# A REVIEW ON THE HYBRIDIZATION OF VARYING LENGTH NATURAL FIBERS FOR CEMENT COMPOSITES

**Muhammad Abrar*[1], Majid Ali[2]**

[1] *Capital University of Science & Technology Islamabad, Pakistan, e-mail: engr.m.abrar@outlook.com*
[2] *Capital University of Science & Technology Islamabad, Pakistan, e-mail: professor.drmajid@gmail.com*

***Corresponding Author**

## ABSTRACT

Concrete is the primary construction material. World is developing day by day so the consumption of concrete is increasing. Due to its flaws of brittleness and having weakness in tension phase there is need to improve the properties of concrete. Agricultural waste produced in developing countries is burnt for energy purposes. So, the burning of this waste is causing environmental pollution. These agricultural wastes have good properties like eco-friendly, low cost and low density. Natural fibers obtained from these agricultural wastes have potential to be used in concrete as construction materials. To obtain the combined effect of fibers the hybridization is becoming popular among researchers. Natural fibers of different lengths can be used to bridge the micro as well as macro cracking of concrete. With the use of natural fibers in concrete, the properties of concrete can be enhanced up to desired strength. The improved toughness, compressive, tensile and flexural strengths can be obtained by the addition of natural fibers in concrete. The purpose of this study is to analyze the effects of utilization of natural fibers in concrete. The specific aim this research is to find out the potential of agricultural wastes to be used in concrete and to study the hybridization of different lengths of natural fibers. For this purpose the state of the art review is conducted on the effects of varying lengths natural fibers in concrete. Remedies of flaws of concrete by the incorporation of these varying lengths natural fibers are also discussed. The results revealed that the jute and wheat straw have good mechanical properties and different lengths of natural these fibers can be used for hybridization to get improved properties of concrete.

***Keywords:*** *Agricultural wastes, fiber reinforced concrete, natural fibers*

## 1. INTRODUCTION

By the growing age, countries are changing from under-developed to developed ones. This phenomenon is enhancing the utilization of construction materials. Concrete is the primary construction material which is widely used in the world (Tian et al., 2020). The urbanization and development are the factors that are enhancing the consumption of concrete which has much adverse ecological effects on environment. On the other hand, agricultural wastes need much land to dump or dispose. Agro wastes produce about 9% of the total energy production. On the other way, agro wastes provide around 35% of the total energy consumption in developing countries (International Energy conference, 2015). Concrete is a brittle material which is stronger in compression phase and weaker in tension (Aslani and Samali, 2014, Khan and Ali, 2019). These waste fibers can be utilized in concrete to enhance the properties of concrete. Many researchers used natural fibers in concrete to attain better properties of concrete than conventional concrete (Farooqi and Ali, 2018, Ali, 2016, Ali, 2014, Tang et al., 2014, Hussain and Ali, 2019). World produces about 2.9 billion of crop straw annually and 66% of these straws are burnt as source of energy (Liu et al., 2018, Ahmad et al., 2018, Li et al., 2018). Open burning of wheat straw is the wastage of natural resources and causing air pollution; severe threat to highway traffic, impairing human health and safety (Romasanta et al., 2017, Zhang et al., 2014).

Due to frequently presence in developing countries, agricultural wastes can provide advantages of low modulus of elasticity and high tensile strength. Because of these advantages they have potential to be used in cement-based composites to attain final product with better properties like good thermal insulation, crack opening control and reduction of composite density (Izquierdo et al., 2017, Ramírez et al., 2019). Incorporation of agricultural wastes natural fibers by mas of cement can reduced the cement content required to prepare concrete mix (Campos et al., 2020). By the hybridization of fibers the combined effect of both fibers may produce better performance in concrete as compared to sole natural fiber. Numerous studies are being conducted by researchers on the combined effect of hybrid fibers of different lengths and their effects towards to fresh and hardened properties of concrete (Li et al., 2021, Balea et al., 2021, Vishaul et al., 2021). Natural fibers were used to improve the out of the plane resistance of mortarless masonry wall (Qamar et al., 2018).

Concrete is week in tension and strong in compression. There is need to alter the properties of concrete and to make it eco-friendly. This can be done by choosing a suitable material that has good physical properties and may have potential to be used in concrete. Agricultural waste natural fibers are eco-friendly and have potential to be used as construction materials. The purpose of this research is to find out the potential of agricultural wastes for using in construction. The different lengths of fibers can bridge the macro and micro cracking so, the effect of different lengths of fiber is considered in this research along with the hybridization of these natural fibers. Being primary construction material concrete has many flaws. So, flaws of concrete and their solution by the incorporation of different lengths of natural fibers is briefly discussed.

