# Potential of Natural and Synthetic Composites For Ballistic Resistance

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***Abstract***

*This review evaluates on the concept and essential of bio composite and the synthetic composite fabric positioned over the years from the previous studies. The sorts and features of matrix and fiber filler reinforcement materials in composites also are discussed. The main findings in this review show that the centre of composite relies on the natural fiber against synthetic and the impact of lamination between them. Therefore, the contemporary hybrid compound for synthetic fiber and bio composite fiber in a composite shape is anticipated performing higher in the issue of mechanical energy in particular within the application of high impact, besides decreased dependency on artificial fiber. The table and figure previous results are comparing the experimental parameters available inside the literature review. This paper goes over the present advancement structure and development procedures included and related works on upgrading low and high impact energy captivation and upgrading the mechanical tenacity for hi gh impact resistance applications.*

***Keywords***: *Composite fibers, synthetic fibers, reinforcement, mechanical test, high impact testI*

## INTRODUCTION

A substantial composite is made up of two or higher combination numbers creating properties that differ from its components. It can be extremely simple because composites are strong and durable, but very mild in weight and the proportions of strength to weight and volume to weight are much superior compared to the properties of metals and aluminium that plastics, ceramics and polymers cannot achieve themselves (Malhotra et al., 2012). Natural fibers are in trend with their excellent mechanical properties in the automotive, manufacturing and aerospace sectors. Such natural fibers include sisal, flax, coir, cotton, jute, kenaf, and more (Samuel et al., 2012). Composites consist of different sections, in particular the material and matrix for reinforcement. The strengthening materials are generally solid with a low density, and the matrix is versatile and challenging to ensure that the composite is able to achieve each of its finest features (Chandramohan.D et al., 2011). Natural fibers are used to reinforce the current basic material structure. These provide a complex configuration with a crystalline cellulose amorphous lignin or hemicellulose matrix, which is reinforced by fibril. The key components of it are cellulose (60% - 80%), hemicellulose (5% - 20%), lining and humidity (20%) (Taj, S.et al., 2007). The chemically modified natural fiber improves the properties compared to untreated fibers. The chemically managed interface grip between fiber roots and polymer matrix has advanced with natural fibers.More specific research directed on the intensity of impact and fatigue consistency of natural fiber reinforcement (Dixit.S et al., 2017). Currently, natural fibers, including sisal and jute fibers, convert glass and carbon fibers because they are easy to use and durable. The use of synthetic fibers is evolving astonishingly and the reality is that every day, particularly within the automotive industry, the manufacturing sector is advancing. Natural fiber composites were previously intrigued by their biodegradability. Typical strands such as silk, coir, sisal and jute are low-cost, plentiful and reusable, lightweight, low-fat, robust and biodegradable. Natural jute strands might use as a substitute for conventional strengthening in compounds for projects that need strict weight control and external weight reductions (Ashik K. P et al., 2015). Kevlar 29 has been produced primarily from coal-related materials, and is the most widely used synthetic fiber for soft and hard armour applications. Reduced oil reserves and green fiber growth have enabled scholars towards investigate the possible usage of natural strand for a substitute to man-made fibers. Besides that, combination of natural fibers against man-made fibers can convey the most remarkable attribute that individual fibers are difficult to achieve. This review offers a relative reading of the classification and construction of different varieties of ballistic constituents, as well as the techniques for upgrading shields and distinctive methods employed to facilitate the absorption of ballistic energy.

### *Natural plant*

Research has recently shown a growing interest in and viability of natural fibers as a reinforcement of the polymer matrix. In order to replace synthetic fibers, natural fibers are proposed for various benefits, such as environmental-friendly, cheap, beautiful, sustainable and strong properties. Natural fibers are extracted and classified accordingly from different plant components (system, leaf and bark) (La Mantia and Morreale 2011). Supportability is defined as the ability to align execution with natural constraints. The capacity of natural fibers, on the other hand, is enormous and therefore requires a complex reuse. The researchers suggested the petroleum resources and growing focus to green materials to explore the possible use of natural fiber as an alternative to synthetic fibers. The hybridization of natural fiber with synthetic fiber will bring with it the best attribute that is difficult to harvest from the individual fibers. This analysis paper offers a comparative report on the classification and efficiency of different types of ballistic materials, the construction methods of the armor panel and various techniques used to increase the ballistic energy absorption ability. However, research has consistently shown that natural fibers also offer the same mechanical tenacity as the synthetic fibers.

