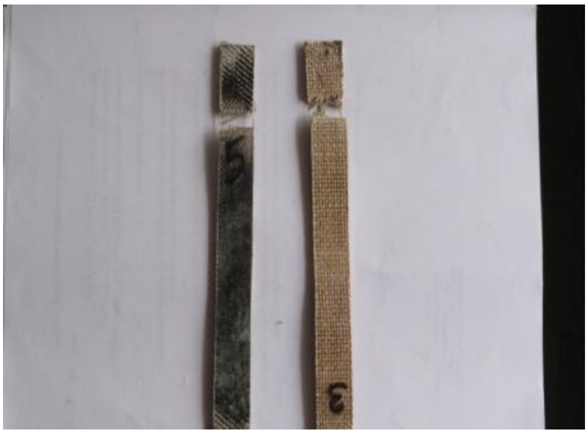


Figure 14: Specimen Before Testing

Figure 15: Specimen After Testing



greater than the combination has only jute fibre reinforced hybrid composite. Like this similarly, the stacking of basalt, basalt, jutefibre rein forced composite was 3.78% greater than basalt, jute, basalt fibre rein forced composite. From, this results the stacking sequence of only basalt fibre rein forced composite has maximum tensile strength of 16% comparing other combination of fibre rein forced hybrid composite

CONCLUSION

The performance of basalt fibre reinforced composites alone with poly ester was superior to the jute fibre reinforced composites.From the impact test, it was seen that, the composite material which contain pure jute shows the maximum Impact strength among other specimens of various stacking of basalt and jute, fabricated with polyester matrix. Based on the Tensile test, the tensile strength exhibited by the composite material with stacking of only Basalt is the higher than the composite in material with other stacking of Basalt and Jute fibre when compared, and is also highest among the other sample specimens.Upon the overall observation, it was observed that the reinforcement of basalt fibres composites originated a newer material with general superior properties and depending on the loading conditions and overcome the jute fibre reinforced polymer composites.

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