## 2. UTILIZATION OF AGRICULTURAL WASTES AS CONSTRUCTION MATERIALS

Every year, about one thousand million tons of agricultural waste is produced in the world. These wastes contain about 80% of solid organic waste like wheat straw, rice straw, jute fibers, bagasse straw, rice husk and cotton stalks etc. (Choi, 2019, Sharma and Singh, 2019). It was investigated that if these agricultural waste short discrete fibers are incorporated in concrete, these fibers act as crack resisters. They also change the behaviour of concrete against dynamic and static loadings (Sultana et al., 2020). When particular length and content of jute fiber is used in concrete, it tends to obtain enriched results of mechanical properties (Zakaria et al., 2018). Jute fibers mixed in high-fluidity concrete provide higher improvement of strength as compared to low fluidity concrete (Kim et al., 2013). A noticeable amount of cement is saved if agricultural waste natural fibers are added by the mass of cement content (Campos et al., 2020). Appropriate content of jute fibers can delay crack initiation and propagation and also reduce micro cracks (Tiezhi Zhang, 2020). It was observed that after the increase of curing age of jute fiber, greater content of jute fiber has positive impact towards the compressive strength (Mohammad and Ahmed, 2018). Agricultural waste jute fiber was used with glace fiber reinforced polymer rebars to enhance the impact resistance against impact loading for concrete wall. It was observed that the toughness and impact load carrying capacity considerably enhanced (Ahmed and Ali, 2020).

Crop straw can be used to prepare fibers, to be used in cement-based composites to make light weight and thermal insulated structures (Korjenic et al., 2016). Singh et al. (2021) used bagasse ash and wheat straw for earth blocks stabilization. It was noticed that the maximum compressive strength obtained, when 5% of wheat straw was used by mass of cement. Concrete blocks were prepared by the addition of agricultural wastes like coffee husk and sugarcane bagasse. The use of 5% sugarcane bagasse showed higher results. It was revealed by research that these agricultural wastes enhanced the compressive strength and the thermal properties of concrete blocks (Souza et al., 2021). Agricultural waste and coconut shells were used by (Prakash et al., 2021) for the mechanical characterization of concrete. It was observed that when only 3% of fiber was added there was increase of 14% in tensile strength and 11% in flexural strength of concrete. Wheat straw agricultural waste can be used as insulating material with cement mortar and reduce thermal conductivity, provide good properties when mixed with mortar (Ismail et al., 2020). Both jute fibers and wheat straw fibers have good mechanical properties to be used as construction materials. Mechanical properties of wheat straw and jute fibers are given in Table 1 (Arooj, 2021).

Table 1: Mechanical properties of jute and wheat straw (Arooj, 2021).

| Parameter | Wheat straw | Jute fiber |
|---|---|---|
| Diameter (mm) | 5-7 | 20-200 |
| Density (Kg/m$^3$) | 1150-1200 | 1300-1490 |
| Tensile modulus (MPa) | 30-32 | 320-800 |
| Young's modulus (MPa) | 6.0-6.6 | 8-78 |
| Max. elongation (%) | 1-1.13 | 1-1.8 |

## 3. EFFECT OF VARYING LENGTH NATURAL FIBERS ON CEMENET COMPOSITES BEHAVIOUR

Varying length natural fibers are used in concrete to create the bridging effect, and short and long fibers resist the macro as well as micro-cracking (Sadrmomtazi et al., 2018). Many researchers reported that by the use of optimum lengths and content, it can improve the mechanical properties and physical properties like flexural strength, splitting tensile strength and impact resistance (Dawood and Ramli, 2014, Ralegaonkar et al., 2018). Micro and macro cracks are formed during the hydration and hardening process of concrete. When specimen is subjected to external loading the propagation of these cracks start which result in failure of structure. The varying length natural fibers can bridge the micro as well as macro cracks and can resist the propagation of micro cracks towards macro cracks (khan and Cao, 2021). The crack bridging mechanism of fibers is shown in Figure 1.

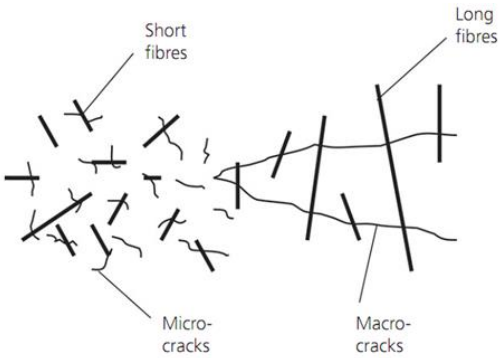


Figure 1: Cracks bridging mechanism of fibers (Khan and Cao, 2021).

Sajin et al. (2021) conducted a study on varying length natural fibers. The results revealed that the fibers length used for reinforcement is directly proportional to the mechanical strength. Ahmad et al. (2020) performed experimental research on the effect of coconut fibers content and length in concrete. Coconut fibers of 25 mm, 50 mm and 75 mm lengths were used in that research. It was observed that the fibers of 50 mm length enhanced the energy absorption and toughness of concrete. So, the optimum lengths of natural fibers in concrete play an important role in attaining energy absorption and toughness. Mugume et al. (2021) carried out a study to find out the influence of fibers length and content on the crack resistance of fibers. Results showed that the addition of low content like 1% and longer lengths increased the tensile strength of banana fiber reinforced concrete. For the use of longer lengths of banana fibers the low content like 0.5% was found effective.