### *Synthetic fibers*

There is no question that synthetic fibers are prominent in Fibre-reinforced plastic (FRP) composites, particularly Glass Fiber Reinforced Plastic (GFRP), but a lot of work has been applied to natural fibers over the past few years in the possibility of replacing synthetic fibers. This is very important as a step towards developing an environmentally friendly solution. As those technological problems of natural fibers seem to be drawbacks to being replacement fibers, the art of improvement embraces the architecture and the method of processing is important. Throughout recent years , natural fibers have been used as a possible substitute for synthetic fibers, such as petroleum products, aramid and glass, due to increased environmental consciousness (Alavudeen et al. 2011) On the other hand, several writers have claimed that hybridizing natural and high-force synthetic fiber hybridization will enhance natural fiber mechanical properties. The product developer is innovative in the form of hybridising to adapt the material properties, and is one of the best features of composites, according to specifications. Many fiber reinforced studies also point to these materials' environmental benefits (Jayabal, Natarajan, and Sathiyamurthy 2011). Natural fibers typically have lower mechanical properties as compared to their synthetic or mineral-based counterparts. Such low mechanical properties are a key consideration in the production of high-performance materials. The hybridization of natural fibers with synthetic fibers is one way to increase their mechanical strength. The benefit of the use of hybrids is that the benefits of a single fiber type will outweigh the drawbacks of the other fiber type. The use of both synthetic and environmental effects of natural fibers is a viable compromise between higher material properties of synthetic fibers. Thus, the right composite material design could achieve a balance in cost, performance and sustainability (Saba et al.
2015). The physical and mechanical properties of traditional synthetic materials are excellent, although these have significant drawbacks, such as non-renewable, non-recyclable, high power consumption during the manufacturing cycle, risk to health and non-biodegradability. Due to these issues, the composite industry of naturally based composites became involved, when green benefits of natural composites (renewability and biodegradability) became important criteria, not primary motivation for top-end mechanical properties. Everything like low density is known to be suitable for use with lightweight structures, although natural fibers may be used for use as a green replacement. Natural fibers are in most circumstances cheaper than synthetic fibers and cause fewer health problems. The interest in the use of natural fibers to enhance the polymer matrix composite was thus highlighted by the engineering, automotive and consumer sectors. In general, a broad variety of natural fibers are produced primarily from vegetable, animal and mineral fibers (Madsen and Gamstedt 2013).

### *Mechanical Properties of Natural Fiber/Synthetic Hybrid Composites*

The considerable mechanical properties of natural fibers can be achieved by hybridization with synthetic fibers, based on the high performance requirements. In addition, the material is biodegradable, economical and mechanically outstanding compared to a particular weight. The thermoset polymers including polyester, epoxy and phenolic are the most commonly used binder or resin. However, the use of these natural fibers as reinforcements in polymers is reduced due to certain disadvantages, such as incompatibility between fibers and polymers, the tendency to form aggregates during processing and poor resistance to moisture. Varios treatments and modifications, including bleaching, acetylation and bonding agents use, are used to improve fiber/mature performance. Low Velocity Impact Properties of Natural Fiber Composites (Salman et al. 2017).

Table 1: Reported research on ballistic resistance properties of natural/synthetic fiber hybrid

| Composites plies | Impact strength (J) | Residual velocity (m/s) | Thickness (mm) | References |
|---|---|---|---|---|
| 4Woven bamboo + 18 woven E-glass | 0.368 | 482.0 | 18.0 | (Ali et al. 2019) |
| 4Kenaf fiber +15 Aramid | 150 | 230.81 | 10.08 | (Salman et al. 2016) |
| 1Kenaf fiber (innermost) + 2Aramid | 131 | 339 | 10.8 | (Yahaya et al. 2014) |
| Kenaf foam(sandwiched) + 2 mild steel | 120 | N/A | 45 | (Hafiz et al. 2013) |
| 12 Coconut sheath + 0.25% GnP + Kevlar 29 | 180 | 280 | N/A | (Naveen et al. 2019) |