## 4. HYBRIDIZATION OF NATURAL FIBERS FOR CEMENT COMPOSITES

Hybridization of natural fibers is accomplished to get the combined effect of two or more fibers. For this purpose, natural fibers are used in concrete to enhance the desired properties of concrete. Boumaaza et al. (2020) used sisal, flax and jute fibers of 5mm, 10 mm and 20 mm lengths. The results revealed that the addition of sisal, flax and jute fiber by the hybridization considerably enhanced the flexural properties of concrete. The maximum flexural strength was obtained by the hybridization of

20 mm length fibers. A study was carried out by the usage of hybrid fibers with the combination of hybridization of 0.3%, 0.4% and 0.5%. The hybridization of natural fibers by the optimum content of 0.3% showed maximum strengths. The hybridization of natural fibers of two different length was carried out. It was found that the hybrid natural fiber after the hybridization provide better flexural strength as compared to the conversional concrete (Madhavan et al., 2021).

Hybrid natural fiber reinforced concrete is used as a replacement of plain concrete (PC). Macro fibers helps to tackle macro-cracks and increase toughness of concrete also the flaws and their remedial measures with varying length natural fibers (Di Maida et al., 2018). In hybrid natural fiber reinforced concrete, the forces across cracks are combined effect of aggregate and fibers. During the resistance to crack propagation, fiber experience frictional slippage, pull-out forces, breaking effect and de-bonding (zhang and Cao, 2014). The presence and surfaces of fibers control the energy dissipation and deformation phenomenon after post cracking (Signorini et al., 2020). Fiber pull-out from matrix promotes the ductile behaviour of concrete because of energy dissipation during the process of post-cracking (Maalej et al., 1995). Fiber reinforced concrete continue to make more loads until the fiber present in fiber reinforced concrete break.

## 5. CONCRETE FLAWS AND THEIR REMEDIAL MEASURES WITH VARYING LENGTH NATURAL FIBERS COMPOSITES

Being widely used material, although concrete has advantages, it also has drawbacks. Concrete is a brittle material which is stronger in compression phase and weaker in tension (Aslani and Samali, 2014). During the hydration of concrete, cracks appear on the surface of concrete which may cause the reduction in strength of concrete. When external load is applied these cracks lead to failure of structure (Khan and Cao, 2021). Natural fibers have good potential to be used in concrete. They act as the cracks arrestor and try to bridge cracking. The advantage of the usage of different lengths natural fibers is to bridge micro as well as macro cracking. Conversional concrete has low toughness and energy absorption as compared to fiber reinforced concrete (Hashmi et al., 2021). During the splitting tensile loading the conventional concrete splits into parts while the bridging effect of fibers tend to take more loading until the fiber breakage occur. The energy absorption and toughness of structure is important factor while making earthquake resistant structures (Ali and Chouw, 2009).

The low tensile strength of concrete always needs to be reinforced. The binding material like cement has adverse ecological effects which produce environmental concerns. For the sustainable development and to reduce energy consumption varying lengths natural fibers can be utilized in concrete. The evaluation of cracking in concrete structure is based on two properties of concrete, which include tensile strength and the tensile strain capacity. The tensile strain capacity is the measure of tensile strain that a concrete structure can withhold without forming cracks throughout the structure. The evaluation of cracking process can do more effectively and easily by considering tensile strain rather than tensile strength property of concrete, the process express forces in form of volumetric changes. A concrete structure under particular loading possesses a relation between tensile load carrying capacity and crack width (Khan et al., 2020). The tensile strain capacity of concrete is measured through modulus of rupture. Despite of good effect on the properties of concrete, natural fibers have drawbacks towards the workability of concrete. The workability of concrete is reduced by the use of natural fibers so plasticizers and increased water to cement ratio can overcome this drawback (Abrar and Ali 2021).

## 6. CONCLUSIONS

The agricultural wastes can be used in concrete. Hybridization of natural fiber is studied to obtain the combined effects of fibers. Concrete flaws and their remedies by the incorporation of varying length natural fibers is taken into count by the state-of-the-art review. Following conclusions are drawn from this research.

- Agricultural wastes instead of burning can be used in concrete to enhance the compressive strength, splitting tensile strength and flexural strength.
- The toughness and energy absorption of concrete is enhanced by natural fibers
- Varying lengths natural fibers can bridge micro as well as macro cracking so the cracking of concrete can be minimised by varying lengths natural fibers
- Hybrid natural fibers are more effective than the sole fiber used in concrete.
- Jute and wheat straw have good mechanical properties so by the hybridization of these fibers better properties can be achieved.

Agricultural wastes have potential to be used in concrete. These fibers when mixed together with different lengths proportion by hybridization can mitigate the flaws of concrete like cracking and weakness in tension phase.

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