The results in **Table 1** indicates that the composites construction with the finer filler offers more efficient energy absorbers than the fabric constructed with the coarse yarn, on an equal areal density basis. The studies on impact strength revealed that, with less fiber interlacing, thicker lamination performed significantly better than plain weave fabric composites. In their detailed studies on the failure mechanisms of natural/synthetic composites upon ballistic impact shows that the position of natural fiber as a reinforcement plays important role in determining the optimum impact strength through residual velocities. The initial velocities lost perpendicularly decreased with the ability of the hybrid plies to absorb the impact from the projectiles.

**Table 2** is related to comparison of the properties between natural and synthetic fibers. In the past decades, significant progress has been made in exploiting the intrinsic properties of the macromolecular chain of natural fibers with regard to ultimate synthetic properties. Aramid 29 has better mechanical properties than natural fibers and a low areal density but still the natural fibers offer competence characteristics. The combination of both natural and synthetic fibers can offer economic and biodegradable composites

**Table 3** explained by the different manufacturing methods involving composite construction for high impact application. The emphasis on the structural formation of a dry fabric or a dry preform will therefore determine the ability to process methods, the efficiency of the matrix and the composite itself. The manufacturing method such as hand lay-up, compression and closed mould was used in the manufacture of natural composite based composite. Even so, the condition of the twisted continuous thread in the biaxial weave preform requires well-suited matrix material and processing methods for the production of a good composite This is important as it involves the wetting process, impregnation and penetration between inter-and intra-filament. Because of native properties, the usual problems are the lack of strong interfacial adhesion, low temperature degradation and poor resistance to moisture, which makes it less attractive than synthetic fiber, which has been the only alternative up to now to reinforce polymeric composites due to their superior mechanical characteristics (Cicala et al. 2010).

Table 2: Reported research on mechanical properties of natural fiber composites

| Properties | Woven Kenaf | Chonta palm wood | Mallow and jute | Coconut sheath | Kevlar 29 |
|---|---|---|---|---|---|
| Density ($g/cm^3$) | 1.2 | 1 | 4.16 | 1.37–1.50 | 1.44 |
| Tensile strength (MPa) | 101 | 16.53 | N/A | 170 | 3000 |
| Young's Modulus (MPa) | N/A | 798.9 | N/A | 5.7 | 600 |
| Elongation (%) | 17.3 | 4.89 | N/A | 15.5 | 2.5-3.7 |
| References | (Salman et al. 2016) | (Haro, Szpunar, and Odeshi 2018) | (Nascimento et al. 2017) | (Naveen et al. 2019) | (Yahaya et al., 2014) |

Table 3: Reported research on hybrid fabrication of natural/synthetic fiber hybrid composites

| Natural fiber | Synthetic fiber | Matrix resin | Fabrication Method | References |
|---|---|---|---|---|
| Woven | Woven E - | Unsaturated | Hand lay-up | (Ali et al. 2019) |
| bamboo | glass | polyester | | |
| Kenaf fiber | Aramid | Polyvinyl Butyral | Hot press | (Salman et al. 2016) |
| Kenaf fiber | Aramid | Epoxy | Hand lay-up | (Yahaya et al. 2014) |
| Chonta palm wood | High Density Poly Ethylene (HDPE) | Micro particles filler | Extrusion | (Haro, Szpunar, and Odeshi 2018) |
| Kenaf fiber | Virgin High Density Polyethylene (vHDPE) | Silane | Non-Woven Matted | (Akubue PC, Igbokwe PK, and Nwabanne JT, 2015) |
| Mallow and jute | - | Epoxy | Lamination | (Nascimento et al. 2017) |
| Coconut sheath | Kevlar | Epoxy and graphene nano platelets | Hand Lay – Up And Hot Press | (Naveen et al. 2019) |

Table 4: Configurations and properties of bamboo/E-glass/ Unsaturated Polyester composite (Ali et al. 2019)

| Specimens descriptions | Specimens thickness (mm) | Fiber volume fraction (%) | |
|---|---|---|---|
| | | Aramid | K |
| 19 Aramid | 8. | 61.94 | 0 |
| 17 Aramid /2 kenaf | 10. | 48.42 | 1 |
| 16 Aramid /3 kenaf | 10. | 43.56 | 1 |
| 15 Aramid /4 kenaf | 11. | 39.14 | 2 |
| 13 Aramid /6 kenaf | 12. | 31.29 | 2 |
| 11 Aramid /8 kenaf | 13. | 24.55 | 3 |
| 9 Aramid /10 kenaf | 14. | 18.75 | 4 |
| 19 Kenaf | 17 | 0 | 6 |

Table 5: Specifications of the Laminated Hybrid Composites (Salman et al. 2016)

| Types of layer arrangement | Number of layers of each material | Dimension (length*width*height)/mm |
|---|---|---|
| Woven | 4/18 | 300*300*18 |
| E-glass | 9/4/9 | 300*300*18 |

Table 6: Layering sequence, penetration energy and maximum load (Yahaya et al. 2014)

| Sample | Layering sequence | Energy absorption (J) | Maximum force (N) |
|---|---|---|---|
| A | All Kevlar layers | 73.3 | 9260 |
| B | Kenaf at the outermost layers | 90.0 | 13,275 |
| C | Kenaf at the innermost layers | 131.0 | 17,440 |
| D | Kenaf and Kevlar are at | 88.1 | 16,440 |
| E | All kenaf layers | 4.8 | 790 |

As the flexibility is the main concern so the thickness of the composite panel should be as thin as possible without jeopardise the aim of ballistic resistance. Therefore the previous studies shows that mostly the thickness of the panel was less than 20 mm as shown in **Table 4** and **Table 5**.The effect of the layering sequence could have an impact on the trauma injury and failure modes of hybrid composite laminates. It is therefore important to determine the configuration of laminate interplies between hybrid natural fibers and synthetic fibers. The structure also defines the energy absorption that represents the capacity of the ballistic resistance composites in real time as shown in **Table 6** and **Table 7**.

The effect characteristics of composites depend on the adhesion between the fiber and the matrix. The impact strength of individually woven composites from natural fiber and hybrid plain is presented in Figure 1. For the same weaving pattern, the impact strength of the composites differs from that of the reinforcement fibers. This assumes that the characteristics and configurations of the individual fiber components are responsible for assessing the impact strength of composites apart from criteria such as interface fiber matrix, design and geometry of composites. However, the influence of inter-laminar delimitation also gives influence strength in addition to interfacial strength with composites reinforced with a weaving pattern. Figure 1 clearly indicates that the hybrid weaving pattern is stronger than pure kenaf woven polyester compounds. This means that the impact intensity depends mainly on the characteristics of each fiber used for hybridisation in the polymer matrix system and no other parameters.

Table 7: Ballistic testing result using gas gun (Yahaya et al. 2014)

| No. | Composites Sample | Speed before ( | Speed after (m/s) | Energy abs (Ea) |
|---|---|---|---|---|
| 1 | Kevlar (0/100) – 8 layers | 3 | 210 | 119.3 |
| 2 | Kevlar (0/100) - 12 layers | 3 | 184 | 207.8 |
| 3 | Kenaf/Kevlar (30/70) - 8 layers | 3 | 235 | 94.5 |
| 4 | Kenaf/Kevlar (30/70) - 12 layers | 3 | 204 | 148.8 |
| 5 | Kenaf/Kevlar (50/50) - 8 layers | 3 | 261 | 69.9 |
| 6 | Kenaf/Kevlar (50/50) - 12 layers | 3 | 243 | 103.6 |
| 7 | Kenaf/Kevlar (70/30) - 8 layers | 3 | 281 | 39.8 |
| 8 | Kenaf/Kevlar (70/30) - 12 layers | 3 | 264 | 73.8 |
| 9 | Kenaf (100/0) - 8 layers | 3 | 288 | 17.6 |
| 10 | Kenaf (100/0) - 12 layers | 3 | 285 | 37.2 |

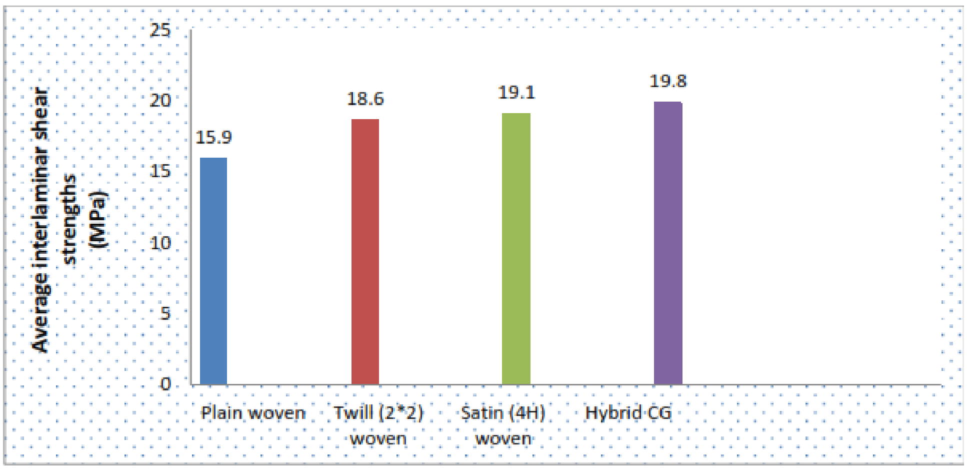


Figure 1: Plot of average strengths vs. laminate of Kenaf composite (Cavallaro 2019)

Table 8: Properties of aramid fiber, mallow fiber, jute fiber and epoxy resin (Fabio et al. 2018)

| Materials | Density (g/cm3) | Tensile resistance (MPa) | Young's modules (GPa) | Specific resistance (MPa) | Specific modules (GPa) |
|---|---|---|---|---|---|
| Aramid | 1.4 | 3000–3150 | 63–67 | 2143–2250 | 45–48 |
| Mallow | 1.4 | 160 | 17.4 | 116 | 13 |
| Jute | 1.3–1.4 | 393–800 | 13–27 | 271–615 | 9.3–21 |
| Epoxy | 1.1–1.3 | 60–80 | 2–4 | 46–73 | 1.5–3.6 |

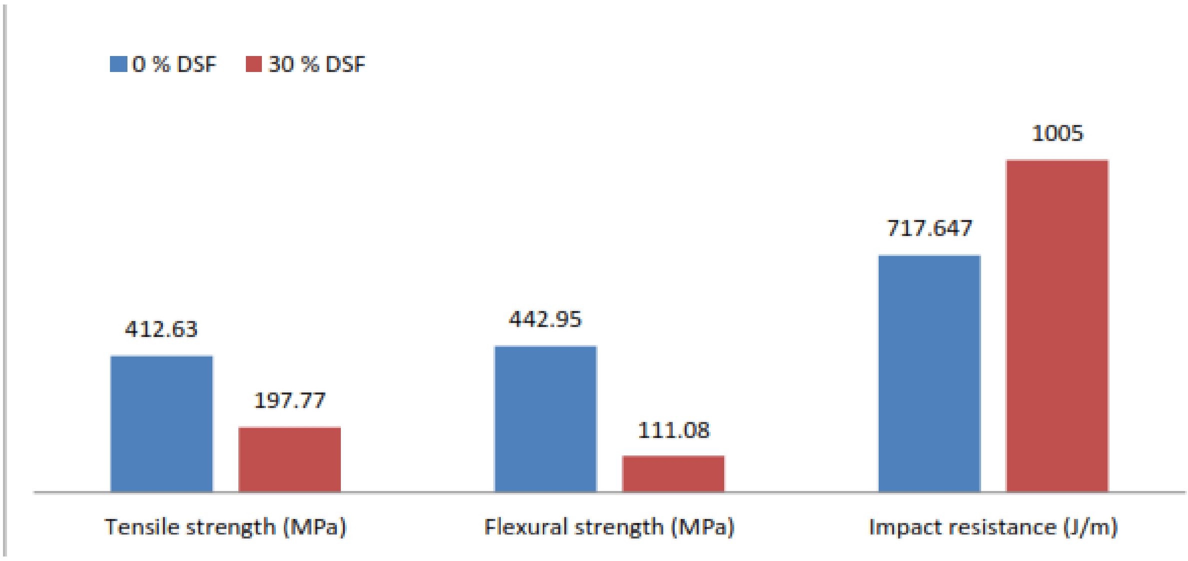


Figure 2: Bar chart of Kevlar Durian Phenolic Skin Hybrid Composites properties specimens (Dawood Salman, Nazmin Binti Md zain, and Bin Leman 2018)

Table 9: Tensile strength and Young modulus of reinforced High Density Poly Ethylene (HDPE) samples for bio composite armours (Haro, Szpunar, and Odeshi 2018)

| Bio-composite specimens | Chonta palm wood micro-particles (wt.%) | Tensile strength /MPa | Strain,Ɛ / % | Young's Modulus /MPa |
|---|---|---|---|---|
| HDPE 1 | 0 | 14.91± | 5.38±1.12 | 496.8±21.2 |
| Ch10 | 10 | 16.16± | 5.45±1.57 | 724.7±17.4 |
| Ch20 | 20 | 16.47± | 6.00±1.36 | 742.2±13.2 |
| Ch25 | 30 | 16.53± | 4.89±1.47 | 798.9±17.3 |
| Ch30 | 40 | 15.19± | 5.13±1.48 | 730.2±12.1 |

Often measured was the mechanical performance in terms of tensile, flexural and impact of laminated composites. The main distinguishing features of composite armour systems mean that the mechanical properties of laminated composites may vary. The specification of the product design for the personal body armour was formulated on the basis of the sustainability and performance requirements. The selection criteria are: fiber orientation, cellulose, quality, availability, density, tensile strength and young modulus as shown in **Table 8**, **Table 9** and **Figure 2.** Multiple criteria for consideration will ensure that the results are more meaningful and reliable. This review focuses on soft body armour instead of hard body armour. Soft body armour contains multiple layers of fabric up to 50 layers (weight less than 4.5 kg). Along the way, soft body armour must also withstand the impact of a projectile up to 500 m/s according to the National Institute of Justice (NIJ) armour standard. The factors of weight and cost are the main consideration in order to design the body armour ergonomically. Low weight of the body armour on the human body prevents fatigue from the operator and does not affect respiratory conditions, especially when the ambient temperature rises.

## CONCLUSION

Latest approaches in materials and panel developments for creating a body shield framework have invigorated scholar to study more on this matters. Even so, it is pertinent to say the reasons leading the plan and development of the body shield product. Likewise, the body armour system's flexibility, manufacturing cost and bio sustainability must also be taken into consideration to achieve user-friendly systems. The utilization of natural fiber as strengthening in polymer mixtures was reviewed based on perspective of the condition and the requirements of natural fibers for enhancements in the polymer composite based. This also provides a means for economic development in rural areas, owing with the use of natural materials in different industrial applications and manufacture activities. This list complies with the Malaysian government concern on the diversification of local woodland-based product besides of craft and furniture industries. The resultant of this review suggests that the properties of reinforced polyester hybrid natural fibers with synthetic fibers embedded with polymers may be improved. But only some investigations carried out on the potential of woven natural reinforcement hybrid with synthetic fibers. There are obvious strength enhancements between the yarns of fibers in the frame of various weaving patterns. The bonding structure upon intraply between fiber yarns and the interply between laminar is still under studied by the previous researches. The literature revealed regarding only few data offered on the investigation process to ascertain the properties of especially lamination on woven natural fibers with synthetic composite. Intent of an effective hybrid with the betterment of stacking series will have optimal weight and cost reduction applications in the ballistic resistance. This leads to upgrades over the mechanical characteristic of woven natural fibers with man-made fiber strengthened compounds by consuming Quasi-static experiment techniques thus validating the results through finite element simulation and statistical analysis. Exploration of effect disruption and high-strength flexibility fiber structure has turn them into favourable constituents not only for army services, but domestic protecting uses, such as personal armour outfit, head covering, and auto parts. Equally for the bio sustainability, long term effect makes the composite biodegradable and practically used for.

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